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SPILLOVER EFFECT AND ECONOMIC EFFECT OF RED LIGHT CAMERAS

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16. Abstract

"Spillover effect" of red light cameras (RLCs) refers to the expected safety improvement at intersections other than those actually treated. Such effects may be due to jurisdiction-wide publicity of RLCs and the general public's lack of knowledge on the exact installation locations of RLCs. Ignoring possible spillover effect could lead to an underestimation of the benefit of RLCs. Both a naïve study and an empirical Bayes study were conducted in this project for selected intersections from the Chicago area, and the results showed that a substantial spillover effect seemed to exist for the studied intersections.

The installation of RLCs would lead to changes in rear-end crashes and right-angle crashes. These crashes are often associated with different severities (K/A/B/C/PDO) and different socioeconomic impacts. Assessing the benefit and cost of installing RLCs could help agencies understand the cost effectiveness of RLCs as a safety countermeasure. Crash reduction estimates at the 41 selected RLC intersections from Project ICT R27-SP32 were used, and the results showed the cost effectiveness of installing RLCs at these intersections.

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Members of the Technical Review Panel were the following:

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EXECUTIVE SUMMARY

"Spillover effect" of red light cameras (RLCs) refers to the expected safety improvement at intersections other than those actually treated. Such effects may be due to jurisdiction-wide publicity of RLCs and the general public's lack of knowledge on the exact installation locations of RLCs. Ignoring possible spillover effect could lead to an underestimation of the benefit of RLCs. Given the 41 RLC installation intersections, the rear-end and right-angle crashes data for 60 immediately signalized adjacent intersections and 24 randomly sampled intersections (from the Du Page, Lake, Kane, Cook Counties) were collected. The data covered crashes that occurred 3 years before and 3 years after the installation of RLCs at the nearest treated intersection. Both naïve study and empirical Bayes study were conducted to quantify the impact of RLCs, and the results showed that the numbers of crashes were reduced significantly for both rear-end and right-angle crashes. As such, a substantial spillover effect seems to exist for the studied intersections.

The installation of RLCs would lead to changes in rear-end crashes and right-angle crashes at those RLC intersections. These crashes are often associated with different severities and different socioeconomic impacts. Assessing the benefit and cost of installing RLCs could help agencies understand the cost effectiveness of RLCs as a safety countermeasure. Crash reduction estimates at the 41 selected RLC installation intersections from Project ICT R27-SP32 were used, and the results showed the cost effectiveness of installing RLCs at these intersections.

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CHAPTER 1: INTRODUCTION

According to the Highway Loss Data Institute, in 2014 alone, 709 people were killed, and about 126,000 were injured in crashes involving red-light running in the United States.[1] Enforcement could be the best way to get people to comply with any law, but it is impossible for the police to be at every intersection. As a remedy, an increasing number of red light cameras (RLCs) were installed in the United States to enforce traffic law at intersections (Figure 1).

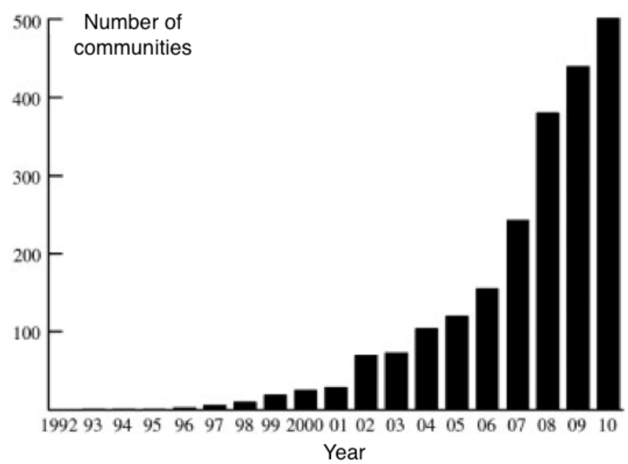

Figure 1. US communities with red light camera enforcement programs, 1992–2010 (Source: Hu et al. 2011).

Studies on the effectiveness of RLCs are relatively scarce. Several researchers reported reduction of red-light violations and crashes (especially right-angle crashes) at intersections after the installation of RLCs (Aeron-Thomas and Hess 2005; Retting et al. 2008), while some other studies mentioned an increase in rear-end crashes (Hillier et al. 1993; Council et al. 2005; Erke 2009). The reported findings of these effects are summarized in Table 1.

Table 1. Recent Studies of Red Light Cameras

Location	Findings	Author
Miami	3% decrease in right-angle crashes 40% increase in rear-end crashes	Llau et al. 2015
Virginia Beach	15.4% safety improvement	Maina et al. 2016

"Spillover effect" is the expected effect of RLCs at intersections other than those treated, which may result from jurisdiction-wide publicity and the general public's lack of knowledge on the exact locations of RLCs installations. It was reported in the 2010 edition of *Highway Safety Manual* (AASHTO 2010) that installing RLCs might lead to either a positive spillover effect or crash mitigation at nearby intersections (or throughout a jurisdiction). A positive spillover effect is defined as the

[1] http://www.iihs.org/iihs/topics/t/red-light-running/topicoverview

reduction of crashes at signalized adjacent intersections without RLCs due to drivers' sensitivity to the possibility of an RLC being present. Crash mitigation is the reduction in crash occurrence at the intersections with RLCs because travel shifts away from RLC locations. However, the existence and magnitude of the effects are yet to be determined.

The installation of RLCs would probably lead to decreases in right-angle crashes, for which injuries are often severe, and decreases (or increases) in rear-end crashes, for which injuries are less severe. It was also noted that for each of these crash types, the average level of injury severity and the expected socioeconomic implications were different (Lund et al. 2009). Hence, the analysis of economic effects might be different from a simple analysis of crash rate changes. The economic and safety analysis should also be conducted to examine how the potential change in rear-end crashes and right-angle crashes may justify the cost of installing the cameras (Council et al. 2005).

CHAPTER 2: LITERATURE REVIEW

2.1 SPILLOVER EFFECT

Studies on the spillover effect have produced contradictory results in the literature. In a national study, Council et al. (2005) found that installation of RLCs could lead to a modest decrease in right-angle crashes, as shown in Table 2. However, whether the observed difference was the result of spillover effect was questionable due to the lack of the expected increase in rear-end crashes. The empirical Bayes (EB) method was used in several studies to estimate crashes expected in the after period without RLCs because it can account for the regression-to-the-mean effect.

Table 2. Before-and-After Results for Total Crashes at Spillover Intersections (Source: Council et al. 2005)

Location	Right-angle crashes	Rear-end crashes
EB estimate of crashes expected in the after period without RLC	3,430	3,802
Count of crashes observed in the after period	3,140	3,873
Estimate of percentage change (standard error)	–8.5(2.2)	1.8(2.3)

Burkey and Obeng (2004) found no clear drop or increasingly negative trend in crash rates after an RLC program began and claimed there was no spillover effect. Shin and Washington (2007) evaluated the magnitudes of reduction or increase in each crash type and found spillover effects. Erke (2009) conducted a meta-analysis and concluded that the installation of RLCs might cause spillover effects. According to Høye (2013), some spillover effects might occur, primarily on right-angle collisions, but the study results were not substantially affected by the control for spillover effects. Vanlaar et al. (2014) found a significant increase in rear-end crashes at intersections in Winnipeg where no RLCs were installed.

Ignoring possible spillover effect at intersections without RLCs could lead to an underestimation of the effect of RLCs, especially when such sites were selected as a comparison group (Council et al. 2005; Erke 2009). To control for spillover effects in statistical analysis, Høye (2013) summarized several methodologies: (1) testing empirically for spillover effects, (2) excluding non-RLC intersections that are near RLC intersections, (3) using unsignalized intersections as a comparison group, and (4) investigating the effects of RLCs at all intersections in cities with RLC programs and comparing them with intersection crashes in cities without RLC program.

2.2 ECONOMIC EFFECTS

Assessing the benefit-and-cost effect of RLCs could help agencies understand the cost effectiveness of RLCs better and select the most economical and effective safety treatments when other safety treatments are available. Several attempts have been made to quantify the economic impacts of RLCs. Council et al. (2005) and Shin and Washington (2007) claimed that it was cost effective to install

RLCs. Council et al. (2005) also summarized the challenges in the study of the economic effect as follows: (1) the RLC systems could probably affect the full injury distribution from fatal injury to no injury—hence, the economic cost and the crash data must cover the complete distribution, (2) the hospital-related data include around 15% of the total crash population, and (3) the cost of crashes might fail to include elements such as lost work productivity, rehabilitation cost, insurance cost, and quality of life losses.

CHAPTER 3: METHODOLOGY

3.1 STUDY SITES SELECTION

For each treatment site (i.e., with an RLC), data was collected for adjacent signalized intersections, as shown in Figure 2. A total of 101 such intersections were identified. In addition, 25 intersections also were randomly sampled from the general jurisdiction, including Du Page, Lake, Kane, and Cook counties in the Chicago area, to make the results more representative.

Those intersections with significant safety improvement projects (e.g., intersection rebuilding or RLC installation) during the study period were excluded from the study so as to avoid influence from these projects. Some other intersections were excluded from the study due to lack of available AADT data, which were necessary for the empirical Bayes method. Eventually, there were 60 adjacent signalized intersections and 24 random intersections selected for the spillover analysis. These will be referred to as "selected intersection" in the rest of the report.

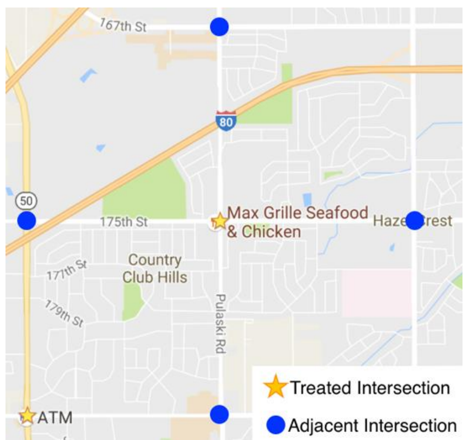

Figure 2. Adjacent signalized intersection example.

3.2 DATA COLLECTION

The following data selection criteria were used in this study.

- The before period for each selected intersection covered 3 years immediately before the installation year of the RLC at the nearest treated intersection. The after period covered 3 years after the installation year (the installation year was excluded) of the RLC at the nearest treated intersection.
- Crash data within a 250-ft distance around the center of the intersection were collected and considered RLC-related spillover for further analysis.
- Rear-end crashes and right-angle crashes were reported to be the two main types of crashes influenced by RLCs. Intersection-related crashes refer to crashes that have critical pre-crash events such as turning left, crossing over, or turning right at an intersection. Compared with

non-intersection-related crashes, they were more likely to be influenced by RLCs. Hence, for each study site, the following types of crash data were collected and analyzed:

- Rear-end, intersection-related crashes
- Rear-end, non-intersection-related crashes
- Right-angle, intersection-related crashes
- Right-angle, non-intersection-related crashes

In this study, the crash categories above were directly extracted from the dataset provided by IDOT.

- Traffic data near the intersections are needed to conduct an empirical Bayes study. The AADT data for each intersection were collected from IDOT website[2]. If some AADT data in certain years were not available, the missing data were obtained from most adjacent years via linear interpolation or extrapolation.

3.3 NAÏVE BEFORE-AND-AFTER STUDY

In the naïve study, the expected crash frequency in the after-modification period is assumed to be the crash frequency in the before period.

$$N_{expected,A} = N_{observed,B}$$

where

$N_{expected,A}$ is the expected crash frequency in the after period

$N_{observed,B}$ is the observed crash frequency in the before period

The total crashes and the annual average crashes during the before period and the after period were calculated from the crash data. The percentage reduction was calculated as

$$\text{percent reduction} = \frac{\left(N_{expected,A} - N_{observed,A}\right)}{N_{expected,A}}$$

where

$N_{observed,A}$ is the observed crash frequency in the after period

3.4 EMPIRICAL BAYES STUDY

Empirical Bayes analysis was also conducted to account for the regression-to-the-mean effect. The following procedure from the *Highway Safety Manual* (AASHTO 2010), with applicable safety performance functions (SPFs), was used to estimate the safety effectiveness.

[2] http://www.gettingaroundillinois.com/gai.htm?mt=aadt#

Step 1: Using the SPFs developed by AECOM[3], calculate the predicted average crash frequency $N_{predicted,B,}$ as follows:

$$N_{predicted,B,RA} = 8.5563 \times 10^{-2} \times AADT_{Total}{}^{0.3182} \quad (1)$$

$$N_{predicted,B,RE} = 1.2094 \times 10^{-7} \times AADT_{Total}{}^{1.6788} \quad (2)$$

where

> $N_{predicted,B,RA}$ and $N_{predicted,B,RE}$ are the mean annual predicted right-angle and rear-end collision frequencies of the studied site

Step 2: Calculate the expected average crash frequency, $N_{expected}$, for each site *i*, summed over the entire before period:

$$N_{expected,B} = w_{i,B} N_{predicted,B} + (1 - w_{i,B}) N_{observed,B} \quad (3)$$

where the weight, $w_{i,B}$, for each site *i*, is determined as:

$$w_{i,B} = \frac{1}{1 + k \times \sum_{before} N_{predicted}} \quad (4)$$

where

> $N_{expected}$ = Expected average crash frequency at site *i* for the entire before period
>
> *k* = Overdispersion parameter for SPFs (0.6608 for the model in Equation 1 and 0.4074 for the model in Equation 2)

Step 3: Using the SPFs, calculate the predicted average crash frequency, $PR_{i,y,A}$, for each site *i* during each year *y* of the after period.

Step 4: Calculate an adjustment factor, r_i, to account for the differences between the before-and-after periods in duration and traffic volume at each site *i* as:

$$r_i = \frac{\sum N_{predicted,A}}{\sum N_{predicted,B}} \quad (5)$$

Step 5: Calculate the expected average crash frequency, $N_{expected}$, for each site *i*, over the entire after period in the absence of the treatment as:

$$N_{expected,A} = N_{expected,B} \times r_i \quad (6)$$

[3] http://www.transportation.alberta.ca/Content/docType47/Production/isdredlightcameraanalysis.pdf

Step 6: Calculate an estimate of the safety effectiveness of the treatment at each site *i* in the form of an odds ratio, *ORi*, as:

$$OR_i = \frac{N_{observed,A}}{N_{expected,A}} \qquad (7)$$

where

OR_i = Odds ratio at site *i*

$N_{observed,A}$ = Observed crash frequency at site *i* for the entire after period

Step 7: Calculate the safety effectiveness as a percentage crash change at site *i* as:

Safety Effectiveness *i* = 100 × (1 – OR_i) (8)

Step 8: Calculate the overall effectiveness of the treatment for all sites combined, in the form of an odds ratio, *OR'*, as follows:

$$OR' = \frac{\sum_{all\ sites} N_{observed,A}}{\sum_{all\ sites} N_{expected,A}} \qquad (9)$$

Step 9: Calculate the unbiased estimate of the treatment effectiveness in terms of an adjusted odds ratio, *OR*:

$$OR = \frac{OR'}{1 + \frac{Var(\sum_{all\ sites} N_{expected,A})}{(\sum_{all\ sites} N_{expected,A})^2}} \qquad (10)$$

where

$$Var(\sum_{all\ sites} N_{expected,A}) = \sum_{all\ sites} \left[(r_i)^2 \times N_{expected,B} \times \left(1 - w_{i,B}\right)\right]$$

Step 10: Calculate the overall unbiased safety effectiveness as a percentage change in crash frequency across all sites as:

Safety Effectiveness = 100 × (1 – *OR*) (11)

Step 11: Calculate the variance of the unbiased estimated safety effectiveness, expressed as an odds ratio, *OR*, as follows:

$$Var(OR) = \frac{(OR')^2\left[\frac{1}{N_{observed,A}} + \frac{Var(\sum_{all\ sites} N_{expected,A})}{(\sum_{all\ sites} N_{expected,A})^2}\right]}{1 + \frac{Var(\sum_{all\ sites} N_{expected,A})}{(\sum_{all\ sites} N_{expected,A})^2}} \quad (12)$$

Step 12: Calculate its standard error as the square root of its variance:

$$SE(OR) = \sqrt{Var(OR)} \quad (13)$$

Step 13: Using the relationship between *OR* and safety effectiveness shown in Equation 13, the standard error of safety effectiveness, *SE* (Safety Effectiveness), is calculated as:

SE (Safety Effectiveness) = 100 × *SE*(*OR*) (14)

Step 14: Assess the statistical significance of the estimated safety effectiveness by making comparisons with the measure *Abs* [Safety Effectiveness/*SE* (Safety Effectiveness)] and drawing conclusions based on the following criteria:

- If *Abs*[Safety Effectiveness/*SE*(Safety Effectiveness)] < 1.7, conclude that the treatment effect is not significant at the (approximate) 90% confidence level.
- If *Abs*[Safety Effectiveness/*SE*(Safety Effectiveness)] ≥ 1.7, conclude that the treatment effect is significant at the (approximate) 90% confidence level.
- If *Abs*[Safety Effectiveness/*SE*(Safety Effectiveness)] ≥ 2.0, conclude that the treatment effect is significant at the (approximate) 95% confidence level.

3.5 ECONOMIC ANALYSIS

3.5.1 Benefit

To capture the cost of crash frequency and injury severity, each crash can be converted into one measure: a dollar value based on the average level of injury severity for that type of crash. After the conversion, the total economic cost of crashes can be used for evaluation. Hence, successful conversion of the crash injury levels to a set of acceptable dollar-cost measures is the key to economic analysis.

An initial attempt was made to estimate the cost of crashes directly using the unit cost of each severity from the *Highway Safety Manual* (AASHTO 2010). However, due to the small sample sizes of type K and A crashes and their relatively large cost, the results could be highly sensitive to the presence of those crash types. Therefore, two crash categories that are widely used in IDOT safety studies (K+A+B and C+O) were used in this study. The crash cost of each category was estimated using a weighted average across different crash types. Illinois crash records from 2012 through 2014[4] by crash type, as well as IDOT's crash cost values by severity, are summarized in Table 3.

Table 3. Crash Information in Illinois

	Total	K	A	B	C+O
2014	296,049	845	9,168	61,084	224,952
2013	285,477	895	9,578	61,001	214,003
2012	274,111	886	9,648	60,252	203,325
sum	855,637	2,626	28,394	182,337	642,280
Proportion	100%	0.31%	3.32%	21.31%	75.06%
Cost(2014 $)		1,503,670	73,760	23,815	13,430 + 9,440

The cost of a crash in the K+A+B category is estimated by multiplying the proportions of such crash types in the category and their costs. For type C+O, there was a lack of data available on the IDOT website; therefore, the weighted cost is based on their proportions in the intersection crash dataset from Appendix A of the final report of a closely related study, Project ICT R27-SP32. The ratio of the number of Type C crashes to the number of Type O crashes is around 0.156 in the dataset. The results are shown in Table 4.

Table 4. Crash Cost Estimates by Severity Level

Crash Severity Level	Expected Cost (2014 $)
K+A+B	48,675
C+O	9,980

For the economic analysis, there were no available SPFs for crashes by severity. Hence, it was necessary to decompose the predicted crashes, by type, into the crashes by severity. The portions of crashes with a certain severity obtained from the observed intersection crash data were used. The benefit measured in the equivalent uniform annual benefit (EUAB) we calculated by multiplying the reduction in crashes of a certain severity by the converted cost.

$$EUAB = \sum \delta_j \times C_j$$

where

δ_j is the reduction of annual crashes in severity level *j*

C_j is the cost of severity level *j*

[4] http://www.idot.illinois.gov/transportation-system/safety/Illinois-Roadway-Crash-Data#tabs-7

3.5.2 Cost

The EUAC is calculated to measure the cost of installing RLCs. To calculate the EUAC, it would be necessary to collect the following information: (1) economic life *n* in years, (2) discount rate *I* as a percentage, (3) salvage value of cameras at the end of life-cycle, (4) annual maintenance cost, and (5) installation cost per approach at RLC intersections.

To calculate the EUAC, it was necessary to first calculate the capital recovery factor (A/P), which is the ratio of a constant annuity to the present value of receiving that annuity for a given length of time:

$$(A/P) = \frac{i(1+i)^n}{(1+i)^n-1} \quad (15)$$

The EUAC was calculated as:

$$EUAC = (\$/\text{approach}) \times (\text{number of approaches}) \times (A/P) \quad (16)$$

3.5.3 Benefit-to-Cost Ratio

The benefit-to-cost ratio (BCR) is calculated as:

$$BCR = \frac{EUAB}{EUAC}. \quad (17)$$

If BCR is larger than 1, the benefit is larger than the cost; if BCR is smaller than 1, the benefit is smaller than the cost.

CHAPTER 4: RESULTS

4.1 SPILLOVER ANALYSIS RESULTS

4.1.1 Naïve Study Results

The summary of crashes at adjacent intersections is shown in Table 5.

Table 5. Crashes at Adjacent Intersections

Crash Type		3 Years Total		Annual Average		Percent Reduction
		Before	After	Before	After	
Rear-End + Right-Angle		2,728	1,717	909.3	572.3	37.06%
Intersection-related	Total	1,999	1,207	666.3	402.3	39.62%
	Rear-End	1,789	1,069	596.3	356.3	40.25%
	Right-Angle	210	138	70	46	34.29%
Non-intersection-related	Total	729	510	243	170	30.04%
	Rear-End	612	433	204	144.3	29.26%
	Right-Angle	117	77	39	25.7	34.10%

The summary of crashes at adjacent intersections and randomly sampled intersections is shown in Table 6.

Table 6. Crashes at Adjacent and Randomly Sampled Intersections

Crash Type		3 Years Total		Annual Average		Percent Reduction
		Before	After	Before	After	
Rear-End + Right-Angle		4,309	2,821	1,436.3	940.3	34.53%
Intersection-Related	Total	3,087	1,930	1,029	643.3	37.48%
	Rear-End	2,728	1,692	909.3	564	37.97%
	Right-Angle	359	238	119.7	79.3	33.75%
Non-Intersection-Related	Total	1,222	891	407.3	297	27.08%
	Rear-End	1,028	745	342.7	248.3	27.55%
	Right-Angle	194	146	64.7	48.7	24.73%

The results in Tables 5 and 6 indicate that both rear-end and right-angle crashes were reduced about 30% at the studied intersections.

The summary of rear-end crashes at adjacent intersections is shown in Table 7.

Table 7. Rear-End Crashes at Adjacent Intersections by Severity

Crash Type		3 Years Total		Annual Average		Percent Reduction
		Before	After	Before	After	
Rear-End Crash Intersection-Related	K	0	0	0	0	—
	A	23	15	7.7	5	35.06%
	B	92	75	30.7	25	18.57%
	C	211	177	70.3	59	16.07%
	PDO	1,463	802	487.7	267.3	45.19%
Rear-End Crash Non-Intersection-Related	K	0	0	0	0	—
	A	7	3	2.3	1	56.52%
	B	37	42	12.3	14	–13.82%
	C	57	55	19	18.3	3.68%
	PDO	511	333	170.3	111	34.82%

The summary of rear-end crashes at adjacent intersections and randomly sampled intersections is shown in Table 8.

Table 8. Rear-End Crashes at Adjacent and Randomly Sampled Intersections by Severity

Crash Type		3 Years Total		Annual Average		Percent Reduction
		Before	After	Before	After	
Rear-End Crash Intersection-Related	K	0	0	0	0	—
	A	33	24	11	8	27.27%
	B	126	120	42	40	4.76%
	C	296	267	98.6	89	9.74%
	PDO	2,273	1,281	757.7	427	43.65%
Rear-End Crash Non-Intersection-Related	K	0	0	0	0	—
	A	15	8	5	2.7	46.00%
	B	54	62	18	20.7	–15.00%
	C	90	93	30	31	–3.33%
	PDO	869	582	289.6	194	33.01%

The summary of right-angle crashes at adjacent intersections is shown in Table 9.

Table 9. Angle Crashes at Adjacent Intersections by Severity

Crash Type		3 Years Total		Annual Average		Percent Reduction
		Before	After	Before	After	
Right-Angle Crash Intersection-Related	K	0	0	0	0	—
	A	23	8	7.7	2.7	64.94%
	B	21	25	7	8.3	–18.57%
	C	21	16	7	5.3	24.29%
	PDO	145	89	48.3	29.7	38.51%
Right-Angle Crash Non-Intersection-Related	K	1	0	0.3	0	sample size too small
	A	1	1	0.3	0.3	sample size too small
	B	6	11	2	3.7	–85.00%
	C	11	5	3.7	1.7	54.05%
	PDO	98	60	32.7	20	38.84%

The summary of right-angle crashes at adjacent intersections and randomly sampled intersections is shown in Table 10.

Table 10. Angle Crashes at Adjacent and Randomly Sampled Intersections by Severity

Crash Type		3 Years Total		Annual Average		Percent Reduction
		Before	After	Before	After	
Right-Angle Crash Intersection-Related	K	0	0	0	0	—
	A	31	15	10.4	5	51.92%
	B	45	40	15	13.3	11.33%
	C	39	34	13	11.3	13.08%
	PDO	244	149	81.3	49.7	38.87%
Right-Angle Crash Non-Intersection-Related	K	1	0	0.3	0	sample size too small
	A	3	2	1	0.6	40.00%
	B	9	17	3	5.7	–90.00%
	C	13	10	4.4	3.4	22.73%
	PDO	168	117	56	39	30.36%

As shown in Table 7 through Table 10, crashes of most severities except for some cases of severity B are reduced significantly.

4.1.2 Empirical Bayes Results

Using the methodology as discussed in Section 3.4, the results as summarized in Table 11 were obtained.

Table 11. Results for Crashes at Studied Intersection Using Empirical Bayes Method

	Total Right-Angle Crashes	**Total Rear-End Crashes**
Crashes expected in the after period without RLC	562.5	3,299
Count of crashes observed in after period	384	2,437
Percentage Reduction	31.7%	26.1%

The results are similar to the naïve before-and-after study, and the adjusted odds ratios for angle crashes and rear-end crashes are 0.68 and 0.74, respectively. The odds ratios are less than 1, which indicates a reduction in crash frequency due to the installation of RLCs. The *Abs* [Safety Effectiveness/*SE* (Safety Effectiveness)] values for angle crash and rear-end crashes are 7.3 and 13.6, respectively, which are both greater than 2. Hence, it was concluded that the treatment effect was significant at the (approximate) 95% confidence level. Based on the results, it was concluded that the crashes at adjacent intersections were reduced significantly and that there might exist a strong spillover effect. It should be noted that the results for rear-end crashes were different from those in several previous studies, and such results might be explained by other factors (e.g., change of traffic conditions and weather) that are not addressed in this study, or by the fact that drivers become more careful at intersections adjacent to RLC intersections.

4.2 ECONOMIC ANALYSIS RESULTS

In this numerical study, RLC cost and life-cycle information are set as follows:

- Economic life n =10 years[5]
- Discount rate i = 3%[6]
- Salvage value is assumed to be $0
- Annual maintenance cost is assumed to be $0
- Cost per approach at RLC intersection is $37,500[7]

[5] Illinois Department of Transportation (IDOT). *Highway Safety Improvement Program: User's Manual Benefit-Cost Tool*. Illinois Department of Transportation, Springfield, IL, 2015.

[6] Holland, W.G. *Illinois Department of Transportation's Life-Cycle Cost Analysis for Road Construction Contracts*. State of Illinois, Office of the Auditor General, Springfield, IL, 2012.

[7] Provided by IDOT, in 2016 dollars.

The crashes statistics for the 41 RLC intersections as shown in Table 12 were directly collected from Appendix A of the final report of Project ICT R27-SP32. In the report, in addition to rear-end crashes and right angle crashes, another type of crashes called other RLR (red light running) crashes (see the definition below) was claimed to be influenced by the RLCs.

- ***Other RLR crashes***—any other crash type, excluding rear-end or angle crashes, that is likely to have resulted due to one or more drivers running a red light. Examples include left-turn opposing through crashes, sideswipe crashes, single vehicle crashes, etc.

Table 12. Naïve Study Results of Average Annual Crashes

Crash Type	Angle + Rear-End + other RLR	
	Before Period	After Period
K+A+B	25.9	21
C+O	176.4	133.3

EUAB = (25.9– 21) x 48,675 + (176.4 – 133.3) x 9,980 = $668,645/year

To calculate the EUAC, it was necessary to first calculate the capital recovery factor:

$$\text{Capital recovery factor (A/P)} = \frac{i(1+i)^n}{(1+i)^n - 1} = 0.11723$$

The EUAC is:

EUAC= $37,500/approach x 60 approaches x (A/P) = $259,370/year

It was necessary to convert it to 2014 dollars, and the result is $255,835/year.[8]

Then the BCR was obtained:

BCR = EUAB/EUAC = 2.61 > 1

Because the BCR is larger than 1, it can be concluded that the benefit associated with RLCs is greater than the cost. It should be noted that the empirical Bayes approach could also be used for the economic analysis, but upon discussion with IDOT, only naïve before-and-after analysis was conducted for the economic analysis.

[8] Bureau of Labor Statistics: https://www.bls.gov/data/inflation_calculator.htm

CHAPTER 5: SUMMARY

Based on the analyses and results discussed in the report, the main findings of this study can be summarized as follows:

- Both rear-end and right-angle crashes were reduced at adjacent intersections and randomly sampled intersections. The results of both naïve before-and-after and empirical Bayes studies showed that a strong spillover effect exists for the studied intersections. The results of different types of percentage reduction were summarized in Table 13 below.

Table 13. Summary of Crashes Reductions at Adjacent Intersections

	Right-Angle Crashes	**Rear-End Crashes**
Percent Reduction using Naive Approach	35.1%	30.6%
Percent Reduction using Empirical Bayes Method	31.7%	26.1%

- Crashes of most injury severities (K/A/B) were reduced except for a few cases of severity B crashes.
- The benefit-to-cost ratios associated with red-light cameras obtained in the naïve study was 2.61, which was greater than 1. Hence, it seems economical to install such cameras at these intersections.

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