NMSU Red Light Camera Study Update

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TO: Brian Denmark, Assistant City Manager

FROM: Dan Soriano, Acting Public Works Director

DATE: 1/3/2012 **FILE:** 12-001

SUBJECT: Report 1 of NMSU Safety Assessment of the Safe Traffic Operations Program (STOP)

The attached report is the first of four which are to be submitted by the College of Engineering at New Mexico State University (NMSU) discussing the safety assessment of the City of Las Cruces' Safe Traffic Operations Program (STOP).

NMSU was contracted by the City of Las Cruces last year to begin researching crash data and perform statistical analysis at the four locations where the camera system was installed. Locations of the initial start up were the intersections of Main St. and Solano Dr., Avenida De Mesilla and Valley Dr., Lohman Ave. and Walnut St., and Lohman Ave. and Telshor Blvd. The program was initiated in 2009 with 8 cameras (2 at each intersection location). Three cameras were deactivated with the New Mexico State Transportation Commission's enactment of Policy 70 in March of 2010 which prohibited the use of this type of enforcement system on roadways within their jurisdiction. Main St. and Solano Dr. (2 cameras), and Avenida De Mesilla and Valley Dr. (1 camera) were those locations effected by the State's ruling.

This initial report and presentation discusses the preliminary findings surrounding the crash analysis over a time period before and after the cameras were first activated in 2009.

Attachments

Assessment of Impact of City of Las Cruces Safe Traffic Operations Program on Intersection Traffic Safety

Before-and-After Analysis of Crash Data

Preliminary Report

by

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ABSTRACT

This report presents results on the analysis of crash data as part of an evaluation of the impact on traffic safety of the Las Cruces Safe Traffic Operations Program. The current study includes about 2,200 crash records collected from 10 signalized intersections in the City of Las Cruces, New Mexico, between January 2004 and April 2011. The goal of this study is to assess the impact of the program on traffic safety during the first 26 months of implementation and in subsequent years of the program. The findings that can be drawn from the statistical analysis are in the following. The program has a positive impact on the traffic safety at the Lohman Ave. and the Telshor Blvd. intersection. After the program operation, the total crash rate reductions, mainly due to the reduction of angle crash rates were marginally significant at the intersection. However, there weren't any significant changes in the rear-end crash rates, property-damage-only crash rates, and the injury crash rates. Two out of six control intersections have experienced statistically significant changes on the rear-end crash rates and marginally significant changes on the property-damage-only crash rates. However, it cannot be concluded that these changes could result from the absence of the operation. This is because the crash rate was increased at one intersection while decreased at another. Other factors such as traffic management and intersection improvements could be the cause.

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1. INTRODUCTION

The City of Las Cruces, NM introduced the Safe Traffic Operations Program (STOP), more commonly known as the red light camera (RLC) enforcement program, in March, 2009. The purpose of the program is to improve traffic safety at signalized intersections by reducing not only red light violations but also speed violations and consequently, crashes at signalized intersection areas. The city placed the cameras in four pilot intersections where red light violations and accidents were persistent. Those intersections are Lohman Avenue/Telshor Blvd. (LOTE), Lohman Avenue/Walnut Avenue (LOWA), Main Street/Solano Drive (MASO), and Valley Drive/Avenida de Mesilla (VAAM). Among them, three cameras were deactivated since May, 2010. One of them is the southbound camera at Valley Drive/Avenida de Mesilla and the other two are at Main Street/ Solano Drive.

Two commonly applied criteria for evaluating the effectiveness of the STOP are: (1) reduction in the number of violations including red light running and speeding, and (2) reduction in the number of crashes after the installation and operation of the camera. Both of these criteria are important justifications for the STOP. Studying data associated with these criteria can lead to an understanding of how the STOP may be improved in order to enhance their positive impact for traffic safety as well. Therefore, the goal of this project is to assess the impact of the STOP on crash rates and violation rates during the first two years of implementation and in subsequent years of the program.

2. CRASH DATA

The observed crashes were obtained from the City of Las Cruces Police Department and were weighted by the number of vehicles passing through the intersection in order to eliminate the bias caused by different traffic volumes. In this study, the number of crashes per 1 million passing vehicles was used as the crash measure for a particular monitored approach of an intersection. The average daily traffic (ADT) on the street that is monitored by the Las Cruces Metropolitan Planning Organization (MPO) is used to represent the number of vehicles passing through the intersection. Monthly traffic volumes at each intersection were calculated using the 24 hour ADT counts. (Note that the Las Cruces MPO conducted traffic counts at the signalized intersections during various times; some count data were relatively recent while others were collected several years ago. It is assumed that ADTs at the intersections remained similar in the past several years. If the intersections do not have complete counts, the approximate ADT values for the intersection would be generated based on available traffic counts from surrounding intersections.)

The current study also includes crash data from six control intersections for comparison study which is a necessary requirement in conducting a proper evaluation of the STOP system. The six control intersections don’t have any cameras installed, but have geometries and traffic volumes similar to at least one of the intersections in the STOP system at the City of Las Cruces. These control intersections are Elks Drive and Main Street (ELMA), Picacho Avenue and Main Street (PIMA), Picacho Avenue and Valley Drive (PIVA), Solano Drive and Missouri Avenue (SOMI), Solano Drive and Spruce Avenue (SOSP), and Valley Drive and Amador Avenue (VAAD). These control intersections were identified by the City of Las Cruces. The crash data of these control intersections and the four camera intersections was analyzed to determine the effect of the STOP on road safety.

For each intersection, the crash report data was compiled based on the types of accidents (angle crash and rear-end crash) and levels of severity (property damage only, injury, and fatality). The given period of analysis for each intersection is from January 2004 until April 2011. In conducting the analysis, crash results are grouped into two distinct periods, namely (1) before the camera installation period and (2) after the camera installation period.

3. METHODOLOGY

After data grouping, the crash analysis was conducted on two levels – one using trend analysis and the other using statistical analysis.

3.1 Trend Analysis

Trend analysis fits a general trend model to time series data and is often used to provide forecasts. A trend line could simply be drawn by using statistical techniques like linear regression. The trend lines typically are straight lines, although some variations use higher degree polynomials. In this paper, we use the linear trend line which is a best-fit straight line and it shows that something is increasing or decreasing at a steady rate. .

3.2 Statistical Analysis

Statistical analyses are conducted to prove if there is a reliable significant difference in the crash rates between before and after the STOP operation. The difference in crash rates between the before and the after periods are tested by the *F*-test and the *t*-test.

3.2.1. Variance test

The *F*-test applied in this report is the variance ratio test. The objective of this test is to investigate the significance of the difference between two population variances. The limitation of this test is that two populations should both follow normal distribution. However, it is not necessary that they should have the same means. Given samples of size n_1 with values $x_1, x_2, \ldots, x_{n1}$ and size n_2 with values $y_1, y_2, \ldots, y_{n2}$ from the two populations, we have

$$\bar{x} = \frac{\sum x_i}{n_1},\ \bar{y} = \frac{\sum y_i}{n_2} \text{ and } S_1^2 = \frac{\sum (x_i - \bar{x})}{n_1 - 1},\ S_2^2 = \frac{\sum (y_i - \bar{y})}{n_2 - 1}$$

$$F = \frac{S_1^2}{S_2^2} \text{ , where } S_1^2 > S_2^2 .$$

Compare the observed *F* value with the critical *F* value from the statistical table at a degree of freedom = $(n_1 - 1, n_2 - 1)$. If the observed *F* value is less than the critical *F* value from the table, the two population variances are not significantly different from each other.

3.2.2. Mean test

The *t*-test has the purpose of determining the significance of difference between two means. The two different *t*-tests used in this report are pooled variance and separate variance techniques. Before applying the *t*-test, the data should be examined first to find the appropriate technique. The pooled variance technique is applied to determine the significance of the difference between two means of data that have no significant difference between the two sample variances and where there is no correlation between the two data groups. The *t* value is computed as follows:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{S_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \ ,$$

where $\bar{X}_1$ is the mean of the first sample, $\bar{X}_2$ is the mean of the second sample, and the pooled standard deviation S_p is computed as follows:

$$S_p = \sqrt{\frac{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2}{n_1 + n_2 - 2}}$$

Here, S_1^2 and S_1^2 are variances of each of the groups.

The separated variance technique is applied to determine the significance of the difference between two means of data that have a significant difference between the two sample variances and where no correlation exists between the two data groups. The *t* value is computed as follows:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_1^2}{n_2}}}$$

4. RESULTS AND DISCUSSION

4.1. Trend Analysis

4.1.1. Yearly trends of the crash data

First, we review the yearly trends of crashes at the signalized intersections, which are illustrated in Figures 1 through 16, where the average annual crash counts per 1 million passing vehicles are recorded over time. The percent changes in the average crash rates are also summarized in the appendices (see Appendix A for the camera intersections and Appendix B for the control intersections). Note that while conducting the crash rate comparisons, the average of the crash rates in 2004 was used as the base period, and the crash rates in the other periods were compared to the crash rate in the base period.

Total Crash Rate: The preliminary view of the yearly trends on the total crash rates varies between all of the selected signalized intersections (see Figures 1 and 2). The pattern over time at the MASO camera intersection is especially jagged. However, the results also show that three out of four camera intersections have experienced a reduction in the total crash rates during the recent years. The average crash rates of the LOWA and MASO camera intersections were reduced by 25% and 38.5%. The LOTE camera intersection experienced the largest amount of reduction, i.e., 65%. Only the VAAM camera intersection experienced an increase in the crash rates. However, the downward trend began in 2010. Note that the MASO camera intersection experienced a substantial jump in 2009, which coincides with the introduction into full operation of the STOP. The yearly total crash counts at the control intersections are more fluctuating. The ELMA control intersection had the upward trend until 2008 and then began the downward trend since then. It is also noticed that there was a substantial jump in 2011 at the PIMA control intersection. Unlike the camera intersections, it is hard to say that there were downward trends at the control intersections during the recent years.

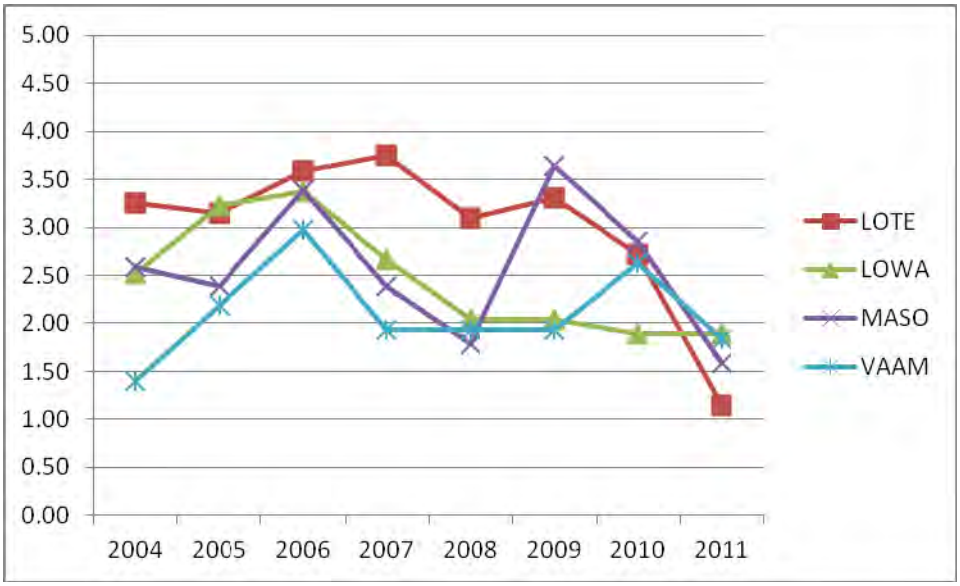


Figure 1. Yearly Trends of Crash Rates at Camera Intersection

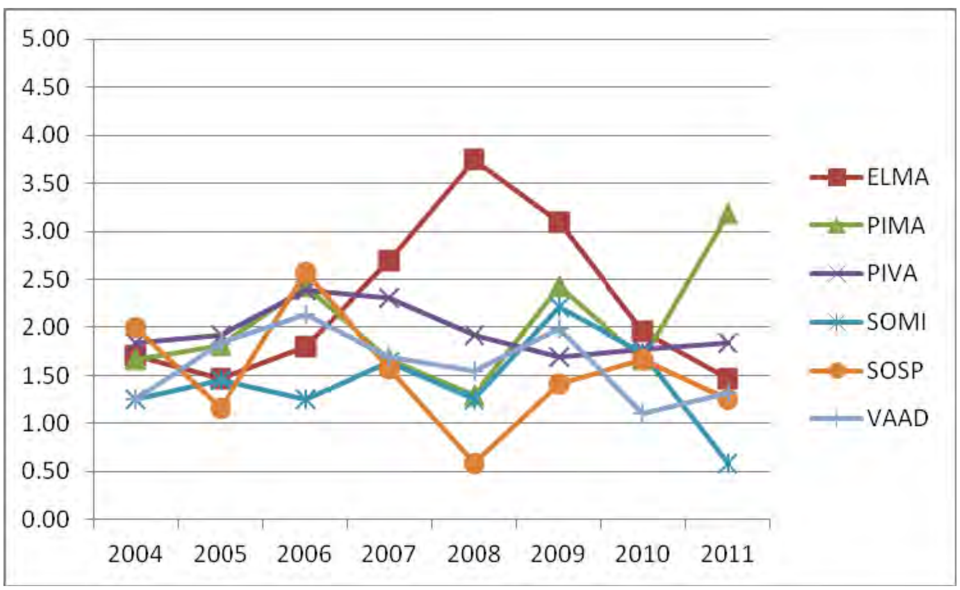


Figure 2. Yearly Trends of Crash Rates at Control Intersection

Angle Crash (AC) Rate: The AC crashes account for 28.25% of the total crashes at the camera intersections and 28.47% at the control intersections. The yearly trends of the AC rates are plotted in Figures 3 and 4. In comparison with the yearly total crash rate (see Figures 1 and 2), except for the LOWA camera intersection and the PIVA control intersection, somewhat flat trends are observed.

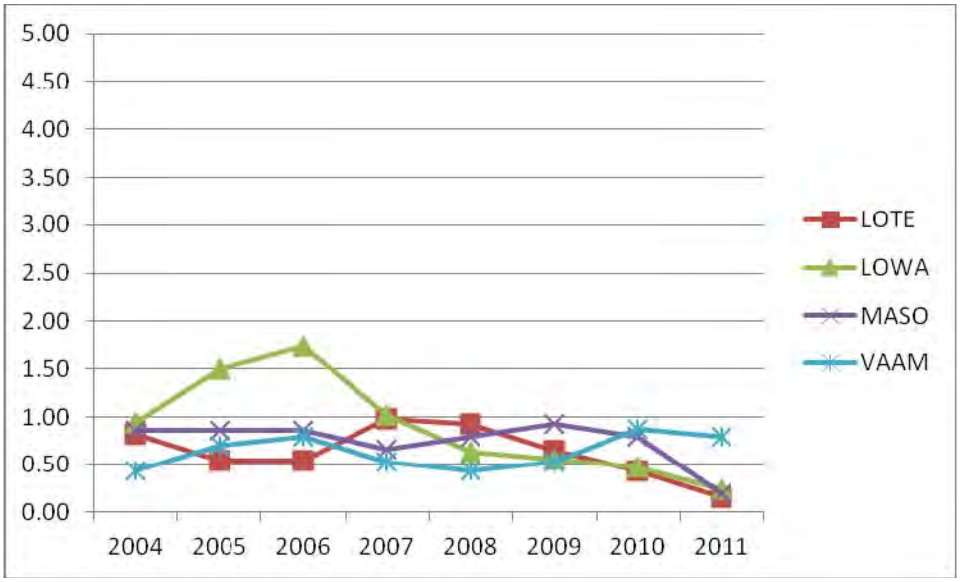


Figure 3. Yearly Trends of Angle Crash Rates at Camera Intersection

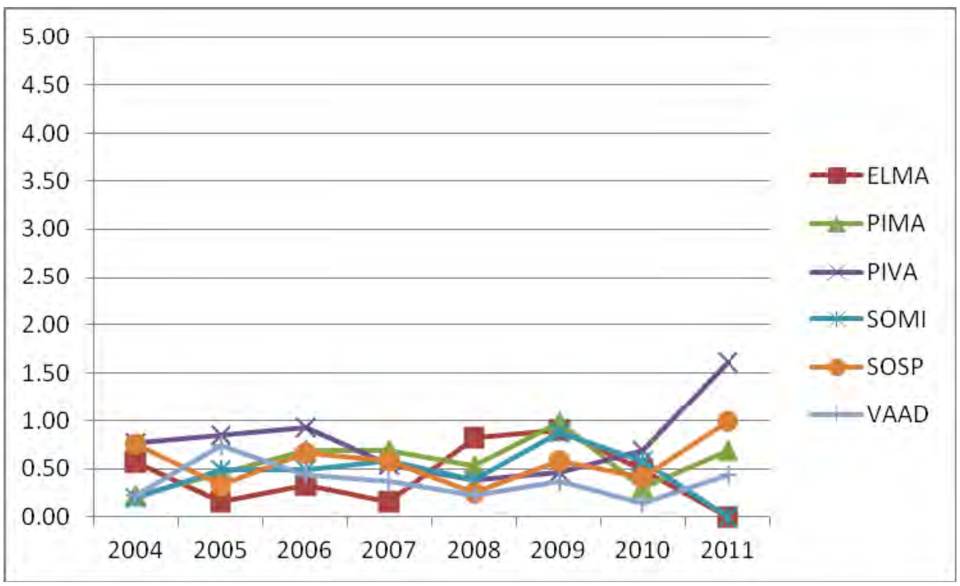


Figure 4. Yearly Trends of Angle Crash Rates at Control Intersection

The LOTE and LOWA camera intersections experienced an increase in the AC rates before the downward trend began in 2008 and 2007. Regarding the camera intersections, compared to the crash rates in the base period, i.e., 2004, only the VAAM intersection experienced an increase in the crash rates. However, all four camera intersections experienced a reduction in the AC rates from 2010 to 2011. On the average, the AC rates are less stable at the control intersections. It is noticed that there was a big jump at the PIVA control intersection in 2011. Table A2 in Appendix A also shows that the average AC rates at the camera intersections were reduced from 0.78 crashes to 0.31 crashes per 1 million vehicles, while it has increased from 0.46 to 0.64 at the control intersections.

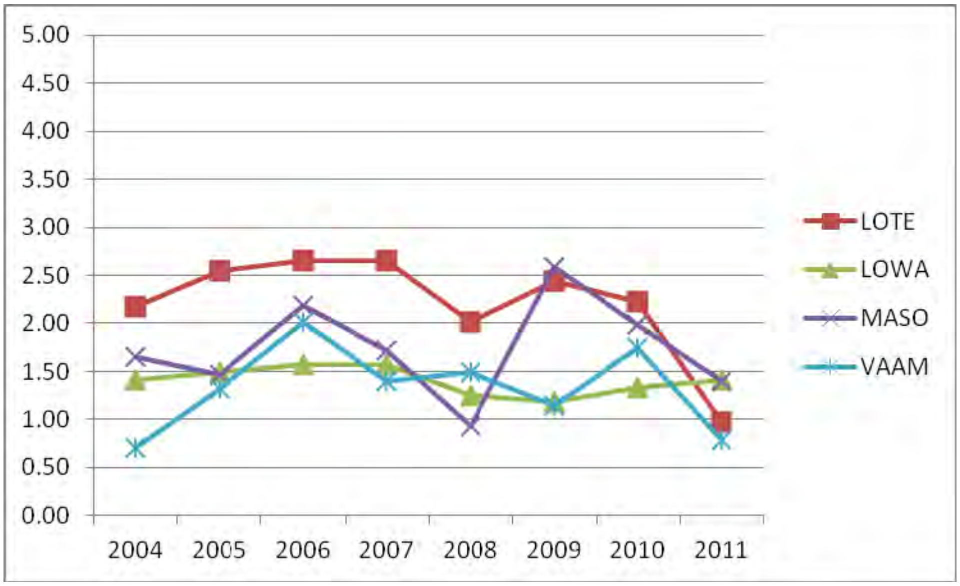


Figure 5. Yearly Trends of Rear-end Crash Rates at Camera Intersection

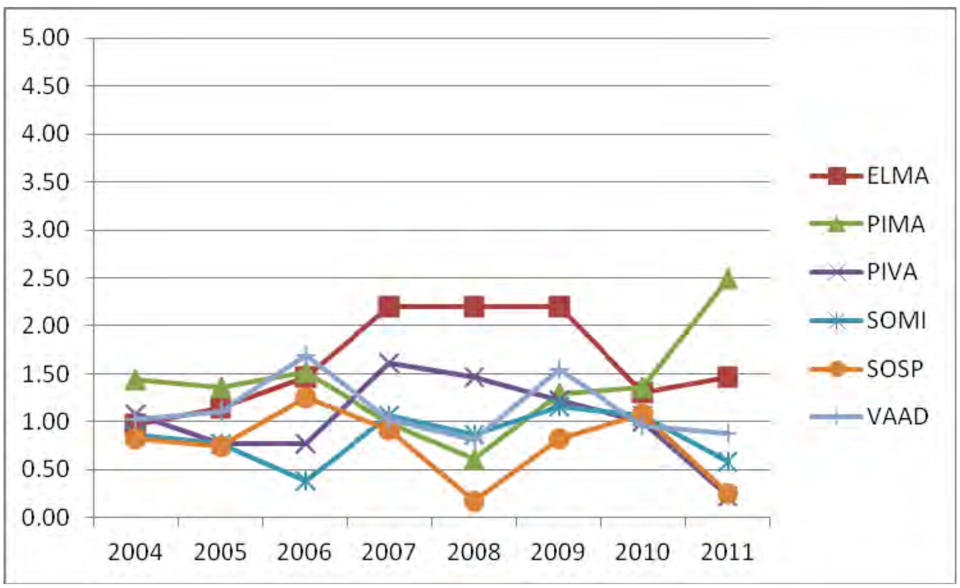


Figure 6. Yearly Trends of Rear-end Crash Rates at Control Intersection

Rear-end Crash (RC) Rate: The RC crashes account for 66.87% of the total crashes at the camera intersections and 62.84% at the control intersections. The camera intersections have very similar trends between the RC rates (see Figure 5) and the total crash rates (see Figure 1). Obviously, there is a downward trend at the LOTE camera intersection and a substantial jump at the MASO camera intersection in 2009, which coincides with the introduction into full operation of the STOP. Over time, the patterns at the control intersections became jagged. The PIMA control intersection began the upward trend since 2008. The ELMA control intersection experienced a relatively high number of RC rates from 2007 to 2009 (see Figure 6).

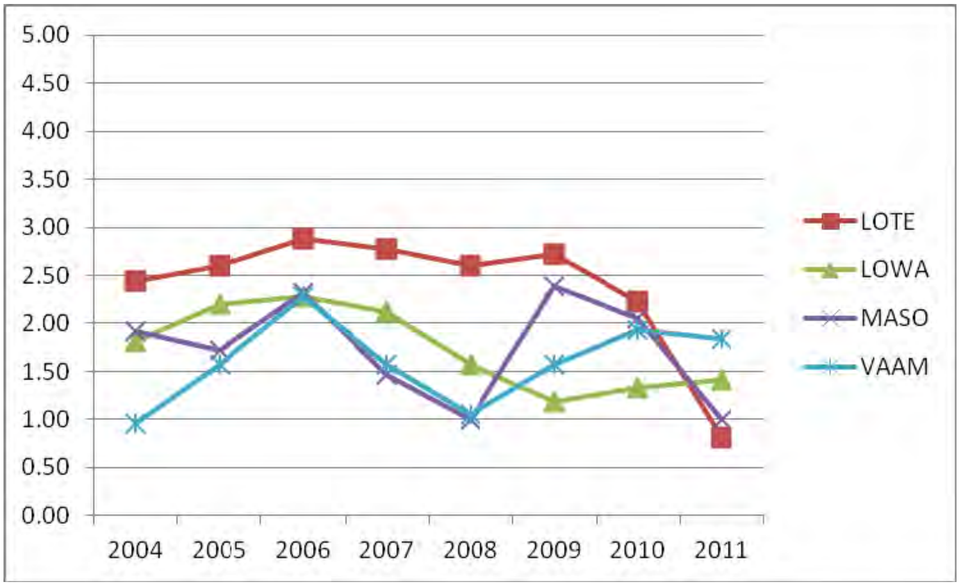


Figure 7. Yearly Trends of Property-Damage-Only Crash Rates at Camera Intersection

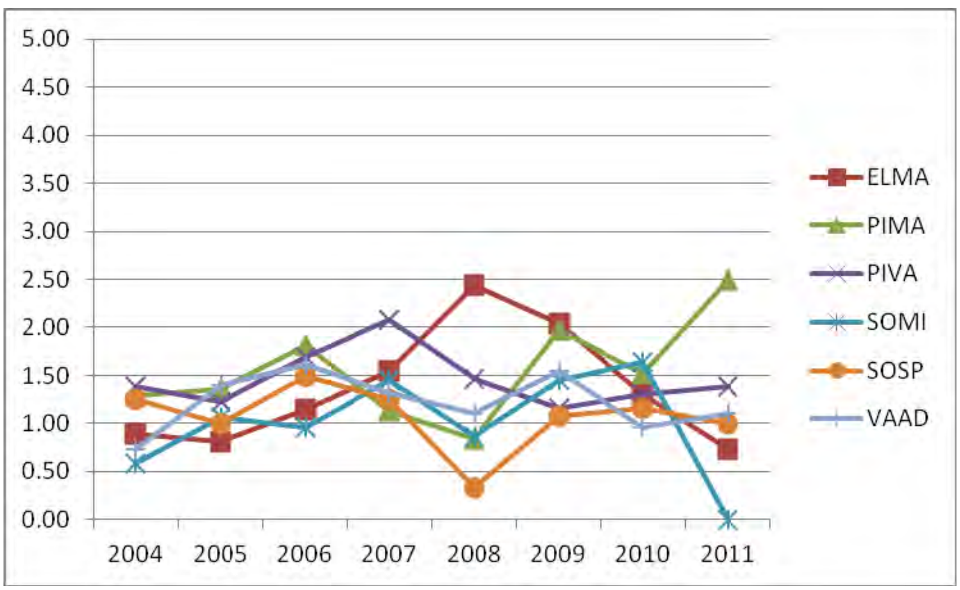


Figure 8. Yearly Trends of Property-Damage-Only Crash Rates at Control Intersection

Property-Damage-Only (PDO) Crash Rate: The PDO crashes account for 73.76% of the total crashes at the camera intersections and 71.72% at the control intersections. Figures 7and 8 show the yearly PDO crash counts per 1 million passing vehicles. Excluding the LOTE camera intersection that shows a downward trend, the patterns at all of the other intersections are very fluctuating. The LOTE camera intersection experienced the largest amount of a reduction on the PDO crash rates, and a substantial drop occurred in 2011. The MASO camera intersection, like the total crash rates and the RC rates, there was a substantial jump in 2009, which coincides with the introduction into the STOP operation. The ELMA control intersection had the upward trend until 2008 and then began the downward trend. Note that the SOMI control intersection didn't experience any crashes in 2011.

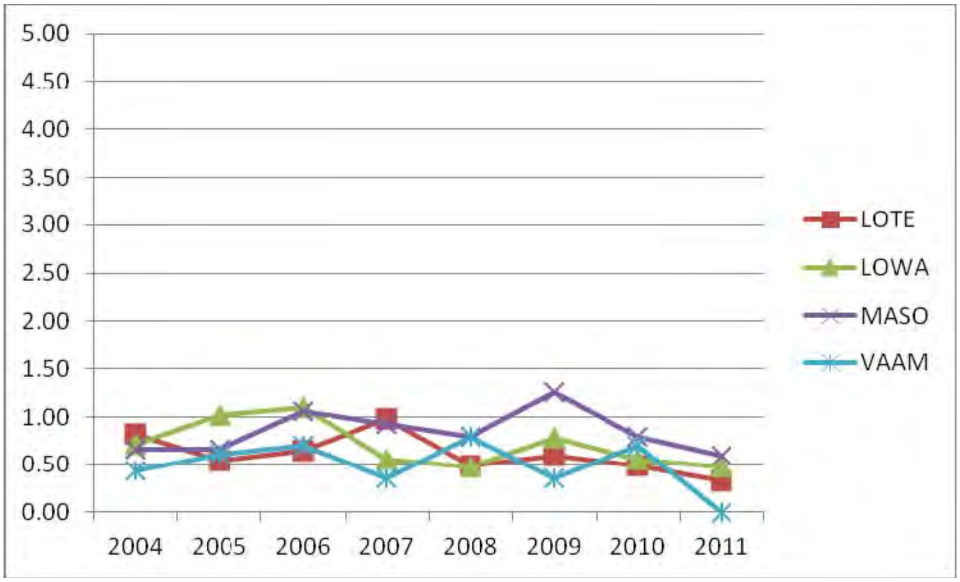


Figure 9. Yearly Trends of Injury Crash Rates at Camera Intersection

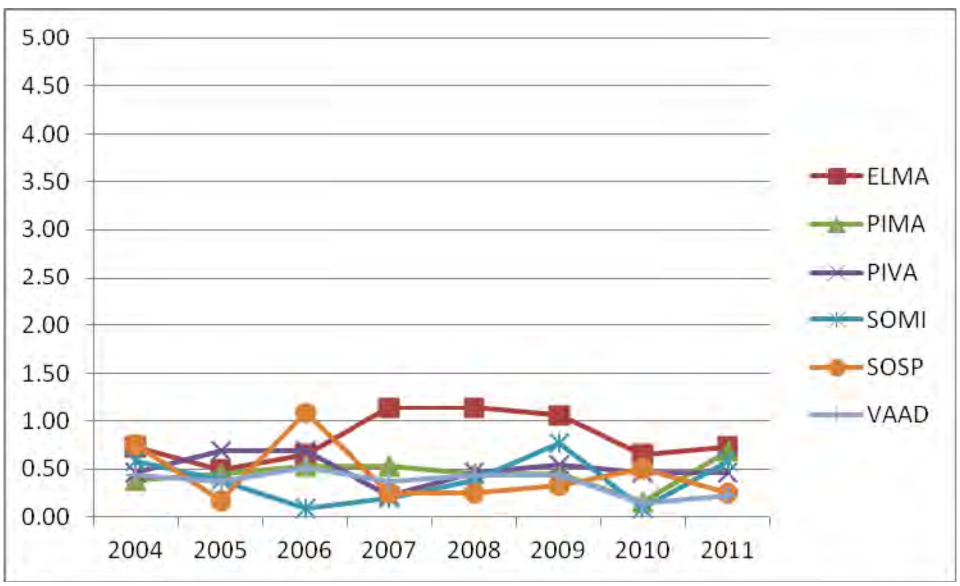


Figure 10. Yearly Trends of Injury Crash Rates at Control Intersection

Injury (INJ) Crash Rate: The injury crashes account for 26.07% of the total crashes at the camera intersections and 26.93 % at the control intersections. Except for the MASO camera intersection which has a small jump in 2009, three other camera intersections provide nearly stable injury crash rates (see Figure 9). Note that the VAAM camera intersection didn't experience any crashes in 2011 so far. Compared to all of the other intersections, the ELMA control intersection has experienced relatively high numbers of injury crash rates from 2007 to 2009 (see Figure 10).

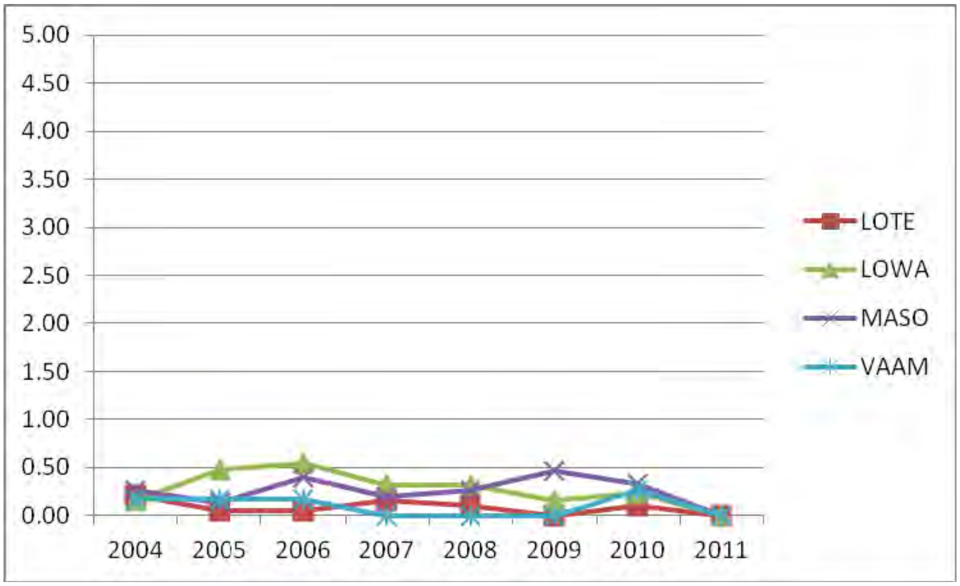


Figure 11. Yearly Trends of Injury-causing Angle Crash Rates at Camera Intersection

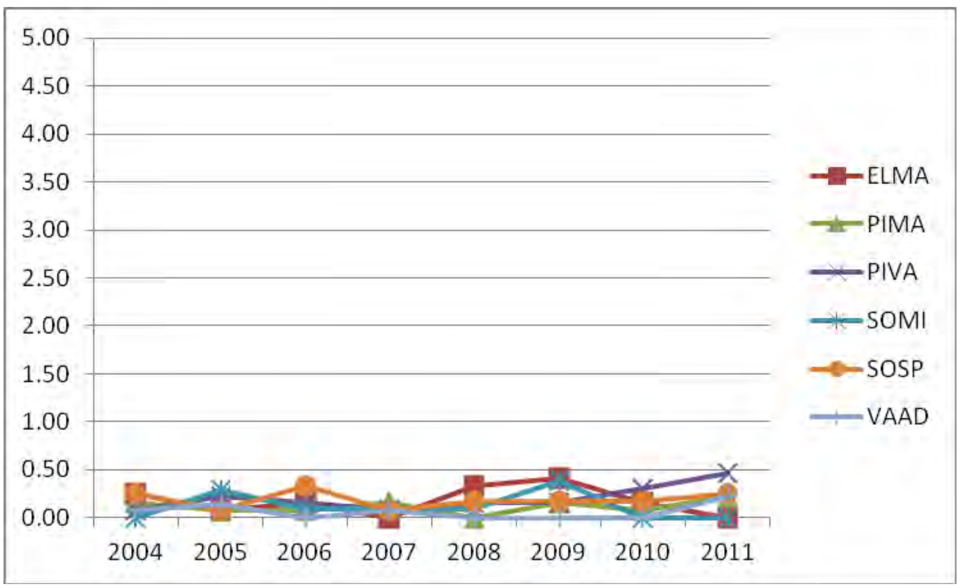


Figure 12. Yearly Trends of Injury-causing Angle Crash Rates at Control Intersection

Injury-causing Angle Crash Rate: The injury-causing angle crashes account for 25.6% of the angle crashes and only 7.24% of the total crashes at the camera intersections, whereas 26.78% and 7.63 % on the rear-end crashes and the total crashes at the control intersections. This fact explains the small number of the injury-causing angle crashes rates depicted in Figures 11 and 12. Overall, all of the camera and the control intersections provide nearly stable crash rates over time. It is noticed that all four camera intersections and two out of the six control intersections didn’t experience any crashes in 2011.

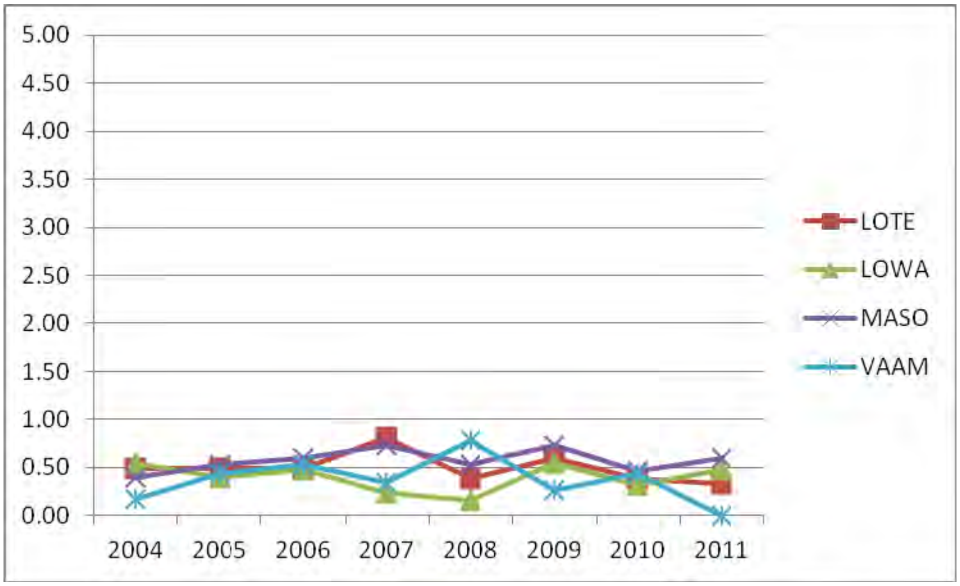


Figure 13. Yearly Trends of Injury-causing Rear-end Crash Rates at Camera Intersection

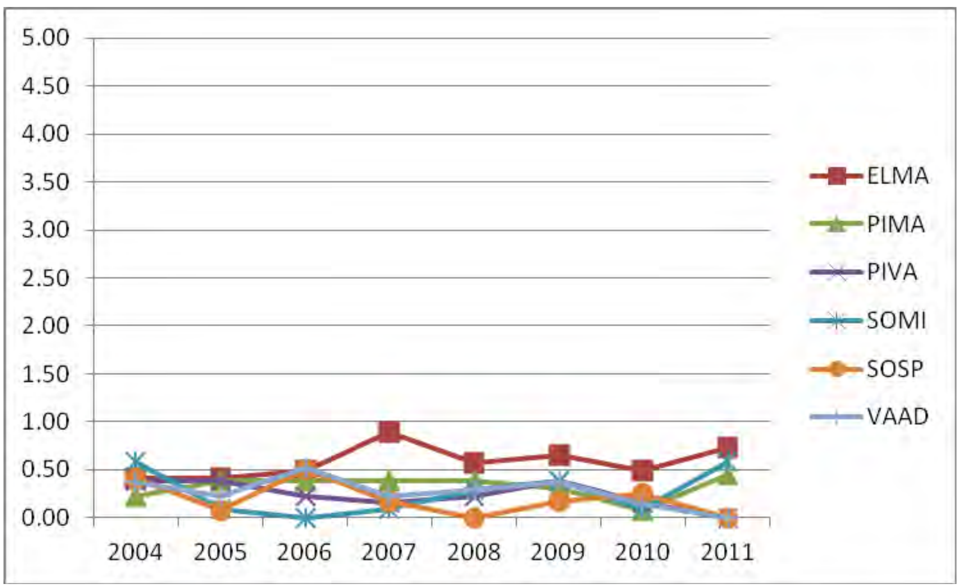


Figure 14. Yearly Trends of Injury-causing Rear-end Crash Rates at Control Intersection

Injury-causing Rear-end Crash Rate: The injury-causing rear-end crashes account for 26.73% of the rear-end crashes and only 17.87% of the total crashes at the camera intersections, where 27.04% and 16.99% on the rear-end crashes and the total crashes at the control intersections. As shown in Figures 13 and 14, the average annual crash counts per 1 million passing vehicles are very low, similar to the results of the injury-causing angle crash rates. The VAAM intersection experienced a small jump in 2008, but didn’t experience any crashes in 2011. Three other camera intersections provide nearly stable crash rates over time.

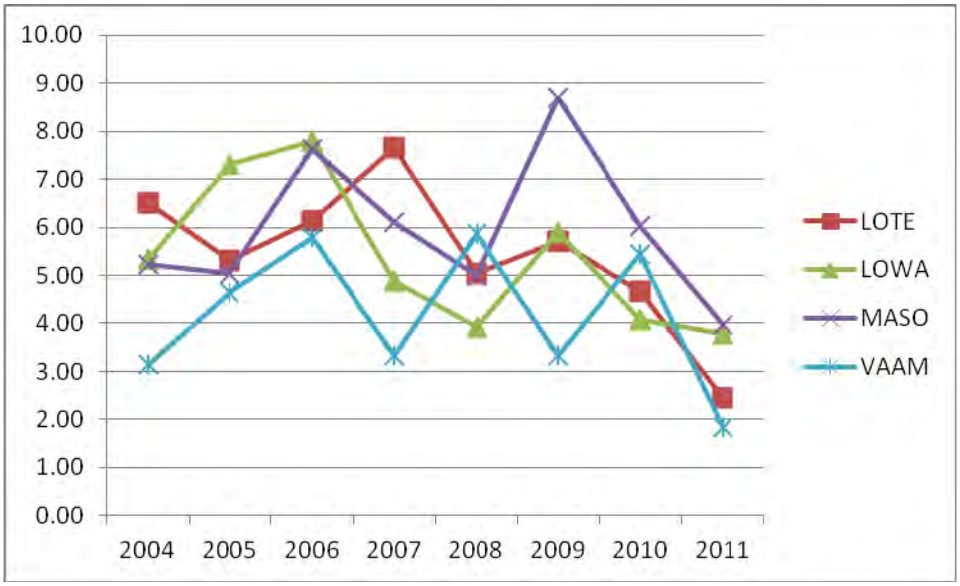


Figure 15. Yearly Trends of Severity Index Rates at Camera Intersection

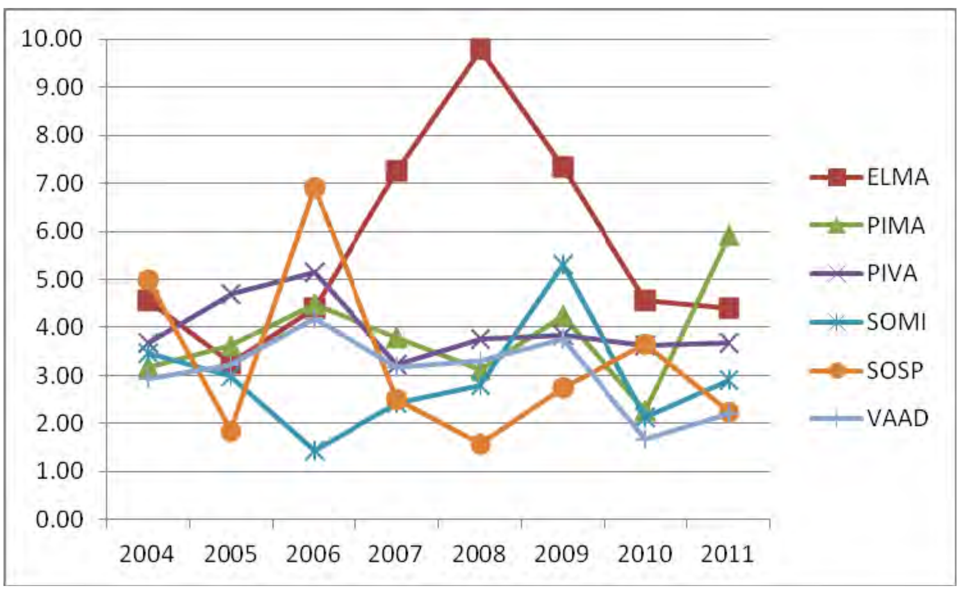


Figure 16. Yearly Trends of Severity Index Rates at Control Intersection

Severity Index (SI) Rate: The severity index (SI) concept was introduced as a means to estimate the crash severity at a given intersection. Crashes are weighted according to their severity level, with fatal crashes being the most severe, followed by injury crashes and property-damage-only crashes. The following equation is used to weight crashes of various severity levels:

$$SI = 10*FAT + 5*INJ + PDO$$

where FAT = total number of fatal crashes
INJ = total number of injury crashes
PDO = total number of property-damage-only crashes

The yearly SI counts per 1 million passing vehicles are depicted in Figures 15 and 16, which show a series of unstable rates. Like the total crash rates, the RC rates, and the PDO crash rates, the MASO camera intersection experienced substantial jumps in 2009. Overall, however, all four camera intersections have experienced reductions on the SI rate during the recent years. The yearly SI counts at the control intersections are much more fluctuating. The highest SI count (9.78) was recorded at the ELMA control intersection in 2008. Unlike the camera intersections, it is hard to say that there have been downward trends during the recent years.

From the review on the yearly trends of the crash data, the following findings are drawn:

1) Overall, it is noticed that there were downward trends on the crash rates at the camera intersections during the recent years. However, it is hard to say so at the control intersections.
2) The yearly crash rates at the camera intersections are less fluctuating than the ones at the control intersections.
3) The MASO camera intersection has experienced a big jump on the total crash rate, RC rate, PDO crash rate, injury crash rate, and the SI rate in 2009, which coincides with the introduction into full operation of the STOP. These increases were then reversed rapidly in 2010 and 2011. It could be concluded that these changes could result from the STOP operation.
4) The LOTE camera intersection has experienced a reduction on the total crash rate, RC rate, PDO crash rate, and the SI rate over time.
5) For the total crash rate and the AC rate at the LOWA camera intersection, the downward trend began in 2006. These decreases are still being continued.
6) The crash rate patterns at the VAAM camera intersection became very jagged over time.
7) The ELMA control intersection experienced very high total crash rates in 2008, mainly due to the increment on the PDO crash, and consequently recorded the highest SI count that year.
8) Only three (i.e., PIMA, SOMI, and VAAD control intersections) out of ten intersections experienced additions on the SI counts from 2010 to 2011. The PIMA control intersection is the one that has the highest SI count in 2011.

4.1.2. Before-and-after trends of the crash data

Next, we compare the crash rates at each camera intersection before and after the STOP operation and determine the direction of crash trends. The monthly crash rates, i.e., the average monthly crash counts per 1 million passing vehicles were graphed in Figures 9 and 16. The blue dotted line shows a linear trend based on before the camera period only (i.e., January 2004 – February 2009), which also provides forecasting, i.e., predicting crash rates after the camera installation. The light green trend line was drawn based on the before-and-after period (i.e., January 2004 – April 2011) and shows the overall pattern of changes in crash rates at each intersection over time.

Total Crash Rate: The monthly trends of the total crash rate at each intersection are shown in Figures 17 and 18. The blue dotted trend line is drawn based on before the camera period only, and thus represents how the total crash rate would have been in the absence of the STOP operation, whereas the light green trend line is based on the before-and-after period and represents what the total crash rate was with the STOP operation. Therefore, the difference between these two linear trend lines implies the total crash rate effect of the STOP operation. In the case shown, it seems that the effect of the STOP operation is beneficial at the LOTE and the VAAM intersections, while the beneficial effect has been seen to fade at the LOWA intersection. However, the effect of the STOP operation is harmful at the MASO intersection. Even though there weren't any STOP operations, three (i.e., the ELMA, PIVA, and the VAAD) out of the six control intersections experienced reductions on the total crash rates, while the total crash rates were increased at the PIMA and the SOSP control intersections.

Angle Crash (AC) Rate: The slopes of the trend lines (i.e., the rate of change in the crash number) in Figure 19 imply that there may be a positive impact of the STOP operation on the AC rates at the LOTE and the LOWA intersections. For the control intersections, where there aren't any cameras installed, there were reductions on the angle crash rates at the PIMA intersections, whereas the PIVA experienced additions on the angle crash rates (see Figure 20).

Rear-end Crash (RC) Rate: Figures 21 and 22 present the monthly trends of the RC. According to the graphs, it seems that the effect of the STOP operation is beneficial at the LOTE and the VAAM intersections, while unfavorable at the MASO intersection. For the control intersections, reductions on the SI rates occurred at the ELMA and the PIVA intersections, while the PIMA and the SOSP intersection experienced increments on the SI rates.

Property-Damage-Only (PDO) Crash Rate: According to Figure 23, three out of four camera intersections show reductions in the PDO crash rate after the STOP operation. Among them, the LOTE intersection experienced the most positive impact on the STOP operation. Like the RC rate, however, the PDO crash rate has a bad impact at the MASO intersection. The yearly PDO crash trends at the control intersections are very similar to the ones on the RC trends (see Figure 24).

Injury (INJ) Crash Rate: It seems that there aren't any beneficial effects of the STOP operation on the injury crash rates at the camera intersections (see Figure 25). Even though there weren't any STOP operations, two (i.e., the ELMA and the VAAD) out of the six control intersections experienced reductions on the injury crash rates (see Figure 26).

Injury-causing Angle Crash Rate: The monthly trends of the injury-causing angle crash rates are shown in Figures 27 and 28. It seems that none of the intersections experienced reductions on the injury-causing angle crash rates. *(Note that the blue dotted trend line represents how the injury-causing angle crash rate would have been in the absence of the STOP operation. This future projection line predicted the occurrence of negative values. One way to improve the interpretability to avoid this situation is to put the rates on a logarithmic scale. A log transformation of the data provides more appropriate and realistic results because it flattens the series of rates. While the overall shape of the trend isn't changed, the increasing rate or the decreasing rate is somewhat altered.)*

Injury-causing Rear-end Crash Rate: There may be a positive impact at the LOWA and VAAM camera intersections. However, the impacts of the STOP operation at all of the other camera intersections are very small and are negligible (see Figures 29). None of the control intersections experienced reductions on the injury-causing rear-end crash rates (see Figure 30).

Severity Index (SI) Rate: Figures 31 and 32 show the monthly trends of the SI rate. There may be a positive impact of the STOP operation on the SI rate at the LOTE and VAAM intersections, while there may be a negative impact at the LOWA intersection. *(Note that the STOP operation impact on the SI rate looks smaller which might give readers the wrong impression about the trend. This is because Figures 31 and 32 use a scale of 0 to 25, unlike other figures which use much smaller scales.)* However, it seems that there aren't any STOP operation impacts at the MASO intersection. For the control intersections, reductions on the SI rates occurred at the

ELMA, PIVA, and the VAAD intersections, while the SOSP intersection experienced additions on the SI counts per 1 million passing vehicles.

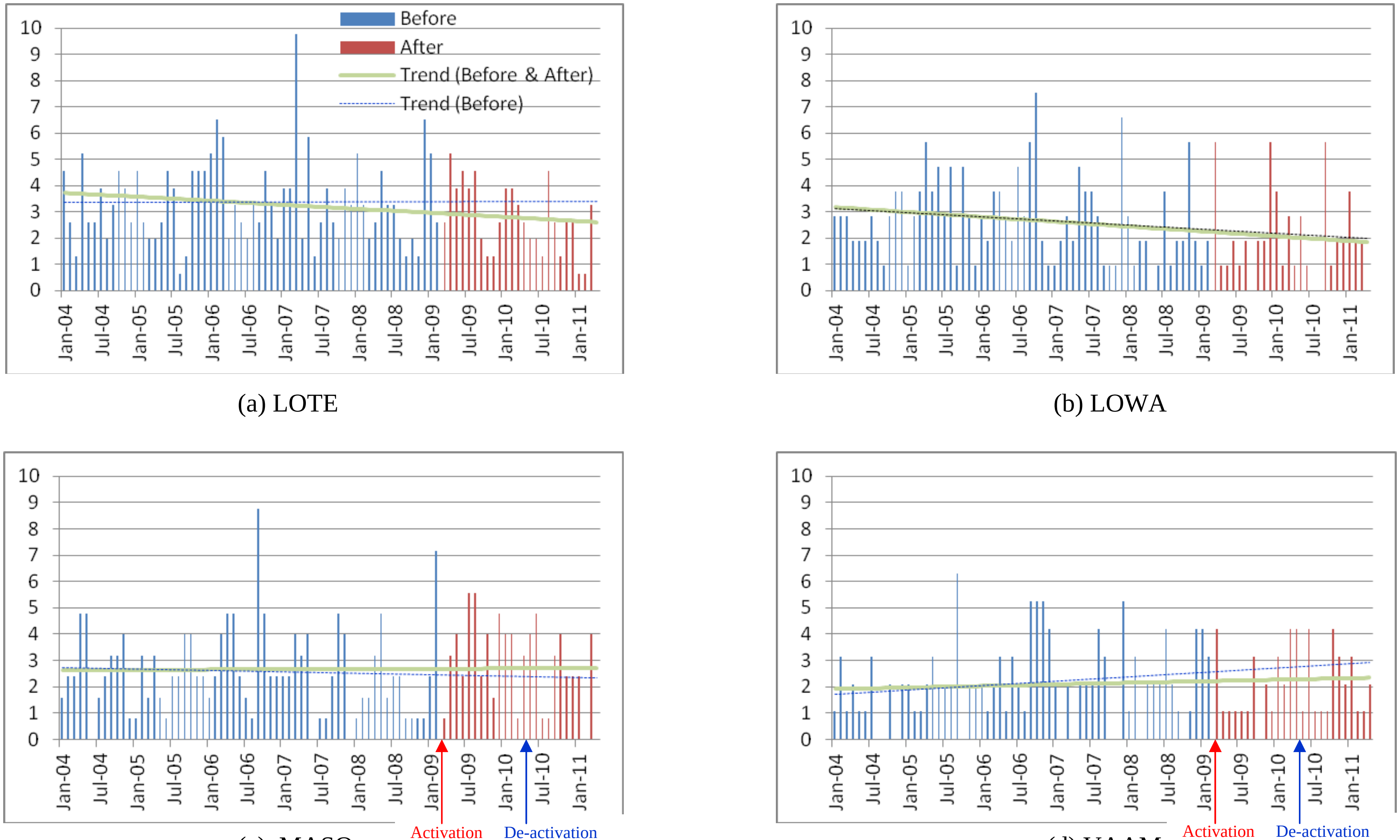
From the crash data analysis, the following findings are drawn (see Table 1):

1) The trend analysis shows that the introduction of the STOP at the LOTE and the VAAM intersections reduce the total crash rates, mainly due to the reduction on the PDO crash rates. As a result, these two intersections show reductions on the SI rate after the STOP operation.
2) Also, the VAAM camera intersection experienced reductions on the injury crash rates, which results in reductions on the SI rate.
3) However, the STOP operation at the LOWA camera intersection seems ineffective on the injury-causing rear-end crash rate, which results in a negative impact on the SI rate.
4) After the STOP operation, the LOTE and LOWA camera intersections experienced reductions on the angle crash rates.
5) The STOP operation may have an effect of reductions on the PDO crash at the LOTE, LOWA, and the VAAM camera intersections.
6) The STOP operation at the MASO camera intersection has a negative effect on total crash rates, RC crash rates, and PDO crash rates.
7) Even though there weren't any STOP operations, the monthly crash rate plots show reductions in the crash rates at certain control intersections for certain crash types.
8) Three (i.e., the ELMA, PIVA, and the VAAD) out of the six control intersections experienced reductions on the SI counts per 1 million passing vehicles, while there was an addition on the SI counts at the SOSP control intersection.
9) For the PIVA control intersection, there was an increase in the angle crash rates. However, there were reductions in most of the other crash types.

Table 1. Summary of Trend Analysis

Intersection	Total Crash	AC	RC	PDO	INJ	INJ-causing AC	INJ-causing RC	SI
LOTE	Decrease	Decrease	Decrease	Decrease	No Change	No Change	No Change	Decrease
LOWA	No Change	Decrease	No Change	Decrease	No Change	No Change	Increase	Increase
MASO	Increase	No Change	Increase	Increase	No Change	No Change	No Change	No Change
VAAM	Decrease	No Change	Decrease	Decrease	No Change	No Change	Decrease	Decrease
ELMA	Decrease	No Change	Decrease	Decrease	Decrease	No Change	No Change	Decrease
PIMA	Increase	Decrease	Increase	Increase	No Change	No Change	No Change	No Change
PIVA	Decrease	Increase	Decrease	Decrease	No Change	No Change	No Change	Decrease
SOMI	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change
SOSP	Increase	No Change	Increase	Increase	No Change	No Change	No Change	Increase
VAAD	Decrease	No Change	No Change	No Change	Decrease	No Change	No Change	Decrease

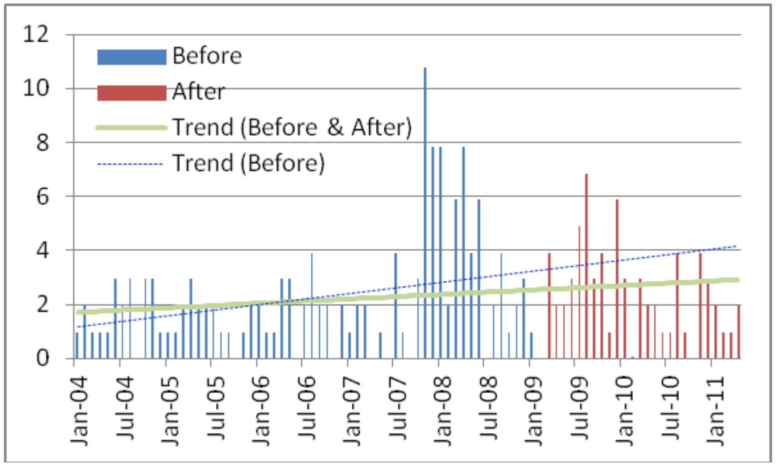
Next, statistical analysis is conducted to prove that there is a reliable and significant difference in these results.



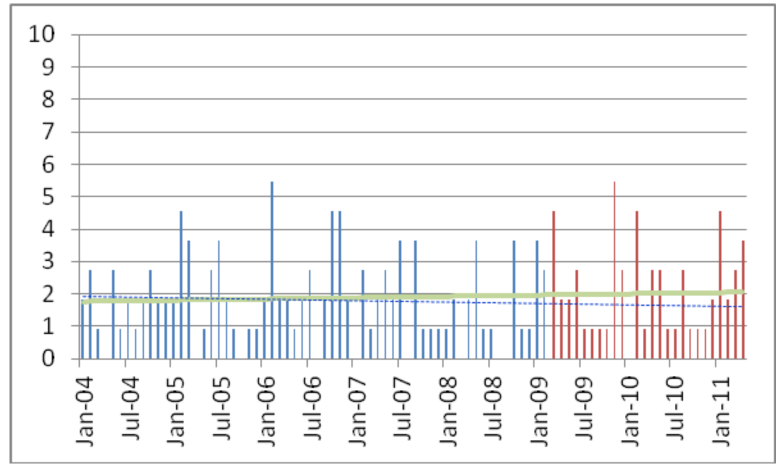
(a) LOTE (b) LOWA

(c) MASO (d) VAAM

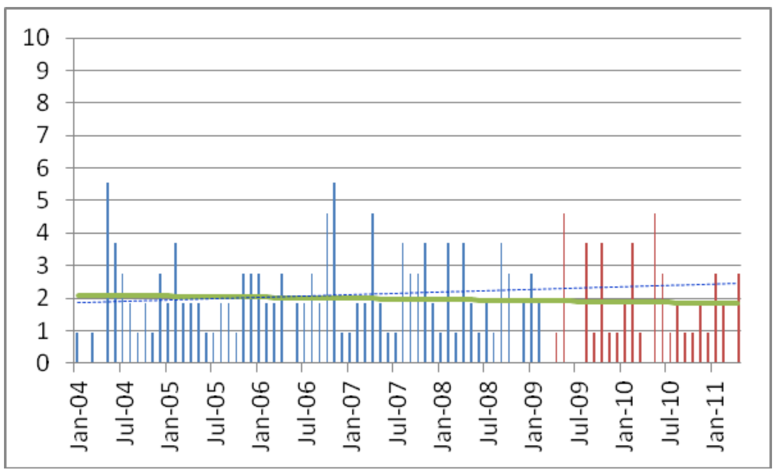
Figure 17. Total Crash Rate at Camera Intersections



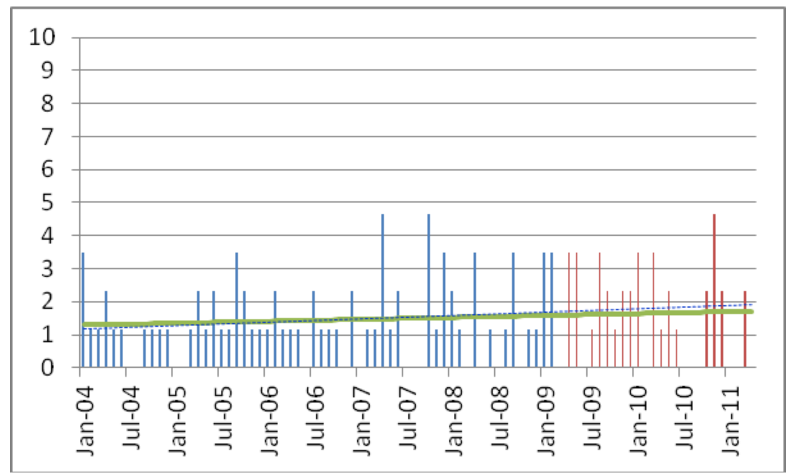
(a) ELMA



(b) PIMA

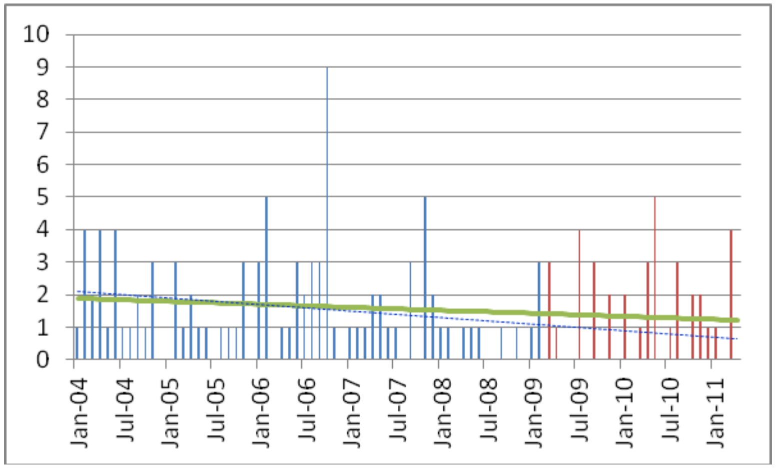


(c) PIVA

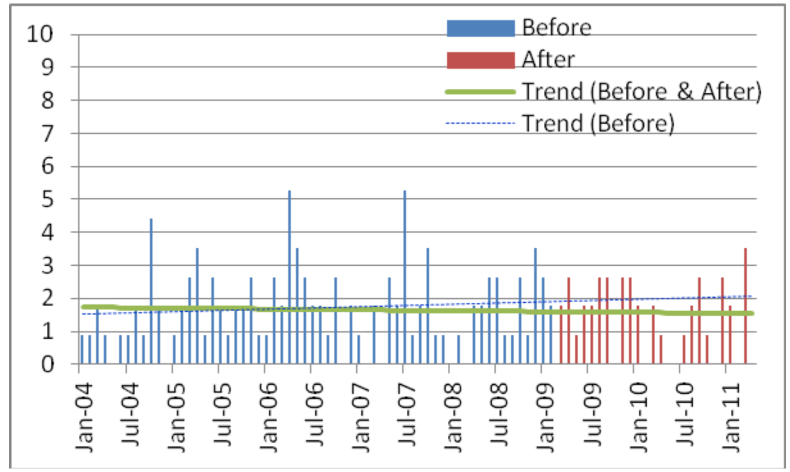


(d) SOMI

Figure 18. Total collisions rate at Control Intersection

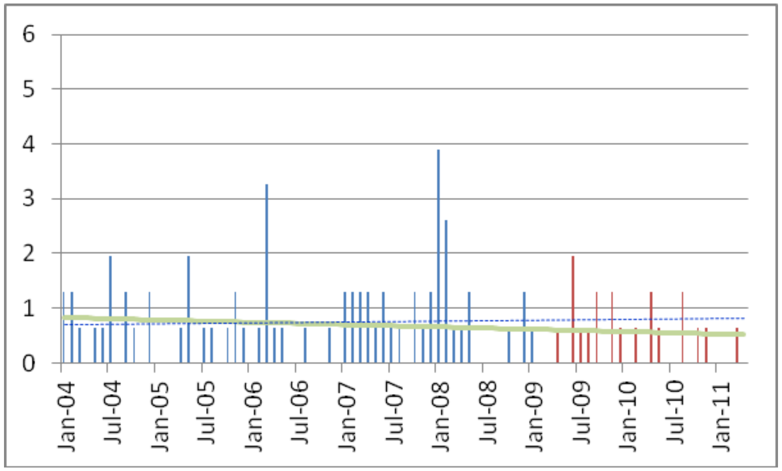


(e) SOSP

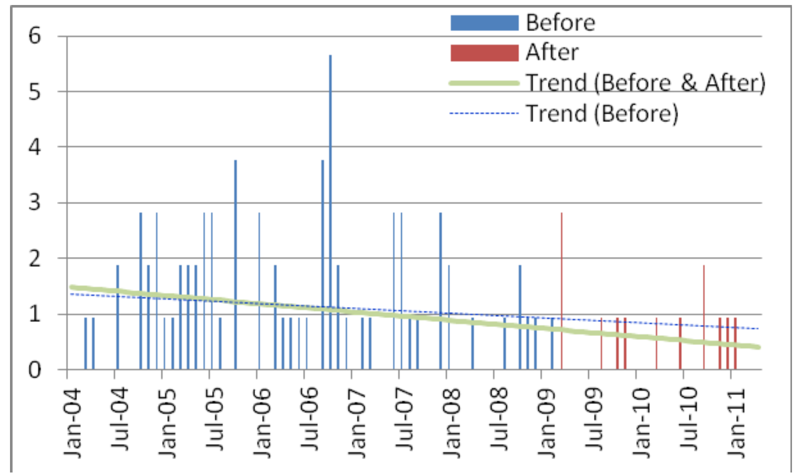


(f) VAAD

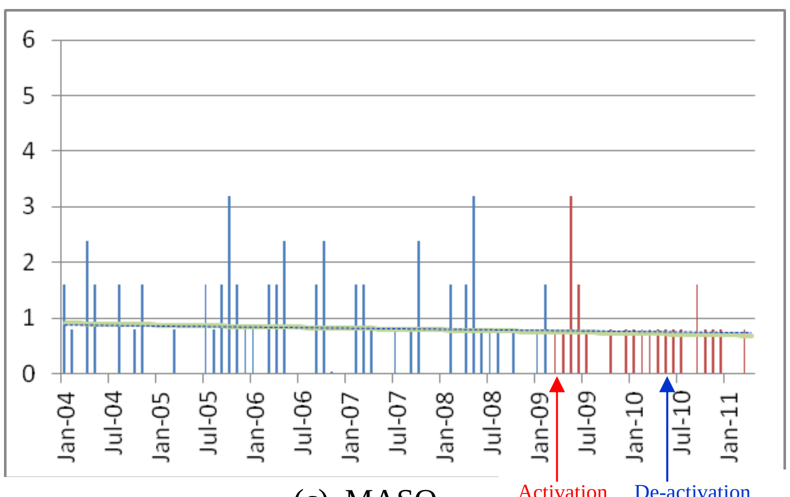
Figure 18. Total collisions rate at Control Intersection ***(Continued)***



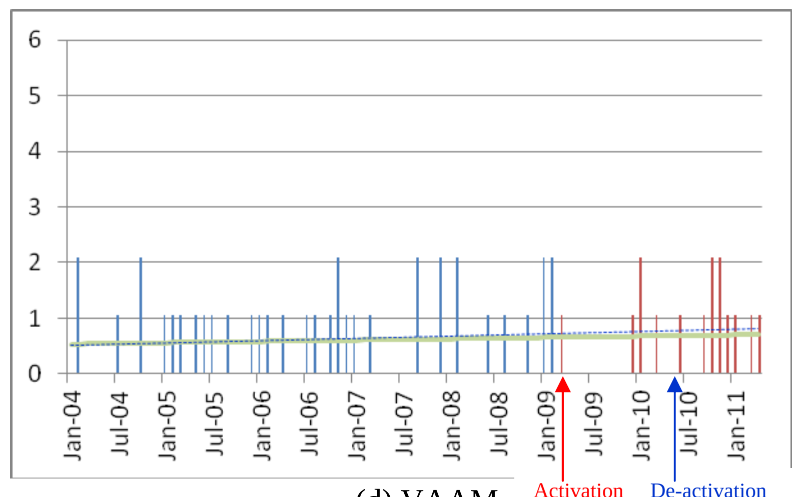
(a) LOTE



(b) LOWA

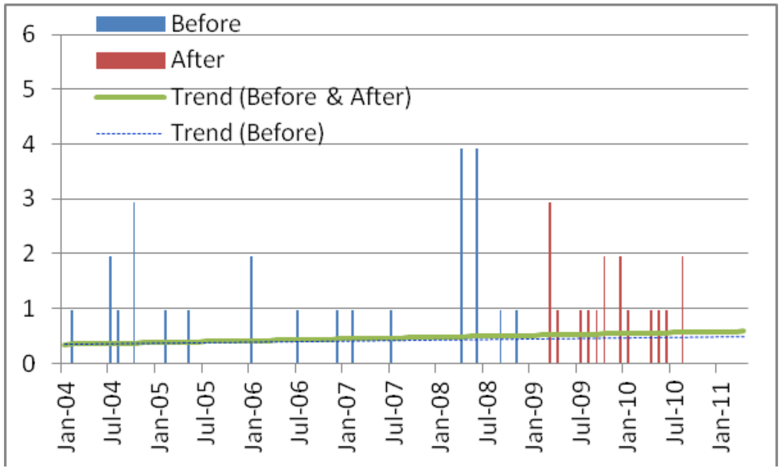


(c) MASO

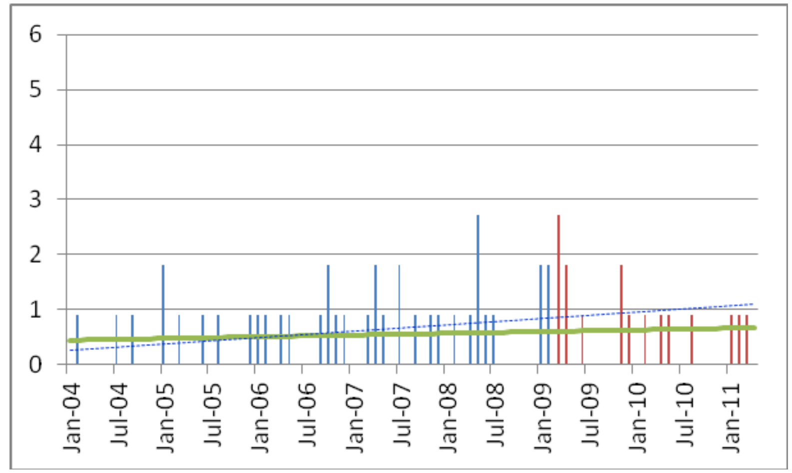


(d) VAAM

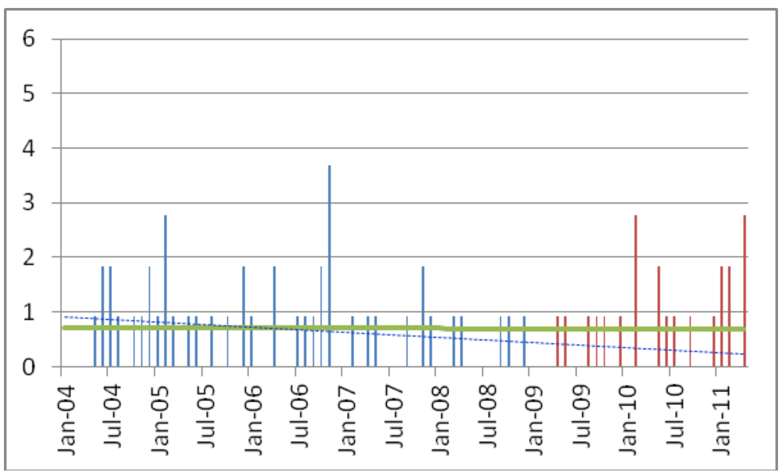
Figure 19. Angle Crash rate at Camera Intersection



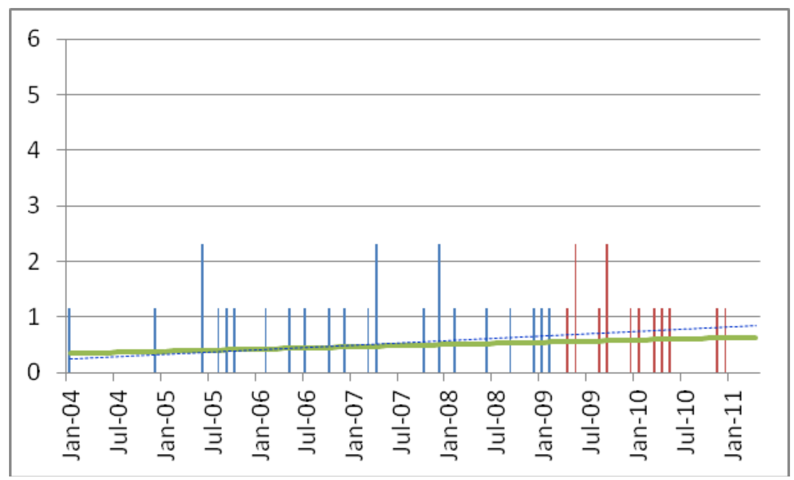
(a) ELMA



(b) PIMA

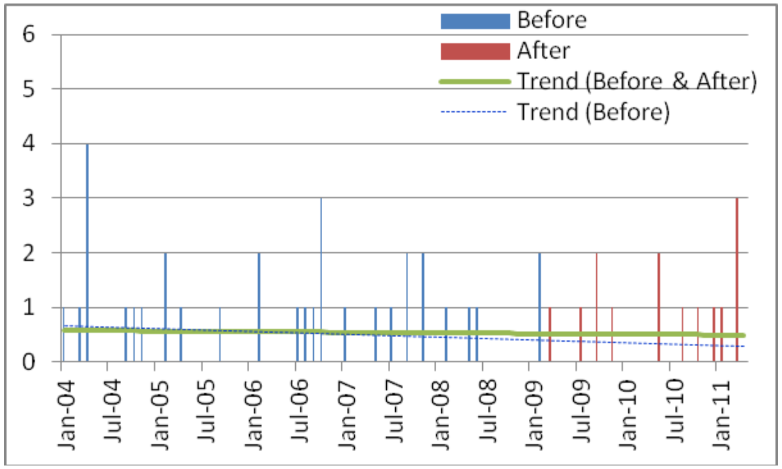


(c) PIVA

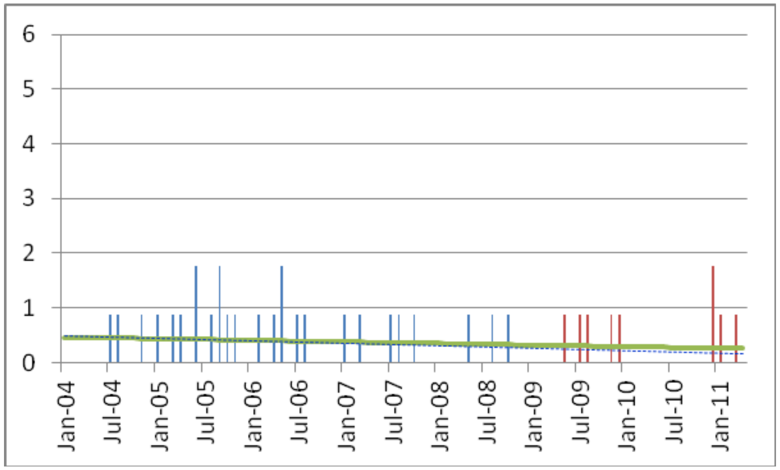


(d) SOMI

Figure 20. Angle collisions rate at Control Intersection

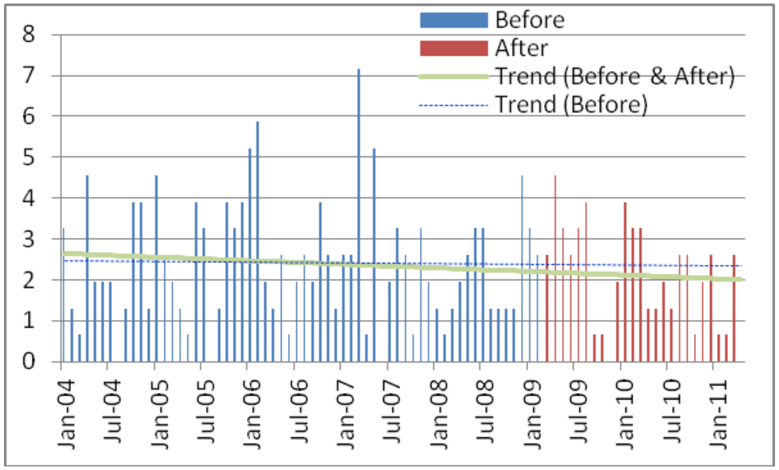


(e) SOSP

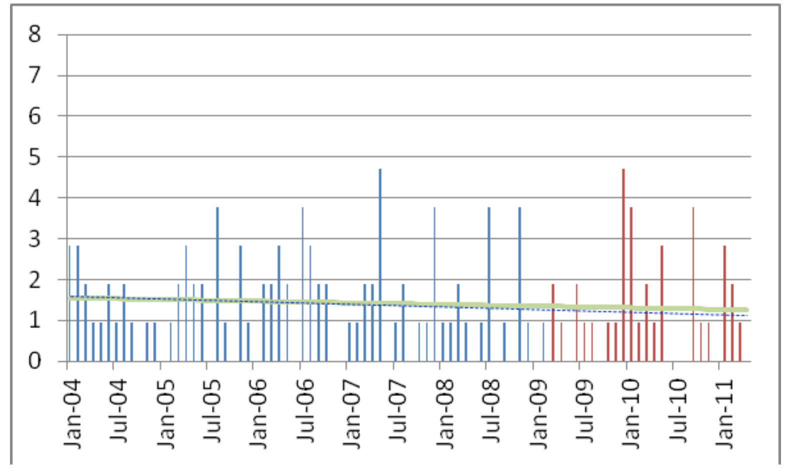


(f) VAAD

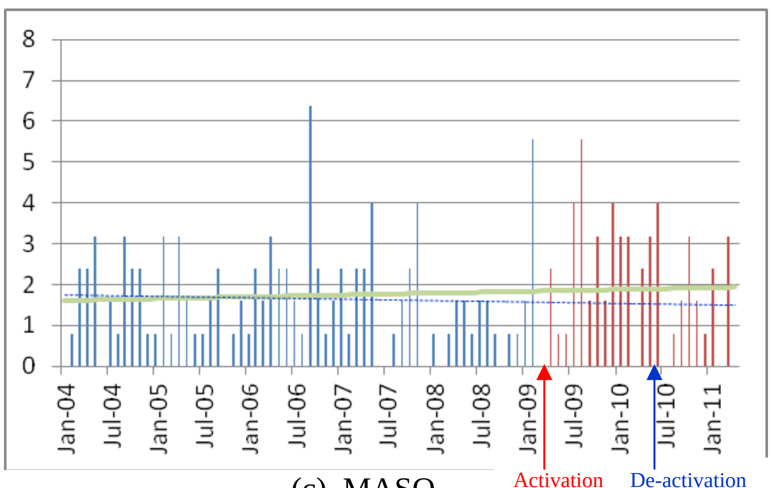
Figure 20. Angle collisions rate at Control Intersection ***(Continued)***



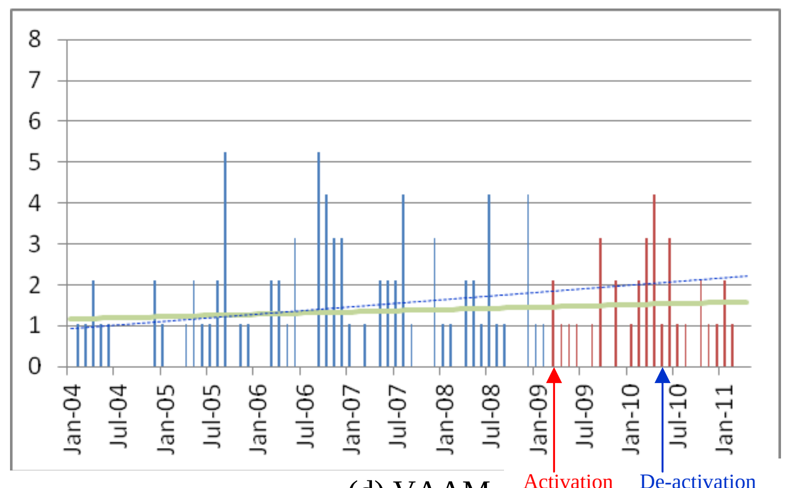
(a) LOTE



(b) LOWA

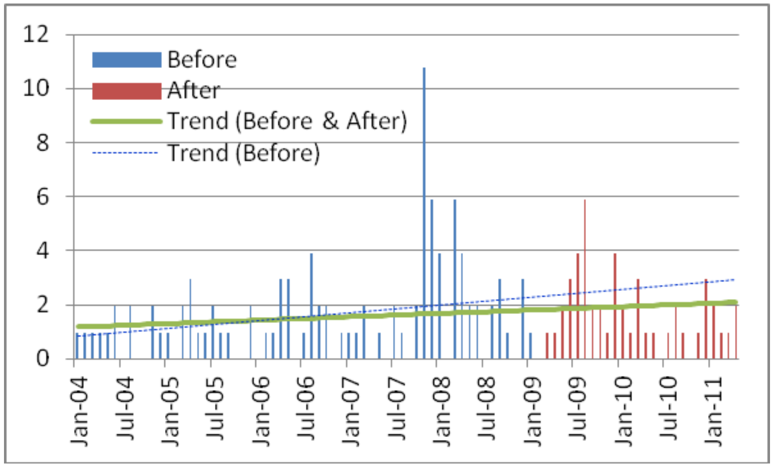


(c) MASO

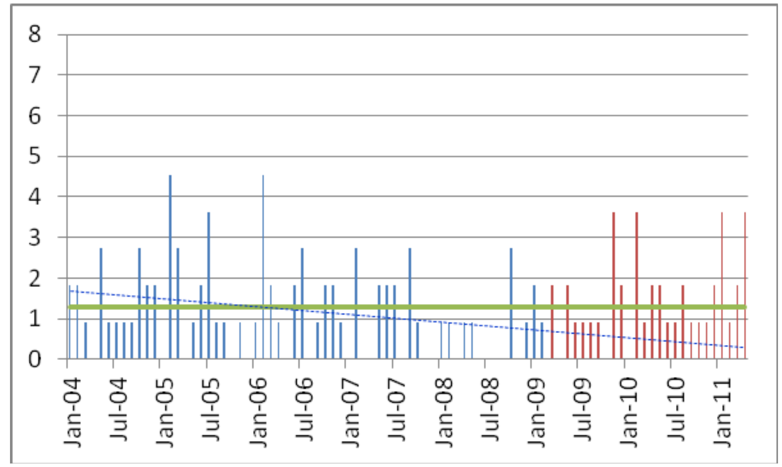


(d) VAAM

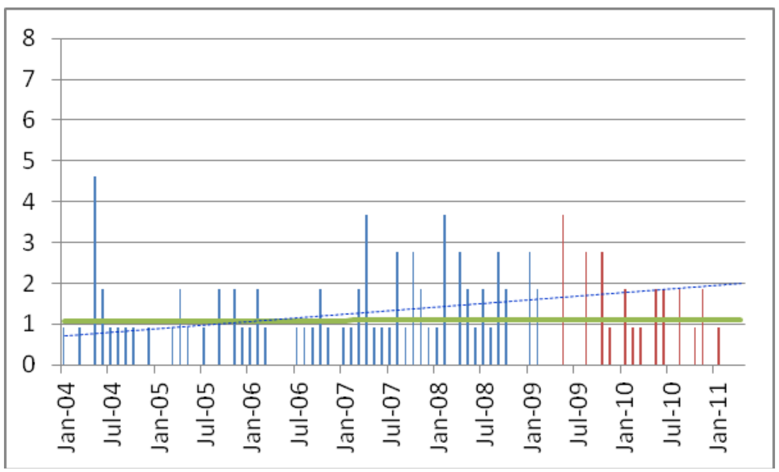
Figure 21. Read-end Crash rate at Camera Intersection



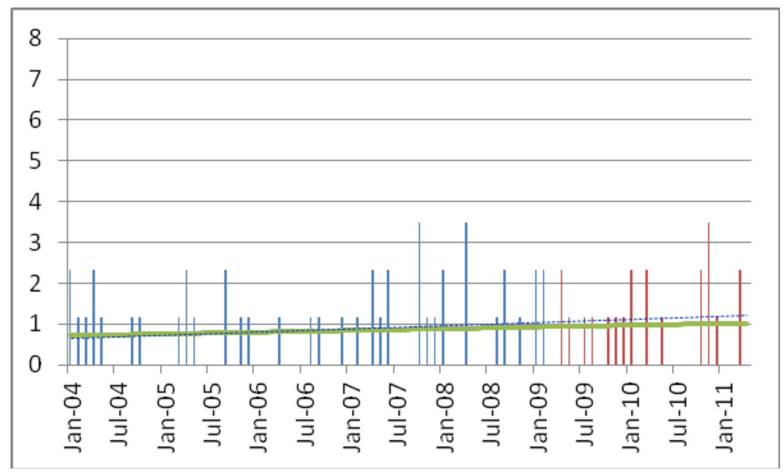
(a) ELMA



(b) PIMA

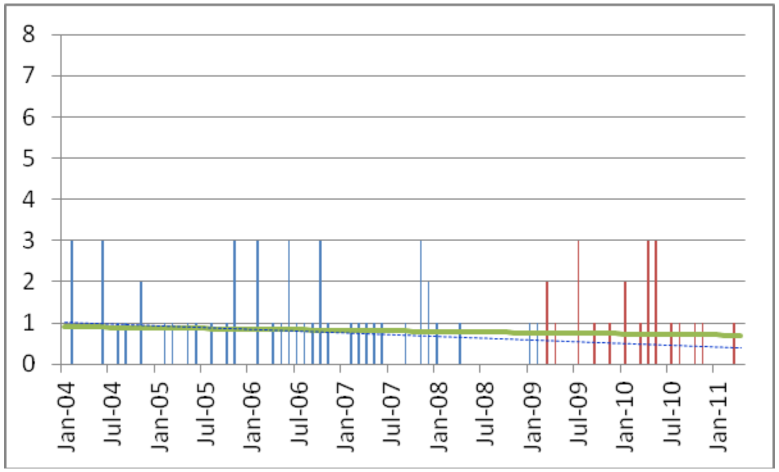


(c) PIVA

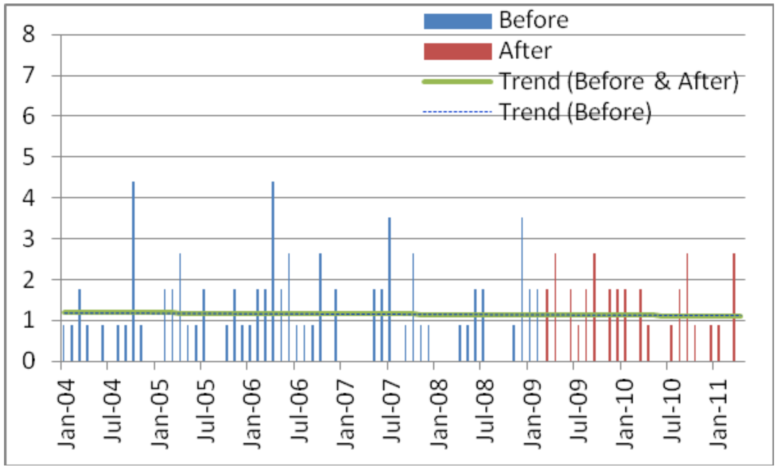


(d) SOMI

Figure 22. Rear-end collisions rate at Control Intersection

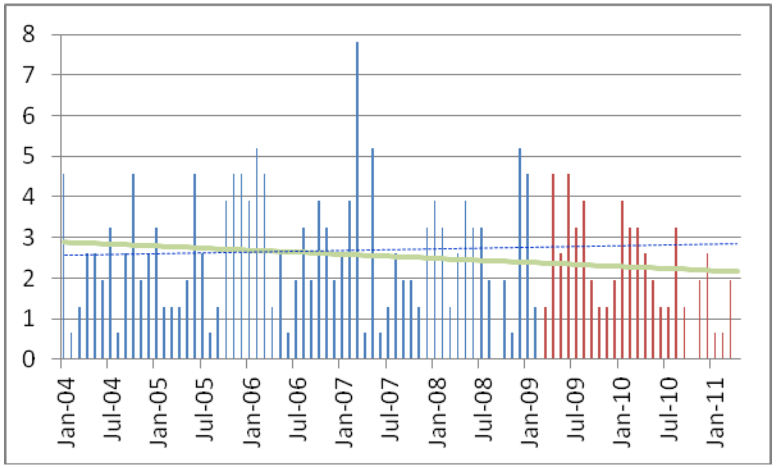


(e) SOSP

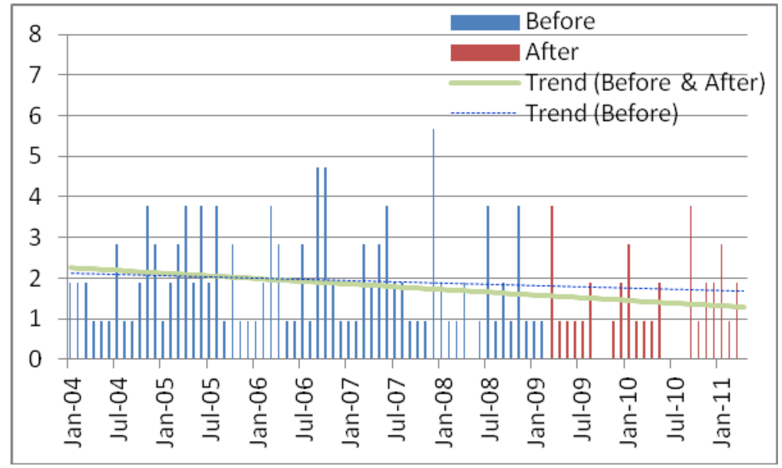


(f) VAAD

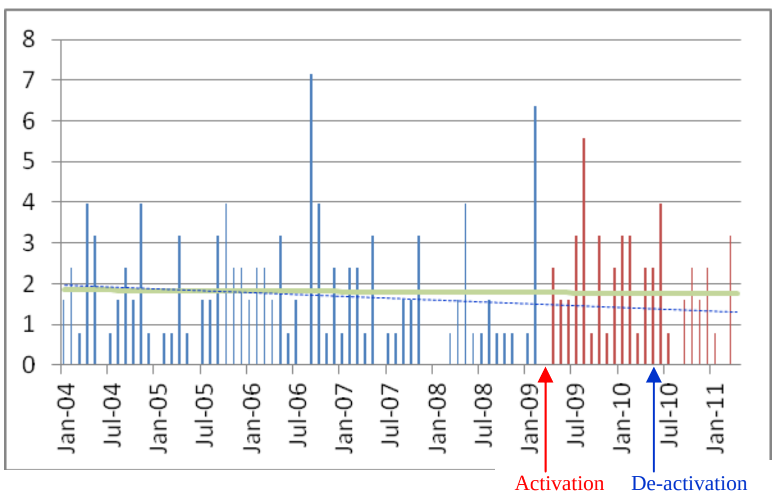
Figure 22. Rear-end collisions rate at Control Intersection ***(Continued)***



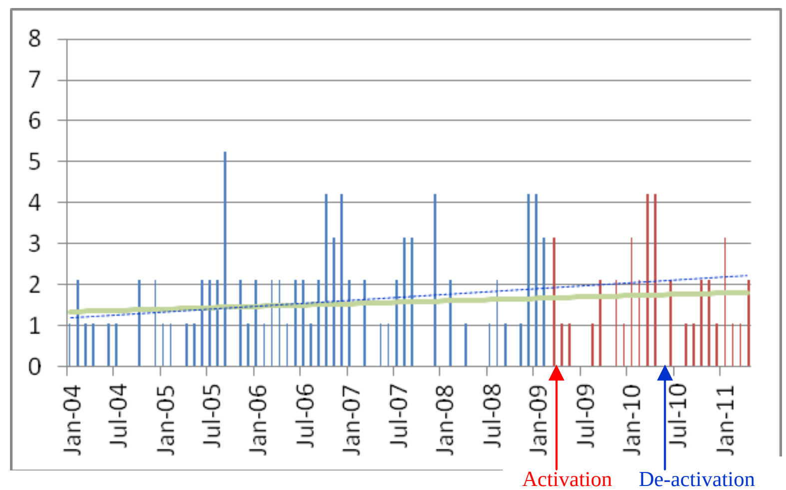
(a) LOTE



(b) LOWA

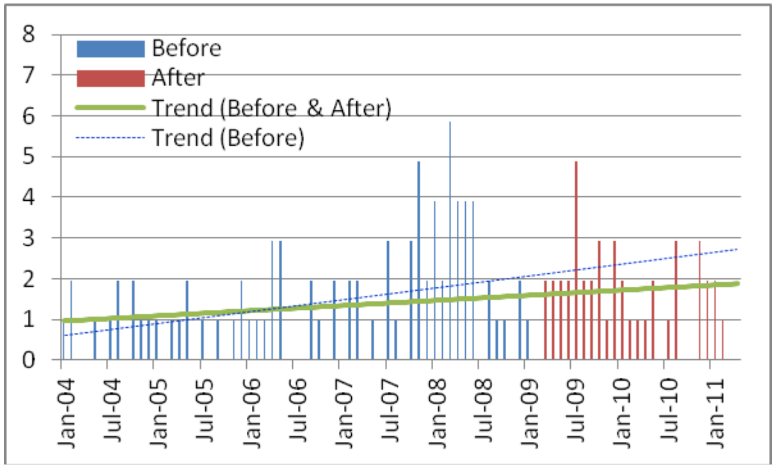


(c) MASO

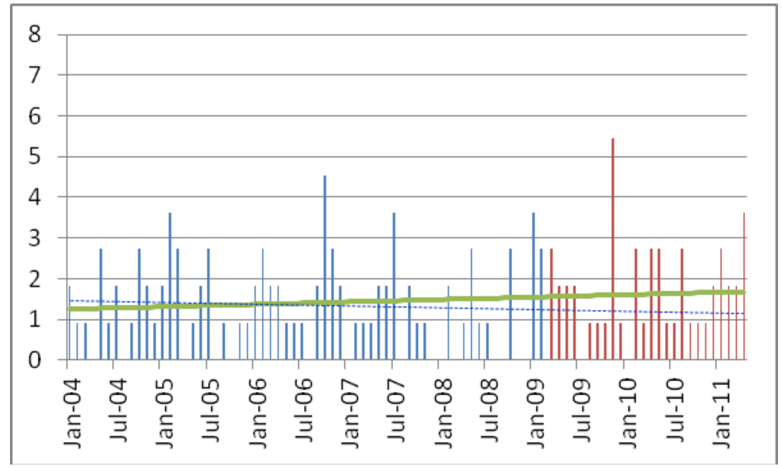


(d) VAAM

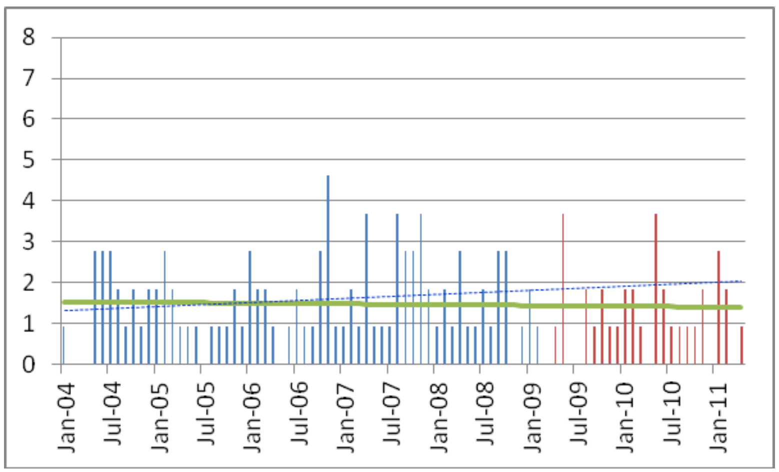
Figure 23. Property-Damage-Only Crash rate at Camera Intersection



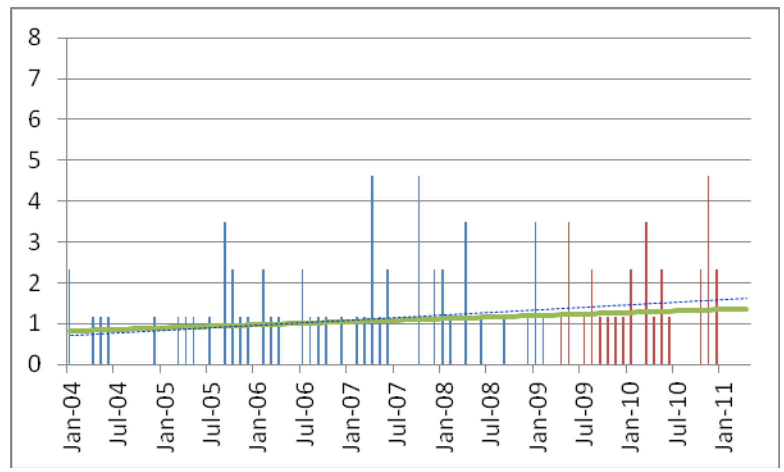
(a) ELMA



(b) PIMA

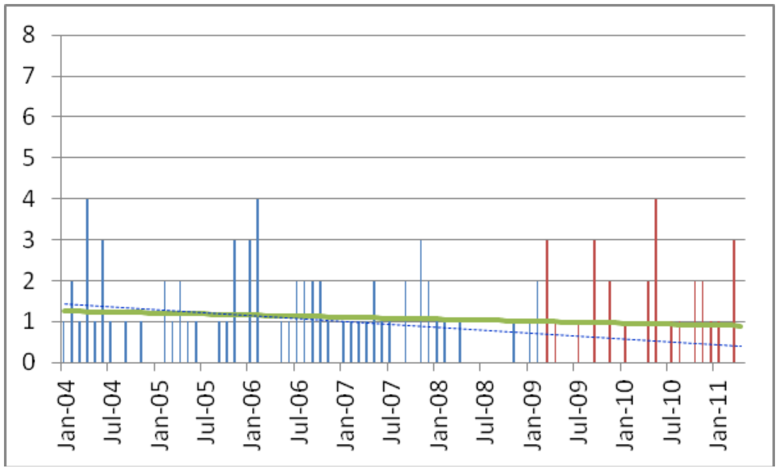


(c) PIVA

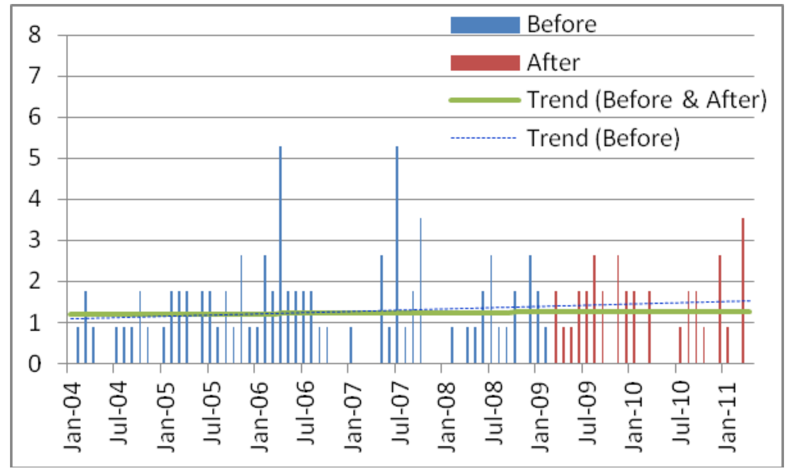


(d) SOMI

Figure 24. Property-Damage-Only collisions rate at Control Intersection

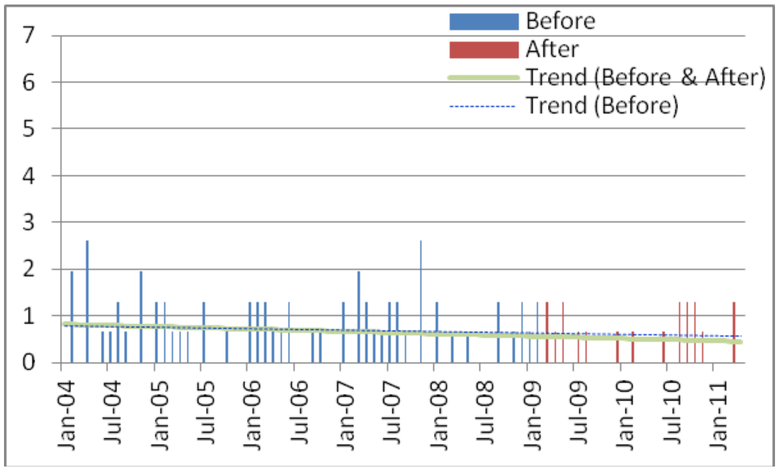


(e) SOSP

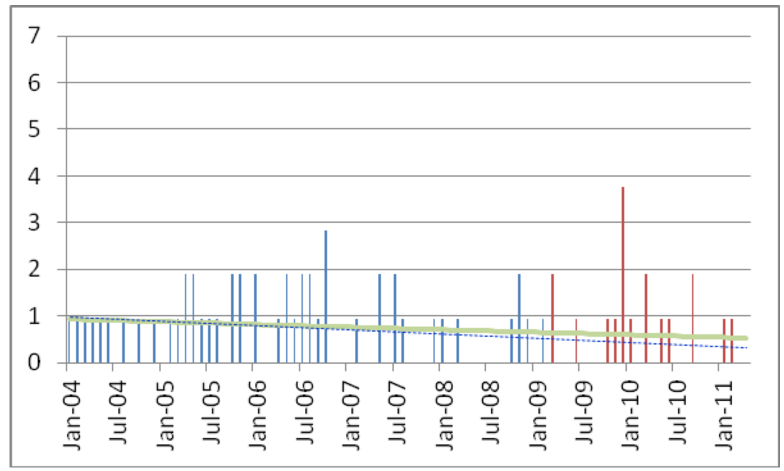


(f) VAAD

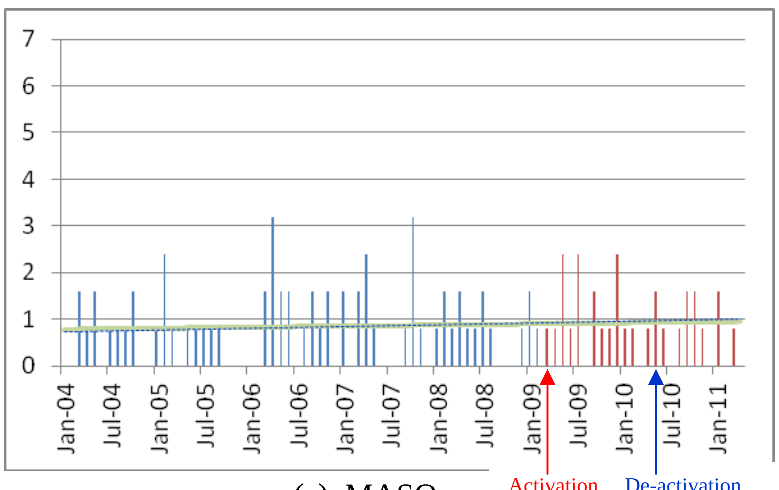
Figure 24. Property-Damage-Only collisions rate at Control Intersection ***(Continued)***



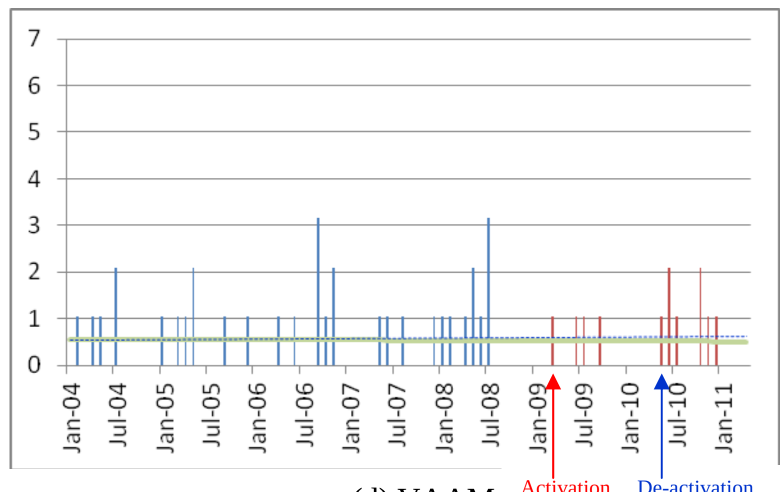
(a) LOTE



(b) LOWA

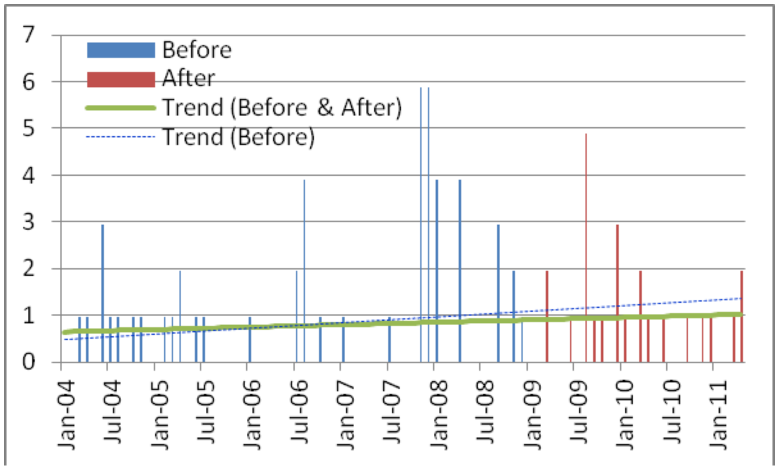


(c) MASO

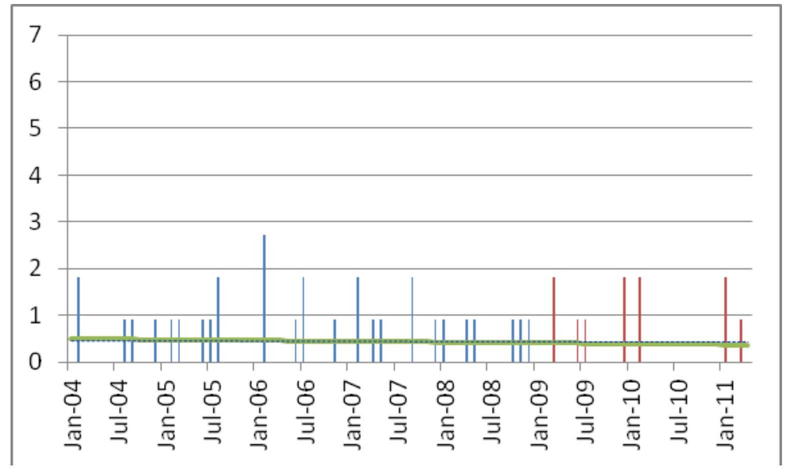


(d) VAAM

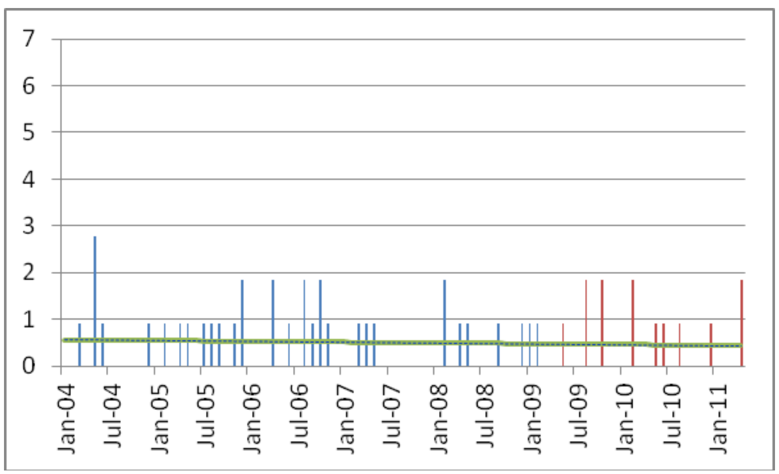
Figure 25. Injury Crash rate at Camera Intersection



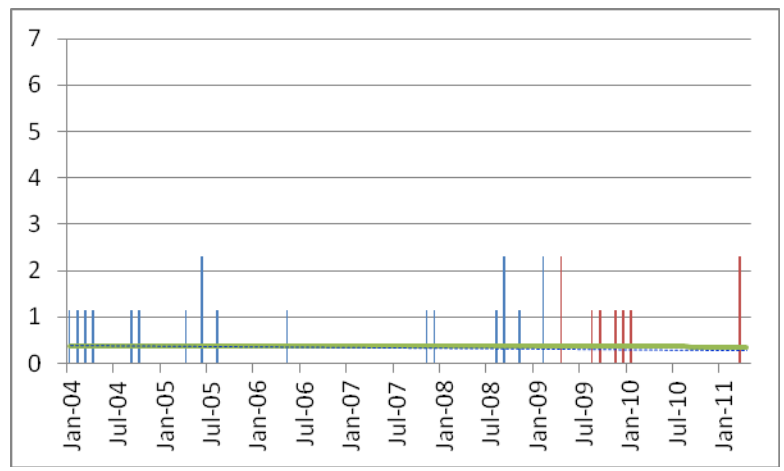
(a) ELMA



(b) PIMA

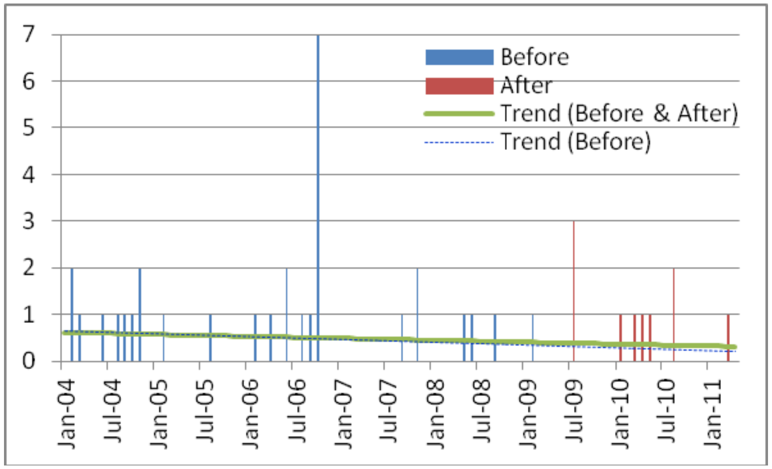


(c) PIVA

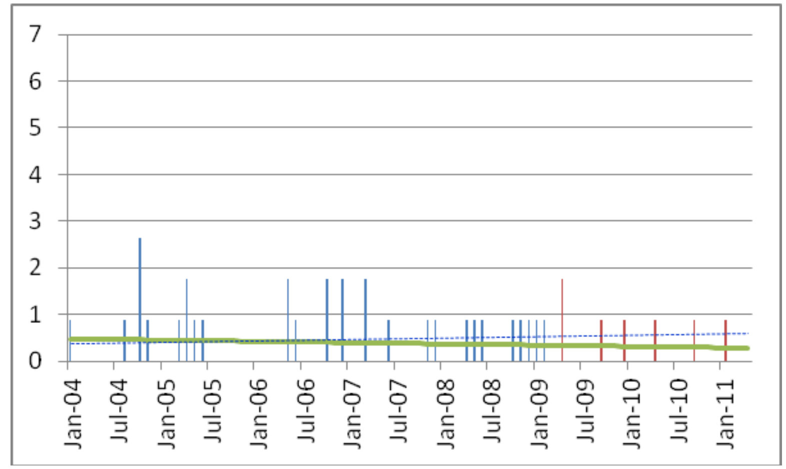


(d) SOMI

Figure 26. Injury Crash rate at Control Intersection

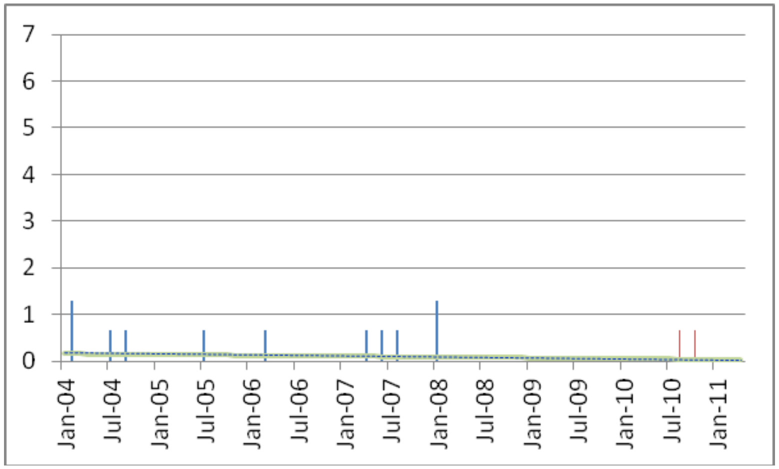


(e) SOSP

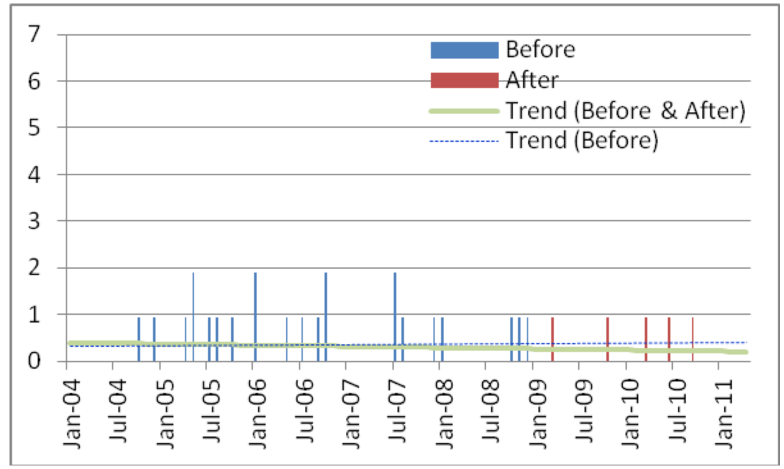


(f) VAAD

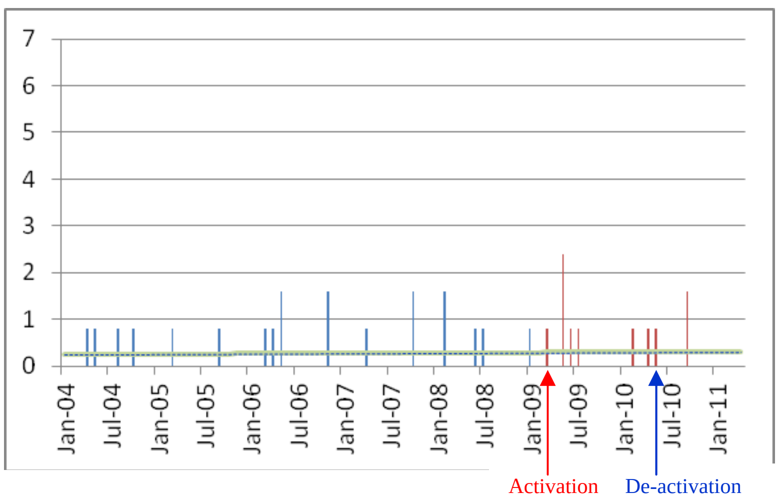
Figure 26. Injury Crash rate at Control Intersection ***(Continued)***



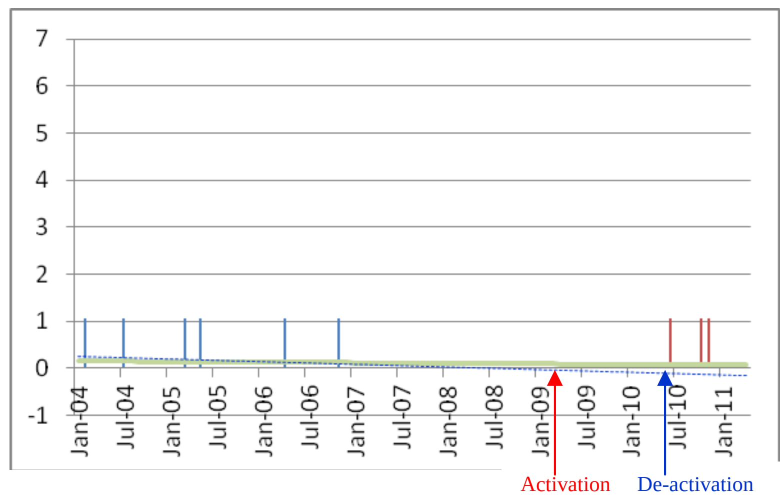
(a) LOTE



(b) LOWA

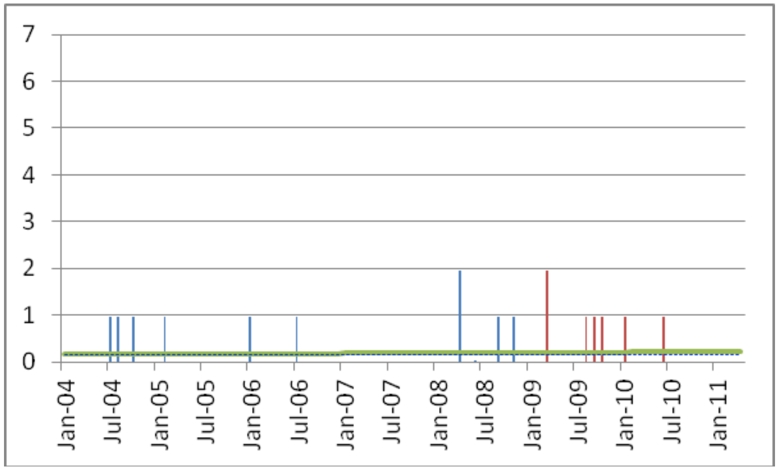


(c) MASO

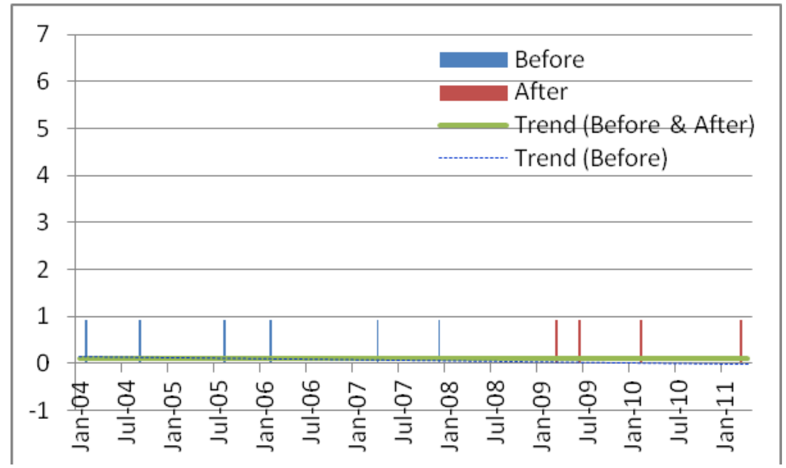


(d) VAAM

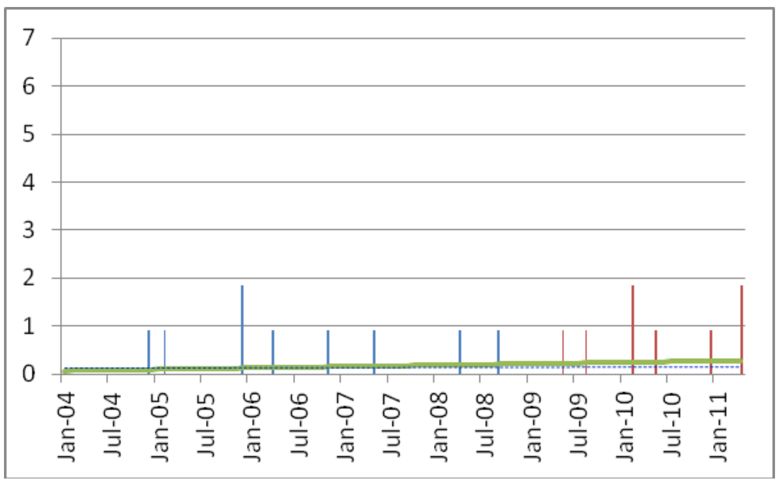
Figure 27. Injury-causing Angle Crash rate at Camera Intersection



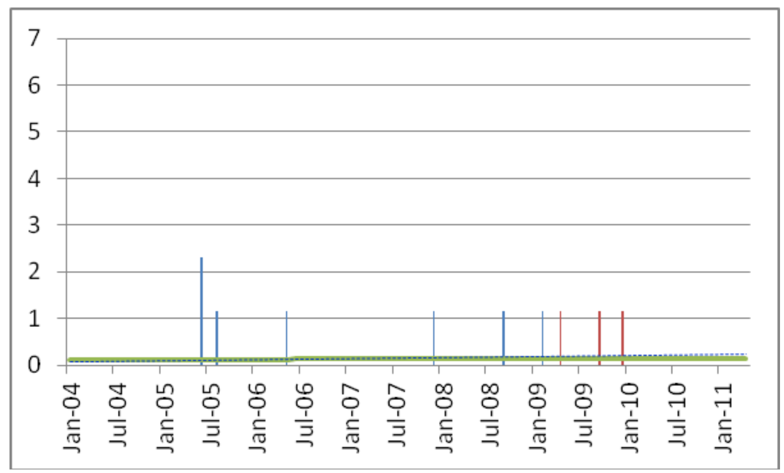
(a) ELMA



(b) PIMA

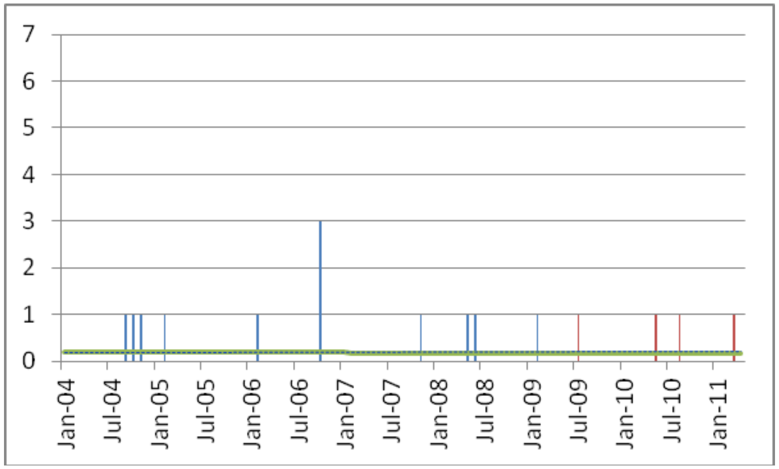


(c) PIVA

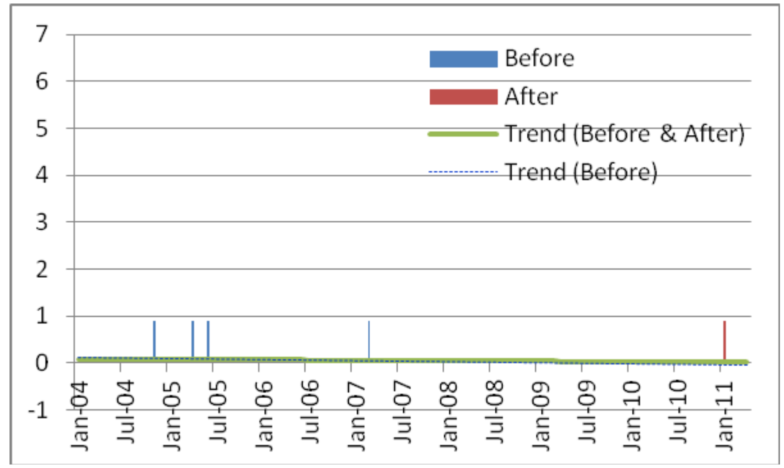


(d) SOMI

Figure 28. Injury-causing Angle Crash rate at Control Intersection

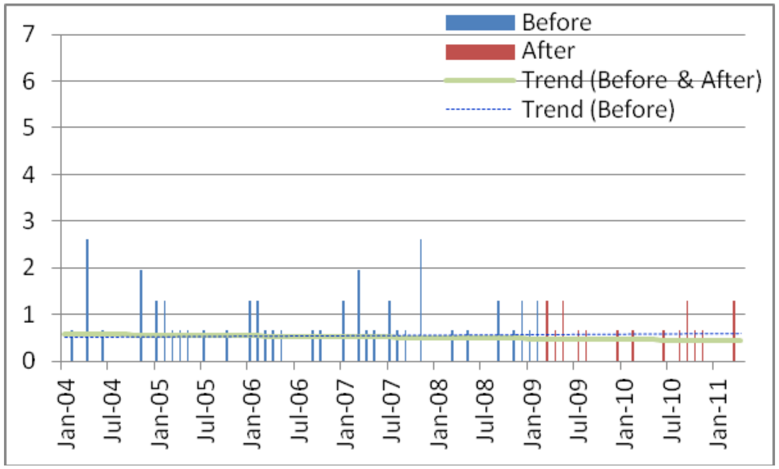


(e) SOSP

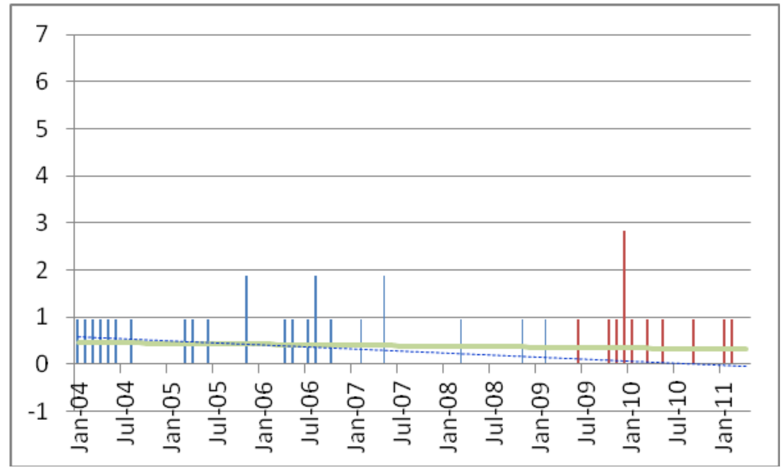


(f) VAAD

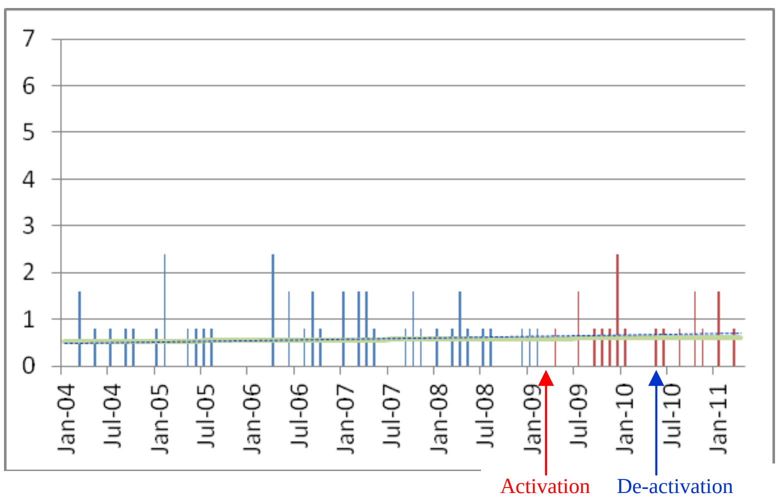
Figure 28. Injury-causing Angle Crash rate at Control Intersection ***(Continued)***



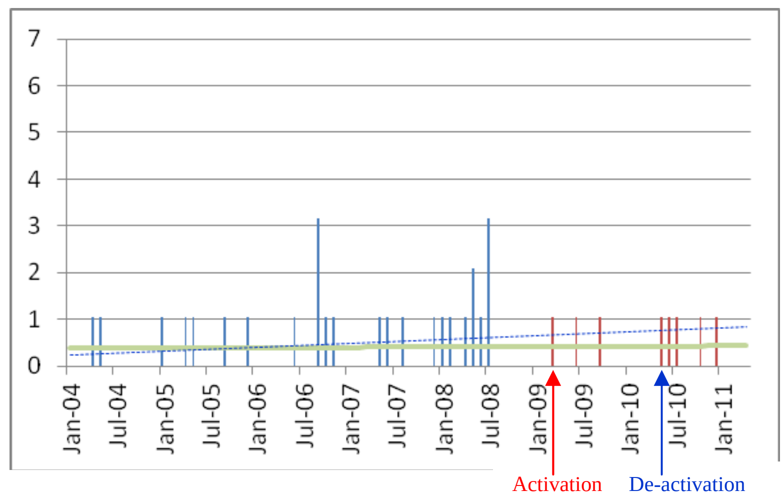
(a) LOTE



(b) LOWA

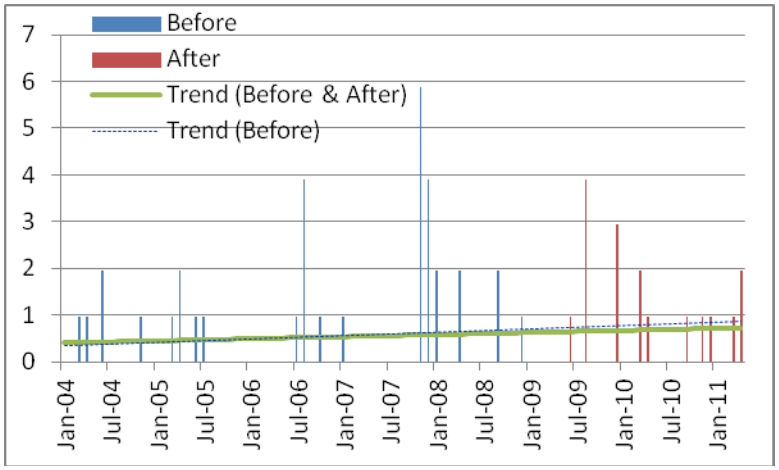


(c) MASO

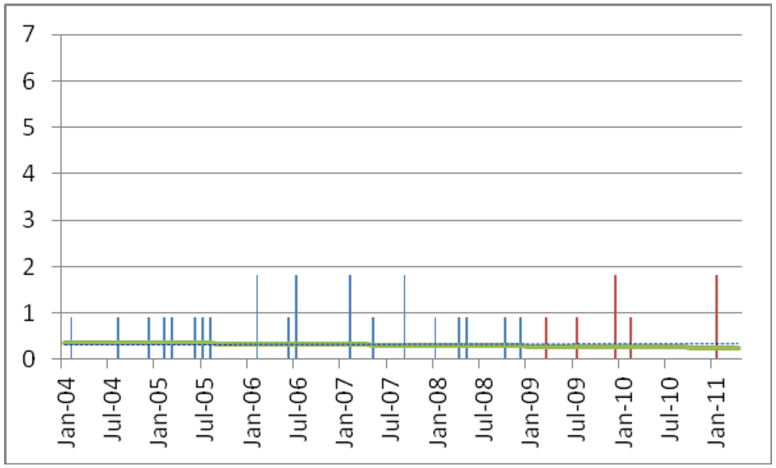


(d) VAAM

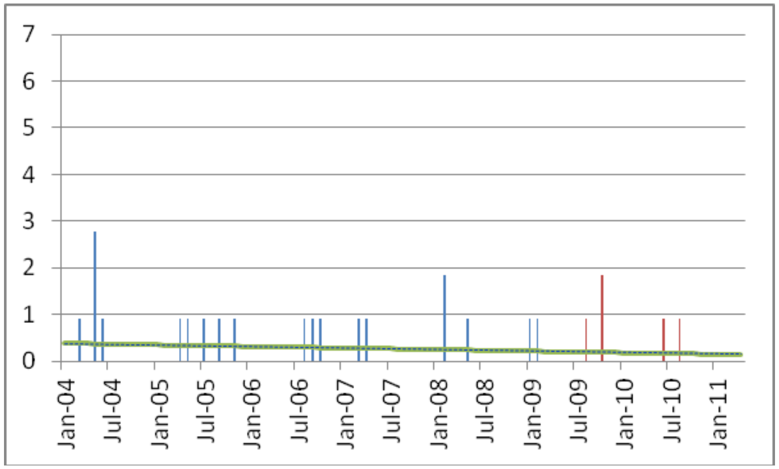
Figure 29. Injury-causing Rear-end Crash rate at Camera Intersection



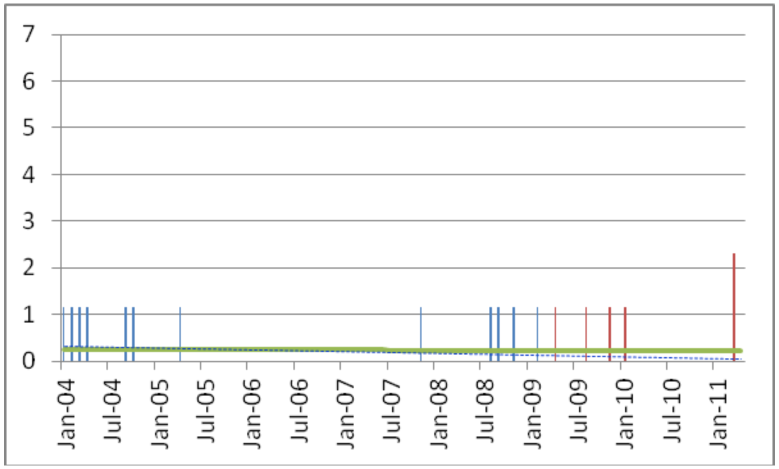
(a) ELMA



(b) PIMA

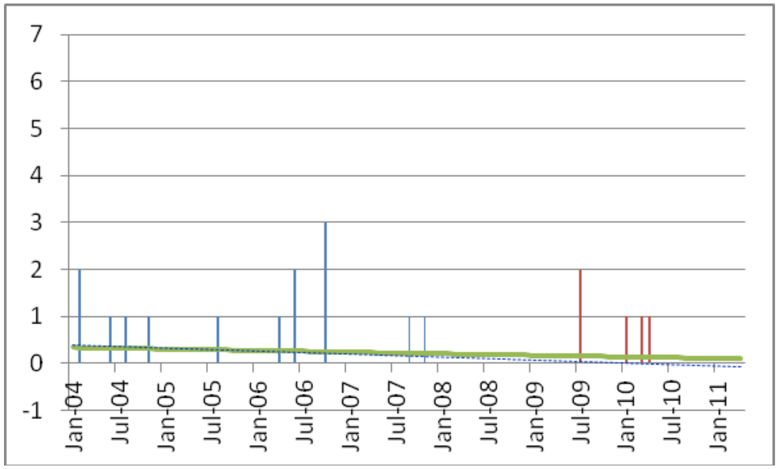


(c) PIVA

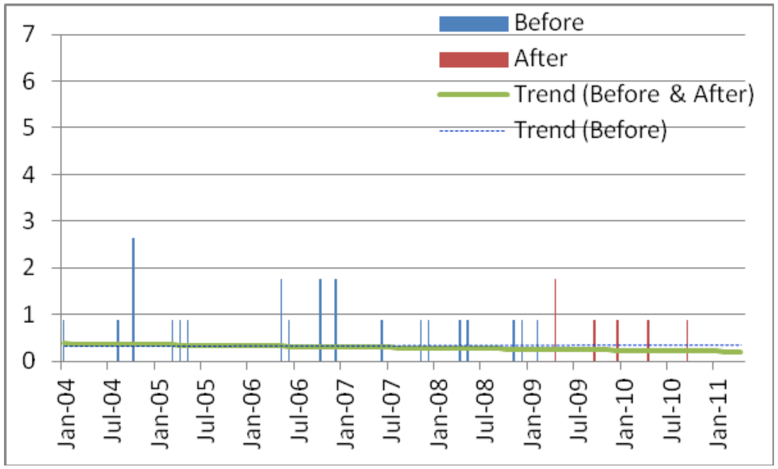


(d) SOMI

Figure 30. Injury-causing Rear-end Crash rate at Control Intersection

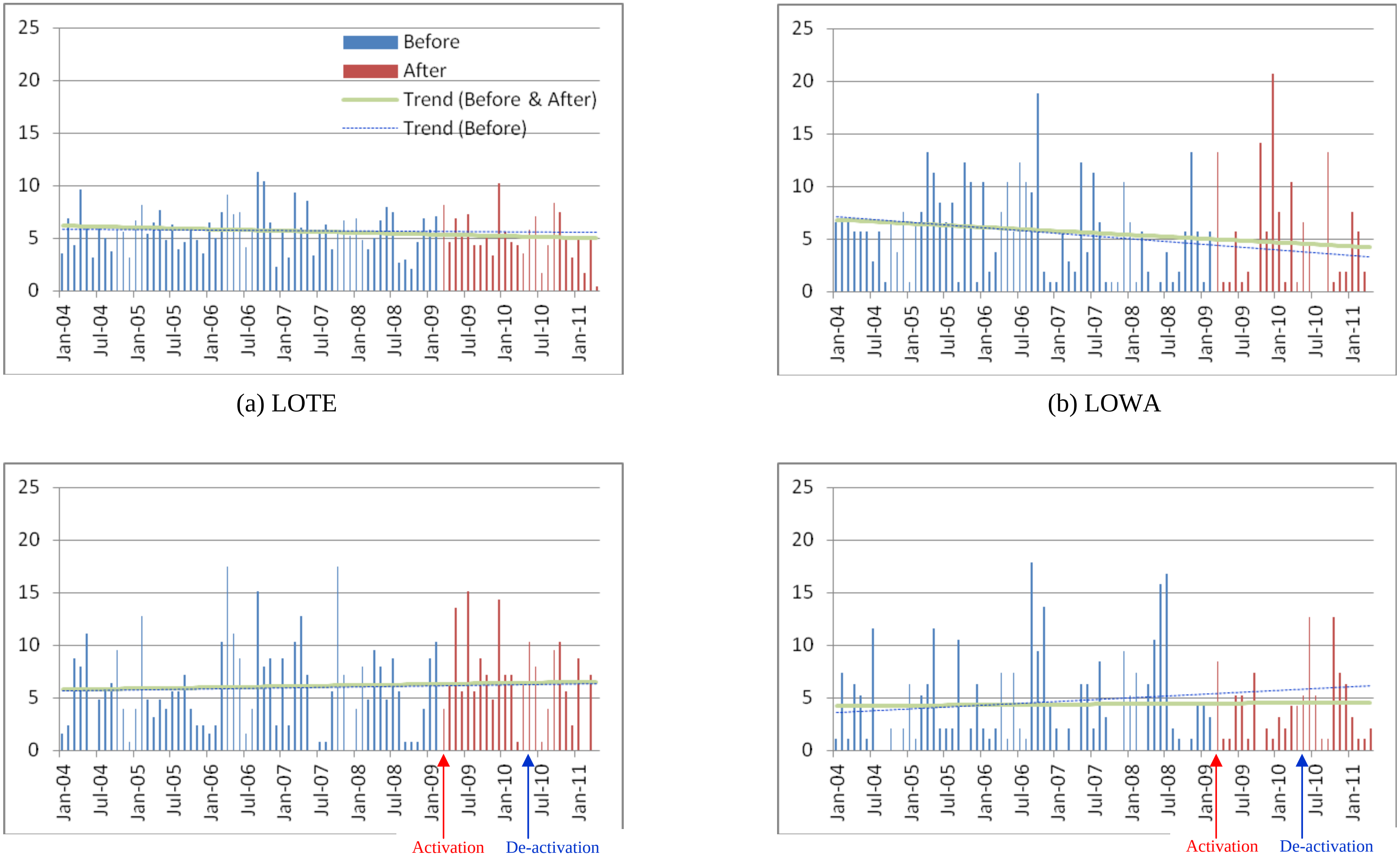


(e) SOSP



(f) VAAD

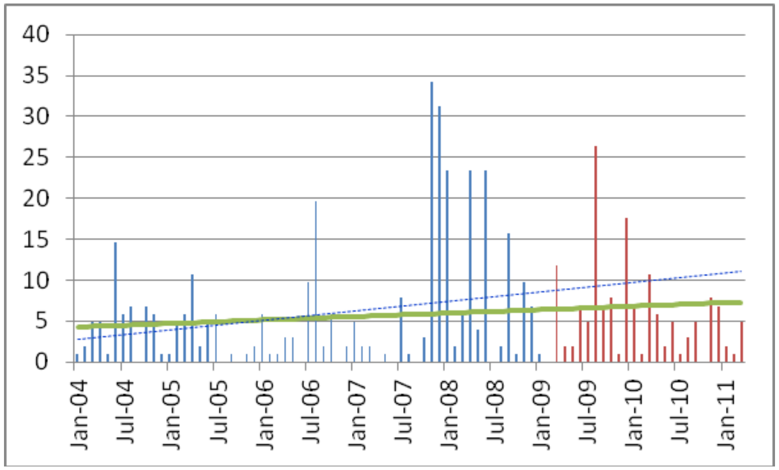
Figure 30. Injury-causing Rear-end Crash rate at Control Intersection ***(Continued)***



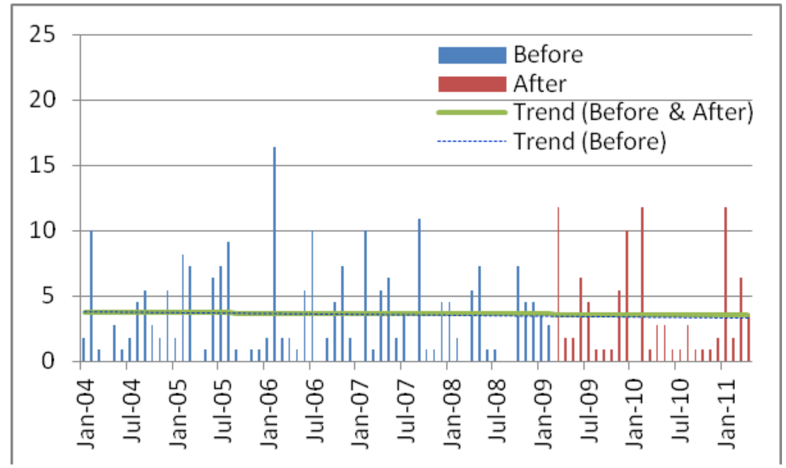
(a) LOTE (b) LOWA

(c) MASO (d) VAAM

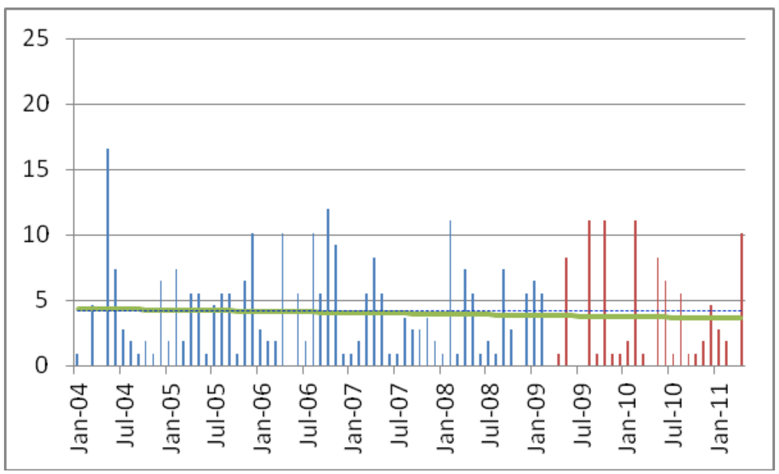
Figure 31. Severity Index at Camera Intersection



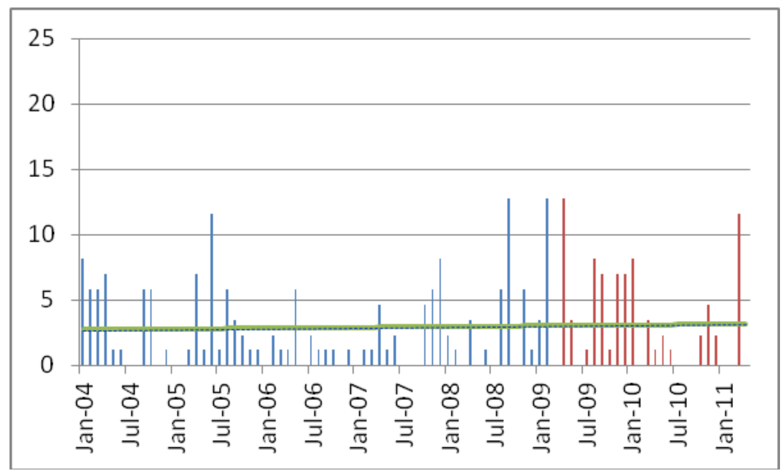
(a) ELMA



(b) PIMA

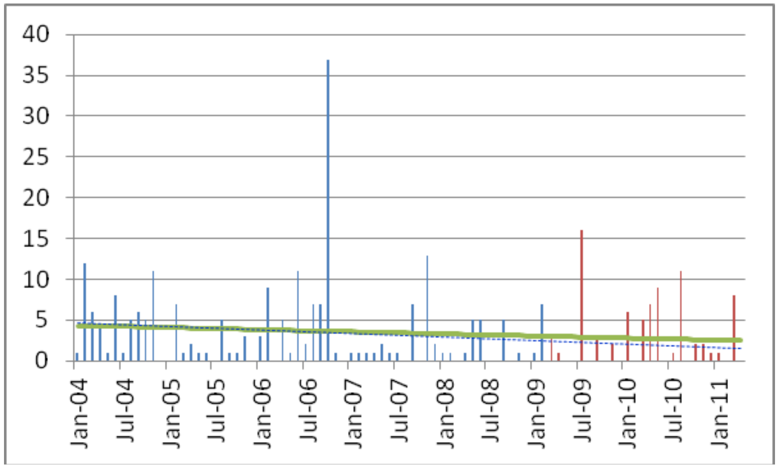


(c) PIVA

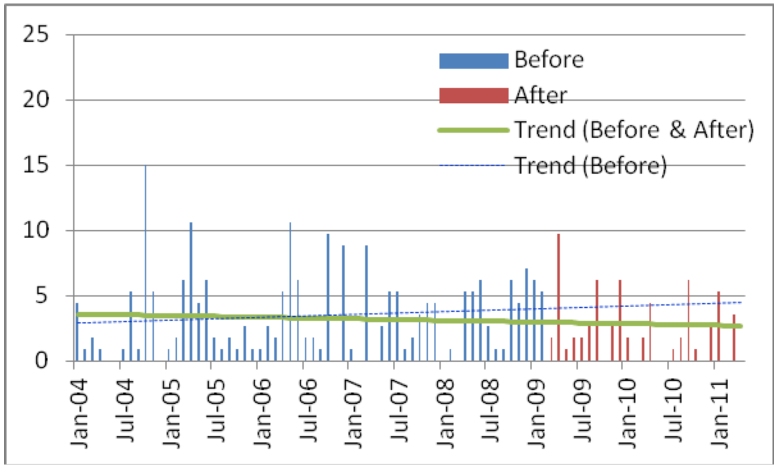


(d) SOMI

Figure 32. Severity Index rate at Control Intersection



(e) SOSP



(f) VAAD

Figure 32. Severity Index rate at Control Intersection ***(Continued)***

4.2. Statistical Analysis

The difference in crash rates between before and after the STOP operation are tested by the F-test and the t-test, and the results are shown in Tables 2 through 9. The F-test conducted is the variance ratio test to look for differences among sample variance. The purpose of the t-test is to determine the significance of differences between two sample means. In each table, the decision 'YES' denotes that there is a significant difference between the before and the after period, and 'M' tells us that a marginally significant difference exists, whereas 'NO' denotes that there is not enough evidence to say that there is a significant difference. The analysis period is based on 26-months before and 26-months after the camera installation. As well, to determine if the change in crash rates is the result of the STOP operation or from other factors, the crash rates at the camera intersections were compared with those at control intersections. The current study includes six control intersections which were identified by the City of Las Cruces.

Total Crash Rate: The results from the t-test show that the crash rate reductions at the LOTE intersection are statistically almost significant (or marginally significant) after the STOP operation (see Table 2). There are no significant changes in crash rates at all other intersections including control intersections. *Note that p-values between 0.06 and 0.1 are commonly referred to as 'marginally significant' or 'almost significant.'* Another analysis examined was the before-and-after change in crash types at the signalized intersections. Below are the results of these analyses.

Table 2. Statistical Analysis on Total Crash Rate

		Variance Test		Mean Test	
		P Value	Decision	P Value	Decision
Camera Intersections	***LOTE***	0.420	NO	***0.090***	***M***
	LOWA	0.826	NO	0.529	NO
	MASO	0.914	NO	0.218	NO
	VAAM	0.876	NO	0.920	NO
	Average	0.584	NO	0.485	NO
Non Camera Intersections	ELMA	0.076	NO	0.501	NO
	PIMA	0.697	NO	0.175	NO
	PIVA	0.446	NO	0.252	NO
	SOMI	0.595	NO	0.915	NO
	SOSP	0.049	Yes	0.417	NO
	VAAD	0.744	NO	0.544	NO
	Average	0.402	NO	0.788	NO

Angle Crash (AC) Rate: Table 3 presents the results of the statistical test that estimates the effects of the STOP operation on the rate of Angle Crashes. The results from the t-test show that the angle crash rate reductions at the LOTE intersection (p-value = 0.057) and the camera intersection (p-value = 0.053) are marginally significant after the STOP operation. We noticed that there is an increase in the angle crash rate at the PIVA intersection (p-value = 0.079), which is also a marginally significant change. All the other intersections have no significant changes in the angle crash rate after the STOP operation.

Table 3. Statistical Analysis on Angle Crash Rate

		Variance Test		Mean Test	
		P Value	Decision	P Value	Decision
Camera Intersections	***LOTE***	0.32	NO	***0.057***	***M***
	LOWA	0.177	NO	0.168	NO
	MASO	0.081	NO	0.887	NO
	VAAM	1.000	NO	1.000	NO
	Average	0.013	NO	***0.053***	***M***
Non Camera Intersections	ELMA	0.484	NO	0.484	NO
	PIMA	0.689	NO	0.509	NO
	PIVA	0.172	NO	***0.079***	***M***
	SOMI	0.831	NO	0.831	NO
	SOSP	0.717	NO	0.717	NO
	VAAD	0.790	NO	0.790	NO
	Average	0.895	NO	0.279	NO

Rear-end Crash (RC) Rate: The results of the t-test for estimating the effects of the STOP operation on the rear-end crash rate are summarized in Table 4. The results at all camera intersections didn't find any significant effects associated with the rear-end crash rate. However, two out of six control intersections have experienced statistically significant changes, i.e., an increase at PIMA intersection but a decrease at PIVA intersection. Below is another statistical analysis examined for the before-and-after change in the severity levels of crashes.

Table 4. Statistical Analysis on Rear-end Crash Rate

		Variance Test		Mean Test	
		P Value	Decision	P Value	Decision
Camera Intersections	LOTE	0.679	NO	0.453	NO
	LOWA	0.804	NO	1.000	NO
	MASO	0.211	NO	0.181	NO
	VAAM	0.641	NO	0.907	NO
	Average	0.364	NO	0.920	NO
Non Camera Intersections	ELMA	0.131	NO	0.631	NO
	PIMA	0.871	NO	***0.024***	***YES***
	PIVA	1.000	NO	***0.021***	***YES***
	SOMI	0.443	NO	0.666	NO
	SOSP	0.331	NO	0.281	NO
	VAAD	0.845	NO	0.555	NO
	Average	0.172	NO	1.000	NO

Property-Damage-Only (PDO) Crash Rate: According to the results in Table 5, there aren't any significant changes in the PDO crash rates at all camera intersections. Two out of six control intersections have experienced marginally significant changes, i.e., an increase at PIMA intersection but a decrease at PIVA intersection.

Table 5. Statistical Analysis on Property-Damage-Only Crash Rate

		Variance Test		Mean Test	
		P Value	Decision	P Value	Decision
Camera Intersections	LOTE	0.226	NO	0.225	NO
	LOWA	0.711	NO	0.162	NO
	MASO	0.471	NO	0.195	NO
	VAAM	0.445	NO	0.748	NO
	Average	0.604	NO	0.611	NO
Non Camera Intersections	ELMA	0.063	NO	0.519	NO
	PIMA	0.873	NO	***0.077***	***M***
	PIVA	0.481	NO	***0.094***	***M***
	SOMI	0.727	NO	1.000	NO
	SOSP	0.101	NO	0.424	NO
	VAAD	1.000	NO	1.000	NO
	Average	0.680	NO	1.000	NO

Injury (INJ) Crash Rate: Table 6 presents the results of the t-test on the injury crash rate. We may conclude that there aren't any significant changes in the injury crash rate at all of the camera and control intersections.

Table 6. Statistical Analysis on Injury Rate

		Variance Test		Mean Test	
		P Value	Decision	P Value	Decision
Camera Intersections	***LOTE***	0.466	NO	0.120	NO
	LOWA	0.516	NO	0.516	NO
	MASO	0.697	NO	0.780	NO
	VAAM	0.845	NO	0.845	NO
	Average	0.046	YES	0.517	NO
Non Camera Intersections	ELMA	0.455	NO	0.726	NO
	PIMA	0.696	NO	0.696	NO
	PIVA	0.683	NO	0.683	NO
	SOMI	0.825	NO	0.825	NO
	SOSP	0.526	NO	0.526	NO
	VAAD	0.143	NO	0.143	NO
	Average	0.221	NO	0.728	NO

Injury-causing Angle Crash Rate: Statistical test results on the injury-causing angle crash rate is summarized in Table 7. All of the p-values are much higher than the significance level of 0.05, which indicates that there isn't enough evidence to say that there is a significant difference on the injury-causing angle crash rate after the STOP operation at all of the camera and control intersections.

Table 7. Statistical Analysis on Injury-causing Angle Crash Rate

		Variance Test		Mean Test	
		P Value	Decision	P Value	Decision
Camera Intersections	***LOTE***	0.300	NO	0.300	NO
	LOWA	0.391	NO	0.391	NO
	MASO	0.550	NO	0.550	NO
	VAAM	0.307	NO	0.307	NO
	Average	0.806	NO	0.882	NO
Non Camera Intersections	ELMA	0.806	NO	0.806	NO
	PIMA	0.395	NO	0.395	NO
	PIVA	0.166	NO	0.166	NO
	SOMI	1.000	NO	1.000	NO
	SOSP	1.000	NO	1.000	NO
	VAAD	1.000	NO	1.000	NO
	Average	0.748	NO	0.263	NO

Injury-causing Rear-end Crash Rate: Table 8 presents the statistical test results on the injury-causing rear-end crash rate. Again, all of the p-values are much higher than the significance level of 0.05, which indicates that there is not enough evidence to say that there is a significant difference on the injury-causing rear-end crash rate after the STOP operation at all of the camera and control intersections.

Table 8. Statistical Analysis on Injury-causing Rear-end Crash Rate

		Variance Test		Mean Test	
		P Value	Decision	P Value	Decision
Camera Intersections	***LOTE***	0.323	NO	0.236	NO
	LOWA	0.184	NO	0.184	NO
	MASO	0.605	NO	0.727	NO
	VAAM	0.279	NO	0.279	NO
	Average	0.502	NO	0.280	NO
Non Camera Intersections	ELMA	0.914	NO	0.914	NO
	PIMA	0.506	NO	0.506	NO
	PIVA	0.591	NO	0.591	NO
	SOMI	0.765	NO	0.765	NO
	SOSP	0.300	NO	0.300	NO

	VAAD	0.576	NO	0.576	NO
	Average	0.590	NO	0.761	NO

Severity Index (SI): The results of the t-test for estimating the effects of the STOP operation on the SI rate are summarized in Table 9. We noticed that there is a decrease in the SI rate at the LOTE intersection (p-value = 0.056), which is a marginally significant change. All the other intersections have no significant changes in the SI rate after the STOP operation.

Table 9. Statistical Analysis on Severity Index

		Variance Test		Mean Test	
		P Value	Decision	P Value	Decision
Camera Intersections	***LOTE***	0.279	NO	***0.056***	***M***
	LOWA	0.356	NO	0.642	NO
	MASO	0.522	NO	0.489	NO
	VAAM	0.317	NO	0.672	NO
	Average	0.690	NO	0.449	NO
Non Camera Intersections	ELMA	0.134	NO	0.455	NO
	PIMA	0.962	NO	0.800	NO
	PIVA	0.406	NO	0.884	NO
	SOMI	0.713	NO	0.831	NO
	SOSP	0.256	NO	0.429	NO
	VAAD	0.290	NO	0.158	NO
	Average	0.165	NO	0.586	NO

From the statistical analysis of the crash data, the following conclusions are drawn (see Table 10):

1) After the STOP operation, the LOTE camera intersection in the City of Las Cruces experienced a marginally significant reduction in the average of total crash rates and the SI rates, whereas at the control intersections, there were no (marginally) significant decrease on the average total crash rates and the SI rates. Therefore, it can be concluded that the reduction in the total crash rate and the SI rate at the LOTE camera intersection could result from the STOP operation.
2) The average angle crash rate reductions at the LOTE camera intersection are marginally significant after the STOP operation, whereas the PIVA control intersection has experienced a marginally significant increase on the average angle crash rate. The angle crash rate reductions at all other control intersections were not higher than that at the LOTE camera intersection. Hence, we can conclude that the reduction in the angle crash rate at the LOTE intersection could result from the STOP operation.
3) Two out of six control intersections have experienced statistically significant changes on the rear-end crash rates and marginally significant changes on the PDO crash rates, i.e., an increase at PIMA intersection and a decrease at PIVA intersection. Comparing the reduction in crash rates between camera and control intersections, 26 months after the

STOP operation, the rear-end crash rate changes at the two control intersections were significantly higher than the ones at the camera intersections. The PDO crash rate changes at the two control intersections were higher than the ones at the camera intersections, as well. However, it cannot be concluded that these changes could result from the absence of the STOP operation. This is because the crash rate was increased at one intersection while decreased at another. Other factors such as traffic management and intersection improvements could be the cause.

Table 10. Summary of Statistical Analysis

Intersection	Total Crash	AC	RC	PDO	INJ	INJ-causing AC	INJ-causing RC	SI
LOTE	Decrease (M)	Decrease (M)	No Change	No Change	No Change	No Change	No Change	Decrease (M)
LOWA	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change
MASO	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change
VAAM	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change
Camera	No Change	Decrease (M)	No Change	No Change	No Change	No Change	No Change	No Change
ELMA	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change
PIMA	No Change	No Change	Increase	Increase (M)	No Change	No Change	No Change	No Change
PIVA	No Change	Increase (M)	Decrease	Decrease(M)	No Change	No Change	No Change	No Change
SOMI	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change
SOSP	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change
VAAD	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change
NonCamera	No Change	No Change	No Change	No Change	No Change	No Change	No Change	No Change

5. Preliminary Conclusions

The following preliminary conclusions can be made:

- The trend analysis of the signalized intersections shows a reduction in the crash rates at certain intersections for certain accident types. Even though the findings from the crash data are encouraging, not all the results from the trend analysis are supported by the statistical analysis.
- Two out of six control intersections have experienced statistically significant changes on the rear-end crash rates and marginally significant changes on the property-damage-only crash rates. However, it cannot be concluded that these changes could result from the absence of the operation. This is because the crash rate was increased at one intersection while decreased at another. Other factors such as traffic management and intersection improvements could be the cause.
- After the program operation, the total crash rate reductions, mainly due to the reduction of angle crash rates were marginally significant at the intersection. However, there weren't any significant changes in the rear-end crash rates, property-damage-only crash rates, and the injury crash rates.
- Based on the statistical analysis and comparing the reductions in crash rates between camera and control intersections, we may conclude that the STOP program has a positive impact on the traffic safety at the LOTE intersection.

6. Future Research

Before a final decision on whether or not the STOP operation has had a positive impact on increasing road safety, there are still several things that need to be analyzed. They are:

- Compiling the crash report data to date, and updating the crash analyses accordingly.
- Analyzing to determine whether there has been a reduction in the red-light violations rate after the STOP operation.
- Conducting accidents/violations rate comparisons with other cities of comparable size.
- Understanding the correlations between accidents/violations and types of accidents, levels of severity, drivers, intersections, and environmental factors.

Appendix A

Percent Changes in Annual Crash Rates at the Camera Intersections

Table A1. Average Crash Rates at Camera Intersections

Year	# of Crashes per 1 million vehicles					% Changes in Crashes per 1 million vehicles				
	LOTE	LOWA	MASO	VAAM	Ave.	LOTE	LOWA	MASO	VAAM	Ave.
2004	3.26	2.51	2.59	1.40	2.55	-	-	-	-	-
2005	3.15	3.22	2.39	2.19	2.84	-3.3	28.1	-7.7	56.3	11.6
2006	3.58	3.38	3.38	2.98	3.40	10.0	34.4	30.8	112.5	33.3
2007	3.74	2.67	2.39	1.93	2.79	15.0	6.3	-7.7	37.5	9.5
2008	3.09	2.04	1.79	1.93	2.36	-5.0	-18.8	-30.8	37.5	-7.5
2009	3.31	2.04	3.65	1.93	2.84	1.7	-18.8	41.0	37.5	11.6
2010	2.71	1.89	2.85	2.63	2.58	-16.7	-25.0	10.3	87.5	1.4
2011	1.14	1.89	1.59	1.84	1.56	-65.0	-25.0	-38.5	31.3	-38.8

Table A2. Average Angle Crash Rates at Camera Intersections

Year	# of Crashes per 1 million vehicles					% Changes in Crashes per 1 million vehicles				
	LOTE	LOWA	MASO	VAAM	Ave.	LOTE	LOWA	MASO	VAAM	Ave.
2004	0.81	0.94	0.86	0.44	0.78	-	-	-	-	-
2005	0.54	1.49	0.86	0.70	0.90	-33.3	58.3	0.0	60.0	15.6
2006	0.54	1.73	0.86	0.79	0.97	-33.3	83.3	0.2	80.0	24.4
2007	0.98	1.02	0.66	0.53	0.82	20.0	8.3	-23.1	20.0	4.4
2008	0.92	0.63	0.80	0.44	0.73	13.3	-33.3	-7.7	0.0	-6.7
2009	0.65	0.55	0.93	0.53	0.68	-20.0	-41.7	7.7	20.0	-13.3
2010	0.43	0.47	0.80	0.88	0.62	-46.7	-50.0	-7.7	100.0	-20.0
2011	0.16	0.24	0.20	0.79	0.31	-80.0	-75.0	-76.9	80.0	-60.0

Table A3. Average Rear-end Crash Rates at Camera Intersections

Year	# of Crashes per 1 million vehicles					% Changes in Crashes per 1 million vehicles				
	LOTE	LOWA	MASO	VAAM	Ave.	LOTE	LOWA	MASO	VAAM	Ave.
2004	2.17	1.41	1.66	0.70	1.58	-	-	-	-	-
2005	2.55	1.49	1.46	1.31	1.82	17.5	5.6	-12.0	87.5	15.4
2006	2.66	1.57	2.19	2.01	2.20	22.5	11.1	32.0	187.5	39.6
2007	2.66	1.57	1.72	1.40	1.93	22.5	11.1	4.0	100.0	22.0
2008	2.01	1.26	0.93	1.49	1.53	-7.5	-11.1	-44.0	112.5	-3.3
2009	2.44	1.18	2.59	1.14	1.94	12.5	-16.7	56.0	62.5	23.1
2010	2.22	1.34	1.99	1.75	1.91	2.5	-5.6	20.0	150.0	20.9
2011	0.98	1.41	1.39	0.79	1.14	-55.0	0.0	-16.0	12.5	-27.5

Table A4. Average PDO Crash Rates at Camera Intersections

Year	# of Crashes per 1 million vehicles					% Changes in Crashes per 1 million vehicles				
	LOTE	LOWA	MASO	VAAM	Ave.	LOTE	LOWA	MASO	VAAM	Ave.
2004	2.44	1.81	1.92	0.96	1.87	-	-	-	-	-
2005	2.60	2.20	1.72	1.58	2.13	6.7	21.7	-10.3	63.6	13.9
2006	2.88	2.28	2.32	2.28	2.50	17.8	26.1	20.7	136.4	33.3
2007	2.77	2.12	1.46	1.58	2.05	13.3	17.4	-24.1	63.6	9.3
2008	2.60	1.57	0.99	1.05	1.68	6.7	-13.0	-48.3	9.1	-10.2
2009	2.71	1.18	2.39	1.58	2.06	11.1	-34.8	24.1	63.6	10.2
2010	2.22	1.34	2.06	1.93	1.96	-8.9	-26.1	6.9	100.0	4.6
2011	0.81	1.41	0.99	1.84	1.20	-66.7	-21.7	-48.3	90.9	-36.1

Table A5. Average Injury Crash Rates at Camera Intersections

	# of Crashes per 1 million vehicles					% Changes in Crashes per 1 million vehicles				
Year	LOTE	LOWA	MASO	VAAM	Ave.	LOTE	LOWA	MASO	VAAM	Ave.
2004	0.81	0.71	0.66	0.44	0.68	-	-	-	-	-
2005	0.54	1.02	0.66	0.61	0.71	-33.3	44.4	0.0	40.0	5.1
2006	0.65	1.10	1.06	0.70	0.88	-20.0	55.6	60.0	60.0	30.8
2007	0.98	0.55	0.93	0.35	0.75	20.0	-22.2	40.0	-20.0	10.3
2008	0.49	0.47	0.80	0.79	0.66	-40.0	-33.3	20.0	80.0	-2.6
2009	0.60	0.79	1.26	0.35	0.76	-26.7	11.1	90.0	-20.0	12.8
2010	0.49	0.55	0.80	0.70	0.62	-40.0	-22.2	20.0	60.0	-7.7
2011	0.33	0.47	0.60	0.00	0.36	-60.0	-33.3	-10.0	-100.0	-46.2

Table A6. Average Injury-causing Angle Crash Rates at Camera Intersections

	# of Crashes per 1 million vehicles					% Changes in Crashes per 1 million vehicles				
Year	LOTE	LOWA	MASO	VAAM	Ave.	LOTE	LOWA	MASO	VAAM	Ave.
2004	0.22	0.16	0.27	0.18	0.21	-	-	-	-	-
2005	0.05	0.47	0.13	0.18	0.21	-75.0	200.0	-50.0	0.0	0.0
2006	0.05	0.55	0.40	0.18	0.28	-75.0	250.0	50.0	0.0	33.3
2007	0.16	0.31	0.20	0.00	0.17	-25.0	100.0	-25.0	-100.0	-16.7
2008	0.11	0.31	0.27	0.00	0.19	-50.0	100.0	0.0	-99.5	-8.3
2009	0.00	0.16	0.46	0.00	0.16	-100.0	0.0	75.0	-100.0	-25.0
2010	0.11	0.24	0.33	0.26	0.23	-50.0	50.0	25.0	50.0	8.3
2011	0.00	0.00	0.00	0.00	0.00	-100.0	-100.0	-100.0	-100.0	-100.0

Table A7. Average Injury-causing Rear-end Crash Rates at Camera Intersections

	# of Crashes per 1 million vehicles					% Changes in Crashes per 1 million vehicles				
Year	LOTE	LOWA	MASO	VAAM	Ave.	LOTE	LOWA	MASO	VAAM	Ave.
2004	0.49	0.55	0.40	0.18	0.42	-	-	-	-	-
2005	0.49	0.39	0.53	0.44	0.47	0.0	-28.6	33.3	150.0	12.5
2006	0.49	0.47	0.60	0.53	0.54	0.0	-14.3	50.0	200.0	29.2
2007	0.81	0.24	0.73	0.35	0.57	66.7	-57.1	83.3	100.0	37.5
2008	0.38	0.16	0.53	0.79	0.49	-22.2	-71.4	33.3	350.0	16.7
2009	0.60	0.55	0.73	0.26	0.56	22.2	0.0	83.3	50.0	33.3
2010	0.38	0.31	0.46	0.44	0.40	-22.2	-42.9	16.7	150.0	-4.2
2011	0.33	0.47	0.60	0.00	0.36	-33.3	-14.3	50.0	-100.0	-12.5

Table A8. Average Severity Index Rates at Camera Intersections

	Severity Index per 1 million vehicles					% Changes in Severity Index per 1 million vehicles				
Year	LOTE	LOWA	MASO	VAAM	Ave.	LOTE	LOWA	MASO	VAAM	Ave.
2004	6.51	5.34	5.24	3.15	5.26	-	-	-	-	-
2005	5.32	7.31	5.04	4.64	5.69	-18.3	36.8	-3.8	47.2	8.3
2006	6.13	7.78	7.63	5.78	6.92	-5.8	45.6	45.6	83.3	31.7
2007	7.65	4.87	6.10	3.33	5.78	17.5	-8.8	16.5	5.6	9.9
2008	5.05	3.93	4.97	5.87	5.15	-22.5	-26.5	-5.1	86.1	-2.0
2009	5.70	5.89	8.69	3.33	6.05	-12.5	10.3	65.8	5.6	15.2
2010	4.67	4.09	6.03	5.43	5.08	-28.3	-23.5	15.2	72.2	-3.3
2011	2.44	3.77	3.98	1.84	3.02	-62.5	-29.4	-24.1	-41.7	-42.6

Appendix B

Percent Changes in Annual Crash Rates at the Control Intersections

Table B1. Average Crash Rates at Control Intersections

	# of Crashes per 1 million vehicles							% Changes in Crashes per 1 million vehicles						
Year	ELMA	PIMA	PIVA	SOMI	SOSP	VAAD	Ave.	ELMA	PIMA	PIVA	SOMI	SOSP	VAAD	Ave.
2004	1.71	1.67	1.84	1.25	1.99	1.25	1.62	-	-	-	-	-	-	-
2005	1.47	1.82	1.92	1.45	1.16	1.84	1.62	-14.3	9.1	4.2	15.4	-41.7	47.1	0.0
2006	1.79	2.42	2.38	1.25	2.58	2.13	2.12	4.8	45.5	29.2	0.0	29.2	70.6	30.6
2007	2.69	1.67	2.31	1.64	1.58	1.69	1.95	57.1	0.0	25.0	30.8	-20.8	35.3	19.8
2008	3.75	1.29	1.92	1.25	0.58	1.54	1.74	119.0	-22.7	4.2	0.0	-70.8	23.5	7.4
2009	3.10	2.42	1.69	2.22	1.41	1.98	2.13	81.0	45.5	-8.3	76.9	-29.2	58.8	31.4
2010	1.96	1.67	1.77	1.74	1.66	1.10	1.65	14.3	0.0	-4.2	38.5	-16.7	-11.8	1.7
2011	1.47	3.18	1.84	0.58	1.25	1.32	1.65	-14.3	90.9	0.0	-53.8	-37.5	5.9	1.7

Table B2. Average Angle Crash Rates at Control Intersections

	# of Crashes per 1 million vehicles							% Changes in Crashes per 1 million vehicles						
Year	ELMA	PIMA	PIVA	SOMI	SOSP	VAAD	Ave.	ELMA	PIMA	PIVA	SOMI	SOSP	VAAD	Ave.
2004	0.57	0.23	0.77	0.19	0.75	0.22	0.46	-	-	-	-	-	-	-
2005	0.16	0.45	0.85	0.48	0.33	0.73	0.51	-71.4	100.0	10.0	150.0	-55.6	233.3	11.8
2006	0.33	0.68	0.92	0.48	0.66	0.44	0.59	-42.9	200.0	20.0	150.0	-11.1	100.0	29.4
2007	0.16	0.68	0.54	0.58	0.58	0.37	0.48	-71.4	200.0	-30.0	200.0	-22.2	66.7	5.9
2008	0.81	0.53	0.38	0.39	0.25	0.22	0.43	42.9	133.3	-50.0	100.0	-66.7	0.0	-5.9
2009	0.90	0.98	0.46	0.87	0.58	0.37	0.68	57.1	333.3	-40.0	350.0	-22.2	66.7	50.0
2010	0.49	0.30	0.69	0.58	0.42	0.15	0.43	-14.3	33.3	-10.0	200.0	-44.4	-33.3	-5.9
2011	0.00	0.68	1.61	0.00	1.00	0.44	0.64	-100.0	200.0	110.0	-100.0	33.3	100.0	41.2

Table B3. Average Rear-end Crash Rates at Control Intersections

	# of Crashes per 1 million vehicles							% Changes in Crashes per 1 million vehicles						
Year	ELMA	PIMA	PIVA	SOMI	SOSP	VAAD	Ave.	ELMA	PIMA	PIVA	SOMI	SOSP	VAAD	Ave.
2004	0.98	1.44	1.08	0.87	0.83	1.03	1.05	-	-	-	-	-	-	-
2005	1.14	1.36	0.77	0.77	0.75	1.10	0.99	16.7	-5.3	-28.6	-11.1	-10.0	7.1	-5.1
2006	1.47	1.51	0.77	0.39	1.25	1.69	1.21	50.0	5.3	-28.6	-55.6	50.0	64.3	15.4
2007	2.20	0.98	1.61	1.06	0.91	1.03	1.32	125.0	-31.6	50.0	22.2	10.0	0.0	25.6
2008	2.20	0.61	1.46	0.87	0.17	0.81	1.02	125.0	-57.9	35.7	0.0	-80.0	-21.4	-2.6
2009	2.20	1.29	1.23	1.16	0.83	1.54	1.38	125.0	-10.5	14.3	33.3	0.0	50.0	32.1
2010	1.30	1.36	1.00	1.06	1.08	0.95	1.13	33.3	-5.3	-7.1	22.2	30.0	-7.1	7.7
2011	1.47	2.50	0.23	0.58	0.25	0.88	1.01	50.0	73.7	-78.6	-33.3	-70.0	-14.3	-3.8

Table B4. Average PDO Crash Rates at Control Intersections

	# of Crashes per 1 million vehicles							% Changes in Crashes per 1 million vehicles						
Year	ELMA	PIMA	PIVA	SOMI	SOSP	VAAD	Ave.	ELMA	PIMA	PIVA	SOMI	SOSP	VAAD	Ave.
2004	0.90	1.29	1.38	0.58	1.25	0.73	1.03	-	-	-	-	-	-	-
2005	0.81	1.36	1.23	1.06	1.00	1.40	1.15	-9.1	5.9	-11.1	83.3	-20.0	90.0	11.7
2006	1.14	1.82	1.69	0.96	1.50	1.62	1.48	27.3	41.2	22.2	66.7	20.0	120.0	42.9
2007	1.55	1.14	2.07	1.45	1.25	1.32	1.48	72.7	-11.8	50.0	150.0	0.0	80.0	42.9
2008	2.44	0.83	1.46	0.87	0.33	1.10	1.19	172.7	-35.3	5.6	50.0	-73.3	50.0	15.6
2009	2.04	1.97	1.15	1.45	1.08	1.54	1.54	127.3	52.9	-16.7	150.0	-13.3	110.0	49.4
2010	1.30	1.51	1.31	1.64	1.16	0.95	1.30	45.5	17.6	-5.6	183.3	-6.7	30.0	26.0
2011	0.73	2.50	1.38	0.00	1.00	1.10	1.17	-18.2	94.1	0.0	-100.0	-20.0	50.0	13.0

Table B5. Average Injury Crash Rates at Control Intersections

Year	# of Crashes per 1 million vehicles							% Changes in Crashes per 1 million vehicles						
	ELMA	PIMA	PIVA	SOMI	SOSP	VAAD	Ave.	ELMA	PIMA	PIVA	SOMI	SOSP	VAAD	Ave.
2004	0.73	0.38	0.46	0.58	0.75	0.44	0.55	-	-	-	-	-	-	-
2005	0.49	0.45	0.69	0.39	0.17	0.37	0.43	-33.3	20.0	50.0	-33.3	-77.8	-16.7	-22.0
2006	0.65	0.53	0.69	0.10	1.08	0.51	0.60	-11.1	40.0	50.0	-83.3	44.4	16.7	9.8
2007	1.14	0.53	0.23	0.19	0.25	0.37	0.46	55.6	40.0	-50.0	-66.7	-66.7	-16.7	-17.1
2008	1.14	0.45	0.46	0.39	0.25	0.44	0.52	55.6	20.0	0.0	-33.3	-66.7	0.0	-4.9
2009	1.06	0.45	0.54	0.77	0.33	0.44	0.59	44.4	20.0	16.7	33.3	-55.6	0.0	7.3
2010	0.65	0.15	0.46	0.10	0.50	0.15	0.34	-11.1	-60.0	0.0	-83.3	-33.3	-66.7	-39.0
2011	0.73	0.68	0.46	0.58	0.25	0.22	0.48	0.0	80.0	0.0	0.0	-66.7	-50.0	-12.2

Table B6. Average Injury-causing Angle Crash Rates at Control Intersections

Year	# of Crashes per 1 million vehicles							% Changes in Crashes per 1 million vehicles						
	ELMA	PIMA	PIVA	SOMI	SOSP	VAAD	Ave.	ELMA	PIMA	PIVA	SOMI	SOSP	VAAD	Ave.
2004	0.24	0.15	0.08	0.00	0.25	0.07	0.13	-	-	-	-	-	-	-
2005	0.08	0.08	0.23	0.29	0.08	0.15	0.15	-66.7	-50.0	200.0	-	-66.7	100.0	10.0
2006	0.16	0.08	0.15	0.10	0.33	0.00	0.13	-33.3	-50.0	100.0	-	33.3	-100.0	0.0
2007	0.00	0.15	0.08	0.10	0.08	0.07	0.08	-100.0	0.0	0.0	-	-66.7	0.0	-40.0
2008	0.33	0.00	0.15	0.10	0.17	0.00	0.15	34.0	-100.0	100.0	-	-33.3	-100.0	10.0
2009	0.41	0.15	0.15	0.39	0.17	0.00	0.20	66.7	0.0	100.0	-	-33.3	-100.0	50.0
2010	0.16	0.08	0.31	0.00	0.17	0.00	0.12	-33.3	-50.0	300.0	-	-33.3	-100.0	-10.0
2011	0.00	0.23	0.46	0.00	0.25	0.22	0.20	-100.0	50.0	500.0	-	0.0	200.0	50.0

Table B7. Average Injury-causing Rear-end Crash Rates at Control Intersections

Year	# of Crashes per 1 million vehicles							% Changes in Crashes per 1 million vehicles						
	ELMA	PIMA	PIVA	SOMI	SOSP	VAAD	Ave.	ELMA	PIMA	PIVA	SOMI	SOSP	VAAD	Ave.
2004	0.41	0.23	0.38	0.58	0.42	0.37	0.39	-	-	-	-	-	-	-
2005	0.41	0.38	0.38	0.10	0.08	0.22	0.27	0.0	66.7	0.0	-83.3	-80.0	-40.0	-31.0
2006	0.49	0.38	0.23	0.00	0.50	0.51	0.36	20.0	66.7	-40.0	-100.0	20.0	40.0	-6.9
2007	0.90	0.38	0.15	0.10	0.17	0.22	0.32	120.0	66.7	-60.0	-83.3	-60.0	-40.0	-17.2
2008	0.57	0.38	0.23	0.29	0.00	0.29	0.30	40.0	66.7	-40.0	-50.0	-100.0	-20.0	-24.1
2009	0.65	0.30	0.38	0.39	0.17	0.37	0.38	60.0	33.3	0.0	-33.3	-60.0	0.0	-3.4
2010	0.49	0.08	0.15	0.10	0.25	0.15	0.20	20.0	-66.7	-60.0	-83.3	-40.0	-60.0	-48.3
2011	0.73	0.45	0.00	0.58	0.00	0.00	0.28	80.0	100.0	-100.0	0.0	-100.0	-100.0	-27.6

Table B8. Average Severity Index Rates at Control Intersections

Year	Severity Index per 1 million vehicles							% Changes in Severity Index per 1 million vehicles						
	ELMA	PIMA	PIVA	SOMI	SOSP	VAAD	Ave.	ELMA	PIMA	PIVA	SOMI	SOSP	VAAD	Ave.
2004	4.56	3.18	3.69	3.47	4.99	2.94	3.79	-	-	-	-	-	-	-
2005	3.26	3.64	4.69	2.99	1.83	3.23	3.30	-28.6	14.3	27.1	-13.9	-63.3	10.0	-12.8
2006	4.40	4.47	5.15	1.45	6.90	4.19	4.50	-3.6	40.5	39.6	-58.3	38.3	42.5	18.8
2007	7.25	3.79	3.23	2.41	2.49	3.16	3.76	58.9	19.0	-12.5	-30.6	-50.0	7.5	-0.7
2008	9.78	3.11	3.77	2.80	1.58	3.31	4.08	114.3	-2.4	2.1	-19.4	-68.3	12.5	7.8
2009	7.33	4.24	3.84	5.31	2.74	3.75	4.50	60.7	33.3	4.2	52.8	-45.0	27.5	18.8
2010	4.56	2.27	3.61	2.12	3.66	1.69	2.98	0.0	-28.6	-2.1	-38.9	-26.7	-42.5	-21.3
2011	4.40	5.91	3.69	2.89	2.24	2.20	3.58	-3.6	85.7	0.0	-16.7	-55.0	-25.0	-5.3

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