

RED LIGHT CAMERA EFFECTIVENESS

A Comparative Analysis from Washington State and Chicago, Illinois

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INTRODUCTION

While red light cameras (RLCs) have been in use for half a century, adoption in the United States has been a recent phenomenon. In Washington State, their application began after a 2005 change in law, while in Chicago the city began a wide scale adoption in 2006. Literature regarding RLC efficacy is widely varied and has variously hindered adoption and informed discussion about the various merits and demerits of their usage. No scientific literature yet exists in regards to Washington State or Chicago based RLC systems.

Red light violations occur when an automobile enters an intersection during the red phase of a traffic light, increasing the likelihood of an accident. The relevant statistics are surprisingly varied, however, when a question of deaths, injuries, etc., ought to be relatively straight forward. More muddled are the reported results of Red Light Camera (RLC) implementation. RLCs are a form of automated traffic enforcement as systems have become more cost effective. The literature may indicate a decrease in all accidents at RLC intersections, an increase in rear-end collisions and a decrease in right angle crashes, or an increase in both, though a more consistent improvement over time has also been indicated.

This paper analyzes the impact of red light cameras (RLCs) on the rates of crashes at signalized intersections. Crashes are broken into two categories – rear ends and the more severe angle crashes, both of which are directly affected by RLC application. A cost-benefit analysis based on the changing ratio of these crashes and the overall change in rate as compared to control site has been conducted. Treatment data from Washington was gathered using Washington State Department of Transportation (WSDOT) from eight Lynnwood sites and compared with 8 sites similar in volume in Bellingham, a location far enough afield to avoid

spillover effects RLC using communities while retaining the same law and cultural structures of the state. Chicago data originated from a freedom of information request by the Chicago Tribune, and encompasses 96 treatment sites and 20 control sites.

In Chicago, data indicates a potential spillover effect when compared to the additional dataset from Washington State. Changes in the rates of accidents vary wider when spillover effects are unlikely to be present. Furthermore, the overall cost-benefit analysis suggests that the safety effect as measured by the cost-benefit analysis is actually negative, even if the changing ratio in terms of accident severity made the average accident less harmful, due to the smaller decline compared to the control sites.

Other negative side effects may exist when RLCs are present, including perverse incentives to vary yellow timing for revenue generation, concerns about loss of privacy, and citizen displeasure with the systems. A ready set of engineering solutions to red light running (RLR) problems exists and may be implemented in lieu of RLC based solutions.

GLOSSARY

ATS -	American Traffic Solutions
FHWA –	Federal Highway Administration
IDOT –	Illinois Department of Transportation
IIHS -	Insurance Institute for Highway Safety
ITE -	Institute of Transportation Engineers
KABCO –	Rating system for crash severity (Killed, Incapacitating, Injury, Possible Injury, Property Damage Only)
NCHRP -	National Cooperative Highway Research Program
NHTSA -	National Highway Traffic Safety Administration
PDO –	Property Damage Only
RLC –	Red Light Camera
RLR –	Red Light Running
WSDOT -	Washington State Department of Transportation

DESCRIPTION OF RED LIGHT INTERSECTION VIOLATIONS

Intersections, the meeting or crossing of two or more roads, come in myriad varieties, including traffic circles, box junctions, forks, et cetera (FHWA 2009, 19). For the purposes of this study, however, we can eliminate much of the variety of intersection types by two criteria: the intersections must be crossroads, and they must be signalized. Non-crossroad intersections far less frequently use signalization, and are not prone to the kind of violations that RLCs may hope to affect. Without signalization, there is no red light indicator to violate, making enforcement a moot point – one could conceivably create a stop sign violation camera, the equivalent violation at a non-signalized intersection typically, but no such device was mentioned in the literature available. Absolute data on the number of intersections, signalized or otherwise, is imprecise – the Federal Highway Administration (FHWA) believes, based on an Institute of Transportation Engineers project, approximately 3,000,000 intersections exist and ten percent of them are signalized, for 300,000 in total, though this is based on a loose rule-of-thumb methodology (Tarnoff 2003).

Signalization – the use of traffic control signals – consists of a series of lights intended to assign right-of-way for traffic movements through an intersection (FHWA 2009, 434). When properly used, they provide for the orderly movement of traffic, increase the traffic-handling capacity of the intersection (if proper layouts and signal parameters are used), reduce the frequency and severity of certain types of crashes (especially right-angle collisions), and may be used to permit pedestrian crossing. If improperly implemented, however, they may lead to excessive delay, excessive disobedience of the signals, increased use of alternate and less suitable routes, and significant increase in the frequency of collisions, especially rear-end

collisions (FHWA 2009, 435). Any of those negative indications may have either engineering solutions, legal solutions, or some combination of the two.

Figure 1. Signalized intersection



At signalized intersections, violation of the red light signal, or entering the intersection while the signal indicates that vehicle is not presently assigned right of way (a red light is active), may cause a collision between vehicles or pedestrians to occur (McGee 2003). Legal definitions can vary, however, as to whether or not a red light violation has occurred. The permissive yellow rule states that a driver may enter the intersection during any point of the yellow duration, and a violation occurs only if they enter during the red phase. Conversely, the restrictive yellow

rule states a driver cannot be in the intersection at all during the red phase, regardless of the phase they entered (Fitzsimmons 2007, 6). Because of these and other discrepancies, the number of legal violations is difficult to report accurately from state to state, or even community to community.

A 2011 analysis determined through a statistical model that 7% of all fatal crashes in the United States occur at signalized intersections in 2009, though 32.1% of those crashes were violations of the red light signal (Lane 2011, 8). Of the enormous number of crashes at signalized intersections (2,278,100 in 2011), only 3.9% involve red light violation (89,100) (Lane 2011, 13). This indicates, as from 3.9% of crashes 32.1% of fatalities were generated, that the relative danger of running a red signal at an intersection is higher than other sorts of crashes. This is perhaps because the kind of crash due to a red light violation is an angle crash – notably more often fatal than sideswipe or rear end crashes (Lane 2011, 12).

According to another set of research compiled using the Fatality Analysis Reporting System (FARS) database, about 21% of all accidents occur at intersections, and of them 65% of accidents occur at non-signalized intersections, 31% at signalized intersections, and 4% are unknown (NHTSA 2007). The numbers varies widely, 18% of all incidents and 44% of all fatalities at signalized intersections involving a red light violation in an earlier study, but all indicate above average danger is incurred (South 1988, 5). The scope and varying statistical methods used to fill in the overall numbers in view of incomplete data may be the cause of the discrepancies. It may be difficult to estimate safety effects on a large scale, however, given how these percentages vary from study to study, and differ from year to year.

DESCRIPTION OF RED LIGHT CAMERAS (RLC)

When red light violations occur, commonly a police officer is to intervene and issue a citation (McGee 2003). However, normal police operations are ineffective at deterring red light running for several reasons – the police to intersection ratio is usually vanishingly small, and yet one must be present to observe and a second must be on the opposite side of the intersection to apprehend the violator (South 1988). Nevertheless, if signalized intersections are disproportionately the site of greater numbers of accidents, treatments applied to those sites intended to ameliorate the problem may have a similarly disproportionate effect. With that in mind, RLCs emerged as a mixed legal/punishment and engineering based solution to this phenomenon.

As a general hypothesis supporting RLC use, a safety effect is supposed via reducing the instances of RLR itself, and thus the associated crashes (McGee 2003). As the threat of legal action in response to their violation, and in so far as this violation is congruent with crash risk, decreases that violation, the safety effect will increase. As angle crashes occur in intersections, preventing intersection violations are likely to reduce their frequency. Angle crashes occur when a violating vehicle is hit by an adjacent vehicle proceeding legally through a green signal display. However, another sort of crash is likely to increase – rear end collisions. Knowing there is a camera system and seeing the yellow display, a more cautious motorist may stop more abruptly, causing the following motorist, not anticipating the need to stop and likely to be following too closely to hit the lead vehicle from behind (South 1988).

Assuming these are equal, crash severity a net benefit would accrue if crash reductions of the angle type exceeded crash increases of the rear end type. However, in general angle crashes are

usually more severe – a zero change in total crashes may prove to be safer if there is a smaller proportion of angle to rear-end crashes (Table 2, Council 2005). Another possibility comes in the form of a spillover effect – behavior could change at more than just the treatment intersections, as people either anticipate the fine or apply a single reaction to all encountered intersections.

Crash severity	Right-angle crash	Rear end crash
K (Fatal)	\$4,090,042	\$3,781,989
A (Disabling Injury)	\$120,810	\$84,820
B (Evident Injury)	\$103,468	\$27,042
C (Possible Injury)	\$34,690	\$49,746
O (No Injury)	\$8,673	\$11,463
Average Accident Cost	\$64,468	\$53,659

The earliest in-use RLC systems employed a wire induction loop embedded at the intersection, accompanied by a film-bearing camera mounted in such a way to take a picture of the intersection, and presumably the violating automobile (South 1988). The concept existed as early as 1905, however, in which a patent describes a “time recording camera for trapping motorists” (Hearst 1905). The public first use came in 1961 through a system adapted by the Dutch company Gatsometer BV initially used to take automatic film pictures of race track laps in order to monitor times more closely (New Scientist 1961). In Europe, these systems have often been used surreptitiously, but this led to lower deterrent rates – ideally, warning signs, visible symbols of enforcement, increased effectiveness elsewhere (South 1988). It took until 1993 for the United States to first see the introduction of RLC systems, though they were not unknown in Europe, Australia, and some Asian markets such as Singapore by then (Emmons 1998). The late adoption in the United States came from a combination of the lack of a universal traffic authority

combined with a lack of convincing scientific data available on the efficacy of the systems (McGee 2003). Modern systems use digital imaging, multiple cameras, and typically light the area in the process via a flash (Figure 3, Jaffee 2011).

Figure 2. Red light camera (Flicker user 'functoruser', used under a Creative Commons license)



Systems today detect offending motorists and issue a citation by mail, though the nature of the citation varies widely amongst jurisdictions (McGee 2003). Often, these programs involve more than just camera systems and collecting fines – they may be combined with education,

publicity, changes in the law, the level of fines, new adjudication procedures, types of signage (at the gateway to the city or at the camera, for instance), changes in baseline traffic signal operations (especially the yellow change interval), and the number of signalized intersections may be expected to influence effectiveness (McGee, 2003). Some but not all systems include a small level of “enforcement tolerance” from 0.1 to 0.3 seconds after the turning of the red light, only after which will the system engage (Burkey,2004). Depending on the jurisdiction, police officers may screen the photos taken by an RLC system in order to exclude emergency vehicles and funeral processions in addition to blurry/unclear views of the license plate. This means that the rate of ticketing from events may be lower – 40.3% in the case of Greensboro N.C., though these rates are very inconsistent across states or even from city to city with varying laws, technology, etc. See appendix table 18 for a comparison in state laws, pages 63-66.

LITERATURE REVIEW

Although the concept of a RLC system has been extant for more than a century, and has been in use in Europe for about half a century, the vast majority of published works or even works referenced by those papers are within the past twenty years (Hearst, 1905). The quality of the literature available varies somewhat, though most are significantly deficient in methodology. The most prevalent report available are those issued by municipalities employing RLCs, which may come with an inherent conflict of interest – no independent assessment available appeared to be commissioned by a town in regards to such a system. These reports usually consist of raw changes in the number of accidents, the number of injuries, and the level of violations without any comparison or control groups to consider. Furthermore, even the independent reports are rarely of the peer-reviewed kind.

This relative paucity of rigorous and vetted literature speaks to the phenomenon of slow adoption of RLC systems in the United States (McGee 2003). Even with that in mind, most of the individual city reports are excluded from this analysis, though it should be noted that in the more anecdotal literature, the trend usually expressed is a decrease in total accidents and injuries, from between 0 to 70 decrease in angle accidents and between 22 to 50 percent increase in rear accidents (Berkey, 2004; Maccubbin, 2001). There are two other prevalent sorts of studies, however – ones commissioned at the state or federal level and performed by government agencies, and ones performed by a secondary institution such as the Insurance Institute for Highway Safety (IIHS).

Nevertheless, though intersection signalization can improve safety and traffic flow when applied properly, these intersections are frequently the sites of crashes. Retting (1995)

concluded that violating red lights was the primary cause of 22% of all crashes, and 45% of those crashes involved an injury. Wissinger (2000) sought to discover the reason why people would violate signalization – often because they are in a hurry. They also typically did not understand red light laws, perhaps in part because they vary from state to state – in one state, passing the nose of your car beyond the “stop bar”, the white line before the intersection, may constitute a violation whereas in another it’s permissible.

Poor signal timing exacerbates the problem, creating situations where at the given speed, a prudent cannot stop during the yellow timing of the light safely, yet also cannot pass through safely, the solution to which would be to extend the yellow timing. Stimpson (1980) found that retiming lights could significantly improve intersection safety, up to a 90% reduction in in the number of vehicles that enter the intersection very shortly after the change from yellow to red (0.2 seconds) with a 30% increase in yellow timing. Williams (2002) studied 51 red light intersections in New York State, of which 41 required adjustments to even meet state standards for yellow length. When adjusted, a five percent decrease in total crashes at these sites occurred.

The National Highway Traffic Safety Administration (NHTSA), a government body with the purpose of advising highway safety and consumer programs, identified ways improve intersection safety, one of which is “automated enforcement of red light running”, or RLC implementation (NHTSA 2000). However, they also suggest changing the timing of traffic signals, removing sight-distance restrictions, changing intersections to roundabouts, use of computerized signal timing changes over the system, and better signage such as brighter stop, yield, and speed information in addition to this enforcement option. Nevertheless, they indicate some level of federal support for RLC programs. Private support comes from institutions such as

the Insurance Institute for Highway Safety (IIHS), a non-profit funded by the insurance industry, which regularly advocates for RLC systems.

The possibility exists that a safety effect can occur from adoption of RLCs. However, these systems can be attractive to other municipalities for several other reasons. According to Berkey (2004), typically an outside contractor will offer to both install and operate the RLC system at no cost to the municipality. In return, the contractor receives a portion of each ticket ultimately issued because of the system, though the town receives the rest, potentially a considerable source of revenue. Chicago earns over sixty million dollars per year from its' RLC camera system, while Lynnwood earned 4.7 million in 2010 (Janati, 2012; King, 2012).

The earliest report on RLCs specifically investigated comes from Victoria, Australia, which studied data before and after the implementation fifty RLC sites in August 1983 with an equally sized control group (South 1988). Application of a study from another country may be somewhat dubious in so much as the variation of laws, vehicle style, traffic makeup, et cetera, may make the results inapplicable to another nation. Nevertheless, this may be the prototypical study, possesses useful rigor, and includes a companion study. The results included a reduction of angle accidents by more than 30 percent at treatment sites, an injury reduction rate of 10.4%, and a reduction in the number of violations from 35 to 60% depending on the site.

In 1995, a report by David Andreassen regarding the Melbourne, Australia RLC program referenced the 1988 South report, suggesting that the angle crashes do not actually significantly change (Andreassen, 1995). This report encompasses 41 camera sites in the city of Melbourne, using four years of before and after data, 1979-1983 and 1985-1989, ignoring the year of installation as one of transition. If one divides the sites into those with greater two accidents per

year and more than two, angle accidents were expected to decrease for two years then cease to change afterwards, whereas those with less than two should expect an increase in the post treatment period. Regardless of the number of accidents, Andreessen finds an increase in rear collisions post treatment greater than national trends. However, he also found that the average number of accidents at RLC treatment sites began at 2.3 times that of other signalized intersections, indicating the non-random nature of site selection – and this treatment did not lower them to or below average rates. The report concludes that there was not a reduction in accidents at RLC sites overall, that an increase in rear accidents occurred, but there were reliability issues regarding the VicRoad database which was the source for comparison sites.

A 2011 study by the IIHS suggested that if every city over 200,000 people were to utilize RLC systems, 815 deaths could have been prevented. This data was derived from a comparison between 14 cities with and 48 without RLC implementation during 2004-2008, comparing the per capita rate of fatal crashes at intersections with cameras and the total rate for cities without camera programs (Hu, 2011). They conclude that RLCs generated a larger reduction in both RLR fatality rates and total fatality rates at signalized intersections. In a peer reviewed critique of the IIHS study published in the Florida Public Health Review, found that the study was highly flawed, however (Langland-Orban, 2012). They found that the IIHS study had neither internal nor external validity, violates basic scientific research methods required for a study to be valid and did not explain the results of their analysis. In their own review of the data, cities using RLCs had 25% higher rate of red light running fatalities in the “after” period in which cameras were used, compared to the control groups. They consider the IIHS’ financial bias by their source of funding, automobile insurance companies and associations with “ambivalence towards

lowering crash costs” but a financial interest in traffic tickets as a means to raise rates.

A particularly long study, 5 years of before and 5 years of after data, in Australia found no overall decrease in accidents from RLC implementation (Andreassen, 1995). Low accident sites experienced more accidents, and high accident sites experienced less, evidence of a regression to mean effect. There was a relatively small reduction in pedestrian accidents at RLC sites, but it was more than offset by a doubling in the number of rear accidents.

Milazzo (2001) suggests that there may be high and low risk RLR events, separating the categories out into more than 1.0 seconds after the onset of red and more than 3.0 seconds after. The study suggests that the former poses little risk of causing an accident, though in this case there is a delay of 1.55 seconds (an “all red” phase which often does not exist at signalized intersections, but has a notable safety effect) before opposing traffic sees a green signal. Since this study is dependent on the green delay, it may not be applicable everywhere. Furthermore, Milazzo’s scope is relatively small – 34 instances of crashes at RLC intersections were studied, and none of them occurred less than 3 seconds after the signal change. Even if more research is needed to create a more robust data set, the suggestion exists that, even though RLR between one and three seconds is almost universally illegal (there is sometimes leeway below one second depending on the jurisdiction), some drivers may be justified in entering the intersection in that short-time window rather than abruptly stopping and risking a rear end accident instead. Drivers who enter an intersection more than three seconds after could be labeled inattentive, reckless or mistaken – and inattention and mistaken at least may be ameliorated with engineering such as signage.

Further consideration of the timing of RLC violations comes from Winn (1995). The

author found that about 70 percent of RLC violations had occurred within the initial second of a signal change, 29 percent from one to five seconds, and one percent longer than five seconds afterwards. After the RLC matured, the number of violations in the first five seconds was reduced by two thirds, though did not affect the longer post five second violations, which did not drop at all during the subsequent three years. These unresponsive longer violations are of the class of inattentive, reckless, or mistaken drivers mentioned by Milazzao and are the most dangerous.

Meta-analysis by Zaidel (2002) suggests a best estimate of the effects of RLCs generates a total eleven percent reduction in accidents. However, in his analysis he notes almost all studies failed to control for changes in design standards, safety improvements, biased selection of sites. Those that did control, such as the prior mentioned Andreassen, along with Kent (1995), found no safety improvement. Flannery (2002) found that only two US based studies used data on individual intersections along with traffic count and usable crash data. Retting's 2002 report on Oxnard, California's program is an often cited report in favor of RLC, which suggests a 7% reduction in injuries, 29% reduction in angle crashes, and a 3% increase in rear crashes. This report is cited by Zaidel and Flannery as insufficient. The study used 29 months of data and 11 cameras in Oxnard, with controls in Bakersfield, San Bernadino California, comparing signalized and non-signalized intersection crashes. However, aggregate data is used for the towns and did not account for traffic counts and the number and types of intersection variations between them. Furthermore, the towns grew at very different rates (from 7.89% in Santa Barbara to 41.32% in Bakersfield), and no accommodation for this change in growth, let alone changes in traffic volume, were considered. The effect attributed to RLCs by Retting in Oxnard is actually the

comparison in accident growth rate between these differing communities.

COUNTERMEASURES

Since multiple reports critical of RLC implementation suggested engineering alternative exist, literature on the possible alternatives ought to be considered. Engineering alternatives come in three flavors – signal operations, i.e. changing the timing and coordination of signals themselves, signal visibility, or enhancing the signage and visibility in reference to the lights and advanced engineering, costly means of modifying the actual geometry or functionality of the intersections.

Countermeasure	Effectiveness	Source
Increase yellow interval	Between 50-70% reduction in RLR	(Bonneson, 2003)
Extend green light via detection	Up to 65% reduction in RLR	(Williams, 1980)
Coordination of signals	Potential reduction (Unstudied %)	(Bonneson, 2004)

Countermeasure	Effectiveness	Source
Add LED signal lenses	54% reduction in RLR violations	(Bonneson, 2004)
Signage prior to intersection	67% reduction in RLR crashes	(Bonneson, 2003)
Widen signal lens from 8 to 12 inches	47% reduction in angle crashes	(McGee 2003)
Back plates added to signal head	32% reduction in angle crashes, 60% reduction in claims	(Polanis 2002)
Add additional signal	33% reduction in angle crashes	(Polanis 2002)
Strobe added to red light indicator	15% reduction in angle crashes	(Fitzsimmons 2007)

Table 4. Countermeasure effectiveness – advanced engineering		
Countermeasure	Effectiveness	Source
Removal of unneeded traffic signals	24% reduction in total crashes	(Retting, 1998)
Add an additional lane	Wide but positive variation	(Bonneson 2003)
Adjust curve geometry	Wide but positive variation	(Bonneson 2003)

LITERATURE REVIEW CONCLUSIONS

In general, many cases lack a proper control group to allow valid comparison of changes. Cameras also tend to be installed at problem locations with a higher than average crash experience, which may need to be tested for regression to mean, at least by the inclusion of control sites. There could be, after all, a statistical tendency for locations to be chosen because of their high crash histories, and they may have lower crash frequencies in subsequent years. And yet, it also must be noted that intersections may be resistant to the regression to mean effect in so much as the problem is persistent and structural – the higher rates of accidents at these sites are probably not a statistical anomaly and are rather a function of design and traffic volume, which may be controlled for somewhat.

A good experimental design evaluation would use a before and after design with a randomized control and treatment group. Signalized intersections would be split into two portions, one receiving treatment, one serving as control site, all other factors equal save for the implementation of the treatment. These groups would be essentially identical yet located far enough apart from each other to prevent a spillover effect from affecting the control group. Spillover effect is the expected effect of RLCs on intersections other than the ones actually treated because of jurisdiction-wide publicity and the general public's lack of knowledge where RLCs are installed (Council, 2005). In reality, control groups are often in the same city and subject to any potential spillover effect. Furthermore, control groups are not necessarily like the treatment groups, and often no means of accounting for those differences applied. Furthermore, random selection of treatment sites is unlikely, as the implementing bodies are governmental institutions which have chosen the treatment sites based on a metric, rather than randomly,

presumably the rate of accidents or the rate of violations at the site normally. With that in mind, a control group ought to be of the same sort chosen treatment, yet not having received treatment at the same time.

There are other measures of effectiveness, such as the rates of violations, the traffic conflicts or near misses, but crashes serve as the ultimate measure of safety effect, the strongest measure of effectiveness. A proper study should include both crash data and, where possible, supporting data such as traffic volume. It should consider the accuracy of the crash data – there may be errors in transferring the data, crashes can be linked to intersections they're not directly related to, and reporting can vary widely from state to state or city to city. Furthermore, the longer the period of data examined, the better, provided there have been no significant changes in conditions that would affect the occurrence of crashes at those intersections other than camera installation. These could include traffic volume, signal timing parameters and changes in law.

Law is problematic for these studies - 23 states have laws permitting RLCs, though in 20 of these states the fines assessed for an intersection violation differ by method of accusation - that is to say, an infraction processed by camera differs in penalty from one assessed by a police officer at the scene. Six states prohibit RLC usage, whereas the remainder have no state laws and often are host to programs with potentially tenuous legality - in Missouri, RLC programs enacted by cities were abolished by state court because no state law permitted their usage (Case 1122-CR00921). See table 18 in the appendix for a delineation of the widely varying state laws. If a study attempts to compare results in one state to another, or in some cases one city to another, the differing laws and their associated incentive systems must be considered.

As an alternative to a pure control group, a comparison group can be selected on the basis

of similarity. Yellow-length interval, number of through lanes, average daily traffic, and approach speed should be comparable between the two groups. If diverse, consider separate comparison groups. If you want to be more rigorous, the comparison intersections would be used to determine what the expected crash frequency would be at the treatment intersections had the cameras not been installed. However, there will be substantial differences between intersections – if the cameras were not randomly installed, the comparison intersections are not likely to be as ‘needy’ as the intersections that were selected (Council, 1997, 22) . An additional problem with the methodology is a spillover effect of the cameras to the intersections without the cameras (Retting, 1997, Persuad, 2001).

Simple before-and-after evaluations have been commonplace, consisting of measurements taken before the change and after a change. This also assumes crash frequency in the after period would have been the same in the before period had the camera not been installed. This requires less effort, but is a weak methodology and should be avoided if possible. Subjects may not, for instance, react simultaneously to a treatment or could exhibit unusual behaviors that bias the study. They may react in random or unstable fashions and factors other than the treatment may cause the changes in the measure of effectiveness. Measure of effectiveness may also mature or change over time, and regression to mean could occur.

Cross-sectional evaluations are not preferable, but compare the difference in crashes at an intersection or group of intersections with RLCs to a similar intersection or group of intersection without RLCs. Cross sectional would be used if crash data before cameras were installed are not available, are insufficient, or are problematic, but most RLC intersections have sufficient crash data history in order to support the installation of RLCs to begin with. Usually involves complex

modeling in which crashes are related to a variety of high-way features in a regression equation, which is beyond my scope, though can be found in (Persaud 2001). Difficulty in attributing differences in the crash experience of the two groups to the cameras can be problematic. Even the most complex of models cannot control for all of the factors, intersections must be similar in all elements that would affect crashes at the intersection (approach volumes, geometry, signal timing, turning treatments) except for the presence of RLCs.

Anecdotal reports, or only showing before and after without control for general trends or the like, do show a general trend of safety improvements at RLC treatment sites. There is evidence that engineering could also improve safety at intersections as well, by implementing an all-red period as in Milazzao's (2001) study, or potentially by any of the countermeasures cited in tables 2, 3 and 4. No study, however, was discovered that directly compared RLC implementation to an alternative program of any of these suggested countermeasures.

METHODOLOGY

This study uses before and after design with comparison sites and accompanying cost-benefit analysis based on accident cost data shown on table 2 (Council 2005). Two separate red light camera programs are examined, one in Chicago, Illinois, and the other in Lynnwood, Washington, with control sites in Bellingham, Washington. Treatment sites are those which have been fitted with RLC systems. In order to determine meaningful information from the data, comparison sites need to follow the same before and after period in time, in order to control for broader trends in accident rates. In order to account for a potential initial learning period, data at least two years before and after treatment beginning will be analyzed. The meaningful comparison will be the variance of rates between control and treatment sites, not the raw declines or increases at the sites, unlike the majority of data reported in the literature review. Codification of data when necessary was performed to ensure uniformity between sites in each example.

In order to conduct this research, the sites were selected according to their demographic, legal and traffic volume similarities with each other, in addition to availability of data for the number of years required. Chicago data was based off freedom of information act data originally made available through a Freedom of Information Act request by the Chicago Tribune (Specter, 2009). Reports do include KABCO, weather, and light data, but due to complexity the entries considered were only those under the heading of “Type of Crash”, “11-Rear end” and “15-Angle”, as these are the kinds directly attributable to RLR and RLC usage (see Appendix example). Those sites with inadequate before or after periods were eliminated, but recent sites with prior data concurrent with the treatment sites but not yet treated at the time were used as control sites for comparison to the initial RLC installation locations. In total, 96 treatment and

20 control sites could be derived from Chicago data. A broad set of overall accident trends for Chicago was acquired from IDOT annual report data, including the ratio of intersection to overall accidents for comparison's sake (IDOT 2012).

In Lynnwood, Washington, an initial 8 sites were installed in the city, available for research. A comparison of an additional 8 sites in Bellingham, Washington were chosen based on relatively similar traffic volume reported at those sites, in order to control for potential volume based differences. The distance between Bellingham and Lynnwood is significant enough to ensure that most residences of either town are unlikely to drive frequently in the other. Unlike in Chicago, this means that a local spillover effect is unlikely to spread to the control sites. And yet, colocation of the control states within Washington State was important, due to the uniform laws and characteristics of the state – RLC adoption was only recently permitted by law RCW 46.63.170 in July 2005, making their history and potential spillover effect recent issues (RCW 46.63.170, 2011). That is to say – few people had a chance to adapt their behavior to RLC presence before the sudden adoption beginning in 2005, meaning the population will not have been acculturated to their presence in a broad sense.

Accident types will be generalized into the rear and angle crashes, other kinds ignored due to attribution difficulties. Severity will be generalized as well because of the sheer rarity of the higher end accidents – a fatality is so rare as to essentially be a black swan event, occurring at a rate of about 0.2% to 0.4% of all intersection accidents (Retting, 1999; Smith, 2000). An expansive data set may be required to meaningfully account for specific severity, with that in mind, as a single K (fatal) level crash could dramatically skew results. Instead, as other studies have relied upon, the average costs of angle (\$64,468) and rear (\$53,659) will be used in a cost-

benefit analysis to determine the safety effect in terms of new average accident cost based on the changing ratio between the pair and total cost reduction, in order to make the results more generalizable (Council, 2005).

In order to meaningfully assess this data in light of the existing body of research, a literature review was performed, in which trends, gaps, and other deficiencies have been noted. The review is used to inform the resulting discussion and contextualize the results of the studies here performed. A second review of the legal variation from state to state was performed in order to further justify the choice in sites by congruence in law given how widely it varies (see table 18 in the appendix). The resulting synthesis is used to suggest additional policy issues and possibilities as regards RLC usage.

Concerns about validity stem from the relative paucity of sites in the Lynnwood data, though this is a function of the relatively recent adoption of the technology in Washington State and the necessity of multiple years of data post treatment. Concerns about the comparability of sites has been addressed by adoption from a list of sites being considered for possible RLC installation in Bellingham, however, and from that matching the volume between the sites as closely as possible, if only in the end year of the study not the beginning. External validity is complicated by the somewhat specific nature of laws from state to state governing the mechanics of red lights, intersection, driving behaviors, et cetera – these results may be most applicable to potential programs within Washington State. General concerns about the validity of cost-benefit data emerge from the unadjusted nature of the average accident costs (see Table 2). Adjusting these costs, however, ought not be done by following the general rate of inflation – the change in medical costs are more complex, for instance, and may exceed the broader rate.

CASE STUDY – WASHINGTON STATE

The results from Washington State are divided by treatment and control groups, and into the total accidents, angle accidents and rear end accidents, as a percentage of the prior time frame. Lynnwood installed its' cameras in 2007, having contracted American Traffic Solutions to install and maintain the systems (Halpert, 2010). Data from WSDOT was requested from 2 years prior to installation and extending two years post. Data for Bellingham was partially preexisting, having been derived from a Gibson Traffic Consultants report commissioned by the city in order to assess the viability of RLC implementation, and used sites being considered for treatment by the city, narrowed down in such a manner as to match the volume of the Lynnwood sites (Sky Valley Chronicle, 2012; Tables 14 and 15, appendix). Further data was then requested from WSDOT, and coded in the same manner.

WSDOT data came in the form of compiled accident reports for the interval and intersection requested, and needed to be coded. Figure 3 in the appendix shows an example of such a report – the relevant data is under collision type, where only those explicitly labeled rear or angle are considered. Tables 14 and 15 in the appendix are a compilation of this data, and show the raw numbers involved. Table 5 shows the percentage rate of total, angle and rear end accidents two years after treatment as compared to two years prior, averaged.

	Total	Angle Crashes	Rear End
Lynnwood (Treatment – 8 intersections)	93.51% of prior	84.74% of prior	108.88% of prior
Bellingham (Control – 8 intersections)	89.82% of prior	89.02% of prior	90.42% of prior
Difference	3.69%	4.28%	18.46%

Table 6 compares the change in ratio of rear to angle accidents in order to gauge a change the average cost of an accident at the intersections on average. Furthermore, it presents the total reduction in cost, which is a function of the change in total accident numbers to the change in average cost of the accident. Average costs by accident type are delineated on Table 2, and represent unadjusted 2005 dollar prices, the most recent data available at this time (Council 2005). Adjusting to present day dollars presents a difficulty in so much as average crash costs are unlikely to follow the overall rate of inflation, given the steeper variations of medical costs during recent time periods.

	Change in average cost of accident	Total reduction in costs
Lynnwood (Treatment)	-\$2,536	8.9%
Bellingham (Control)	-\$914	9.2%
Difference	1,622	0.3%

	Average traffic volume per day per intersection
Lynnwood (Treatment)	19,875
Bellingham (Control)	20,338
Difference	443

While differences may exist that no data is available for between Bellingham and Lynnwood sites, the difference in average traffic rates between the sites specifically amounts to 443 additional cars in Bellingham per intersection per day, or 102% of Lynnwood's volume (Table 7). Of the sites available in Bellingham, these intersections most closely matched the volume levels, not just on an overall level, but individually between intersections as well. This may be important in so much as the rate of accidents at intersections as related to the volume, though not a complete correlation, is not linear (Persaud, 2001). See tables 14 and 15 in the appendix to review WSDOT data for the most recent year of the study for each intersection.

CASE STUDY – CHICAGO SYSTEM

The results from Chicago are divided by treatment and control groups, and into the total accidents, angle accidents and rear end accidents, as a percentage of the prior time frame.

Chicago installed its' cameras beginning in 2006, having contracted Redflex Traffic Systems to install and maintain the systems (CBS Chicago, 2012). Data from the IDOT was made available to the Chicago Tribune, which in turn links to them in their raw form (Specter, 2009). Data from sites now possessing RLC systems but not during the duration of the two year before and after periods of the 96 (out of 190 available as of 2012) here studied was used to form the control group. No data exists regarding the volume of traffic at these intersections, which represents a deficiency in control site selection, in addition to the vulnerability of control sites to spillover effects. However, they're highly alike in so much as they derive from the same jurisdiction, and were all sites ultimately chosen for treatment, presumably either by the level of violations or the level of accidents at those sites.

Table 8 shows the percentage rate of total, angle and rear end accidents two years after treatment as compared to two years prior, averaged.

	Total	Angle Crashes	Rear Crashes
Treatment (96 sites)	94.69% of prior	71.88% of original	124.92% of original
Control (20 sites)	96.24% of prior	85.22% of original	105.58% of original
Difference	1.55%	13.34%	19.34%

Table 9 compares the change in ratio of rear to angle accidents in order to gauge a change the average cost of an accident at the intersections on average. Furthermore, it presents the total

reduction in cost, which is a function of the change in total accident numbers to the change in average cost of the accident. Average costs by accident type are delineated on Table 2, and represent unadjusted 2005 dollar prices, the most recent data available at this time (Council 2005). Adjusting to present day dollars presents a difficulty in so much as average crash costs are unlikely to follow the overall rate of inflation, given the steeper variations of medical costs during recent time periods.

	Change in average cost of accident	Total reduction in costs
Treatment (96 sites)	-\$3,266	9.08%
Control (20 sites)	-\$2,562	0.99%
Difference	704	8.09%

Table 10 represents the overall trend in crashes in the Chicago area beginning at the first year of RLC treatment, and is derived from raw IDOT data, which in turn references the NHTSA’s FARS system (IDOT, 2012).

Year	Total Crashes	Intersection Crashes	% of Total
2006	141,204	36,861	26.1
2007	135,545	30,497	22.5
2008	127,104	30,295	23.83
2009	111,705	35,546	31.82
2010	102,072	32,961	32.29

See tables 15 and 16 in the appendix to review WSDOT data for the most recent year of the study for each intersection.

DISCUSSION – RESULTS

Over the course of four years in both studies both control and treatment sites in both Chicago and Washington State studies experienced a decline in overall accident rates. In a more general sense, accident rates have been declining in the United States continuously since record keeping began in the 1920s. According to the NHTSA, even the absolute number of crashes has been falling since 1972, further lowering the ratio (Longthorne, 2008). This is to say we should expect, in general, a decline in the rate of accidents in most studies, all things being equal.

What ought to then matter is the difference in the rate of change between the control and the treatment sites. A supposition about the efficacy of RLC systems is that they may increase rear accidents and decrease angle accidents, but even if there is no overall decline in the total number of incidents, due to the differing general severity of those categories there may be a positive cost benefit. Inherent in the cost benefit analysis is the assumption that, since medical costs are an integral part of the average costs, greater damage to health is correlated with the greater costs incurred. In this way, the cost benefit analysis extends to a safety effect, even though discovering the direct costs in health and life lost are beyond the scope of this study due to the overwhelming data requirements involved. As estimates of fatalities caused by red light running are between about 700 and 1200 per year, or 0.2% to 0.4% of all intersection accidents – in order to determine the number of lives saved by RLC intervention, one needs to extrapolate results to a grand scale (Retting, 1999; Smith, 2000). Nevertheless, though relatively few fatal accidents occur out of all RLR accidents, they are disproportionately those of angle accidents, as vanishingly few rear accidents are fatal even in comparison, a fact which contributes to their higher than average cost (Council, 2005). When a decrease in angle accidents compared to rear

accident occurs, a potential remains that a life may be saved by this means of intervention.

There are discrepancies in the ratio in which this change occurs between Washington State and Chicago, but one also must consider the nature of the control sites in such an analysis. In Chicago, if drivers are reacting in a broad sense to RLC installation rather than purely strategically changing their behavior at the treatment intersections, then we may see evidence of a spillover effect, a phenomenon suggested in alternate studies (Council, 2005). Other issues confounding easy comparison between Chicago and the Washington study include variation in law, ticketing rates and the suburban versus urban venue of the cameras, which cannot easily be controlled for. That having been said, it's conceivable that, as the total accidents at control versus treatment sites present opposing results, a portion of the explanation may be part of the spillover effect. Chicago's control sites had 1.55% more accidents relative to the treatment sites, in terms of their rate of change from prior and post periods, whereas the control in Washington, Bellingham, had 3.69% fewer accidents in total. A change in population is not an issue in Chicago, either, because this is relative – and in the case of Washington, the change in population should have been in Lynnwood's favor, in so much as Bellingham is increasing in population at a far more rapid pace (20% in 10 years versus 4%) (City-data.com, 2012). RLC sites may still provoke a stronger reaction and level of caution when known, and yet may change driving behavior across the region, evening out the effects – it could be that we see that taking place in Chicago.

Further suggesting this effect is the way the ratio changes in Chicago versus Washington between treatment and control – the ratio of angle to rear accidents changes very little in Bellingham compared to a much greater spread in Lynnwood, which we should expect if RLCs

affect accident types as the literature suggests. Were the control sites in Chicago not subject to a spillover effect, one should anticipate very little change in the ratio – but instead, there is a large gap, and even though the total level of accidents decline, rear end accidents actually increase in the same period. Interestingly, as seen in Table 10, the total number of crashes in Chicago has naturally been on the decline as well, though at a much greater rate than either the treatment or control sites – 27% fewer crashes overall, versus between 6-4% fewer crashes at intersections. As a percentage of the total, the number of intersections crashes expanded from 26.1 to 32.29%, though not without an initial decline to 22.5% after the first year. This effect was not anticipated in the literature explicitly – it could be worthy of further examination. Perhaps changes at intersections due to RLCs are illusory if the general trend is being defied in an undesired way by RLC implementation – could Chicago have seen even fewer intersection crashes without them? Or, perhaps RLC systems somehow reduce accidents other than intersection accidents, through some unthought-of means?

If overall accident rates are higher with RLC implementation than they would be without it, this would seem to match the experience in Washington, assuming there are no grand confounding factors between Bellingham and Lynnwood. The Lynnwood sites do see a greater ratio change, which in turn sees the average cost per accident decline in comparison to Bellingham. And yet, since Bellingham experienced a greater total decrease in accidents, the overall reduction in costs according to this analysis was greater there. If the Lynnwood study had included intersections within the city itself, it would have been instructed to see if they followed a pattern similar to Chicago, in which case the gap between total change in costs between Lynnwood and Bellingham may be greater still. If this is the case, and safety effect as

represented by cost-benefit analysis is the result, perhaps alternatives to RLC systems ought to be considered first.

DISCUSSION – OTHER COSTS

There is a great deficiency in limiting the discussion to safety and cost-benefit effects when trying to determine the value of RLC systems. The analysis relies on past research on the direct financial costs of the treatment, which is very narrow criteria, but one which is accessible to many of the standards of scientific scrutiny commonly considered testable. But it has largely left the following question unanswered – are there intangible elements in the realm of ethics, as opposed to the purely tangible financial and health based benefits? And even in the realm of the financial, should the role of finances and fees be considered as well?

No scientific literature attempted to address the financial motives of the companies and governmental bodies involved in RLC usage, though there are inherently implications to the revenue of all the entities involved. And yet, no city or governmental statement could be found in the course of this research which stated revenue from cameras was a consideration for their usage. Drivers as well, be they those who receive the fine or not, have a stake in RLC implementation – financially, any recorded infractions are naturally transfers of money from the driver to the corporation and agency with policing authority, while all drivers may suffer a psychological unease from being monitored. RLC implementation could also have effects on traffic rates, be they through generally changed behavior or the rates of accidents, which may affect the freedom of movement for all involved.

At the start of 2011, in Redmond, Washington, the city implemented four RLC cameras at prominent intersections (Hefter, 2012). In response, Redmond Initiative 1#, indicating that it was the first ever initiative to be brought to the city voters, collected 6,050 signatures of 3,845 needed to be on the ballot (Eyman, 2011). This initiative would have prevented Redmond from

employing RLC systems, and mirrored prior initiatives throughout the state, such as one in Mukilteo Washington which passed with greater than 2/3rds majority (71%). This appears to be a fairly strong reaction to the cameras – but why?

Privacy and civil liberties are cited as being violated by the “practice of photographing drivers and declaring them guilty before they can defend themselves,” according to the Redmond initiative group (Hefter, 2011). They additionally worry that law enforcement, a core responsibility of government, is being handled here by an out-of-state (in this instance) for-profit industry, whose interests may not lay impartially on safety but on naturally on profit. A concern was expressed that cameras threaten the credibility of cities and police officers by subverting law to profit and revenue motives at the expense of drivers. Since the notably deficient research had been a prior check to the adoption of RLCs before, the present, expanded rate of adoption could be driven in part by revenue concerns (McLean, 2003; Biller, 2012).

In response to the initiative, the mayor and city council of Redmond decided that they would not accept it, as the state constitution gave the right to determine traffic issues to the cities rather than the people (Moran, 2011). However, with the initiative stopped, the city decided to end their contract with American Traffic Solutions, citing no significant change in the safety of the intersections in question (Marchione, 2011). The Washington State Supreme Court subsequently agreed with Redmond’s assessment, though through striking down the mentioned initiative in Mukilteo, which in turn invalidated successful initiatives in Longview, Monroe and six other towns (Hefter, 2012). While this has been settled de-jure, it seems clear that through the multiple successful initiatives, a public concern lost an avenue of being voiced.

After installation of cameras, it is often difficult for a town to remove them later due to

the revenue generated through fines, Redmond notwithstanding.

Lynnwood, the city hosting the Washington treatment sites in this study, earns the equivalent of \$14.73 per month per resident from its' RLC systems, though it can be assumed that much of that revenue comes from out of city individuals passing through (King, 2012). This accounted for more than 15% of the 2010 city budget for Lynnwood, though communities around it collected 1-5% of their revenue in traffic fines as a whole, for comparison (King, 2011). There is anecdotal evidence that the cameras affect the wellbeing of Lynnwood businesses. *"What I'm hearing from folks, both inside and outside of Lynnwood, is people don't have a positive feeling about red light cameras,"* said Lynnwood councilwoman Kerri Loneran-Dreke in an interview with Lynnwood Today (Murphy, 2012). *"We've had a lot of folks who have written to us, saying 'we will no longer come to Lynnwood; we won't shop in Lynnwood.'"*

A former councilman, Jim Smith, believed the city could not now remove the RLC program if it wanted to, due to their reliance on the revenue generated by it (King, 2012). *"It's not how it was supposed to be,"* he said. *"It was supposed to be totally for the sake of public safety. Now the cameras can't just be cut off. It's like a heroin addict; you have to wean them off slowly with other means."* Smith also does not believe that a single life has been saved by the systems since their inception, based on the data he saw on the city council. Though anecdotal, this may be the seed of a question which should be rigorously investigated.

Part of that seed may arise from the kind of violation most often caught – those occurring 0.2-0.3 seconds after the turning of the signal (Thill, 2010). Milazzao (2001) and Winn (1995) noted that the majority of accidents occurred well after that time period, most dangerously five seconds out from the turning of the light, and those were the kinds of violations causing the

worst and most frequent RLR crashes. If safety effect was the sole concern, then perhaps there would be universal grace periods in RLC camera systems for those first few seconds. Yet, it may be difficult to argue that, in the face of a very deontological view which may be expressed by proponents. *"Yet red light runners are law breakers, so why should we be concerned any more about their privacy than that of a thief caught in the act of a holdup,"* professed Richard Retting (author of numerous studies on RLCs) in the Detroit News (Laurie, 2001).

Revenue issues may encourage cities to ignore safety issues in favor of revenue generation, and such events have been reported. Chattanooga, Tennessee, Dallas, Texas, Springfield, Missouri, Lubbock, Texas, Nashville, Tennessee and Union City California have been explicitly caught adjusting the yellow light timing at RLC sites, shortening durations in order to increase the level of fines generated in spite of safety concerns (Thill, 2010).

ALTERNATIVE POLICY POSSIBILITIES

Since multiple reports critical of RLC implementation suggested engineering alternative exist, literature on the possible alternatives ought to be considered. Engineering alternatives come in three flavors – signal operations, i.e. changing the timing and coordination of signals themselves, signal visibility, or enhancing the signage and visibility in reference to the lights and advanced engineering, costly means of modifying the actual geometry or functionality of the intersections. As well, if signals are not set properly, optimizing change intervals to the time determined using the ITE formula is a very low cost countermeasure and very effective. It is critical to the success of any potential red-light camera program.

Countermeasure	Effectiveness	Source
Increase yellow interval	Between 50-70% reduction in RLR	(Bonneson, 2003)
Extend green light via detection	Up to 65% reduction in RLR	(Williams, 1980)
Coordination of signals	Potential reduction (Unstudied %)	(Bonneson, 2004)

Table 12. Countermeasure effectiveness – signal visibility		
Countermeasure	Effectiveness	Source
Add LED signal lenses	54% reduction in RLR violations	(Bonneson, 2004)
Signage prior to intersection	67% reduction in RLR crashes	(Bonneson, 2003)
Widen signal lens from 8 to 12 inches	47% reduction in angle crashes	(McGee 2003)
Back plates added to signal head	32% reduction in angle crashes, 60% reduction in claims	(Polanis 2002)
Add additional signal	33% reduction in angle crashes	(Polanis 2002)
Strobe added to red light indicator	15% reduction in angle crashes	(Fitzsimmons 2007)

Table 13. Countermeasure effectiveness – advanced engineering		
Countermeasure	Effectiveness	Source
Removal of unneeded traffic signals	24% reduction in total crashes	(Retting, 1998)
Add an additional lane	Wide but positive variation	(Bonneson 2003)
Adjust curve geometry	Wide but positive variation	(Bonneson 2003)

CONCLUSIONS

Though there is an extant and growing body of literature regarding the efficacy of RLC programs there is little agreement and a paucity of rigor in research methods. Lack of clear research and standards may have prevented the United States from adopting such programs widely and consistently, though they are becoming more prevalent (McGee, 2003). Since states are free to set their own laws regarding RLC usage no consistent legal format has emerged. 23 states have laws permitting RLCs, though in 20 of these states the fines assessed for an intersection violation differ by method of accusation - that is to say, an infraction processed by camera differs in penalty from one assessed by a police officer at the scene. Six states prohibit RLC usage, whereas the others have no state laws and often are host to programs with potentially tenuous legality - in Missouri, RLC programs enacted by cities were abolished by state court because no state law permitted their usage (Case 1122-CR00921). See table 18 in the appendix for a delineation of the widely varying state laws. This inconsistency potentially confounds data studied between two states, including that in this report – however compartmentalized, perhaps the results would be different based on the influence of the differing laws between the two states, if all else had been equal.

Nevertheless, both control and treatment sites in both Chicago and Washington State studies experienced a decline in overall accident rates, though this must be balanced against the overall national decline which is at least partially independent of RLC programs due to their inconsistent application. If a reduction in more dangerous angle accidents can be attributed to RLCs, and that reduction outweighs any subsequent increase in rear accidents, a case may be made that the cameras have an overall positive safety benefit. In Washington, the control sites

saw a greater overall decline in accidents to the treatment sites. The ratio of rear to angle accidents did change to a less damaging mix at the treatment sites, but it was not enough to overcome the greater decline at control sites over this time period. Chicago did see a greater decline overall at treatment sites, though this is subject to potential spillover effects due to the colocation of treatment and control sites within the same locale.

In Chicago, control sites had 1.55% more accidents relative to the treatment sites, in terms of their rate of change from prior and post periods, whereas the control in Washington, Bellingham, had 3.69% fewer accidents in total. This speaks to the potential spillover effect - RLC sites may still provoke a stronger reaction and level of caution when known, and yet may change driving behavior across the region, evening out the effects – it could be that we see that taking place in Chicago. In Washington, the control and treatment sites were far enough apart to potentially control for spillover effect, and as such it's notable that the treatment sites experienced a smaller decrease in total accidents. In Chicago, the rate of intersection accidents as a ratio of total accidents increased from 26.1 to 32.29, possibly indicating a trend defying the overall decline and worsening the overall rate of accidents in comparison to what they could have been without RLCs (See table 10). It may be worth comparing Chicago to another control city in Illinois, to see if the relative change in overall intersection accidents is slower in the treatment city, as with the Washington example.

Further studies should include control groups as this one did while striving for increased breadth in sites and times studied. There are myriad confounding factors to consider, however – the complexity of intersections in general may require either incredibly precise site location, or a large enough group of intersections to create a representative sample. The relative newness of

RLC implementation in Washington State limited the number of treatment sites greatly, as the years of data required narrowed the number of acceptable candidates. Chicago is more ideal in that respect, having about a dozen times more treatment sites. Chicago would have benefited from three sets of data, however – one direct treatment, one indirect treatment (which the control in this study in effect is, due to colocation within the city) for spillover effects, and one control in an alternate city far away but subject to the same laws and similar or identical traffic patterns.

Limitations in data do narrow what researchers may accomplish, however – data collection is widely varied from place to place, and may even vary in quality and reporting methods, which may in turn confound results or at least comparisons from one study to others in different locations. The ideal study may include truly random treatment and control groups, which in the case of treatment has never occurred – RLC sites are chosen for particular reasons, such as volume or crash rates. The logistical problems of committing such a study are myriad – expense, legality, and the moral issues how the study will affect drivers at the test intersection would need to be considered. As such, it seems likely that any further research will be limited to existing sites and by varying reporting methods and laws, requiring more complex or narrowly focused research designs.

The results of the data here do not suggest there is a strong or clear safety rationale for the usage of RLCs. The literature reports conflicting findings and does not provide an overwhelming trend, especially in light of their limitations, in favor of implementation. Neither does the data condemn usage directly – more study is clearly required to get a better picture of the actual effects of the cameras. Yet, since the potential for decreased safety exists as well, it ought to behoove jurisdictions seeking to improve conditions at intersections to refrain from

experimenting with the cameras until more conclusive research can be done. Instead they may consider the many alternate means of improving intersection safety, which may potentially be more efficacious and cheaper (see Tables 11-13).

It may be worthwhile to attempt to study the ethical dimensions of RLC implementation as well. Revenue generation occurs with the implementation of these systems, and in some cases communities may become reliant on the funds generated by cameras, as in Lynnwood. It could be that communities may structure laws, fines, and even roadways in order to meet revenue rather than safety goals – a potentially perverse incentive. There are extant examples of municipalities changing yellow light timing at RLC intersections in a manner which may increase the number of fines issued, though to prove a financial rationale for such changes may be difficult. A potential study may measure yellow light timing, for instance, at RLC sites before and after implementation over a wide number of cities, to see if there is any systemic pattern of changes.

20 of the 23 states with legal structures for RLC implementation differentiate the penalty for infractions assessed by the cameras versus those by police officers – does the differing legal structure change the efficacy of the cameras themselves? Is there an ethical dimension to be explored when the same crime is punished differently from based on this method? Is there an effect on safety when the law varies from state to state and community to community – are drivers affected by this legal complexity and uncertainty? Also largely unstudied are the personal reactions to RLCs – there have been multiple successful initiatives, for instance, in Washington state to prohibit the local use of such systems. Survey and other studies may be useful to shed light on the public’s rationale for opposition, regardless of actual efficacy. With

that in mind, it may be recommended that cities refrain from further RLC implementation and research be implemented to further assess the efficacy and the implications these systems.

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APPENDICES

Figure 3. Example WSDOT report

STATE ROUTE: 539		STATE OF WASHINGTON - DEPARTMENT OF TRANSPORTATION STANDARD COLLISION HISTORY DETAIL REPORT SORTED BY SR/SRMP/DATE										DATE TIME 08/31/11 07:38 AM	Page 1 of 10
SRMP: 0.08 to 0.14												UNDER 23 UNITED STATES CODE - SECTION 409, THIS DATA CANNOT BE USED IN DISCOVERY OR AS EVIDENCE AT TRIAL IN ANY ACTION FOR DAMAGES AGAINST THE WSDOT, OR ANY JURISDICTIONS INVOLVED IN THE DATA	
Date Range: 01/01/01 to 12/31/10		TOTAL NUMBER OF COLLISIONS: 217											
AT TELEGRAPH ROAD													
*As of 1/1/2009 Citizen Reports are no longer being captured (Report # begins with "C")													
STATE ROUTE	SRMP	A *ACCDNT / REPORT NUMBER	DIAGRAM ANALYSIS DATA	M # # S # I F V J J T H	VEH1 TYPE	VEH2 TYPE	U U I N R T C F E	FIRST COLLISION TYPE / OBJECT STRUCK	UNIT 1 CONTR CIRCUMSTANCE 1	UNIT 2 CONTR CIRCUMSTANCE 1			
539	0.08	1826882	03/19/05 16:33 5BA065BQD1	1 0 0 2	2	2	1 2 1	From same direction - both going straight - one stopped - rear-end	Inattention	None			
539	0.08	2594236	03/26/09 17:29 1AA061AQA1	7 1 0 2	2	1	4 1 1	From same direction - both going straight - one stopped - rear-end	Follow Too Closely	None			
539	0.08	3219285	11/09/09 15:06 1AS051ASA3	1 0 0 2	1	1	4 2 1	From same direction - both going straight - both moving - sideswipe	Did Not Grant RW to Vehicle	None			
539	0.08	3217958	06/20/10 16:14 1AA061AAA1	1 0 0 3	2	0	4 1 1	From same direction - both going straight - both moving - rear-end	None	Other			
539	0.09	1874015	05/08/04 21:45 7BC33000D9	1 0 0 1	1		3 1 4	Curb, Raised Traffic Island or Raised Median Curb	Improper Turn				
539	0.10	1148982	01/08/02 11:39 5BA065BQD3	1 0 0 2	1	1	4 2 1	From same direction - both going straight - one stopped - rear-end	Inattention	None			
539	0.11	1157417	01/23/01 10:35 1AA061AQA2	7 1 0 2			1 1 1	From same direction - both going straight - one stopped - rear-end	Follow Too Closely	None			
539	0.11	0821066	03/03/01 16:25 5BA065BQD1	7 1 0 2			1 1 1	From same direction - both going straight - one stopped - rear-end	None	Follow Too Closely			

Table 14. Violation and collision rates at RLC intersections, Lynnwood Wa.

Intersection	Average Violations Per Month (Total Angle, Total Rear Collisions in Year)				
	2 year prior	1 year prior	1 year post	2 year post	Average Daily Traffic (2010)
196th Street SW and Highway 99	ND (2, 20)	ND (2, 21)	175.1 (4, 18)	146.9 (4, 23)	23,000
196th Street SW and 36th Avenue W	ND (2, 9)	ND (5, 15)	66.1 (1, 11)	56.0 (4, 12)	14,000
Alderwood Mall Boulevard at 200th Street SW and 44th Avenue W	ND (3, 10)	ND (3, 11)	400.2 (1, 14)	292.2 (1, 12)	21,000
176th Street SW and Highway 99	ND (1, 6)	ND (2, 9)	148.7 (2, 11)	124.9 (0, 11)	22,000
44th Avenue W and 196th St. SW.	ND (4, 10)	ND (2, 12)	114.8 (5, 20)	89.2 (2, 16)	6,000

Westbound Maple Road at Alderwood Mall Parkway	ND (4, 7)	ND (3, 10)	337.0 (0, 8)	310.1 (0, 7)	33,000
Eastbound 184th St. SW and Alderwood Mall Parkway	ND (1, 6)	ND (1, 12)	160.0 (0, 12)	118.8 (3, 9)	19,000
Eastbound 200th St. SW and 44th Ave. W.	ND (3, 10)	ND (3, 11)	45.5 (1, 14)	38.5 (1, 12)	21,000
Averages	ND (2.5, 9.75)	ND (2.6, 9.5)	149.2 (2.5, 12.65)	121.4 (2.2, 10.5)	19,875

Intersection	Total Angle, Total Rear Collisions in Year				
	2 year prior	1 year prior	1 year post	2 year post	Average Daily Traffic (2010)
SR539 After Jct Horton Rd	(2, 10)	(0, 12)	(3, 10)	(1, 6)	23,000
SR539 After Jct Front St	(4, 9)	(1, 10)	(3, 11)	(3, 9)	14,000
SR539 After Jct Kelly Rd	(5, 19)	(3, 22)	(4, 20)	(5, 19)	23,000
SR542 Before Jct Woburn St*Hannegan Rd	(0, 11)	(3, 10)	(2, 10)	(3, 13)	23,000
SR542 After Jct Sand Rd	(2, 19)	(0, 15)	(2, 12)	(1, 15)	7,700
SR539 at SR 5 SB*BEG Route	(4, 22)	(5, 24)	(2, 20)	(3, 19)	36,000
SR539 Before Jct Front St.	(1, 9)	(2, 9)	(1, 11)	(0, 9)	18,000
SR539 After Jct E Laurel Rd	(2, 11)	(1, 10)	(4, 10)	(1, 10)	18,000
Averages	(2.5, 13.85)	(2.4, 13.5)	2.6, 12.95)	(2.3, 12.1)	20,338

Intersection	Angle, Rear, and Total Collisions in Year								
	Two years prior (avg)			Two years after (avg)			Change %		
	Total	Angle	Rear	Total	Angle	Rear	Total	Angle	Rear
Halsted-Fullerton-Lincoln	26	4.5	6	33.5	2	11.5	128.85	44.44	191.67

Ashland-Lawrence	16.5	2	6	26	3.5	11.5	157.58	175	191.67
Western-Montrose	16.5	6.35	4.5	19.5	3.5	8.5	118.18	53.85	188.98
Kedzie-Irving Park	14	2.5	4.5	19	4	8.5	118.18	53.85	118.89
Cicero-Peterson	18	3	2.5	24	3	11.5	133.33	100	460
California-Irving Park	15	6	2.5	16.5	1.5	8	110	25	320
Ashland-Irving Park	21.5	3.5	5.5	24	2	11	11.63	57.14	200
Western-Lawrence	23	3.5	8	27.5	2	13.5	119.57	57.14	168.75
Western-Devon	20.5	3	7	31	2	12	151.22	66.67	171.43
Pulaski-Lawrence	16	3.5	3	18	2	6.5	112.50	57.14	216.67
Kimball-Lincoln	15	3.5	5	22	3	11.5	146.67	85.71	230
Elston-Foster	11.5	5.5	3.5	10.5	0.5	6	91.3	9.09	171.43
California-Devon	16.5	3	5	13.5	2.5	3.5	81.82	83.33	70
Clark-Ridge	17	3	3.5	31.5	4	16	185.29	133.33	457.14
Clark-Irving Park	10.5	3	5	16.5	2	5.5	157.14	66.67	110
Western-Diversey-Elston	33	10	10	34	5.5	11.5	103.03	55	115
Western-Armitage-Milwaukee	17.5	2.5	6	16	5	6	91.43	200	100
Damen-Diversey-Clybourn	23.5	5	4.5	26.5	5.5	8	112.77	110	177.78
Central-Irving Park	17	2.5	6	20.5	3.5	10	12.59	140	166.67
Austin-Irving Park	18	2	5.5	16	3	7	88.89	150	127.27
Laramie-Fullerton	18.5	6	6.5	25	3	7.5	135.14	50	115.38
Austin-Diversey	17	6.5	1	16.5	2.5	3.5	97.06	38.46	350
Austin-Addison	16.5	4.5	4.5	12.5	5	3.5	75.76	111.11	77.78
Lake Shore Nb-Belmont	12.5	3.5	2.5	11.5	2	2.5	92	57.14	100
King-31St	22	8	3.5	18	5.5	5	81.82	68.75	142.86
Clark-Cermak	21	4	2.5	16.5	1.5	3.5	78.57	37.5	140

Halsted-Roosevelt	18	2	5.5	30	2.5	12	166.67	125	218.18
Halsted-Madison	15	4	2	17	2	3	113.33	50	150
Cicero-Washington	18.5	8	4.5	15.5	2.5	9.5	83.78	31.25	211.11
Western-Van Buren	9.5	2.5	1.5	15	4	2	157.89	160	133.33
Pulaski-Armitage	13.5	5	2.5	11.5	2.5	1.5	85.19	50	60
Hamlin-Lake	13	3.5	2	16	3.5	4	123.08	100	200
Damen-63Rd	12	3	0.5	13	2	5	108.33	66.67	1000
Cicero-North	27.5	5.5	7.5	29	6	10	105.45	109.09	133.33
Halsted-115Th	19	6.5	2.5	20.5	5.5	3.5	107.89	84.62	140
Kostner-Ogden	18.5	6.5	3	20	5	2.5	108.11	76.92	83.33
Kedzie-31St	19.5	5.5	1	19.5	7	3	100	127.27	300
Western-Pershing - Western Blvd	41.5	15.5	4	48.5	9	14.5	116.87	58.06	362.5
California-35Th	13	2.5	0.5	10.5	1	4	80.77	40	800
Stony Island-83 Rd	15	6	4	16.5	2.5	8	110	41.67	200
Ashland-Garfield	15	4	2.5	13.5	3.5	3.5	90	87.5	140
Halsted-95Th	23	7.5	5	29	5	9.5	126.09	66.67	190
Halsted-79Th	17.5	3	4.5	20	4	6.5	114.29	133.33	144.44
Cottage Grove-71St-South Chicago	22	4	8	16	3	3.5	72.73	75	43.75
Halsted-Belmont	16.5	5.5	2.5	15	1	6	90.91	18.18	240
Cicero-47Th	21	5	5.5	36	7.5	15	171.43	150	272.73
Kedzie-47th	23	5	5.5	22	2.5	6.5	95.65	50	118.18
Ashland-Roosevelt	21	5	6	27	3	12	128.57	60	200
Sheridan-Foster	11	3.5	2	9.5	1.5	1	86.36	42.86	50
Ashland-63rd	17	2.5	3.5	19.5	2.5	6.5	114.71	100	185.71
Western-North	25	3	6.5	35	6	8.5	100	200	130.77
Vincennes-111th	14	3.5	3.5	13	5	3.5	92.86	142.86	100
Stony Island-Cornell-67th	19.5	3	7	22	4.5	8	112.82	150	114.29
Kedzie-63rd	15	2.5	2.5	11.5	1.5	5	76.67	60	200
Jeffery-95th	24.5	8.5	5.5	23.5	3.5	7.5	95.92	41.18	136.36
Cicero-Archer	20	4.5	6.5	28	8.5	10.5	140	188.89	161.54
Western-63rd	19	3.5	6	21	3.5	7.5	110.53	100	125
Western-Irving Park	30	8	9.5	35	4.5	16.5	116.67	56.25	173.68

Pulaski-Archer-50th	20	7	8	17	2.5	6.5	85	35.71	81.25
Narrgansett-55th-Archer	17.5	4.5	5	17.5	1.5	7	100	33.33	140
Ashland-Division	21	8	6	20	1	6.5	95.24	12.5	108.33
Elston-Addison	18.5	4.5	4	18	4	7.5	97.3	88.89	187.5
Sheridan-Hollywood	33.5	6.5	7.5	32	1.5	10.5	95.52	23.08	140
Pulaski-Foster	19	3	6	20.5	3	8	107.89	100	133.33
Broadway-Sheridan-Devon	21.5	3	3.5	29	2.5	9.5	134.88	83.33	271.43
Broadway-Foster	17.5	6.5	3.5	16.5	1.5	6	94.29	23.08	171.43
Homan-Kimball-North	15	6.5	2.5	16.5	3	5.5	110	46.15	220
Cicero-Chicago	26	4	4	26.5	4	8.5	101.92	100	212.5
Central-Fullerton	27.5	7.5	5.5	18	4.5	6	65.45	60	109.9
Ashland-Archer	22	10.5	2.5	13.5	2	6	61.36	19.05	240
Clark-Fullerton	15	1.5	1.5	11.5	2.5	2.5	76.67	166.67	166.67
Harlem-Northwest Highway	16.5	3.5	7	18.5	3	7.5	12.12	85.71	107.14
Harlem-Belmont	25.5	4.5	9.5	23.5	4.5	10	92.16	100	105.26
Western-Foster	27	5	7.5	28	6.5	12	103.7	130	160
Pulaski-Fullerton	26.5	6.5	3	19	1.5	4.5	71.7	23.08	150
Pulaski-Belmont	27	9	5	18.5	3	6.5	68.52	33.33	130
Cicero-Belmont	25.5	5.5	10.5	25	4	11.5	98.04	72.73	109.52
Austin-Belmont	19.5	8.5	3	16	5	5.5	82.05	58.82	183.33
Western-Chicago	11.5	2.5	2.5	11.5	2	2.5	100	80	100
Western-79th	26.5	9	3	16.5	3.5	4.5	62.26	38.89	150
Western-51st	25	8.5	4	18.5	5	4	74	58.82	100
Stony Island-79th-South Chicago	86	23.5	20.5	69	18	25	80.23	76.6	121.95
Cottage Grove-79th	15.5	2.5	2.5	14.5	2.5	2	93.55	100	80
Pulaski-63rd	24	6	6	14.5	3	4	60.42	50	66.67
Ashland-87th	22.5	4	8	26	5	8	115.56	125	100
Kingsbury-Ontario	0.5	0	0	1	0.5	0.5	200	∞	∞
State-Roosevelt	27	4	10.5	25.5	2.5	11.5	94.44	62.5	109.52
Ashland-Cortland	38	12	4.5	33.5	7.5	6.5	88.16	62.5	144.44
Cicero-Fullerton	39	7.5	12.5	36	12	11	92.31	160	88

Damen-Fullerton	59	23	12	34	12	7.5	57.63	52.17	62.5
Kedzie-Fullerton	28	7	10	16	5	5.5	57.14	71.43	55
California-Diversey	29.5	8.5	6.5	32	11.5	6	108.47	135.29	92.31
State-63 rd	29.5	7	5	30	11.5	8	101.69	164.29	160
Kedzie-79th-Columbus	39	22	5.5	30	13.5	5	76.92	61.36	90.91
Halsted-99th	26.5	8	7	23.5	5	3.5	88.68	62.5	50
Halsted-111th	22	4.5	3	14.5	4.5	2.5	65.91	100	83.33
Totals	2,072	543	485	2,066.5	390.5	697.5	99.73	71.92	124.92
Per Intersection	44.44	10.86	9.7	41.33	7.81	13.95	-0.11	-3.05	4.25


Table 17. Collision Rates at RLC control intersections, Chicago, Il.

Intersection	Two years prior (avg)			Two years after (avg)			Change %		
	Total	Angle	Rear	Total	Angle	Rear	Total	Angle	Rear
California-35Th	13	2.5	0.5	10.5	1	4	80.77	40	800
Stony Island-83 Rd	15	6	4	16.5	2.5	8	110	41.67	200
Ashland-Garfield	15	4	2.5	13.5	3.5	3.5	90	87.5	140
Halsted-95Th	23	7.5	5	29	5	9.5	126.09	66.67	190
Halsted-79Th	17.5	3	4.5	20	4	6.5	114.29	133.33	144.44
Cottage Grove-71St-South Chicago	22	4	8	16	3	3.5	72.73	75	43.75
Halsted-Belmont	16.5	5.5	2.5	15	1	6	90.91	18.18	240
Cicero-47Th	21	5	5.5	36	7.5	15	171.43	150	272.73
Kedzie-47th	23	5	5.5	22	2.5	6.5	95.65	50	118.18
Ashland-Roosevelt	21	5	6	27	3	12	128.57	60	200
Sheridan-Foster	11	3.5	2	9.5	1.5	1	86.36	42.86	50
Ashland-63rd	17	2.5	3.5	19.5	2.5	6.5	114.71	100	185.71
Western-North	25	3	6.5	35	6	8.5	100	200	130.77
Vincennes-111th	14	3.5	3.5	13	5	3.5	92.86	142.86	100
Stony Island-Cornell-67th	19.5	3	7	22	4.5	8	112.82	150	114.29
Kedzie-63rd	15	2.5	2.5	11.5	1.5	5	76.67	60	200
Jeffery-95th	24.5	8.5	5.5	23.5	3.5	7.5	95.92	41.18	136.36
Cicero-Archer	20	4.5	6.5	28	8.5	10.5	140	188.89	161.54
Western-63rd	19	3.5	6	21	3.5	7.5	110.53	100	125
Western-Irving Park	30	8	9.5	35	4.5	16.5	116.67	56.25	173.68

Totals	432	132	112	448.5	93.5	198	94.69	85.22	105.58
Per Intersection	40.22	9.20	8.3	39.22	6.12	12.95	-5.31	-3.20	5.23

Figure 4. Example IDOT report

Report No : SDM-RC002
Sorted by : Mile / Date / ICN



Illinois Department of Transportation
Division of Traffic Safety

Report Produced : 10/8/2009 10:12 AM
By: CENTRALADAMSCH
Page : 1 of 9

Collision Diagram
1/1/2005 to 12/31/2005

Crash Route: TS255 | From MileStation 14.54 to 14.54 | County : Cook | Intersection Related: Intersections | *See Notes at End of Report.

Date	Weather	Roadway	A	Injuries B	C	Killed	Type of Crash	Light Condition	Mile	Vehicle Type	DIRP	Maneuver	Event 1	Loc 1	Event 2	Loc 2	Event 3	Loc 3	Unit
50046143																			
1/7/2005 4:30 PM	Sleethail	Snow or slush	0	0	1	0	1-Pedestrian	Dusk	14.54	Passenger	North	Straight ahead	Pedestrian	On-pavement (roadway)	Unknown	Unknown	Unknown	Unknown	1
50193275																			
1/11/2005 2:45 PM	Clear	Dry	0	0	0	0	12-Sideswipe same direction	Daylight	14.54	Passenger	East	Straight ahead	Motor vehicle in traffic	Intersection	(UNK)	Unknown	Unknown	Unknown	1
										Sport utility vehicle (SUV)	East	Slow/stop-left turn	Motor vehicle in traffic	Intersection	(UNK)	Unknown	Unknown	Unknown	2
50363811																			
1/26/2005 9:30 PM	Clear	Dry	0	0	0	0	11-Rear end	Daylight	14.54	Van/mini van	West	Straight ahead	Motor vehicle in traffic	On-pavement (roadway)	(UNK)	Unknown	Unknown	Unknown	1
										Passenger	West	Straight ahead	Motor vehicle in traffic	On-pavement (roadway)	(UNK)	Unknown	Unknown	Unknown	2
50348192																			
1/29/2005 12:50 AM	Clear	Dry	0	1	0	0	10-Turning	Darkness, lighted road	14.54	Passenger	West	Turning left	Motor vehicle in traffic	Unknown	(UNK)	Unknown	Unknown	Unknown	1
										Passenger	East	Straight ahead	Motor vehicle in traffic	Unknown	(UNK)	Unknown	Unknown	Unknown	2
51788483																			
1/31/2005 2:23 PM	Clear	Dry	0	1	0	0	10-Turning	Daylight	14.54	Passenger	North	Turning left	Motor vehicle in traffic	On-pavement (roadway)	(UNK)	Unknown	Unknown	Unknown	1
										Tractor w/ semi-trailer	West	Straight ahead	Motor vehicle in traffic	On-pavement (roadway)	(UNK)	Unknown	Unknown	Unknown	2
50335987																			
1/31/2005 3:30 PM	Clear	Wet	0	0	0	0	11-Rear end	Daylight	14.54	Tractor w/ semi-trailer	South	Straight ahead	Motor vehicle in traffic	On-pavement (roadway)	(UNK)	Unknown	Unknown	Unknown	1
										Passenger	South	Straight ahead	Motor vehicle in traffic	On-pavement (roadway)	(UNK)	Unknown	Unknown	Unknown	2
50843499																			
3/7/2005 5:25 PM	Snow	Dry	0	0	0	0	15-Angle	Daylight	14.54	Pickup	East	Skidding/control loss	Motor vehicle in traffic	On-pavement (roadway)	(UNK)	Unknown	Unknown	Unknown	1

Table 18. Legal summary by state, derived from <http://www.ghsa.org/html/stateinfo/> and links to appropriate state webpages therefrom. Current at time of publication.
* indicates that fines differ when caught by camera versus by a police officer.

Alabama	No state laws.
Alaska	No state laws.
Arizona*	Legal as of 1997, system must be approved by majority of voters in each district; jurisdictions may collect a fee from the vendor for each ticket. State requires photograph of a vehicle and its driver with a record of the speed and time of violation, so both front and rear photographs are necessary. Penalty must be at least \$250, and violators must attend Traffic Survival School. Later, this was reduced to \$165 (traditional violation still \$250), and three points are assessed as well. Citations mailed out regardless of state.
Arkansas	Prohibited with narrow exceptions.
California	Legal since 1995 with rail enforcement, since 1997 at other intersections. Only warning notices for the first 30 days. Local jurisdictions must announce publically 30 days before the program begins, too. One point must be assessed as part of the fine. A sign requiring the presence of the system is required, it must be made visible to traffic approaching from all directions of the intersection, and at all major entrances to the city. Driver identification is explicitly required, meaning a frontal photo of the driver and the front license plate are necessary. Traditional costs and fines are the same. Additional laws in 2003 (Bill 1022).
Colorado*	Legal since 1999 with House bill 1364 permitting automated vehicle identification systems. No portion of any fine collected through the system may be paid to the manufacturer or vendor of the system. Appropriate signage must be provided in a noticeable place, and maximum penalty is capped at \$75, though doubled in school zones. Uniquely (as far as I can tell), first violations must only be warnings, no fines or surcharges. If the owner of the vehicle has any evidence that they were not operating it at the time, it may be submitted, and the penalty may be avoided. Traditional violation costs \$111 and 4 points on license.
Connecticut	No state laws.
Delaware*	Legal statewide, requires two or more images of the vehicle to be taken, fine goes to the registered owner of the vehicle, \$110 fine max via camera versus between \$75-\$230 for traditional violations.
Washington D.C.*	Legal district wide, cameras fine the registered owner of the vehicle. RLC fine is \$75, whereas traditional fine also includes 2 points on the registered owner's license.
Florida*	Legal state wide, fines are issued to the registered vehicle owner and are \$158 for RLC violations versus \$125 and 3 points for traditional violations.

Georgia*	Legal statewide, fines are issued to the registered vehicle owner and are \$70 max, may not be used to convict a person, or record the offense for posterity, or be considered a moving violation, or considered by insurers. Traditional penalties are capped at \$1,000 and 3 points.
Hawaii*	Legal in 2003, House Bill 57 permits, two or more photographs, microphotographs, electronic images, videotape, or any other medium showing the rear of a vehicle and the plate number, must show the face of the driver and plate number. Signs for the systems are completely optional. Maximum penalty capped at \$100, traditional fines set locally. Registered owner may defend themselves in court if their vehicle was stolen or not operated by the owner at the time of the violation. Also simultaneously made license plate covers which may obscure the plate numbers illegal.
Idaho	No state laws.
Illinois*	Legal in 2003, Senate Bill 2159, only states that communities in the state shall be legally allowed to install automated red light cameras, that the photographs must show the vehicle and plate clearly, and nothing else. Since then, fines are now set at \$100 and/or traffic reeducation program, no moving violations or record offenses permitted. Traditional violation maxes at \$500 with 20 points on license.
Indiana	No state laws.
Iowa	No state laws.
Kansas	No state laws.
Kentucky	No state laws.
Louisiana*	Legal, requires only that convictions from RLC violations are not reported on the driving record, otherwise penalties are set by jurisdictions as they see fit.
Maine	Prohibited by law.
Maryland*	Legal by 1997, requires two or more photographs, microphotographs, electronic images, video tape, or any other medium which shows the rear end of the vehicle and registration plate number of the vehicle. Fines max at \$100, owners may appear in court if they were not operating the vehicle at the time of violation. Traditional violation \$500 max, 2 points required.
Massachusetts	No state laws.
Michigan	No state laws.
Minnesota	No state laws.
Mississippi	Prohibited by law.
Missouri	No state laws.
Montana	Prohibited by law.
Nebraska	No state laws.
Nevada*	Banned (with narrow exceptions) by law, where permitted fines remain traditional - \$1,000 max and 4 points on license.
New Hampshire	Prohibited by law.

New Jersey	Requires a local ordinance be enacted and an application to the Transportation Commissioner to proceed with pilot programs. Registered owner and current driver are jointly responsible. Fine must be less than \$85, though court costs can be included and have no limits – same as traditional violation.
New Mexico	Banned on state and federal roads, legal at the local level. Localities must post a beacon and warning signs. Penalties same as traditional – maximum \$75 fine, civil penalty, no criminal sanctions or points permitted, municipality assumes all costs whereas fines must go to court construction, drug courts and driving while intoxicated prevention programs.
New York*	Legal by 1993 for cities greater populations greater than 1,000,000 or by specific local ordinance. Bill A0565, requires evidences of violation via at least two photographs/micrographs/videotape and other recorded images. Maximum fine was set at \$50, vehicle owner to receive penalty, all other details left to municipality. Traditional infraction maxes at \$100, 3 points on license.
North Carolina*	Limited RLC camera programs permitted, \$50 maximum penalty to vehicle owner which may be doubled if payment comes late. Traditional fine starts at \$100 and includes 3 points.
North Dakota	No state laws.
Ohio	No state laws.
Oklahoma	No state laws.
Oregon	Legal since 2001, House Bill 2085, requires a public information campaign in any community before installation, signs indicating a camera may be in operation at a practical distance from the intersection. Citations are mailed along with a form called “notice of innocent”, which a driver may return signed with photocopies of driver’s license, if they were not driving the vehicle at the time – if done, the violation is dismissed. Businesses or public agencies may send a certificate of non-liability stating the vehicle was in the custody of an employee, renter, or lessee at the time of the violation, to avoid the fee. Penalties for violations will be the same as for the violation initiated by other means (ie, if a police officer catches you, which may include points and a large fine). Mirrors traditional fines, which have been set at \$260, doubling in school/work zones, to \$1,000 max.
Pennsylvania*	Legal, registered owner of the vehicle is liable, fine is set at a maximum of \$100 with no operating record permitted. Traditional fine maxes out at \$25, though includes 3 points on the driver’s license.
Rhode Island*	Legal statewide, requires two or more images of the vehicle both including a clear view of the license plate. Fine goes to the registered owner and is set at \$500, and may not be used for criminal prosecution, moving violation, and may not be considered by insurers. Traditional fines do not have the same restrictions, though the \$500 fine is the same.
South Carolina	Prohibited by law.
South Dakota	No state laws.

Tennessee*	Permitted by law statewide except for non-“workzone” interstates, but not reportable to insurance agencies, no points may be issued. Rate is determined by municipality, versus traditional fines capped at \$50.
Texas*	Legal since 2003, house bill 901. Not allowed to directly compensate a manufacturer via a percentage of fines collected, though monthly fees and other types of payment are permissible. Texas may be the only state which requires the municipality conduct a traffic engineering study at the intersection to determine what other changes to the intersection could make it safer, and implement them as well or in place of the system. Public awareness campaigns must be launched simultaneously as the system, and persist for at least a year. Two photos of the rear plate are required to prove the violation; penalties must not exceed \$75. If a vehicle is being rented or leased, the owner may be accepted from the penalty, though in all other cases the registered owner is responsible for the fine, like with parking tickets. Traditional fine is \$200 at maximum.
Utah	No state laws.
Vermont	No state laws.
Virginia*	Legal since 2003 with House Bill 1696. Public awareness program must be conducted prior to implementation. There need to be two proofs, and they may come in the form of photographs, micrographs, video tape, or other recorded images. One photo must show a vehicle illegally entered into the intersection, and another must show the same vehicle after it has passed. Warning signs at the intersection are required and must be conspicuous, explaining a photo-monitoring system is in use. Penalties may not exceed \$50. Timing and other location-specific safety features must be considered before installation, but are not required, nor is a study required. Length of yellow must follow guidelines by the Institute of Transportation Engineers (ITE). Annual evaluation of each system must occur, and only 25 locations in any city may use RLCs. Traditional fine is \$200 max, 4 points.
Washington*	Legal since 2005, RLC may be implemented where two arterial roads intersect. Goes to vehicle’s registered owner. Vehicle license tag must be in picture. Fines are to be max parking violation fine in the town implementing the system, no record, no points. Traditional violations are capped at \$250, no points.