Houston's Digital Automated Red Light Enforcement Program

Revised Report

Benjamin Stevenson, Rice University
Robert Dahnke, Rice University
Dr. Tim Lomax, Texas Transportation Institute
Dr. Robert Stein, Rice University

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RICE
Center for Civic Engagement

Texas Transportation Institute

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Executive Summary

The Original Houston Digital Automated Red Light Enforcement Program (DARLEP) Report

In January of 2009, we released a report analyzing the effect of red light cameras at the 50 DARLEP intersections. The report concluded that red light cameras were mitigating a general increase in collisions at the monitored intersections. We based this conclusion on the fact that collisions occurring on intersection approaches with red light cameras were rising at a significantly slower rate than collisions occurring on approaches without camera monitoring. This conclusion was based on data drawn from a collection of individual incident reports provided by the Houston Police Department (HPD).

In the spring of 2009, the Texas Department of Transportation (TxDOT) released an updated statewide database of collisions digitizing all paper incident reports available. The database is known as the Crash Record Information System (CRIS). In theory, the CRIS data for the 50 DARLEP intersections and the original HPD data should be identical as they are both based on the same incident reports. However, in a comparison of the two datasets, we found CRIS reported over 250% more collisions during the before-camera period and over 175% more collisions during the after-camera period. From the comparison of CRIS to the HPD data and after consultation with HPD, we determined the original data in first report was inaccurate as a result of a substantial undercounting of collisions in both the before- and after-camera periods. We then conducted an analysis similar to the original report, **but with the new CRIS data**. We compared the rate of collisions before the red light cameras were installed to the rate of collisions after the cameras were installed. Because the cameras were installed on only one approach at each intersection[1], we separated the data into those approaches that were not monitored by red light cameras and those approaches that were monitored by red light cameras.

Results

The comparison of collisions at monitored and unmonitored approaches leads us to conclude that the Houston red light camera program is reducing collisions at the 50 DARLEP intersections (see Exhibit 1). After the implementation of red light cameras, collisions per month at monitored approaches decreased by 11%. This decline was statistically significant - that is, not due to random variations in the data, with over 90% confidence. The number of collisions per month at unmonitored approaches increased by approximately 5%. This difference from the before-camera period was not, however, statistically significant; the probability that the observed change did not occur due to chance was less than 90%.

[1] This study investigates the effect of red light cameras at the first 50 intersections approaches to be monitored. Cameras would later be installed at more than one approach per intersection; however, this installation fell outside of the scope of our study based on available data. Only 12 of the 1400 data points (monthly collisions at a single intersection), or less than 1%, occurred when more than one approach to each intersection was monitored.

When analyzed by collision type, the data reveals a significant decrease in monitored approach side-impact collision rates and no significant increase or decrease in monitored approach rear-impact or swipe collision rates. Unmonitored approach collision rates of all types experienced no significant increase or decrease after the implementation of red light cameras. Based on the analysis of collision types, we believe the DARLEP program is effective in reducing total collisions, especially side-impact collisions, while not increasing the rate of rear-impact collisions.

The most significant limitation to this analysis is insufficient post-implementation data; there is less than one year of data for all intersections after all cameras became operational. Accordingly, there may be additional seasonal effects that are not accounted for in this report. Minor obstacles include possible confusion over exact locations of accidents in relation to monitored intersections, as well as an inability to use all of the same inclusion rules of the original analysis with the CRIS dataset.

Exhibit 1-Unmonitored and Monitored Collision Rates Before and After the Implementation of Red Light Cameras for Total, Side-Impact, and Rear-Impact Collisions

	Collisions per Month					
	Before Red Light Cameras		*After Red Light Cameras*			
	Unmonitored	Monitored	Unmonitored	Monitored	Change at Unmonitored	Change at Monitored
Total	61.3	48.5	64.3	43.1	4.8%~	-11.1%^
Side-Impact	32.1	39.7	34.4	33.3	7.1%~	-16.1%*
Rear-Impact	5.7	2.2	5.5	1.4	-2.7%~	-35.8%~

~less than 90% confidence ^over 90% confidence *over 95% confidence

Note: % confidence refers to the certainty that the change is not due to chance.

Future Research

The next step of the evaluation of DARLEP is to investigate the effect of red light cameras at individual intersections. Central to this study is analyzing intersection characteristics such as signal visibility, lane striping, volume, intersection type and yellow light timing for any correlations with collision rates. In addition, we expect updated CRIS data to be available in the near future, allowing for an analysis of the red light camera program though 2008.

HOUSTON'S DIGITAL AUTOMATED RED LIGHT ENFORCEMENT PROGRAM

REVISED REPORT

Introduction

The evaluation of the Houston red light camera program began in the spring of 2007. The data for the initial investigation was provided by Houston Police Department (HPD) officer reports, which were collected by hand from Department storehouses. Rice University student researchers then used these reports to build a database of collisions at the 50 DARLEP intersections. All reports presented to HPD on the camera program by Rice University thus far have used this database.

The original study of the Houston Digital Automated Red Light Enforcement Program (DARLEP) reported a significant increase in the number of vehicle collisions after the installation of red light cameras at the fifty selected intersections. This observation was consistent at intersection approaches with and without cameras. However, the rate at which collisions increased after implementation of the red light camera program was significantly lower at approaches with cameras than without cameras.

The dramatic increase in collisions at DARLEP intersections revealed by the original HPD data was neither anticipated nor consistent with previous research.[2] The findings reported in our first study prompted us to continue investigating both the source and potential remedies for the increase in intersection collisions, especially at monitored approaches.

As part of our continuing study of the red light camera program we acquired new data from the Crash Record Information System (CRIS), a database compiled by the Texas Department of Transportation (TxDOT) to further understanding about vehicle collisions.[3] CRIS relies on paper collision reports acquired by TxDOT from all local public safety agencies in Texas.[4] Public safety agencies are required by law to submit these reports to TxDOT within 10 days of a motor vehicle collision.[5] TxDOT compiles their database from the same HPD police reports used in our initial analysis. Therefore, the CRIS database contains data fields identical to the original HPD database.

Although the CRIS and HPD databases used the same record source, the difference in the datasets was considerable. The total accident counts provided by the CRIS collection of data were far greater than those of the original database (see Exhibit 2). Furthermore, the steady downward trend of the CRIS data contrasts the steady flow then sharp increase of the HPD data. Because both datasets in theory came from the same records, we looked at the level of correspondence between the two datasets by matching collision reports using date, time, and location. We found that as time progresses, the original HPD data begins to contain an increasing percentage of accidents contained in the CRIS data.

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[2] Increases in collisions after the implementation of red light cameras are, of course, not unheard of. However, the staggering rise in collisions seen in the original HPD dataset (a 133% increase in unmonitored approach collisions) is not within the range of increases observed in other red light camera studies. Furthermore, most studies attribute increases in collisions after the implementation of red light cameras to an increased occurrence of rear-impact collisions. The increased observed in the HPD dataset was driven by side-impact collisions. These atypical results led us to question the validity of the HPD data.

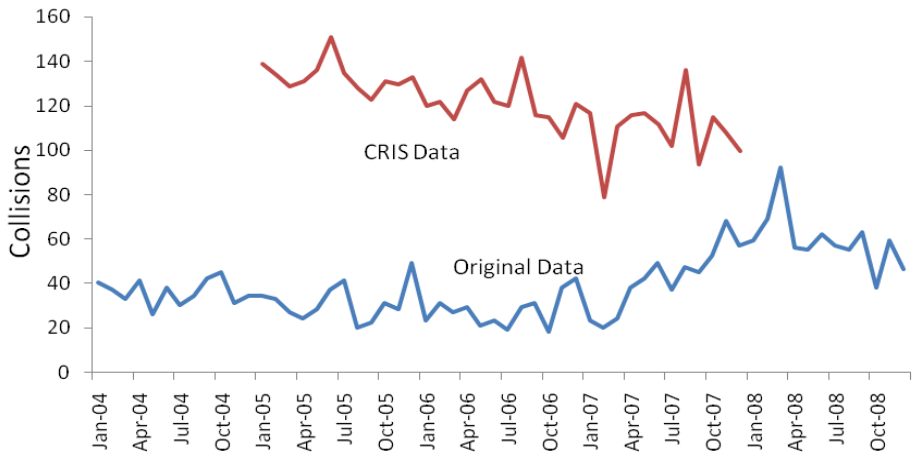
[3] We gratefully acknowledge the assistance of Houston-Galveston Area Council of Governments, and specifically Jeff Kaufman for their assistance in providing us with access to the CRIS data base.

[4] See: http://www.txdot.gov/drivers_vehicles/crash_records/reports.htm

[5] Texas Transportation Code, Section 550.061

Based on these observations, we conclude that the original HPD data base was incomplete, and undercounted vehicle collisions at monitored intersections between 2004 and 2007. It appears that HPD did not provide all crash reports for these locations, possibly due to the extreme difficulty of picking incident reports at DARLEP intersections out of the hundreds of thousands of physical crash reports stored by the Department. Started in 2006, the original data search required police to cull through incident reports over two years in the past, many of which might have been incorrectly stored or moved. The incompleteness of collision reports provided by HPD is greater in the earlier years (2004-2006) than in later ones (2007-2008) in the time series, creating the illusion of increasing collision rates after the implementation of red light cameras in late 2006 and early 2007.

Exhibit 2- Comparison of Total Collisions in CRIS and Original HPD Data by Month



We are confident that the CRIS database provides a more accurate accounting of vehicle collisions at intersections selected for camera monitoring. The CRIS data includes all available historical crash records and does not require a search of thousands of paper records for specific reports. We believe the data from the CRIS database should be used in all future evaluations of the red light camera program and related programs.

In using the CRIS collection of relevant police records, we applied a method of analysis almost identical to the one used to investigate the original data.

- First, we filtered the CRIS data to include only collisions occurring within 500 ft. of a DARLEP intersection labeled "at intersection" or "intersection related."
- Next, collisions were divided into those occurring on approaches which were monitored by a red light camera and those collisions occurring on unmonitored approaches (not observed by a camera).

- The definition for a monitored collision was somewhat broader than in the original analysis. Because the CRIS dataset did not include a variable identifying any citations given to the drivers involved in the collision, the four inclusion rules of the original analysis for the HPD dataset could not be replicated with the CRIS data.[6]

Implementation of DARLEP

Between September, 2006 and August, 2008, red light cameras were installed at 50 intersections and 70 approaches in five groups of ten approaches and one group of twenty approaches.[7] Group 1 began operating in September, 2006, with a new group coming online approximately every two months. Intersections with a high incidence of crashes were selected for the installation of a red light camera based on the number of crashes reported for the years 2000 through 2005. HPD, in consultation with the camera operators, selected one approach per intersection for the installation of a red light camera. The location of the camera was determined by an 8-hour trial period, which identified the intersection approach with the highest rate of red light camera violations. The other three approaches to the intersection remained without a red light camera.

Since DARLEP installed a camera at only one approach per intersection, collisions at each intersection can be divided into "monitored" collisions - those involving a vehicle on an approach which has or will have a red light camera - and "unmonitored" collisions which involve vehicles on approaches with no red light camera. We expect the rate of monitored collisions occurring at DARLEP intersections to be reduced by the installation of red light cameras and the rate of unmonitored collisions to remain unaffected.

As a result of the phasing-in of the red light cameras over an eight month period, the implementation date and number of months in operation varies by intersection group. To look at the effect of red light cameras, we organized the CRIS data into collisions occurring before implementation and after implementation according to intersection group and the calendar month in which the collision occurred. This produces a different before and after period for each group of ten intersections. Exhibit 3 below represents a timeline of "implementation month" necessitated by the staggered implementation of the red light cameras. Implementation month "0" (the month cameras were implemented in each group), consists of collision data from September 2006, November 2006, January 2007, March 2007, and May 2007.

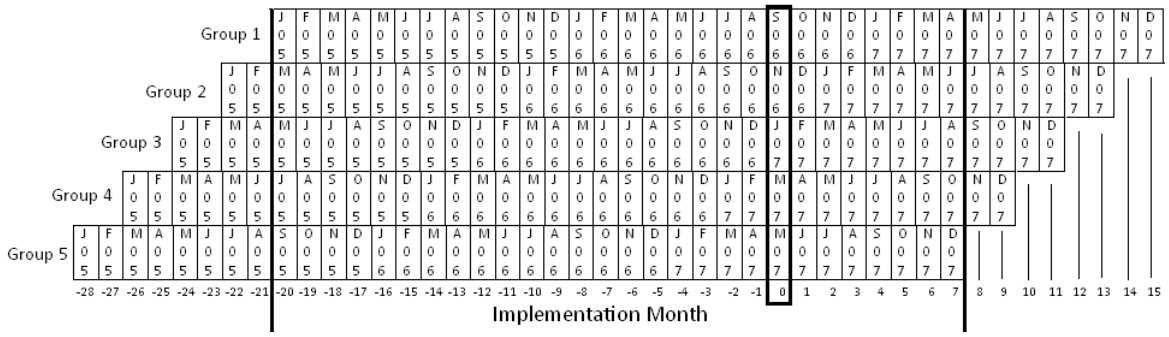
In order to analyze the DARLEP program as a whole and because collisions at each intersection group are infrequent, we concluded that data from all five intersection groups is necessary for a thorough analysis. As a result of this requirement, implementation months in which data is not available for all intersections must be removed. Out of the original 36 months

[6] 1) One more or more vehicle in the camera-monitored approach is cited [Included]. 2) No vehicle cited, but one or more vehicles are in the camera-monitored approach [Included]. 3) Vehicle cited is not in the camera-monitored approach [Not Included]. 4) Neither vehicle in camera-monitored approach [Not Included].We recognize these rules are in no way a perfect definition of "monitored collision". However, the rules were consistently applied to both the pre- and post-implementation datasets.

[7] This study investigates the effect of red light cameras at the first 50 intersections approaches. Only 12 of the 1400 data points (monthly collisions at a single intersection), or less than 1%, occurred when more than one approach to each intersection was monitored.

of data for each group, we can use only the 28 months (20 months of "before cameras" and 8 months of "after cameras") for which we have data for all 5 intersection groups.

Exhibit 3- Visualization of the Effects of Staggered Camera Implementation on Intersection Groups



Each box represents a calendar month (e.g. S05= September 2005), the bold lines bracket the implementation months in which CRIS has data for all five intersection groups, the bold box highlights implementation month 0: the month in which RLCs were first operational for each group (September 2006, November 2006, January 2007, March 2007, and May 2007).

Methodology

Based on the division of approaches into monitored and unmonitored approaches and the separation of months into "before cameras" and "after cameras" according to implementation month, all collisions at DARLEP intersections between 2005 and 2007 can be placed into one of the four categories:

1) Unmonitored collisions in the before period
2) "Monitored" collisions in the before period [8]
3) Unmonitored collisions in the after period
4) Monitored collisions in the after period

We investigate the effect of red light cameras by comparing the change in monitored and unmonitored collision rates at each intersection between the before- and after-camera periods. The unequal number of months before (20 months) and after cameras (8 months) requires the use of collision rates for observing each group. The rate is expressed as collisions per month.

Because the observations are collected from the same intersection approaches at two different times (before and after camera implementation), our methodology resembles a matched pair analysis. In this type of analysis, two matched subjects are each observed at two different points in time. In between the two observations, one of the subjects is given a treatment (e.g., placed on a new drug prescription) while the other similar subject is not given the treatment. In

[8] Although collisions were not actually monitored by red light cameras in the "monitored" approaches prior to camera implementation, we use this category of collisions to compare between collision rates at the same approaches over time.

the second (post-treatment) observation, any changes in the treated subject not observed in the untreated one will most likely be the result of the treatment. To describe the experimental design in terms of our study, any change in the collision rate at monitored approaches which is not observed at the unmonitored ones, will likely be the result of red light cameras.

Each intersection will have four collision rates: the rate of collisions at unmonitored approaches before cameras, the rate of collisions at unmonitored approaches after cameras, the rate of collisions at monitored approaches before cameras, and the rate of collisions at monitored approaches after cameras. The unmonitored approach collision rates form the untreated "pair" of observations while the monitored approach collision rates are the treated pair. When each of the differences at all DARLEP intersections within each pair is analyzed, we will use a difference of means statistical test to determine whether differences in collision rates at monitored and unmonitored approaches are significant or the result of normal variations in collision rates. This analysis is conducted for total collisions as well as three types of collisions: side-impact, rear-impact, and swipes.

Results of CRIS Data Analysis

Total Collisions

Exhibit 4- Average Collisions per Month for Monitored and Unmonitored Collisions Before and After Red-Light Cameras

Intersection ID	Intersection Name	Before Unmonitored	Before Monitored	After Unmonitored	After Monitored	Change at Unmonitored	Change at Monitored
-	**TOTAL**	**61.3**	**48.5**	**64.3**	**43.1**	**4.8%**	**-11.1%**

Exhibit 4 consolidates the entire CRIS dataset for the red light camera program into a straightforward comparison. The table reveals that compared with a 4.8% rise in average monthly collisions at unmonitored intersection approaches, approaches monitored by red light cameras experienced 11% fewer collisions after the implementation of red light cameras. Furthermore, the 4.8% increase in unmonitored collisions per month was not statistically significant; while the 11% decrease at monitored approaches is statistically significant at the 90% confidence level (i.e. the decrease in monitored collision rates from the before- to after-camera period has less than a 10% likelihood of being the result of chance).

Side-Impact Collisions

Exhibit 5-Average Collisions per Month for Monitored and Unmonitored Side-Impact Collisions Before and After Red-Light Cameras

Intersection ID	Intersection Name	Before Unmonitored	Before Monitored	After Unmonitored	After Monitored	Change at Unmonitored	Change at Monitored
-	**TOTAL**	**32.1**	**39.7**	**34.4**	**33.3**	**7%**	**-16%**

Exhibit 5 reveals the expected strength of the DARLEP program: reducing side-impact collisions. Prior to the installation of red light cameras, the rate of monthly side-impact collisions at monitored approaches was higher than at unmonitored ones (39.65 collisions/month compared with 32.10 collisions/month). After the cameras became operational, monitored approaches experienced fewer side collisions per month than unmonitored ones (33.25 collisions versus 34.38). While the 7% increase in side-impact collisions at unmonitored approaches was statistically insignificant, our analysis determined the 16% decrease in side-impact collisions at monitored approaches to be statistically at the 95% confidence level.

Rear-Impact Collisions

Exhibit 6- Average Collisions per Month for Monitored and Unmonitored Rear-Impact Collisions Before and After Red-Light Cameras

Intersection ID	Intersection Name	Before Unmonitored	Before Monitored	After Unmonitored	After Monitored	Change at Unmonitored	Change at Monitored
-	**TOTAL**	**5.7**	**2.2**	**5.5**	**1.4**	**-3%**	**-36%**

While some studies have concluded that red light cameras may decrease the level of side-impact collisions they have also found that red light cameras increase rear-end collisions. The analysis of rear-end collisions at Houston DARLEP intersections indicates that red light cameras have no statistically significant impact on the rate of rear-impact collisions. Almost all intersections which experienced this type of collision (41 of 50 did) reported less than one collision every four months. Despite a 36% decrease in the rate of rear-end collisions at monitored approaches, the decline amounts to less than one collision per month over all DARLEP intersections.

Swipe Collisions

Exhibit 7- Average Collisions per Month for Monitored and Unmonitored Swipe Collisions Before and After Red-Light Cameras

Intersection ID	Intersection Name	Before Unmonitored	Before Monitored	After Unmonitored	After Monitored	Change at Unmonitored	Change at Monitored
-	**TOTAL**	**23.2**	**6.6**	**24.1**	**7.9**	**4%**	**20%**

Swipe collisions, which occur when one or more vehicles traveling in the same direction make an incorrect turn, are the least affected by the implementation of red light cameras. Because these types of collisions usually occur after the vehicle has stopped at the traffic signal, excessive speed is not a causal factor. Although the swipe collision rate at monitored approaches increased 20%, this change is not statistically significant due to the small number of collisions and wide variation in swipe collision rates across monitored approaches.

Conclusion

This study concludes that the Houston red light camera program is reducing the rate of collisions at Digital Automated Red-Light Enforcement Program (DARLEP) intersections. We reached this conclusion through a comparison of monitored approaches and unmonitored approaches before and after the implementation of red light cameras. Through the comparison of the change in the collision rates at monitored and unmonitored approaches at the time red light cameras were implemented, we tested the effect of red light cameras at treated approaches to untreated approaches. The results of this comparison revealed lower levels of collisions of all types at monitored approaches after the implementation of cameras compared with these same approaches before cameras were introduced. These lower levels of collision rates are statistically significant at the 90% or 95% level of confidence. No statistically significant changes in collision rates were observed at unmonitored approaches between the before and after periods.

These findings lead us to conclude that the reduction in collisions at monitored approaches is due in large part to the introduction of red light cameras at these intersection approaches. The Houston red light camera program seems to be most effective in reducing side-impact collisions without increasing the occurrence of rear-end collisions.

Current limitations of this study include the short span of post-implementation data (8 months) as well as a host of mitigating factors which limit the effectiveness of the red light cameras. While many engineering factors such as poor lane striping and obscured traffic signals were corrected as the red light cameras were implemented, other mitigating factors are unchangeable. These factors include drunk driving, drivers without insurance and the age of the vehicle and driver which can have an effect on collision rates.

Future research will focus on the role of intersection-related factors in the success or failure of red light cameras. With the 2008 CRIS data expected in the near future, we can produce an updated version of this analysis within a few months of its release.

Appendix A - Data Tables

Exhibit 8- Collisions per Month for Monitored and Unmonitored Approaches Before and After Red-Light Cameras[9]

Intersection ID	Intersection Name	Before Unmonitored	Before Monitored	After Unmonitored	After Monitored	Change at Unmonitored	Change at Monitored
-	**TOTAL**	**61.30**	**48.50**	**64.25**	**43.13**	4.81%	**-11.08%**
1	Harwin at Hillcroft	0.95	0.25	0.75	0.13	-21%	-50%
2	Milam at Elgin	0.70	0.45	1.13	0.00	61%	-100%
3	Richmond at Dunvale	0.80	0.65	0.38	0.63	-53%	-4%
4	Bellaire at Wilcrest	0.60	0.15	0.50	0.25	-17%	67%
5	Richmond at Hillcroft	1.05	0.55	0.75	0.13	-29%	-77%
6	Brazos at Elgin	0.10	0.10	0.00	0.25	-100%	150%
7	Travis at Webster	0.20	0.65	0.13	0.50	-38%	-23%
8	John F. Kennedy at Greens Rd.	0.15	0.30	0.13	0.13	-17%	-58%
9	Bay Area Blvd at El Camino Real	0.80	1.20	0.50	2.00	-38%	67%
10	Pease at LaBranch	0.00	0.50	0.00	0.00	0%	-100%
11	Hillcroft at Southwest Fwy	1.80	1.90	1.25	1.50	-31%	-21%
12	Bissonnet at West Sam Houston S	3.75	1.30	3.00	1.63	-20%	25%
13	FM 1960 W at Tomball Pkwy	4.10	3.20	3.88	3.63	-5%	13%
14	Chimney Rock at Southwest Fwy	1.00	1.25	1.00	0.75	0%	-40%
15	Westpark at Southwest Fwy	0.45	0.85	0.75	1.50	67%	76%
16	Westheimer at West Loop S	0.75	0.45	1.13	0.25	50%	-44%
17	West Sam Houston S at Beechnut	2.60	1.20	2.88	1.38	11%	15%
18	Gessner at Beechnut	1.80	1.65	1.75	1.88	-3%	14%
19	East Fwy at Uvalde	1.30	1.00	1.38	0.50	6%	-50%
20	Southwest Fwy at Fountain View	1.35	0.75	2.13	0.63	57%	-17%
21	West Loop S at San Felipe	0.90	1.20	0.50	0.63	-44%	-48%
22	Southwest Fwy at Bellaire	3.05	1.90	2.75	1.75	-10%	-8%
23	El Dorado at Gulf Fwy	n/a	n/a	n/a	n/a	-	-
24	West Rd at North Fwy	1.40	2.10	0.25	1.75	-82%	-17%
25	Hollister at Northwest Fwy	1.25	1.10	3.25	0.63	160%	-43%
26	North Wayside at East Fwy	2.20	1.05	2.25	1.13	2%	7%
27	Chartres at St. Joeseph Pkwy	1.20	1.85	1.13	0.88	-6%	-53%
28	Southwest Fwy at Beechnut	1.30	1.05	0.75	0.63	-42%	-40%
29	Southwest Fwy at Fondren	1.05	0.60	1.25	0.75	19%	25%
30	Bissonnet at Southwest Fwy	1.05	1.25	2.00	0.88	90%	-30%
31	West Sam Houston S at Bellaire	1.70	1.30	3.75	1.38	121%	6%
32	Greens Road at North Fwy	2.50	2.00	1.25	1.00	-50%	-50%
33	North Shepherd at North Loop W	1.15	2.00	0.75	2.00	-35%	0%
34	Southwest Fwy at Wilcrest	n/a	n/a	n/a	n/a	-	-
35	Main St at South Loop W	1.55	1.35	2.13	1.50	37%	11%
36	North Fwy at Rankin	2.70	1.40	3.00	2.38	11%	70%
37	East Fwy at Normandy	1.15	0.90	3.38	1.38	193%	53%
38	Monroe at Gulf Fwy	n/a	n/a	n/a	n/a	-	-
39	Scott at South Loop E	0.90	0.35	1.50	0.88	67%	150%
40	Antoine at Northwest Fwy	1.25	0.30	1.63	0.88	30%	192%
41	Gulf Fwy at South Wayside	1.10	0.85	1.63	0.25	48%	-71%
42	Gulf Fwy at Woodridge	1.90	1.35	1.38	1.00	-28%	-26%
43	West Bellfort at Southwest Fwy	0.60	1.15	1.00	0.75	67%	-35%
44	Northwest Fwy at Fairbanks N. Houston	1.75	1.15	1.63	0.63	-7%	-46%
45	Westpark at West Sam Houston S	2.10	2.10	0.50	0.88	-76%	-58%
46	Gulf Fwy at FM 2351	0.80	0.30	0.63	0.50	-22%	67%
47	West Loop S at Post Oak Blvd	0.10	0.25	0.38	0.25	275%	0%
48	Northwest Fwy at Mangum	0.70	0.70	0.88	0.50	25%	-29%
49	South Sam Houston Fwy at Telephone	1.30	0.45	1.38	0.13	6%	-72%
50	South Loop West at Sella Link	0.40	0.15	0.00	0.25	-100%	67%

[9] The CRIS data did not include unique intersection IDs. Matches to DARLEP intersections were therefore based on latitude and longitude.

Exhibit 9- Collisions per Month for Monitored and Unmonitored Side-Impact Collisions Before and After Red-Light Cameras

Intersection ID	Intersection Name	Before Unmonitored	Before Monitored	After Unmonitored	After Monitored	Change at Unmonitored	Change at Monitored
-	**TOTAL**	**32.10**	**39.65**	**34.38**	**33.25**	7%	-16%
1	Harwin at Hillcroft	0.25	0.05	0.50	0.00	100%	-100%
2	Milam at Elgin	0.45	0.40	0.63	0.00	39%	-100%
3	Richmond at Dunvale	0.55	0.50	0.38	0.38	-32%	-25%
4	Bellaire at Wilcrest	0.30	0.00	0.25	0.25	-17%	n/a
5	Richmond at Hillcroft	0.75	0.55	0.63	0.13	-17%	-77%
6	Brazos at Elgin	0.05	0.10	0.00	0.13	-100%	25%
7	Travis at Webster	0.05	0.60	0.00	0.38	-100%	-38%
8	John F. Kennedy at Greens Rd.	0.15	0.30	0.13	0.13	-17%	-58%
9	Bay Area Blvd at El Camino Real	0.15	1.15	0.50	1.75	233%	52%
10	Pease at LaBranch	0.00	0.50	0.00	0.00	0%	-100%
11	Hillcroft at Southwest Fwy	0.70	1.45	0.88	1.25	25%	-14%
12	Bissonnet at West Sam Houston S	1.90	1.20	1.88	1.25	-1%	4%
13	FM 1960 W at Tomball Pkwy	2.85	2.75	2.50	3.38	-12%	23%
14	Chimney Rock at Southwest Fwy	0.50	0.90	0.50	0.50	0%	-44%
15	Westpark at Southwest Fwy	0.25	0.85	0.50	1.25	100%	47%
16	Westheimer at West Loop S	0.30	0.45	0.75	0.13	150%	-72%
17	West Sam Houston S at Beechnut	1.55	0.95	1.25	1.13	-19%	18%
18	Gessner at Beechnut	1.40	1.60	1.38	1.75	-2%	9%
19	East Fwy at Uvalde	0.15	0.65	0.50	0.38	233%	-42%
20	Southwest Fwy at Fountain View	0.50	0.60	1.00	0.50	100%	-17%
21	West Loop S at San Felipe	0.65	1.00	0.38	0.63	-42%	-38%
22	Southwest Fwy at Bellaire	1.75	1.60	1.25	1.13	-29%	-30%
23	El Dorado at Gulf Fwy	n/a	n/a	n/a	n/a	-	-
24	West Rd at North Fwy	1.00	1.85	0.00	1.13	-100%	-39%
25	Hollister at Northwest Fwy	0.65	1.05	1.38	0.38	112%	-64%
26	North Wayside at East Fwy	1.25	0.90	1.88	1.13	50%	25%
27	Chartres at St. Joeseph Pkwy	0.95	1.75	0.75	0.63	-21%	-64%
28	Southwest Fwy at Beechnut	0.55	0.70	0.38	0.25	-32%	-64%
29	Southwest Fwy at Fondren	0.30	0.50	0.50	0.50	67%	0%
30	Bissonnet at Southwest Fwy	0.40	1.05	0.63	0.75	56%	-29%
31	West Sam Houston S at Bellaire	1.10	1.30	3.13	1.25	184%	-4%
32	Greens Road at North Fwy	1.40	1.80	0.50	1.00	-64%	-44%
33	North Shepherd at North Loop W	0.70	1.65	0.38	1.88	-46%	14%
34	Southwest Fwy at Wilcrest	n/a	n/a	n/a	n/a	-	-
35	Main St at South Loop W	1.00	1.15	1.63	1.25	63%	9%
36	North Fwy at Rankin	1.35	0.80	1.63	1.88	20%	134%
37	East Fwy at Normandy	0.25	0.60	1.25	0.38	400%	-38%
38	Monroe at Gulf Fwy	n/a	n/a	n/a	n/a	-	-
39	Scott at South Loop E	0.50	0.30	1.00	0.63	100%	108%
40	Antoine at Northwest Fwy	0.65	0.15	0.63	0.63	-4%	317%
41	Gulf Fwy at South Wayside	0.35	0.60	0.38	0.13	7%	-79%
42	Gulf Fwy at Woodridge	0.85	0.85	0.50	0.63	-41%	-26%
43	West Bellfort at Southwest Fwy	0.30	1.00	0.63	0.63	108%	-38%
44	Northwest Fwy at Fairbanks N. Houston	0.40	0.80	0.38	0.13	-6%	-84%
45	Westpark at West Sam Houston S	1.60	1.85	0.25	0.88	-84%	-53%
46	Gulf Fwy at FM 2351	0.20	0.20	0.00	0.13	-100%	-38%
47	West Loop S at Post Oak Blvd	0.10	0.25	0.13	0.13	25%	-50%
48	Northwest Fwy at Mangum	0.40	0.25	0.25	0.25	-38%	0%
49	South Sam Houston Fwy at Telephone	0.55	0.05	0.50	0.13	-9%	150%
50	South Loop West at Sella Link	0.10	0.10	0.00	0.25	-100%	150%

Exhibit 10- Collisions per Month for Monitored and Unmonitored Rear-Impact Collisions Before and After Red-Light Cameras

Intersection ID	Intersection Name	Before Unmonitored	Before Monitored	After Unmonitored	After Monitored	Change at Unmonitored	Change at Monitored
-	**TOTAL**	**5.65**	**2.15**	**5.50**	**1.38**	**-3%**	**-36%**
1	Harwin at Hillcroft	0.05	0.00	0.00	0.00	-100%	0%
2	Milam at Elgin	0.05	0.00	0.00	0.00	-100%	0%
3	Richmond at Dunvale	0.05	0.00	0.00	0.13	-100%	n/a
4	Bellaire at Wilcrest	0.10	0.05	0.00	0.00	-100%	-100%
5	Richmond at Hillcroft	0.05	0.00	0.13	0.00	150%	0%
6	Brazos at Elgin	0.00	0.00	0.00	0.00	0%	0%
7	Travis at Webster	0.00	0.00	0.00	0.00	0%	0%
8	John F. Kennedy at Greens Rd.	0.00	0.00	0.00	0.00	0%	0%
9	Bay Area Blvd at El Camino Real	0.10	0.00	0.00	0.13	-100%	n/a
10	Pease at LaBranch	0.00	0.00	0.00	0.00	0%	0%
11	Hillcroft at Southwest Fwy	0.30	0.15	0.00	0.13	-100%	-17%
12	Bissonnet at West Sam Houston S	0.30	0.00	0.00	0.00	-100%	0%
13	FM 1960 W at Tomball Pkwy	0.55	0.10	0.50	0.00	-9%	-100%
14	Chimney Rock at Southwest Fwy	0.10	0.15	0.13	0.13	25%	-17%
15	Westpark at Southwest Fwy	0.05	0.00	0.00	0.00	-100%	0%
16	Westheimer at West Loop S	0.10	0.00	0.13	0.00	25%	0%
17	West Sam Houston S at Beechnut	0.30	0.05	0.38	0.00	25%	-100%
18	Gessner at Beechnut	0.10	0.00	0.13	0.00	25%	0%
19	East Fwy at Uvalde	0.20	0.10	0.13	0.00	-38%	-100%
20	Southwest Fwy at Fountain View	0.15	0.05	0.38	0.00	150%	-100%
21	West Loop S at San Felipe	0.00	0.00	0.00	0.00	0%	0%
22	Southwest Fwy at Bellaire	0.55	0.00	0.25	0.00	-55%	0%
23	El Dorado at Gulf Fwy	n/a	n/a	n/a	n/a	-	-
24	West Rd at North Fwy	0.05	0.00	0.00	0.13	-100%	n/a
25	Hollister at Northwest Fwy	0.00	0.00	0.50	0.00	n/a	0%
26	North Wayside at East Fwy	0.20	0.10	0.00	0.00	-100%	-100%
27	Chartres at St. Joeseph Pkwy	0.00	0.00	0.00	0.00	0%	0%
28	Southwest Fwy at Beechnut	0.15	0.10	0.13	0.00	-17%	-100%
29	Southwest Fwy at Fondren	0.15	0.00	0.13	0.13	-17%	n/a
30	Bissonnet at Southwest Fwy	0.10	0.05	0.50	0.00	400%	-100%
31	West Sam Houston S at Bellaire	0.20	0.00	0.13	0.00	-38%	0%
32	Greens Road at North Fwy	0.20	0.05	0.13	0.00	-38%	-100%
33	North Shepherd at North Loop W	0.10	0.00	0.13	0.00	25%	0%
34	Southwest Fwy at Wilcrest	n/a	n/a	n/a	n/a	-	-
35	Main St at South Loop W	0.15	0.10	0.25	0.00	67%	-100%
36	North Fwy at Rankin	0.15	0.40	0.38	0.13	150%	-69%
37	East Fwy at Normandy	0.05	0.10	0.25	0.25	400%	150%
38	Monroe at Gulf Fwy	n/a	n/a	n/a	n/a	-	-
39	Scott at South Loop E	0.15	0.05	0.13	0.13	-17%	150%
40	Antoine at Northwest Fwy	0.10	0.00	0.13	0.13	25%	n/a
41	Gulf Fwy at South Wayside	0.05	0.05	0.13	0.00	150%	-100%
42	Gulf Fwy at Woodridge	0.20	0.15	0.00	0.00	-100%	-100%
43	West Bellfort at Southwest Fwy	0.00	0.10	0.13	0.00	n/a	-100%
44	Northwest Fwy at Fairbanks N. Houston	0.15	0.00	0.25	0.00	67%	0%
45	Westpark at West Sam Houston S	0.05	0.05	0.00	0.00	-100%	-100%
46	Gulf Fwy at FM 2351	0.15	0.10	0.00	0.00	-100%	-100%
47	West Loop S at Post Oak Blvd	0.00	0.00	0.00	0.00	0%	0%
48	Northwest Fwy at Mangum	0.00	0.10	0.13	0.00	n/a	-100%
49	South Sam Houston Fwy at Telephone	0.10	0.00	0.00	0.00	-100%	0%
50	South Loop West at Sella Link	0.10	0.00	0.00	0.00	-100%	0%

Exhibit 11- Collisions per Month for Monitored and Unmonitored Swipe Collisions Before and After Red-Light Cameras

Intersection ID	Intersection Name	Before Unmonitored	Before Monitored	After Unmonitored	After Monitored	Change at Unmonitored	Change at Monitored
-	**TOTAL**	**23.15**	**6.55**	**24.13**	**7.88**	**4%**	**20%**
1	Harwin at Hillcroft	0.65	0.20	0.25	0.13	-62%	-38%
2	Milam at Elgin	0.20	0.05	0.50	0.00	150%	-100%
3	Richmond at Dunvale	0.20	0.15	0.00	0.13	-100%	-17%
4	Bellaire at Wilcrest	0.20	0.10	0.25	0.00	25%	-100%
5	Richmond at Hillcroft	0.25	0.00	0.00	0.00	-100%	0%
6	Brazos at Elgin	0.05	0.00	0.00	0.13	-100%	n/a
7	Travis at Webster	0.15	0.05	0.13	0.13	-17%	150%
8	John F. Kennedy at Greens Rd.	0.00	0.00	0.00	0.00	0%	0%
9	Bay Area Blvd at El Camino Real	0.50	0.00	0.00	0.13	-100%	n/a
10	Pease at LaBranch	0.00	0.00	0.00	0.00	0%	0%
11	Hillcroft at Southwest Fwy	0.80	0.30	0.38	0.13	-53%	-58%
12	Bissonnet at West Sam Houston S	1.55	0.10	1.13	0.25	-27%	150%
13	FM 1960 W at Tomball Pkwy	0.65	0.35	0.88	0.25	35%	-29%
14	Chimney Rock at Southwest Fwy	0.40	0.20	0.38	0.13	-6%	-38%
15	Westpark at Southwest Fwy	0.10	0.00	0.25	0.25	150%	n/a
16	Westheimer at West Loop S	0.35	0.00	0.25	0.13	-29%	n/a
17	West Sam Houston S at Beechnut	0.70	0.20	1.25	0.25	79%	25%
18	Gessner at Beechnut	0.30	0.05	0.25	0.13	-17%	150%
19	East Fwy at Uvalde	0.95	0.25	0.75	0.13	-21%	-50%
20	Southwest Fwy at Fountain View	0.70	0.10	0.75	0.13	7%	25%
21	West Loop S at San Felipe	0.20	0.20	0.13	0.00	-38%	-100%
22	Southwest Fwy at Bellaire	0.70	0.30	1.13	0.25	61%	-17%
23	El Dorado at Gulf Fwy	n/a	n/a	n/a	n/a	-	-
24	West Rd at North Fwy	0.35	0.25	0.25	0.38	-29%	50%
25	Hollister at Northwest Fwy	0.60	0.05	1.38	0.25	129%	400%
26	North Wayside at East Fwy	0.70	0.05	0.38	0.00	-46%	-100%
27	Chartres at St. Joeseph Pkwy	0.25	0.10	0.38	0.25	50%	150%
28	Southwest Fwy at Beechnut	0.60	0.25	0.25	0.38	-58%	50%
29	Southwest Fwy at Fondren	0.60	0.10	0.63	0.13	4%	25%
30	Bissonnet at Southwest Fwy	0.55	0.15	0.88	0.13	59%	-17%
31	West Sam Houston S at Bellaire	0.40	0.00	0.50	0.13	25%	n/a
32	Greens Road at North Fwy	0.90	0.15	0.63	0.00	-31%	-100%
33	North Shepherd at North Loop W	0.35	0.35	0.25	0.13	-29%	-64%
34	Southwest Fwy at Wilcrest	n/a	n/a	n/a	n/a	-	-
35	Main St at South Loop W	0.40	0.10	0.25	0.25	-38%	150%
36	North Fwy at Rankin	1.20	0.15	1.00	0.38	-17%	150%
37	East Fwy at Normandy	0.80	0.20	1.88	0.75	134%	275%
38	Monroe at Gulf Fwy	n/a	n/a	n/a	n/a	-	-
39	Scott at South Loop E	0.25	0.00	0.38	0.13	50%	n/a
40	Antoine at Northwest Fwy	0.50	0.15	0.88	0.13	75%	-17%
41	Gulf Fwy at South Wayside	0.70	0.15	1.13	0.13	61%	-17%
42	Gulf Fwy at Woodridge	0.85	0.35	0.75	0.38	-12%	7%
43	West Bellfort at Southwest Fwy	0.30	0.05	0.25	0.13	-17%	150%
44	Northwest Fwy at Fairbanks N. Houston	1.20	0.35	1.00	0.50	-17%	43%
45	Westpark at West Sam Houston S	0.45	0.20	0.25	0.00	-44%	-100%
46	Gulf Fwy at FM 2351	0.45	0.00	0.63	0.38	39%	n/a
47	West Loop S at Post Oak Blvd	0.00	0.00	0.25	0.13	n/a	n/a
48	Northwest Fwy at Mangum	0.30	0.35	0.50	0.25	67%	-29%
49	South Sam Houston Fwy at Telephone	0.65	0.40	0.88	0.00	35%	-100%
50	South Loop West at Sella Link	0.20	0.05	0.00	0.00	-100%	-100%

Statistical Tests

All statistical tests mentioned in this report were performed using statistical analysis software (SPSS) using a two-tailed paired-samples difference of means test. This test analyzes the variance of the two groups (i.e., rate of collisions at unmonitored approaches before cameras and rate of collisions at unmonitored approaches after cameras) on a case by case basis to determine if the average difference between the groups is significantly different than zero. The paired-sample t-test is frequently used when testing identical subjects more than once. Measuring heart rates in the same patients before and after running laps is one example. In the DARLEP study the identical subjects are not people, but intersection approaches observed both before and after the implementation of red light cameras. These are the results from performing the paired-samples t-test on two pairs of cases, unmonitored approaches and monitored approaches:

Exhibit 12: Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-Unmonitored	1.3043	47	.89624	.13073
	Post-Unmonitored	1.3670	47	1.04107	.15186
Pair 2	Pre-Monitored	1.0319	47	.66123	.09645
	Post-Monitored	.91755	47	.729464	.106403

Exhibit 12 shows the descriptive statistics for each pair. Pair 1 contains collision rates at all 47 unmonitored approaches before (pre-unmonitored) and after (post-unmonitored) the implementation of red light cameras. Pair 2 contains identical data, but for monitored approaches. We can see the rates at unmonitored approaches increase post-implementation while the rates at monitored approaches decrease post-implementation.

Exhibit 13: Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Pre-Unmonitored & Post-Unmonitored	47	.726	.000
Pair 2	Pre-Monitored & Post-Monitored	47	.786	.000

Exhibit 13 contains the correlations of each pair, or how well each pre-camera collision rate at matches up to its post-camera counterpart at the same intersection. The correlation is computed for both monitored and unmonitored collision rates. Correlations are computed on a scale from -1 to1 and both 0.726 (unmonitored) and 0.786 (monitored) represent a high positive

correlation. This means that for both monitored and unmonitored collision rates, an approach with a higher rate before cameras will also have a higher rate after the implementation of cameras. This does not mean that collision rates are increasing, only that an approach's collision rate relative to other approaches will remain relatively stable before and after red light cameras. In essence, this confirms that approaches have different "natural" collision rates than one another due to traffic volume, signal visibility, and other characteristics unique to each intersection approach.

Exhibit 14: Paired Samples Test

	Paired Differences					
	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1 Pre-Unmonitored & Post-Unmonitored	-.06277	.72928	.10638	-.590	46	.558
Pair 2 Pre-Monitored & Post-Monitored	.114362	.459020	.066955	1.708	46	.094

Exhibit 14, the final table of the paired-sample t-test, compares the average difference between each case in the pair and computes the standard deviation or variability of those differences. For example, the number sets (0,5,10,15,20) and (8,9,10,11,12) have the same average (10), but the second set has a much smaller standard deviation.

From the table, the first pair (unmonitored approaches) has a smaller average difference between case pairs and a larger standard deviation that the second pair (monitored approaches). This reveals that unmonitored approaches experienced less difference pre- to post-camera and had more variable differences. Monitored approaches on the other hand (pair 2), experienced a larger and more consistent difference. The t-test of significance confirms that collision rates at monitored approaches before and after the implementation of red light cameras are significantly different, while collision rates at unmonitored approaches before and after red light cameras are statistically indistinguishable from one another. The difference in collision rates at monitored approaches pre- and post- red light cameras is stated with a significance of 0.094, signifying that this difference has around a 9.5% chance of occurring due to random variance in the data. Although rigorous statistical differences are considered significant when 0.05 or less, a significance of less than 0.1 in policy evaluation usually represents a significant finding.

In the tables below, we report the descriptive statistics, correlations, and paired-samples t-test for the comparisons of side-impact, rear-impact, and swipe impact collision rates between unmonitored approaches pre- and post-cameras and monitored approaches pre- and post-camera.

Side-Impact Collisions

Exhibit 15: Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-Unmonitored	.68298	47	.588409	.085828
	Post-Unmonitored	.73138	47	.672630	.098113
Pair 2	Pre-Monitored	.84362	47	.600599	.087606
	Post-Monitored	.70745	47	.666185	.097173

Exhibit 16: Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Pre-Unmonitored & Post-Unmonitored	47	.671	.000
Pair 2	Pre-Monitored & Post-Monitored	47	.780	.000

Exhibit 17: Paired Samples Test

		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1	Pre-Unmonitored & Post-Unmonitored	-.048404	.517215	.075444	-.642	46	.524
Pair 2	Pre-Monitored & Post-Monitored	.136170	.424994	.061992	2.197	46	.033

Rear-Impact Collisions

Exhibit 18: Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-Unmonitored	.12021	47	.123209	.017972
	Post-Unmonitored	.11702	47	.148370	.021642
Pair 2	Pre-Monitored	.04574	47	.072103	.010517
	Post-Monitored	.02926	47	.059509	.008680

Exhibit 19: Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Pre-Unmonitored & Post-Unmonitored	47	.381	.008
Pair 2	Pre-Monitored & Post-Monitored	47	.283	.054

Exhibit 20: Paired Samples Test

		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1	Pre-Unmonitored & Post-Unmonitored	.003191	.152570	.022255	.143	46	.887
Pair 2	Pre-Monitored & Post-Monitored	.016489	.079447	.011589	1.423	46	.162

Swipe Collisions

Exhibit 21: Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-Unmonitored	.4926	47	.33427	.04876
	Post-Unmonitored	.5133	47	.43084	.06284
Pair 2	Pre-Monitored	.139	47	.1216	.0177
	Post-Monitored	.16755	47	.152597	.022259

Exhibit 22: Paired Samples Correlations

		N	Correlation	Sig.
Pair 1	Pre-Unmonitored & Post-Unmonitored	47	.693	.000
Pair 2	Pre-Monitored & Post-Monitored	47	.318	.029

Exhibit 23: Paired Samples Test

		Paired Differences					
		Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1	Pre-Unmonitored & Post-Unmonitored	-.02074	.31257	.04559	-.455	46	.651
Pair 2	Pre-Monitored & Post-Monitored	-.028191	.162070	.023640	-1.193	46	.239