Red Light Camera Study Update (NMSU)

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To: Robert Garza, City Manager

From: Dan Soriano, Traffic Engineer, Transportation Department

Date: August 20, 2012

Subj: **Report 2 of NMSU Safety Assessment of the Safe Traffic Operations Program (STOP)**

Please find attached the second report from Dr. Hansuk Sohn and his staff from New Mexico State University (NMSU) on the Safe Traffic Operations Program in Las Cruces.

Along with an update to the various crash analyses conducted since the last presentation in January of this year, the second report contains additional information related to violation/citation data collected by all of the camera devices. Data was obtained from the three cameras at Main/Solano and southbound Avenida De Mesilla/Valley up to October, 2010 after they were deactivated earlier in May of that year. This provides interesting results on how driver behavior changed over the five month time period.

NMSU representatives along with City staff will be available to answer City Council's questions after the presentation at the August 27th work session.

cc: Brian Denmark, ACM/COO
Lisa Murphy, Director, Transportation Department
Jeff Honeycutt, Administrator, Street/Traffic Operations

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

Before-and-After Analysis of Crash and Violation Data

Preliminary Report

by

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ACKNOWLEDGEMENTS

The crash data used in this report were provided by the City of Las Cruces Police Department. We would like to thank Mr. Mike Johnson, Mr. Dan Soriano, and Deputy Chief Chris Miller for many fruitful discussions and helpful comments during the course of this research. We would also like to thank Dr. Ivan Rodriguez, Sharita Gause, Faris Almansour, Sarah Lawrence, Spyros angelis, Yuzhe Yan, Iyere Imoisi, Jesus Ibarra, and Swathi Moukthi for their help on data extraction and analyses as well.

ABSTRACT

The Safe Traffic Operations Program (STOP) in the City of Las Cruces, NM, was introduced in March 2009. This update study is conducted as a part of an evaluation of the impact on traffic safety of the STOP. The current study includes about 2,400 crash records collected from ten signalized intersections in the city between January 2004 and February 2012. The goal of this study is to assess the impact of the program on traffic safety during the first 3 years of implementation and in subsequent years of the program. Note that both of the cameras at the Main & Solano intersection, as well as the southbound camera at the Valley & Avenida de Mesilla intersection, had deactivated since May 2010. Hence, in conducting the analysis at these two intersections, crash results are grouped into three distinct periods. The findings that can be drawn from the trend and statistical analyses are in the following. The effect of the STOP is beneficial on the traffic safety at the Lohman & Telshor intersection since there were significant reductions on the total crash rates, mainly due to the reduction on the rear-end crash rates and the property-damage only crash rates. However, the Lohman & Walnut intersection experienced an overall, negative impact. After the STOP operation, there were significant increases in every category of the crashes. The Main & Solano intersection also experienced an overall, negative impact as a result of the STOP operation. After the camera was installed, the trend has an upward spike after which the rates remain steady until the deactivation, when they trend downward quickly indicating a negative effect made by installing the camera. The Valley & Avenida de Mesilla intersection showed a mixture of reduction and increment in the crash rates after the launch and deactivation of the STOP program. However, we cannot make a solid conclusion on the camera effect at the Valley & Avenida de Mesilla intersection since its southbound camera had deactivated and thus, was no longer operable since May 2010. Even though there weren't any STOP operations, the statistical tests show significant reductions in the crash rates at certain control intersections for certain crash types. Our study also includes a total of 38,169 red-light violation records collected between March 2009 and February 2012. Descriptive statistics suggest that a majority of the red-light violations occurred during the daytime with two peak hours at 12 pm and 4pm, and the highest red-light violations occurred on Friday. The highest volume of the red-light violations occurred within 1 second after the onset of the red-light signal, whereas the second highest volume of the red-light violations occurred more than 3 seconds after the red-light signal. About 12,400 speeding violation records are also collected from five camera sites in the city between May 2010 and April 2012 for the violation analysis. The Lohman & Walnut westbound camera sites experienced the highest monthly average speeding violation counts whereas the Lohman & Telshor westbound recorded the lowest number. However, during the given study periods, the Lohman & Walnut westbound experienced a significant downward trend on it. There aren't any significant changes on the monthly average speed of the vehicles at the time of the violations.

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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 speeding 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 three years of implementation and in subsequent years of the program.

2. CRASH DATA ANALYSIS

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 were 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 February 2012. 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. Note that for both MASO and VAAM intersections, the crash results are grouped into three periods. They are (1) before the camera installation period, (2) the camera activation period, and (3) the camera deactivation period.

2.1 Methodology

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

2.1.1 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. .

2.1.2 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.

2.1.2.1 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.

2.1.2.2 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_2^2 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:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}}$$

2.2 Results and Discussion

2.2.1 Trend Analysis

2.2.1.1 Yearly trends of the crash data

First, we review the yearly trends of crashes at the signalized intersections, which are illustrated in Figures 2-1 through 2-16, 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 2-1 and 2-2). 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 6.3% and 17.9%. The LOTE camera intersection experienced the largest amount of reduction, i.e., 41.7%. 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 were substantial jumps in 2011 at the PIMA and PIVA control intersections. These may be attributed to the fact that there were lane closures due to construction at each of these intersections during that period which resulted in more congested conditions. Unlike the camera intersections, it is hard to say that there were downward trends at the control intersections during the recent years.

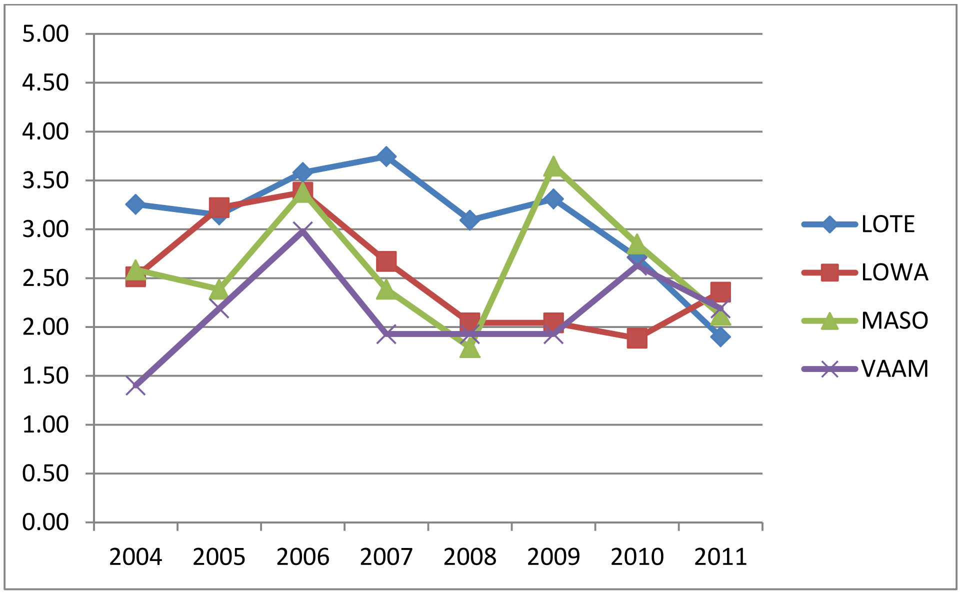


Figure 2-1. Yearly Trends of Crash Rates at Camera Intersection

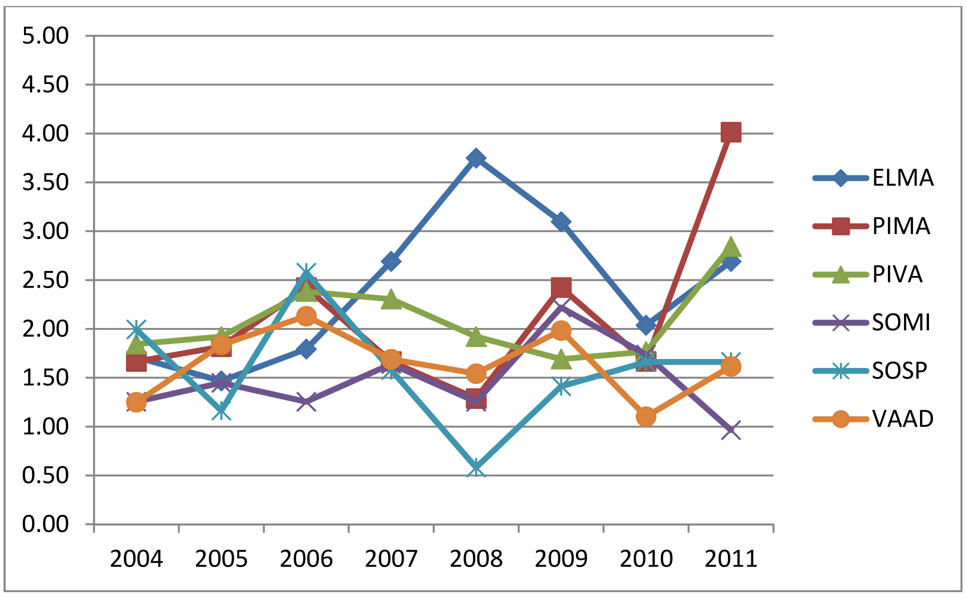


Figure 2-2. Yearly Trends of Crash Rates at Control Intersection

Angle Crash (AC) Rate: The AC crashes account for 27.53% of the total crashes at the camera intersections and 28.36% at the control intersections. The yearly trends of the AC rates are plotted in Figures 2-3 and 2-4. In comparison with the yearly total crash rate (see Figures 2-1 and 2-2), except for the LOWA camera intersection and the PIMA and PIVA control intersections, somewhat flat trends are observed.

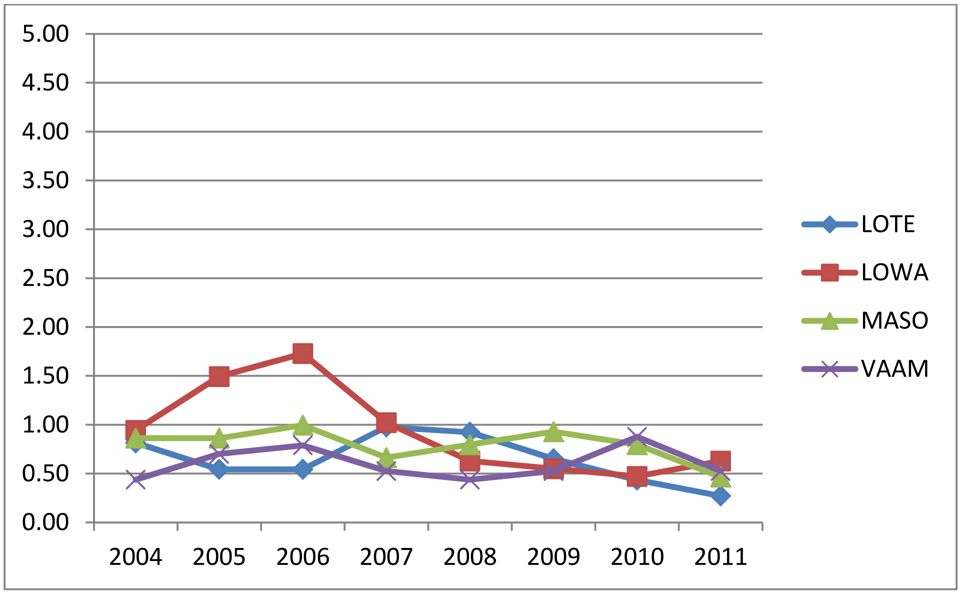


Figure 2-3. Yearly Trends of Angle Crash Rates at Camera Intersection

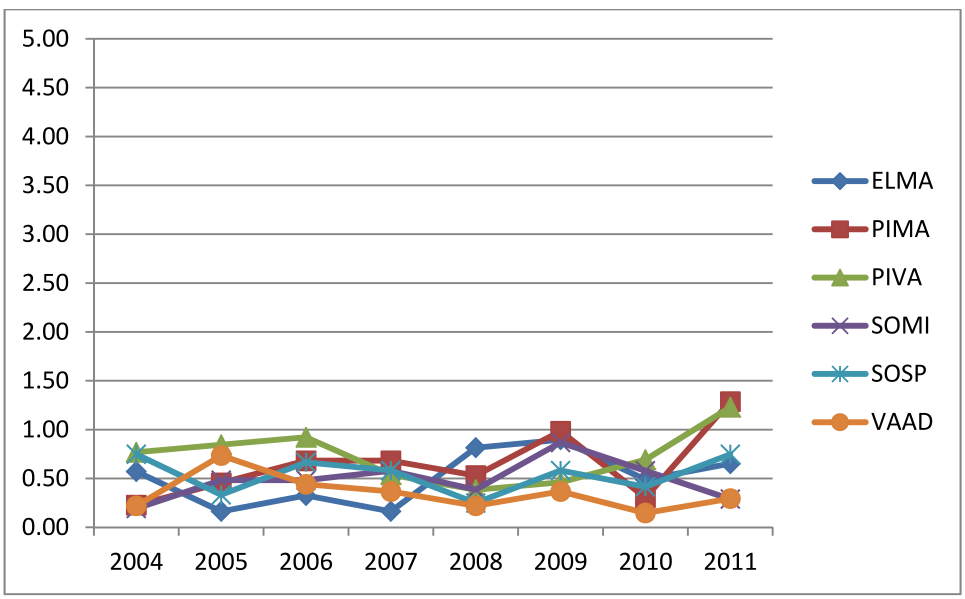


Figure 2-4. Yearly Trends of Angle Crash Rates at Control Intersection

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. On the average, the AC rates are less stable at the control intersections. It is noticed that there was a big jump at the PIMA and PIVA control intersections 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 0.45 crashes per 1 million vehicles, while it has increased from 0.46 to 0.77 at the control intersections.

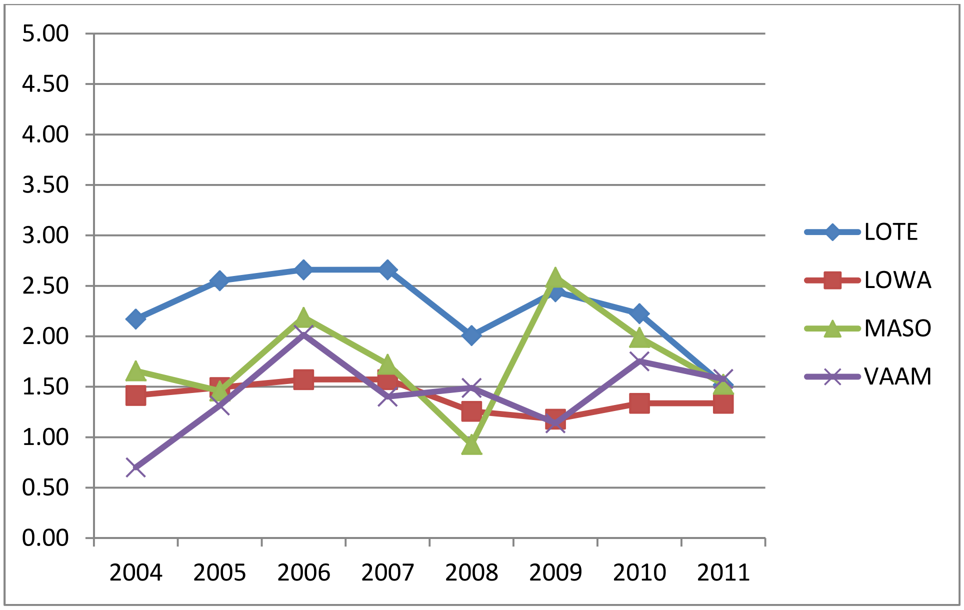


Figure 2-5. Yearly Trends of Rear-end Crash Rates at Camera Intersection

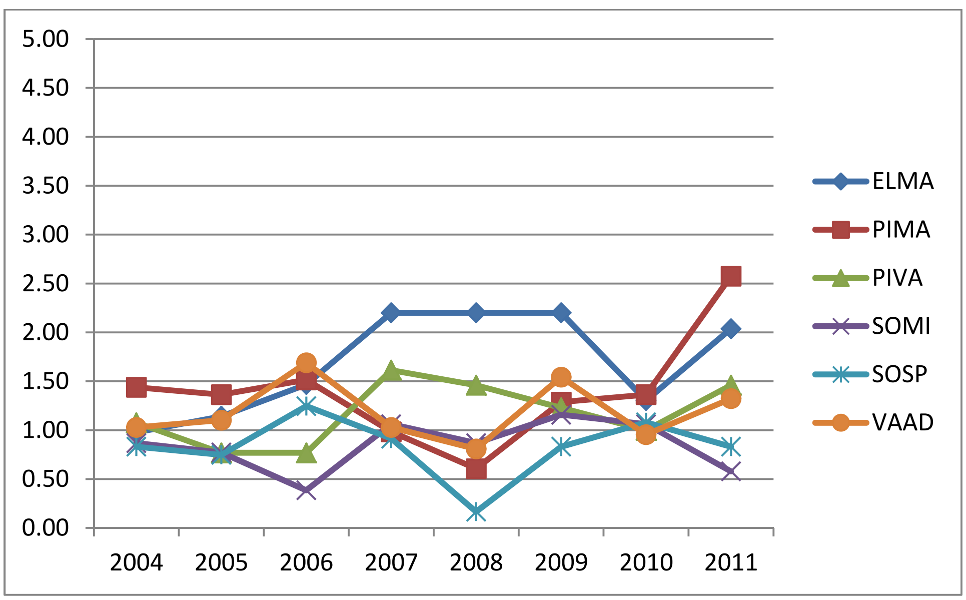


Figure 2-6. Yearly Trends of Rear-end Crash Rates at Control Intersection

Rear-end Crash (RC) Rate: The RC crashes account for 67.06% of the total crashes at the camera intersections and 63.31% at the control intersections. The camera intersections have very similar trends between the RC rates (see Figure 2-5) and the total crash rates (see Figure 2-1). 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 2-6).

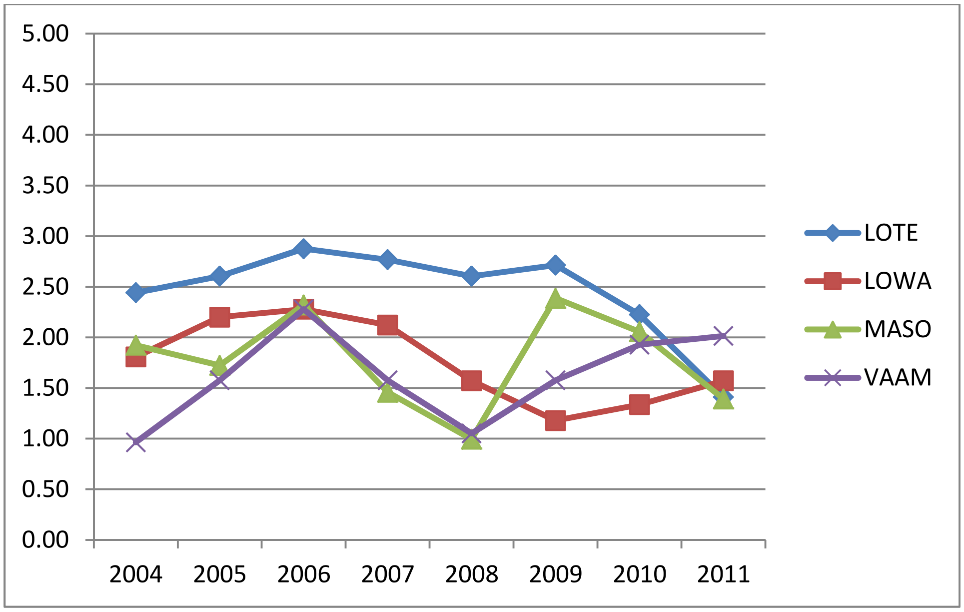


Figure 2-7. Yearly Trends of Property-Damage-Only Crash Rates at Camera Intersection

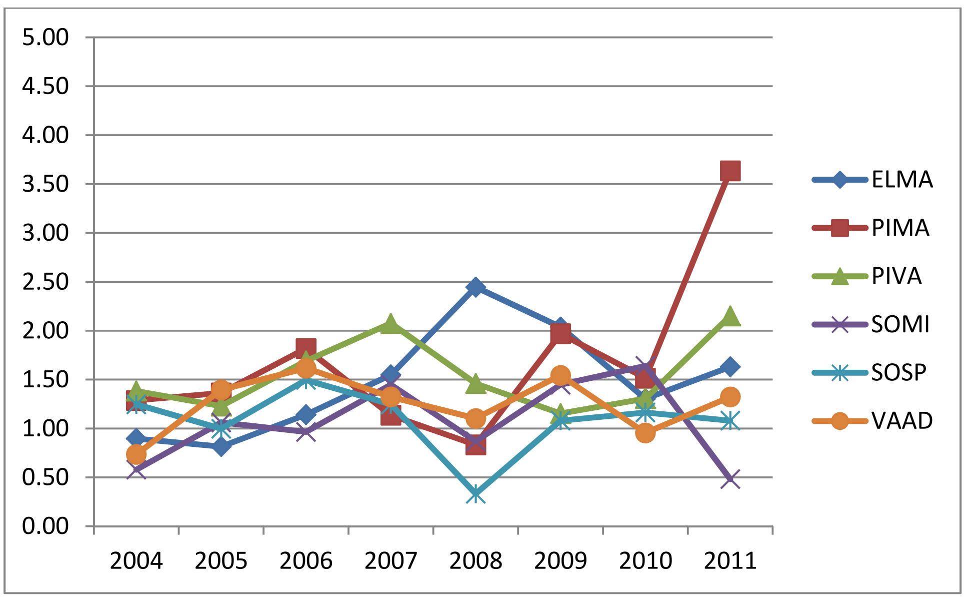


Figure 2-8. Yearly Trends of Property-Damage-Only Crash Rates at Control Intersection

Property-Damage-Only (PDO) Crash Rate: The PDO crashes account for 73.75% of the total crashes at the camera intersections and 72.51% at the control intersections. Figures 2-7 and 2-8 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 there was a substantial jump in 2011 at the PIMA control intersection.

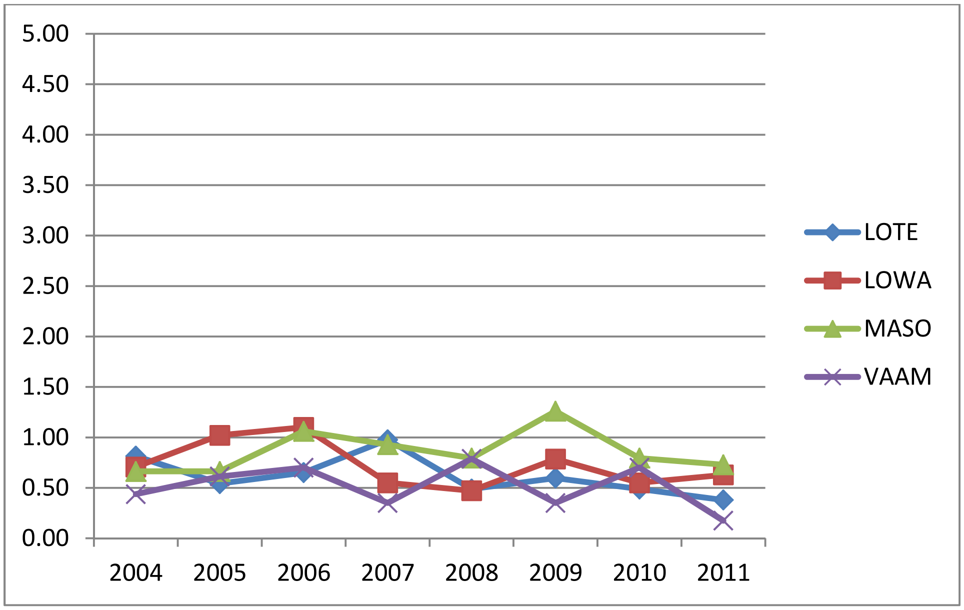


Figure 2-9. Yearly Trends of Injury Crash Rates at Camera Intersection

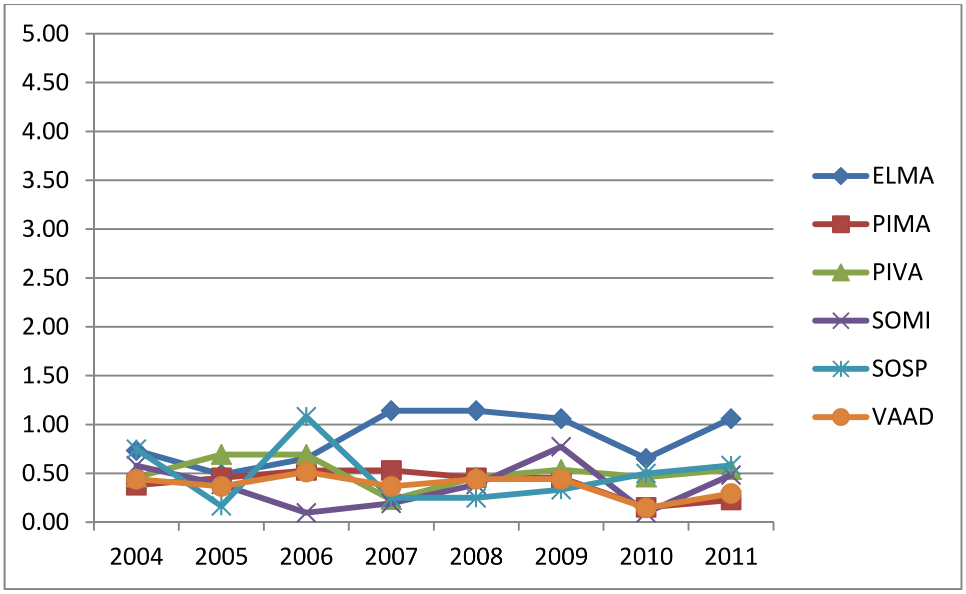


Figure 2-10. Yearly Trends of Injury Crash Rates at Control Intersection

Injury (INJ) Crash Rate: The injury crashes account for 25.70% of the total crashes at the camera intersections and 26.02% 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 2-9). Compared to all of the other control intersections, the ELMA control intersection has experienced relatively high numbers of injury crash rates from 2007 to 2009 and 2011 as well (see Figure 2-10).

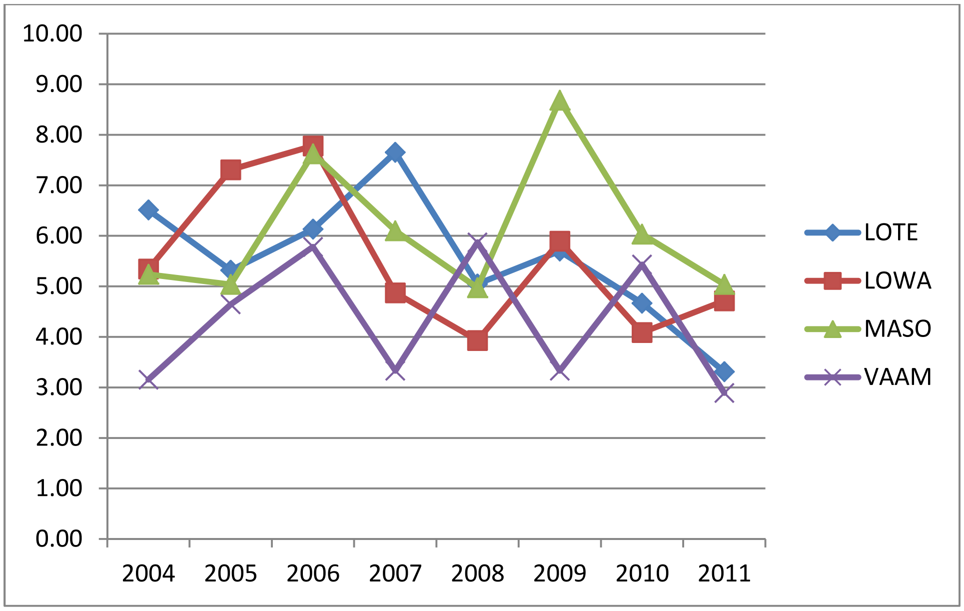


Figure 2-11. Yearly Trends of Severity Index Rates at Camera Intersection

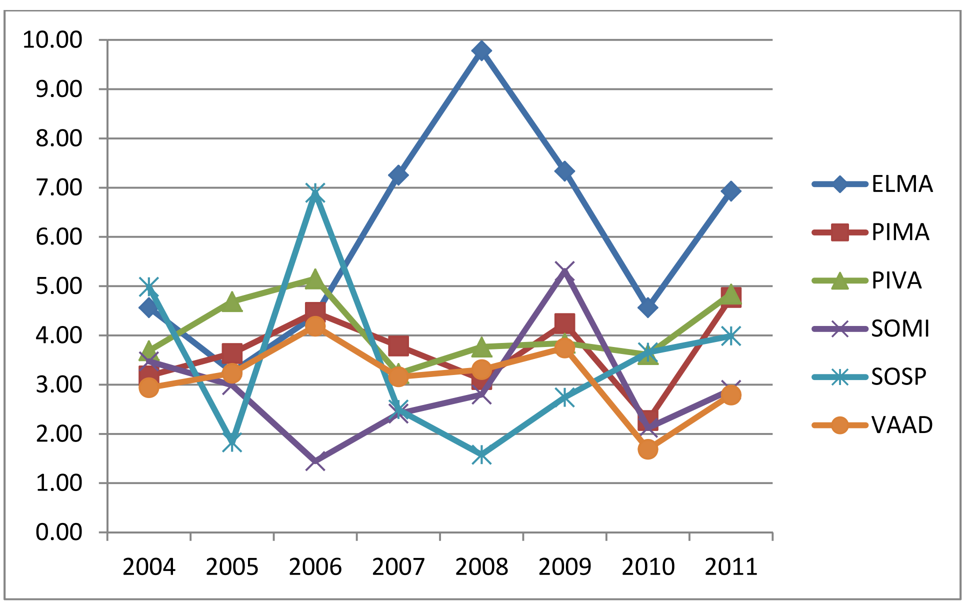


Figure 2-12. Yearly Trends of Severity Index Rates at Control Intersection

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 2-11 and 2-12, 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.

Severity Index (SI) Rate for Angle Crash: The yearly SI rates based on the AC are depicted in Figures 2-13 and 2-14. In comparison with the yearly SI rate (see Figures 2-11 and 2-12), except for the LOWA and MASO camera intersections and the ELMA and SOMI control intersections, somewhat flat trends are observed. Regarding the camera intersections, compared to the SI rates in the base period, i.e., 2004, all four camera intersections experienced a decrease in the SI rates. The LOWA camera intersection experienced an increase in the SI rates for the AC before the downward trend began in 2007. It is noticed that there was a big jump at the ELMA control intersection in 2008.

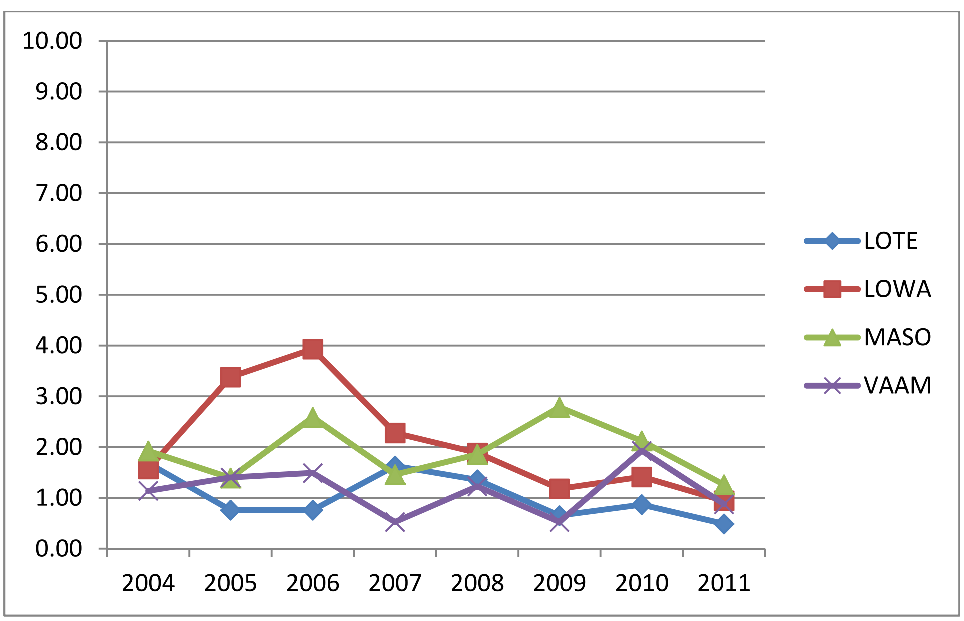


Figure 2-13. Yearly Trends of Severity Index Rates for Angle Crash at Camera Intersection

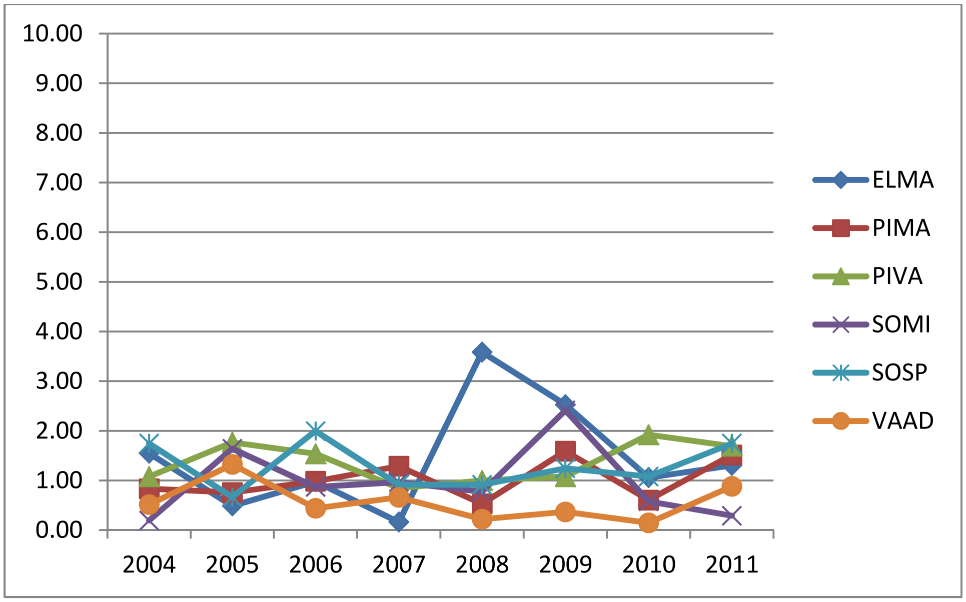


Figure 2-14. Yearly Trends of Severity Index Rates for Angle Crash at Control Intersection

Severity Index (SI) Rate for Rear-end Crash: The yearly SI rates for RC are shown in Figures 2-15 and 2-16. The SI rates are very fluctuating at all four camera intersections as well as three out of the six control intersections. There is a substantial jump at three out of the four camera intersections in 2009, which coincides with the introduction into full operation of the STOP.

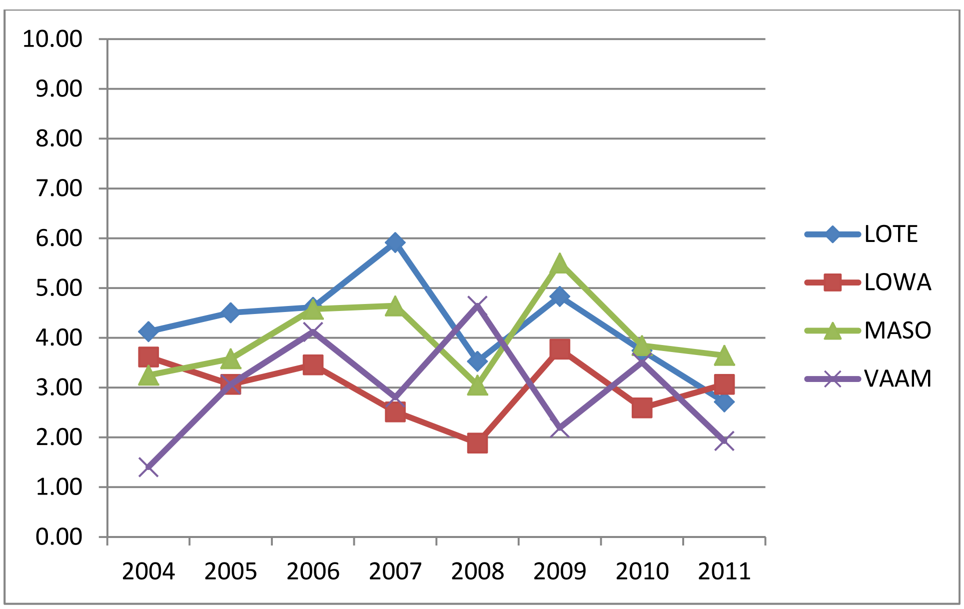


Figure 2-15. Yearly Trends of Severity Index Rates for Rear-end at Camera Intersection

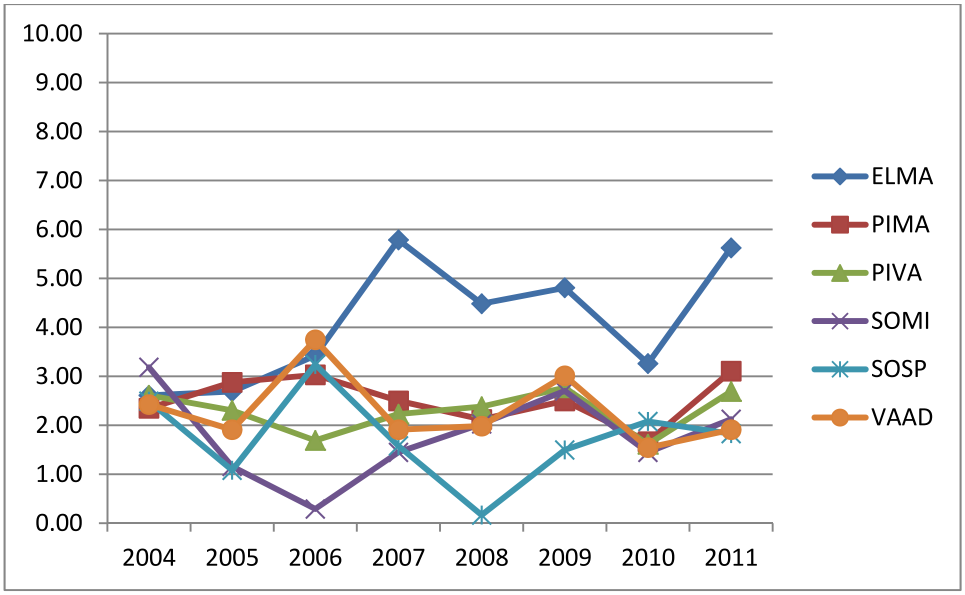


Figure 2-16. Yearly Trends of Severity Index Rates for Rear-end at Control Intersection

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

1) Since 2009, the LOTE camera intersection has experienced a reduction on the every category, i.e., the total crash rate, AC rate, RC rate, PDO crash rate, Injury crash rate, total SI rate, SI rate for the AC, and SI rate for the RC. It could be concluded that these changes could result from the STOP operation.
2) For the total crash rate, the AC rate, and the PDO crash rate, the LOWA camera intersection began the downward trend in 2006. However, there were upward trends during the recent years. These increases are still being continued.
3) The MASO intersection has experienced a big jump on the total crash rate, RC rate, PDO crash rate, injury crash rate, total SI rate, the SI rate for the AC, and the SI rate for the RC in 2009, which coincides with the introduction into full operation of the STOP. These increases were then reversed rapidly in 2010 and 2011.
4) The crash rate patterns at the VAAM intersection became very jagged over time.
5) The ELMA control intersection experienced very high total crash rates in 2008, mainly due to the increment on the PDO crash. The PIMA and PIVA control intersections had a huge spike in 2011 due to a high jump on the PDO crash rates. These may be attributed to the fact that there were lane closures due to construction at each of these intersections during that period which resulted in more congested conditions.
6) Overall, the SI patterns at the selected signalized intersections are very fluctuating. It is noticed, however, that the LOTE camera intersection had the downward trends on the SI counts during the recent years. The MASO intersection experienced a substantial jump on the SI counts in 2009 after which trended downward quickly.
7) The ELMA control intersection is the one that has recorded the highest SI count throughout the entire study period.

2.2.1.2 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 Appendix C (see Figures C1 through C16). In the graph, the blue dashed line shows a linear trend based on 3 years before the camera period only (i.e., March 2006 – February 2009), which also provides forecasting, i.e., predicting crash rates after the camera installation. The red dashed trend line was drawn based on 3 years after the camera installation (i.e., March 2009 – February 2012) and shows what has to be estimated on the crash rates with the camera operation. Hence, when compared to the blue line, it offers a method of comparison between the projected trends with and without the STOP program in place.

It is important to note that the MASO and VAAM intersections had a total of three cameras deactivated in May 2010. That is, both cameras at the MASO intersection had deactivated, and thus no longer have operable cameras at the MASO intersection since May 2010. The southbound camera at the VAAM intersection had deactivated in May 2010 as well. This should be kept in mind while going through data analysis of both the MASO and the VAAM intersections. Therefore, in conducting the analysis at the MASO and VAAM intersections, crash results are grouped into three distinct periods, namely (1) before the camera installation period, (2) the camera activation period, and (3) the camera deactivation period. The red dashed line in the graph for both MASO and VAAM intersections was drawn based on 14 months of camera activation (i.e., March 2009 – April 2010), and thus provides forecasting crash rates after the camera deactivation as well as estimating how the crash rate was with the camera operation. The green dashed line is drawn based on 22 months after the camera deactivation, which estimates how the total crash rate was in the absence of the camera operation. Therefore, when compared to the red dashed line, it offers the projected trends with and without the camera deactivation.

Total Crash Rate: The monthly trends of the total crash rate at each intersection are shown in Figures C1 and C2 (see Appendix C). The effect of the STOP operation is beneficial at the LOTE intersection, whereas the trend shows a negative impact on the LOWA intersection. The green lines observed in MASO and VAAM show real trends of the total crash rate after the camera deactivation in those intersections. The red lines during the camera deactivation period shows how the total crash rate would have been with the STOP operation. Therefore, the difference between these two linear trend lines implies the total crash rate effect of the camera deactivation. In the case shown, it seems that the effect of the STOP operation is not beneficial at both MASO and VAAM intersections. After the camera was installed at MASO, the trend has an upward spike after which the rates remain steady until the deactivation, when they trended downward quickly indicating a negative effect made by installing the camera. While there appears to be an initial benefit at the VAAM camera intersection where the trend dips and then steeply rises, the trend dips again before adopting an uptrend after the camera was deactivated. However, we cannot make a solid conclusion on the camera effect at the VAAM intersection since the VAAM had its southbound camera deactivated in May 2010. Of the control intersections, ELMA and SOMI saw the most noticeable decrease in total crashes, with the PIMA, PIVA, and SOSP intersections experiencing an increase. VAAD experienced very little change. *(Note that the blue dashed line in Figure C2-e represents how the total 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 hasn't changed, the increasing rate or the decreasing rate is somewhat altered.)*

Angle Crash (AC) Rate: The slopes of the trend lines (i.e., the rate of change in the crash number) in Figure C3 imply that there may be a positive impact of the STOP operation on the AC rates at the LOTE camera intersection. After the camera activation, LOWA began a slight upward trend, which shows a negative impact. The trends for the VAAM camera intersection also show a drop in average AC rates after the implementation of the STOP. MASO seems to have experienced some benefits from the camera installation. The MASO intersection shows an upward spike when the camera installation occurred and then trends down. This pattern is repeated upon the camera deactivation where an upward spike in violation rates is observed that then trends down. There appears to be an initial benefit of the STOP operation at the VAAM camera intersection where the trend dips and then rises. After the camera was deactivated, the VAAM intersection begins a down trend that counters the previously rising trend observed after the camera installation. For the control intersections, where there aren't any cameras installed, there were reductions on the angle crash rates at the ELMA and PIMA intersections, and the SOMI intersection's trend slope indicates a positive impact after the introduction of STOP, with the rate of angle crashes on a decreasing trend. The PIVA intersection experienced an increase in angle crash rates, as well as a slight increase in the SOSP and VAAD intersections (see Figures C3 and C4 in the Appendix C).

Rear-end Crash (RC) Rate: Figures C5 and C6 in the Appendix C present the monthly trends of the RC. According to the trend lines, the stop program may have had a positive impact on the RC rates at the LOTE camera intersection while there was a negative impact at the LOWA intersection. The trend shows a negative impact on the MASO intersection. At the MASO intersection, the down trend is interrupted by an initial upward spike on camera activation that continues the upward trend. This trend is broken by a downward spike on camera deactivation which is continued. It seems that the effect of the STOP operation is beneficial at the VAAM intersection. There appears to be an initial benefit at the VAAM intersection. The RC crashes begin to increase after the initial drop in crashes at the intersection. This up trend continues at a steeper rate on deactivation of camera which may indicate that the camera may have had a positive effect considering the trend on deactivation. The RC rates for the control intersections increase after the implementation of STOP at the PIMA, SOSP, and VAAD intersections. Reductions in the RC rates occurred at the ELMA, PIVA, and SOMI intersections.

Property-Damage-Only (PDO) Crash Rate: According to Figure C7, all four camera intersections were trending downward before camera installation, i.e. reduction in the rate of PDO crashes. Among them, a positive effect was made only on the LOTE intersection which experienced a steeper decreasing trend after the initial jump in the PDO rates as a result of camera installation. The trends for the LOWA followed an upward pattern after the camera installation. The MASO experienced an upward spike and then trended up. When the camera on MASO was deactivated, a drop in PDO crash rates was observed, which was followed by a downward trend which paralleled the previous declining trend, although the crash rates were much higher. VAAM, upon camera deactivation, experienced an initial drop in PDO crash rates which then trended up. Despite there being no cameras installed, the control intersections experienced some changes (see Figure C8). The SOSP and the VAAD intersections, which were following a downward trend, had upward spikes followed by declining trends; the ELMA, which was trending downward, experienced a change in trend to an upward trend right and the PIMA, which was also trending down, experienced a steeper upward incline after the STOP program was started in camera intersections.

Injury (INJ) Crash Rate: All four camera intersections were trending downward (see Figure C9). The LOTE seems unaffected by the cameras installed. After the camera installation, the LOWA intersections experienced upward spikes in the INJ crash rates then, continued to trend downward with its pattern parallel to the previous camera trend. This implies a negative effect from the camera installation. After the camera installation, the MASO intersection experienced upward spikes in the INJ crash rates, but then continued to trend downward with a steeper rate. When the camera was deactivated, an upward spike in INJ crash rates was observed followed by a downward trend. The camera had a negative impact which followed through after deactivation at MASO. The VAAM experienced a big drop in trend upon camera activation followed by a downward trend which spiked up upon camera deactivation followed by a downward trend which indicated that the camera had a positive impact at this intersection. For the control intersections, the PIMA had a slight downward spike followed by downward trend. All of the other control intersections experienced some change in trend direction of some form, although no spikes were seen (see Figure C10).

Severity Index (SI) Rate: Figures C11 and C12 show the monthly trends of the SI rate. The MASO and the LOWA exhibited negative effects which were followed by declining trends in the SI rates. The LOTE showed positive effects on implementation of the STOP operation. The trend in severity was sloping downward for all four camera intersections before the STOP operation was introduced. After cameras were installed, the LOTE intersection had a sudden small drop in the SI rates severity followed by a continued downward trend. This positive effect can be attributed to the STOP operation. The LOWA camera intersection experienced an upward hike in the SI rates which was followed by a slow decline in trend at the implementation of the STOP operation. The MASO experienced an upward spike followed by a slight up trend which stopped in favor of a downward trend when the camera was deactivated. Of the four camera intersections, little effect was seen at the VAAM intersection during the camera operation. After deactivation, an upward spike was observed that then trended down at a faster rate. Three out of the six control intersections, i.e., ELMA SOMI and VAAD experienced slight downward trends, which may be linked to implementation of the STOP program at camera intersections. The PIMA showed a slight upward jump above the continuing trend followed by continued steady decline very close to the trend made before STOP operation. The PIVA and SOSP exhibit changes in trend with no spikes involved. *(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 C11 and C12 use a scale of 0 to 25, unlike other figures which use much smaller scales.)*

Severity Index (SI) Rate for Angle Crash: Figures C13 and C14 show the monthly SI rates for the angel crashes. Among the camera intersections, the MASO intersection shows the most noticeable negative effects in the trends, a possible result of the STOP program. The SI trends for the other camera intersections show little deviation from the data before the camera installation.

After the MASO and VAAM cameras were deactivated, the trend followed a down ward pattern at MASO while at VAAM there was an upward spike followed by a steep downward trend, which implies negative effects of the STOP operation. At the control intersections, the ELMA, PIMA, and SOMI show trends with an initial increase in the SI rate after the camera installation, although a decrease as time passes. The PIVA's SI trend shows a negative impact after the camera installation.

Severity Index (SI) Rate for Rear-end Crash: Figures C15 and C16 show the monthly trends for the rear-end crash rates. The LOTE camera intersection follows an upward trend which spikes downward and changes to a declining trend after the camera installation. This shows a positive effect of the STOP operation on this intersection. The LOWA, the MASO and the VAAM intersections exhibit downward trends before the STOP operation. Upon camera installation, VAAM seems to follow the trend closely, even after the camera deactivation, so we can argue that no effect was felt. The MASO and the LOWA show upward spikes that remain at steady rates over time. After deactivation, the MASO SI rate for rear crashes trends downward indicating a negative impact of the STOP operation at MASO intersection. The LOWA intersection can be said to have experienced a negative impact as well. Among the six control intersections, the ELMA, the PIMA, the SOSP, and the VAAD seem to follow the same trend before and after the camera installation with only minor deviations. The SOMI and the PIVA experience small downward spikes. Then, the SOMI shows a slight declining trend while the PIVA follows a parallel trend as the slope set before.

From the trend analysis, the following findings are drawn. Note that the trend analysis was based on the 6 year data, i.e., a combination of 3 years before and after camera installation. The data before the camera installation is used for forecasting the crash rates with the absence of the camera operation, while the data after the camera installation is used for estimating the crash rates with the camera operation. It should be also noted that the MASO intersection had both its cameras deactivated in May 2010 and the VAAM southbound camera was also deactivated at the same time. Thus, for the MASO and VAAM intersections, a trend analysis following camera deactivation is made as well. For the most part, trends change considerably upon deactivation:

1) The trend analysis shows that the LOTE camera intersection experienced an overall positive impact as a result of the STOP operation. The introduction of the STOP at the LOTE intersection reduces the total crash rates, mainly due to the reduction on the RC rates and the PDO crash rates. As a result, the LOTE intersection shows reductions on the total SI rates and the SI rates for the AC.
2) The LOWA camera intersection, however, experienced an overall negative impact as a result of the STOP operation. For almost every category of the crash and the severity index, the rates were increased at the LOWA intersection.
3) The MASO intersection experienced an overall negative impact as a result of the STOP operation. For almost every category of the crash and the severity index, the rates were increased at the MASO intersections. However, we also note that the MASO intersection experienced a positive impact in AC rates as a result of camera deactivation.
4) It seems that the PDO crash rates were increased at the VAAM intersection. But it is also observed that the VAAM intersection experienced reductions on the RC rates, which results in reductions on the SI for RC rates. However, we cannot make solid conclusions

on the camera effect at the VAAM intersection. This is because the northbound camera is still operable while the southbound camera at the VAAM was deactivated in May 2010 and is not operable anymore.

5) Even though there weren't any STOP operations at the control intersections, the monthly crash rate plots show reductions in the crash rates at certain control intersections for certain crash types.
6) The notable observation made was that every category of crash and severity index represented decreased in the ELMA and the SOMI control intersections.
7) For the PIVA control intersection, there were additions on the SI count for the AC, whereas reductions on the SI count for the RC.
8) The PIMA, the SOSP, and VAAD control intersections experienced increases on the SI counts for the RC mainly due to increases on the RC rates and the PDO rates.

2.2.2 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 2-1 through 2-8. 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, '+' sign implies that a positive impact is drawn, whereas '–' a negative impact. Also, 'NO' denotes that there is not enough evidence to say that there is a significant difference. The analysis period is based on 3 years before and 3 years 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.

Table 2-1. Statistical Analysis on Total Crash Rate

		Variance Test		Mean Test	
		P Value	Decision	P Value	Decision
Camera Intersections	LOTE	0	YES	0	YES +
	LOWA	0	YES	0	YES -
	MASO	0.27	NO	0	YES -
	VAAM	0	YES	0	YES -
	Average	0.615	NO	0	YES -
Non Camera Intersections	ELMA	0.269	NO	0	YES +
	PIMA	0	YES	0	YES -
	PIVA	0	YES	0.038	YES -
	SOMI	0	YES	0	YES +
	SOSP	0	YES	0	YES -
	VAAD	0.601	NO	0	YES -
	Average	0	YES	0	YES -

Total Crash Rate: The results from the t-test (also referred to as mean test) show that all the camera intersections show statistical significance in total crash rates after the STOP operation (see Table 2-1). There was an overall increase in crash rates with contributions from three of the four camera intersections (i.e., LOWA, MASO, and VAAM) showing significant increase (i.e., negative impact) while the LOTE camera intersection showed a significant decrease (i.e., positive impact). These results were observed from the trend analysis in the previous section. The same goes for all control intersections which exhibit significant changes in crash rates overall given the average increase. Two of the four control intersections exhibited decreases, while the other intersections showed increases.

Table 2-2. Statistical Analysis on Angle Crash Rate

		Variance Test		Mean Test	
		P Value	Decision	P Value	Decision
Camera Intersections	LOTE	0	YES	0.006	YES +
	LOWA	0	YES	0	YES -
	MASO	0	YES	0	YES -
	VAAM	0.525	NO	0	YES +
	Average	0.018	YES	0	YES -
Non Camera Intersections	ELMA	0.481	NO	0	YES +
	PIMA	0.583	NO	0	YES +
	PIVA	0	YES	0	YES -
	SOMI	0.251	NO	0	YES +
	SOSP	0.163	NO	0	YES -
	VAAD	0	YES	0	YES +
	Average	0.002	YES	0	YES -

Table 2-3. Statistical Analysis on Rear-end Crash Rate

		Variance Test		Mean Test	
		P Value	Decision	P Value	Decision
Camera Intersections	LOTE	0	YES	0	YES +
	LOWA	0	YES	0	YES -
	MASO	0.099	NO	0	YES -
	VAAM	0	YES	0	YES +
	Average	0.117	NO	0	YES -
Non Camera Intersections	ELMA	0	YES	0	YES +
	PIMA	0	YES	0	YES -
	PIVA	0.002	YES	0	YES +
	SOMI	0	YES	0	YES +
	SOSP	0	YES	0	YES -
	VAAD	0	YES	0	YES -
	Average	0	YES	0	YES -

Angle Crash (AC) Rate: Table 2-2 presents the results of the statistical test that estimates the effects of the STOP operation on the rate of the AC. The results from the t-test show that the angle crash rates exhibited significant changes one way or the other at the all camera intersections (p-values 0.006 and 0s) after the STOP operation. Since March 2009, two camera intersections (i.e., LOWA and MASO) show increase in the AC rates, while the LOTE and the VAAM show decreases, and these results contribute to an average increase in the AC rates at the camera intersections. All control intersections show significant changes as well according to the mean test, two showed increase while the other four showed decrease. There was average increase depicted by the mean test for both camera and control intersections.

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 2-3. The results at all camera intersections found significant effects associated with the rear-end crash rates at p-values of 0 for all. The LOWA and the MASO camera intersections experienced increases (i.e., negative impacts) while the LOTE and the VAAM showed decreases (i.e., positive impacts). The average result was a significant increase. The same result was obtained at the six control intersections which experienced statistically significant changes, i.e. with p-values of 0. Decreases were observed at the ELMA, the PIVA and the SOMI, while the PIMA, the SOSP, and the VAAD intersection showed increases. The average result exhibited is an increase in crash rate at control intersection.

Table 2-4. Statistical Analysis on Property-Damage-Only Crash Rate

		Variance Test		Mean Test	
		P Value	Decision	P Value	Decision
Camera Intersections	LOTE	0	YES	0	YES +
	LOWA	0	YES	0	YES -
	MASO	0.115	NO	0	YES -
	VAAM	0	YES	0	YES -
	Average	0.776	NO	0	YES -
Non Camera Intersections	ELMA	0.174	NO	0	YES +
	PIMA	0	YES	0	YES -
	PIVA	0	YES	0	YES +
	SOMI	0	YES	0.028	YES -
	SOSP	0	YES	0	YES -
	VAAD	0	YES	0	YES -
	Average	0	YES	0	YES -

Property-Damage-Only (PDO) Crash Rate: Results are presented in Table 2-4. According to the table, all camera intersections exhibit significant changes in the PDO crash rates. Three of the four intersections experienced increases (i.e., LOWA, MASO, and VAAM) while the other one experienced a decrease (i.e., LOTE). The average result is an increase in the PDO crash rate at the camera intersections. The same case applies to the six control intersections which experienced significant changes, i.e., increases at four intersections except at the ELMA and the

PIVA intersections which experienced decreases, and as a result increase in control intersection crash rates.

Injury (INJ) Crash Rate: Table 2-5 presents the results of the mean test on the injury crash rate, which suggest that two of the four intersections experienced negative impacts (i.e., LOWA and MASO) while the other two experienced positive impact (i.e., LOTE and VAAM). The same case applies to the six control intersections which experienced significant changes, i.e., positive impacts at four intersections except at the PIVA and the SOSP intersections which experienced negative impacts.

Table 2-5. Statistical Analysis on Injury Rate

		Variance Test		Mean Test	
		P Value	Decision	P Value	Decision
Camera Intersections	LOTE	0.008	YES	0	YES +
	LOWA	0.001	YES	0	YES -
	MASO	0.628	NO	0	YES -
	VAAM	0.147	NO	0.02	YES +
	Average	0.57	NO	0	YES -
Non Camera Intersections	ELMA	0	YES	0	YES +
	PIMA	0	YES	0	YES +
	PIVA	0	YES	0	YES -
	SOMI	0	YES	0	YES +
	SOSP	0	YES	0	YES -
	VAAD	0.09	NO	0	YES +
	Average	0	YES	0	YES +

Table 2-6. Statistical Analysis on Severity Index

		Variance Test		Mean Test	
		P Value	Decision	P Value	Decision
Camera Intersections	LOTE	0	YES	0	YES +
	LOWA	0	YES	0	YES -
	MASO	0.477	NO	0	YES -
	VAAM	0.603	NO	0	YES +
	Average	0.625	NO	0	YES -
Non Camera Intersections	ELMA	0	YES	0	YES +
	PIMA	0	YES	0	YES -
	PIVA	0	YES	0	YES -
	SOMI	0	YES	0	YES +
	SOSP	0	YES	0	YES -
	VAAD	0	YES	0	YES +
	Average	0.004	YES	0	YES +

Severity Index (SI): The results of the t-test for estimating the effects of the STOP operation on the SI rates are summarized in Table 2-6. The results at all camera intersections found significant effects associated with the SI rates at p-values of 0 for all. Two of the four camera intersections experienced positive impacts (i.e., LOWA and MASO) while the other two showed negative impacts (i.e., LOTE and VAAM). For the control intersections, decreases were observed at the ELMA, the SOMI and the VAAD, while the PIMA, the PIVA, and the SOSP intersection showed increases.

Table 2-7. Statistical Analysis on Severity Index for Angle Crash

		Variance Test		Mean Test	
		P Value	Decision	P Value	Decision
Camera Intersections	LOTE	0	YES	0.01	YES +
	LOWA	0	YES	0	YES -
	MASO	0	YES	0	YES -
	VAAM	0	YES	0	YES +
	Average	0.443	NO	0	YES -
Non Camera Intersections	ELMA	0.116	NO	0	YES +
	PIMA	0	YES	0.143	No Changes
	PIVA	0.165	NO	0	YES -
	SOMI	0.001	YES	0	YES +
	SOSP	0	YES	0	YES -
	VAAD	0.014	YES	0	YES -
	Average	0.001	YES	0	YES -

Table 2-8. Statistical Analysis on Severity Index for Rear-end Crash

		Variance Test		Mean Test	
		P Value	Decision	P Value	Decision
Camera Intersections	LOTE	0	YES	0	YES +
	LOWA	0	YES	0	YES -
	MASO	0.465	NO	0.007	YES -
	VAAM	0.039	YES	0	YES +
	Average	0.009	YES	0	YES -
Non Camera Intersections	ELMA	0	YES	0	YES +
	PIMA	0	YES	0	YES -
	PIVA	0.002	YES	0	YES +
	SOMI	0	YES	0	YES +
	SOSP	0	YES	0	YES -
	VAAD	0.523	NO	0	YES -
	Average	0.058	NO	0	YES -

Severity Index (SI) Rate for Angle Crash: Table 2-7 presents the results of the statistical test that estimates the effects of the STOP operation on the SI counts for the angle crashes. The results show that the angle crash rates exhibited significant changes at the all camera intersections (p-values 0.01and 0s) after the STOP operation. Two camera intersections (i.e., LOWA and MASO) show increase (i.e., negative impact) in the AC rates, while the LOTE and the VAAM show decreases (i.e., positive impact). All control intersections show significant changes as well according to the statistical test, three showed increase while the other two showed decrease and one of them no changes.

Severity Index (SI) Rate for Rear-end Crash: The results of the t-test for estimating the effects of the STOP operation on the SI rates for the rear-end crashes are summarized in Table 2-8. The results are the same as those from the RC rates for all ten intersections. That is, the LOWA and the MASO camera intersections experienced negative impacts while the LOTE and the VAAM showed positive impacts. For the control intersections, decreases were observed at the ELMA, the PIVA and the SOMI, while the PIMA, the SOSP, and the VAAD intersection showed increases on the SI rates for the rear-end crashes.

From the statistical analysis of the crash data, the following conclusions are drawn:

1) The statistical analysis shows that the LOTE camera intersection in the City of Las Cruces experienced an overall positive impact as a result of the STOP operation. For the LOTE camera intersection, there were significant reductions in every category of the crash and the severity index.
2) The LOWA camera intersection, however, experienced significant increases in every category of crashes after the launch of the STOP program.
3) Both cameras at the MASO intersection had deactivated, and thus no longer have operable cameras at the MASO since May 2010. From the trend analysis, it is observed that the MASO intersection experienced an overall negative impact as a result of the STOP operation. These findings are supported by the statistical analysis.
4) The statistical tests show significant changes in the crash rates at the VAAM intersection for certain crash types after the launch of the STOP program. However, we cannot make a solid conclusion on the camera effect at the VAAM intersection since the VAAM had its southbound camera deactivated in May 2010.
5) Even though there weren’t any STOP operations, the statistical tests show significant reductions in the crash rates at certain control intersections for certain crash types.
6) The ELMA and the SOMI control intersections experienced statistically significant decreases in the most crash categories, while the SOSP control intersection experienced statistically significant increases in the all crash categories. The remaining control intersections varied greatly in increases and decreases across crash categories.

3. RED-LIGHT VIOLATION DATA ANALYSIS

The red-light violation (RLV) data was obtained from the City of Las Cruces Police Department. The provided data covers eight camera sites at four intersections. They are Lohman and Telshor Eastbound (LOTE-EB), Lohman and Telshor Westbound (LOTE-WB), Lohman and Walnut Eastbound (LOWA-EB), Lohman and Walnut Westbound (LOWA-WB), Main and Solano Westbound (MASO-WB), Main and Solano Eastbound (MASO-EB), Valley and Avenida de Mesilla Southbound (VAAM-SB), and Valley and Avenida de Mesilla Northbound (VAAM-NB). The given study periods are varied by each camera site, i.e., March 2009 – February 2012 (LOWA-EB and LOWA-WB), April 2009 – February 2012 (VAAM-NB), May 2009 – February 2012 (LOTE-EB), May 2010 – February 2012 (LOTE-WB), March 2009 – October 2010 (MASO-WB and MASO-EB), and April 2009 – October 2010 (VAAM-SB). Note that even though the three cameras (i.e., MASO-WB, MASO-EB and VAAM-SB) were turned off in May 2010, the police department was still able to obtain the red-light violation data from them up until October 2010. However, the actual number of the violations during this period was unknown since the pictures taken by the camera during the deactivation period were not reviewed by the Department of Motor Vehicles (DMV) officers. Therefore, we use an estimate of the violation counts based on an average violation rate for the remaining cameras during the deactivation period. On average 73% of the total number of pictures taken by the camera lead to violations. Note that there is a grace period of $1/10^{th}$ of a second for all red-light violations. The record log of the violation data includes the RLV count based on different times of the day, the days of the week, elapsed time since the red-light signal, and different lanes of the intersection. However, there aren't any connections between each category of the record log and only individual counts are available. Moreover, the database does not include information about the red-light violators. We should note that all of these factors limit our study considerably.

3.1 Methodology

To study the red-light violations and related factors, two levels of data analysis were conducted – one is using trend analysis and the other is using statistical analysis.

3.1.1 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 study, 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.

3.1.2 Statistical Analysis

Statistical analyses are conducted to prove if there is a reliable significant difference in red-light violation trends after the launch of the STOP.

3.1.2.1 Mann-Whitney test

Mann-Whitney test is statistical technic to compare two data groups. The Mann-Whitney test, sometimes also called the Wilcoxon-Mann-Whitney test or the Wilcoxon Rank Sum test, is often interpreted to test whether the median of the distributions are the same. Similar to the Kruskal-Wallis Test, the Mann-Whitney uses non-parametric technics. After ranking the observations, summation of ranking for each group is calculated based on following:

$$U_1 = R_1 - \frac{n_1(n_1+1)}{2}$$

$$U_2 = R_2 - \frac{n_2(n_2+1)}{2}$$

where n_i is a sample size for group *i* and R_i is sum of ranks in group *i*.
Note that the minimum value of U_i will be used to find the P-value on significance table.

3.1.2.2 Kruskal-Wallis test

Kruskal-Wallis test is an extension of the Mann-Whitney test for comparing more than two non-parametric data groups. This test is appropriate when the data does not fulfill the assumptions of ANOVA test such as normality and equal variance. The Kruskal-Wallis test is a one way analysis of variance by ranking the data. Note that the ANOVA is a parametric one way analysis of variance for more than two groups. The statistic value will be calculated from the following formula:

$$K = (N-1)\frac{\sum_{i=1}^{g} n_i(\bar{r}_{i.} - \bar{r})^2}{\sum_{i=1}^{g}\sum_{j=1}^{n_i}(r_{ij} - \bar{r})^2}$$

where n_i is the number of observations in group i, r_{ij} is the rank (among all observations) of observation *j* from group *i*, *N* is the total number of observations across all groups,

$\bar{r}_{i\cdot} = \frac{\sum_{j=1}^{n_i} r_{ij}}{n_i}$, and $\bar{r} = \frac{(N+1)}{2}$ is the average of all the r_{ij}

$$\Pr(\chi^2_{g-1} \geq K)$$

The P-value is calculated based on a probability:

3.2 Results and Discussion

3.2.1 Trend Analysis

3.2.1.1 Monthly Red-light Violation Trends

There were 38,169 red-light violations (RLV) recorded at the signalized intersections during the study period (i.e., March 2009 – February 2012). Table 3-1 summarizes the number of RLV at each intersection with the recorded periods, and the monthly average values of the violations are shown in Figure 3-1. For example, the LOTE-EB recorded 9,092 violations for a 34 month period with the monthly average value of 267.4 violations. During the study period, the VAAM-SB experienced the highest violation of 386.9 per month, whereas the LOTE-WB shows the lowest number of 66.5.

Table 3-1. Total number of the red-light violations and the recorded periods

	LOTE-EB	LOTE-WB	LOWA-EB	LOWA-WB	MASO-WB	MASO-EB	VAAM-SB	VAAM-NB
# of RLV	9092	1462	3314	4233	2430	3128	7352	7158
# of Month	34	22	36	36	20	20	19	35

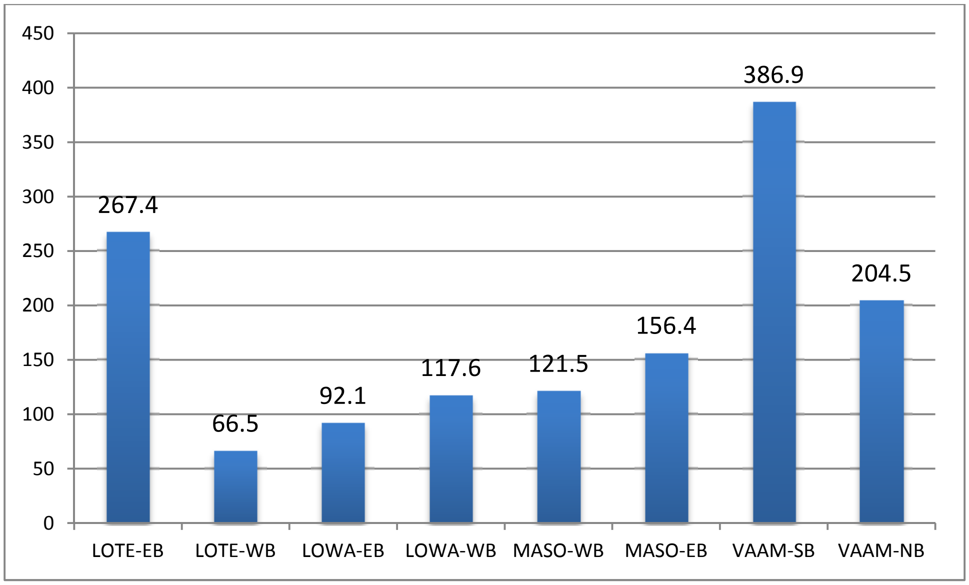


Figure 3-1. Monthly average number of the red-light violations

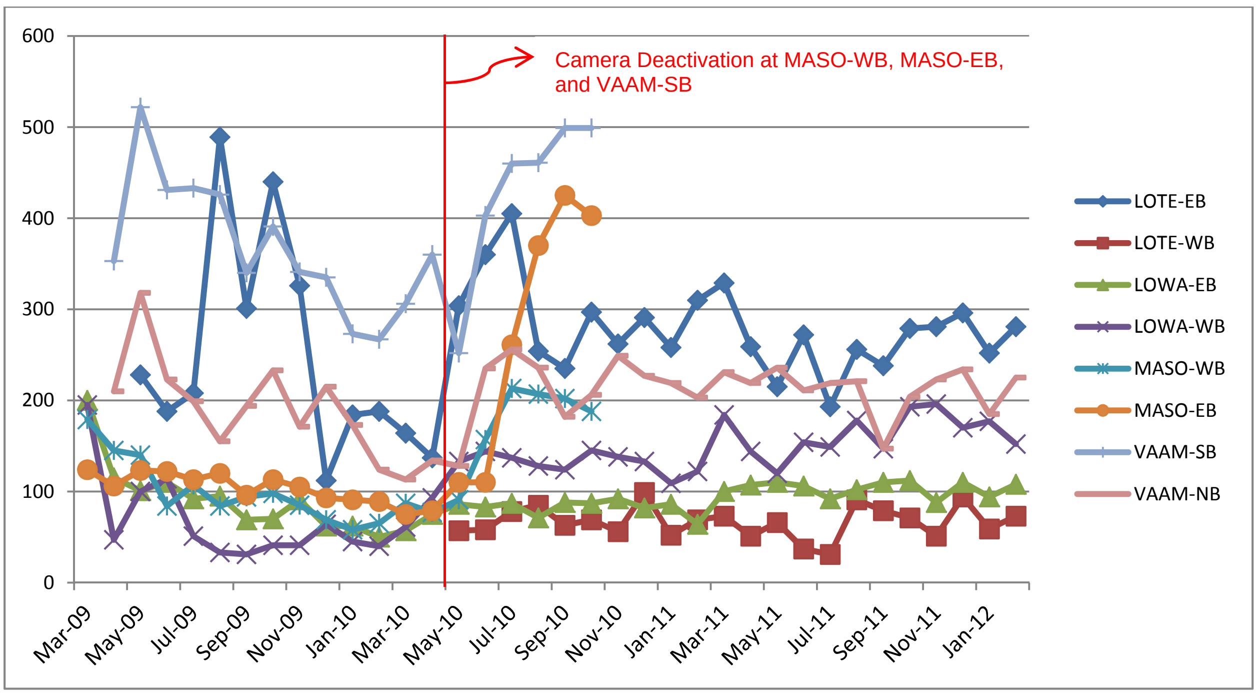


Figure 3-2. Monthly red-light violation trends

We review the monthly trends of the RLV at the signalized intersections, which are illustrated in Figure 3-2, where the monthly violation numbers are recorded over time. We also include a set of graphs in Appendix D to show clearer behaviors at each intersection (see Figures D1 through D8). In the graphs, the blue dashed line shows a linear trend based on the camera activation period only, which also provides forecasting, i.e., predicting violation rates after the camera deactivation. The red dashed trend line was drawn based on 6 months of camera deactivation period and shows what has to be estimated on the violation rates without the camera operation, and thus, when compared to the blue dashed line, offers a method of comparison between the projected trends with and without the STOP operation in place. That is, the difference between these two linear trend lines implies the effect of the STOP operation on the monthly red-light violation trends.

Lohman and Telshor – Eastbound (LOTE-EB): The graph shows the RLV counts since May 2009. The pattern at LOTE-EB intersection is very fluctuating, especially until August 2010. The highest violation of 489 was recorded in August 2009 and the lowest count was 122 in December 2009. It is also noticed that there was a considerable drop in the number of violations between December 2009 and April 2010. (see Figure D1 as well). Overall, however, there weren't any upward or downward trends at the LOTE-EB. On the average, 267 RLV were recorded per month at LOTE-EB.

Lohman and Telshor – Westbound (LOTE-WB): Compared to the LOTE-EB, there were a lot less RLV at the LOTE-WB. The highest violation of 99 occurred in December 2009. It is very interesting to note that during this period, LOTE-EB recorded the lowest RLV. At the LOTE-WB, the lowest violation of 31 occurred in July 2011. Overall, the LOTE-WB provides a nearly stable RLV (see Figure D2). Note that the RLV counts at LOTE-WB are available only for a limited time period (i.e., May 2010 – February 2012). On the average, 66 RLV were recorded per month at LOTE-WB.

Lohman and Walnut – Eastbound (LOWA-EB): The RLV counts were recorded since March 2009 until February 2012. The highest violation of 200 occurred in March 2009, which coincides with the introduction into the STOP operation. The lowest count of 50 was in February 2010. Similar to LOTE1 and LOTE2, however, there weren't any upward or downward trends on the RLV over time (see Figure D3).

Lohman and Walnut – Westbound (LOWA-WB): Similar to LOWA-EB, the RLV counts at LOWA-WB were recorded during the entire study period, i.e., (March 2009 – February 2012). Even though the LOWA-WB started with its second highest violation count of 195, the RLV counts considerably drop for almost a year. As a result, the RLV in the first year are considerably lower than those during the following years. Overall, the LOWA-WB provides an upward trend on the RLV and is the only one showing the upward trend among the eight camera sites (see Figure D4).

Main and Solano – Westbound (MASO-WB): Both of the cameras in the Main and Solano intersections were deactivated on May 2010. However, the camera system was able to record the red-light violation data until October 2010. Therefore, 20 month period of RLV is available at MASO-WB (i.e., March 2009 – October 2010). After the camera deactivation, the MASO-WB experienced upward spikes in the monthly average RLV then continued to trend upward. This presents the conclusion of a negative effect from camera deactivation (see Figure D5).

Main and Solano – Eastbound (MASO-EB): The RLV counts at MASO-EB were recorded from March 2009 through October 2010. After the camera deactivation, the MASO-EB experienced a very steep upward trend in the monthly average RLV. It can be concluded that these changes could result from the absence of the STOP operation (see Figure D6).

Valley and Avenida de Mesilla – Southbound (VAAM-SB): The southbound camera at VAAM was deactivated on May 2010. Similar to MASO intersection, camera system was able to record data until October 2010 and 19 month period of data (i.e., April 2009 – October 2010) is available at this site. The VAAM-SB provides the highest RLV counts among the eight camera sites, and the monthly average of 387 RLV was recorded. Since the camera deactivation, the VAAM-SB begins to increase considerably in the monthly average RLV after the initial drop. This also implies a negative effect from camera deactivation (see Figure D7).

Valley and Avenida de Mesilla – Northbound (VAAM-NB): The RLV counts at VAAM-NB were recorded from April 2009 through February 2012. There was a big jump on the RLV on May 2009 and small drops occurred in early 2010 and again September 2011. Overall, a slight upward trend is observed at this site (see Figure D8).

3.2.1.2 Different Times of the Day

Next, we review the hourly trends of the monthly average RLV (see Figure 3-3). A majority of RLV occurred during the daytime with two peak hours (i.e., 12pm and 4pm). The hourly trends of the RLV at each camera intersections are also illustrated in Figure 3-4, where the monthly average RLV counts are recorded based on different times of the day. In Appendix E, the hourly behaviors for each individual intersection are depicted, as well (see Figures E1 through E8). It is very clear that the two (i.e., LOTE-EB and VAAM-SB) camera sites have experienced a lot more RLV than other sites (see Figure 3-4).

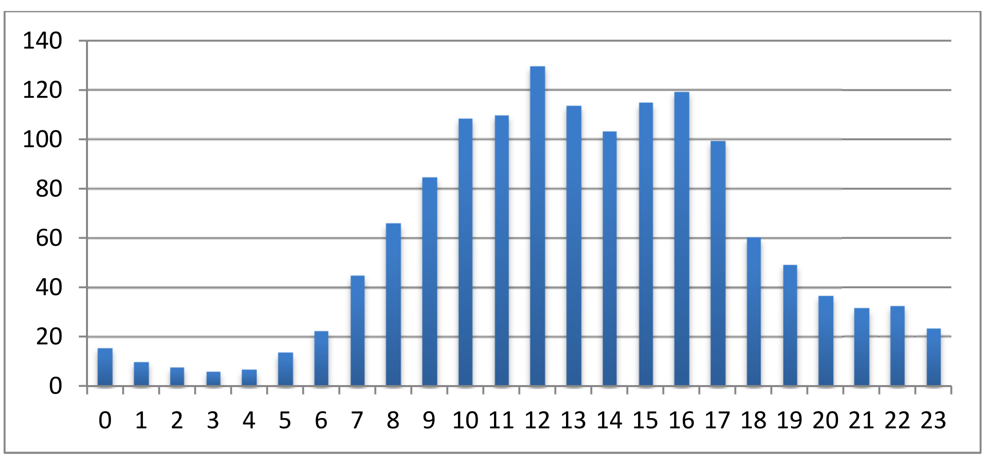


Figure 3-3. Red-light violations by different times of the day (all camera sites)

Lohman and Telshor – Eastbound (LOTE-EB): About 75% of violations at LOTE-EB occurred from 10am until 6pm and the highest RLV (12%) was recorded at noon. The next peak hours are 1pm, 3pm, and 4pm (see Figure E1).

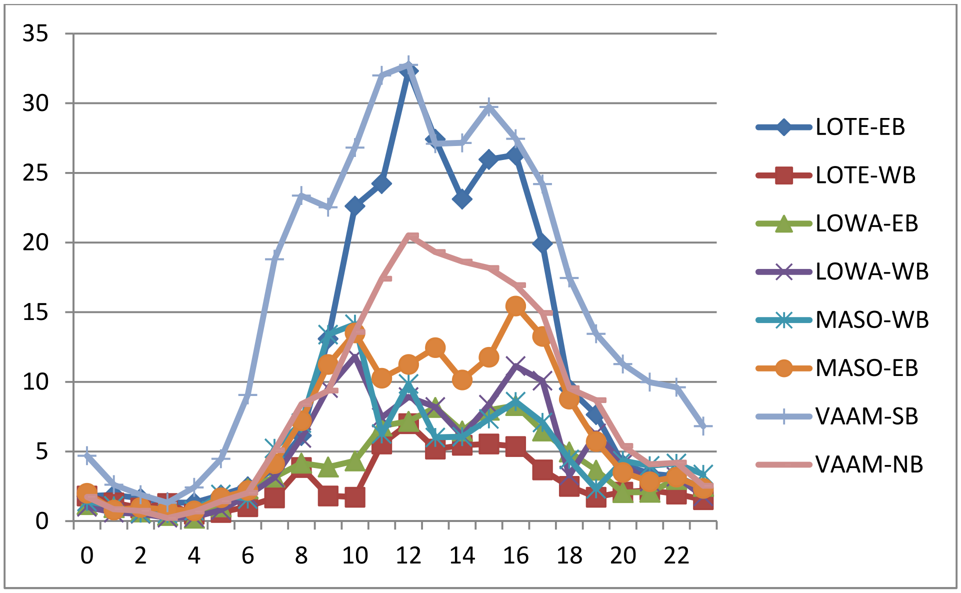


Figure 3-4. Red-light violations by different times of the day

Lohman and Telshor – Westbound (LOTE-WB): Like the LOTE-EB, large portion (63%) of RLV occurred from 10am until 6pm. Compared to the LOTE1, there were a lot less RLV at the LOTE-WB. The highest violation rate (11%) was at noon (see Figure E2).

Lohman and Walnut – Eastbound (LOWA-EB): About 65% of violations at LOWA-EB occurred between 11am and 6pm. The highest rate was at 4pm with 9% of the total violations. The next peak hours are 1pm and 3pm (see Figure E3).

Lohman and Walnut – Westbound (LOWA-WB): Like other camera sites, a majority of the RLV occurred during daytime. There are two peak time windows at LOWA-WB. They are 10am and 4pm (see Figure E4).

Main and Solano – Westbound (MASO-WB): Like the LOWA-WB, there are two peak times. The highest rate occurred between 9am and 10am. The second highest rate was at 4pm (see Figure E5).

Main and Solano – Eastbound (MASO-EB): Most violations (nearly 70%) occurred between the time intervals 9am and 6pm. Two peak time windows at MASO-EB are 4pm-5pm and 9am-10am (see Figure E6).

Valley and Avenida de Mesilla – Southbound (VAAM-SB): Among the eight camera sites, the VAAM-SB has recorded the highest RLV during most times of the day. The highest peak occurred at 12pm (see Figure E7).

Valley and Avenida de Mesilla – Northbound (VAAM-NB): Starting from 3am, the RLV increases until 12pm when there is a peak hour, and then decreases (see Figure E8).

3.2.1.3 The Days of the Week

Next, we review the daily trends of the monthly average RLV (see Figure 3-5). Overall, the highest RLV occurred on Friday whereas the lowest RLV on Sunday. In Figure 3-6, the daily trends of the RLV at each camera intersections are also depicted, where the monthly average RLV counts are recorded based on the days of the week. The daily behaviors for each individual intersection are shown in Appendix F (see Figures F1 through F8). Six out of eight sites have experienced the highest RLV on Friday and the other two on Wednesday and Saturday. The average daily traffic volume and businesses around the intersection could be the reason for different violation rates between the days of the week.

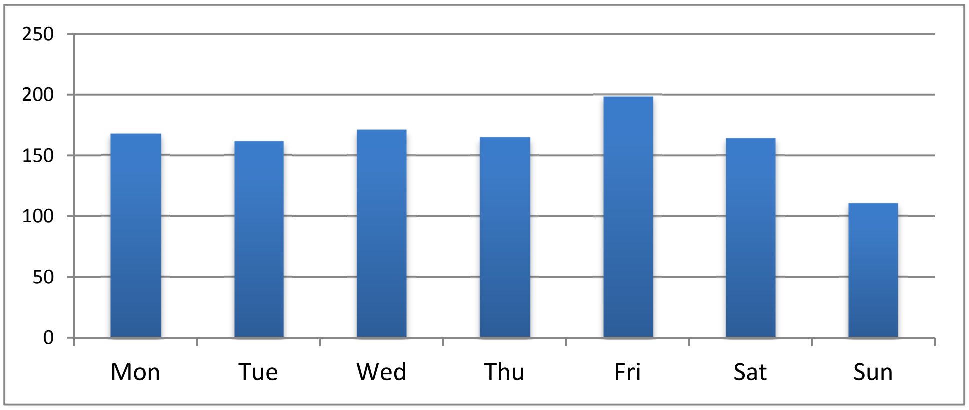


Figure 3-5. Red-light violations by the days of the week (all camera sites)

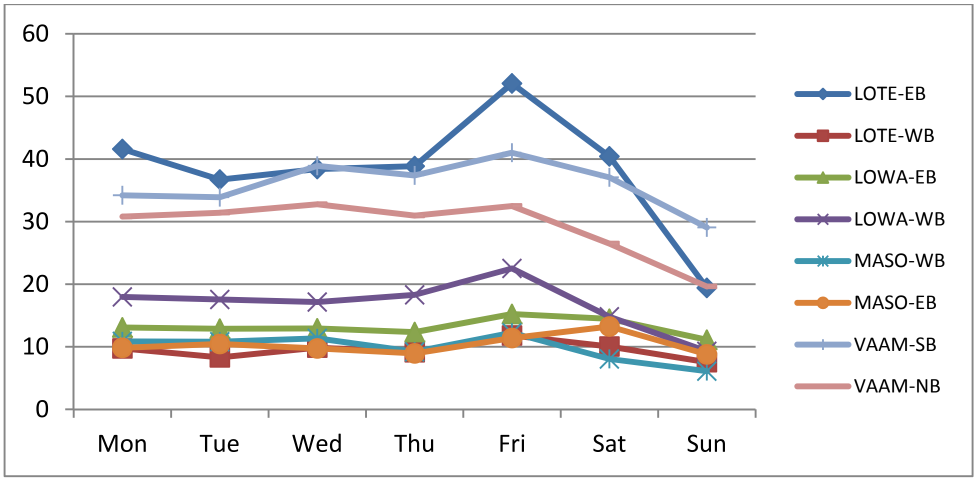


Figure 3-6. Red-light violations by the days of the week

Lohman and Telshor – Eastbound (LOTE-EB): The highest RLV occurred on Friday whereas the lowest RLV on Sunday. Weekdays provide a nearly stable RLV (see Figure F1).

Lohman and Telshor – Westbound (LOTE-WB): Like the LOTE-EB, the highest RLV occurred on Friday and the lowest RLV on Sunday (see Figure F2).

Lohman and Walnut – Eastbound (LOWA-EB): Similar to the LOTE intersections, the LOWA-EB has experienced the highest RLV on Friday and the lowest on Sunday (see Figure F3).

Lohman and Walnut – Westbound (LOWA-WB): Similar to LOWA-EB, the highest RLV occurred on Friday and the lowest on Sunday. It is interesting to note that the second lowest RLV at LOWA-WB was recorded on Saturday (see Figure F4).

Main and Solano – Westbound (MASO-WB): Like the LOTE and LOWA intersections Fridays have the most violations and Sundays have the least (see Figure F5).

Main and Solano – Eastbound (MASO-EB): Unlike other camera sites, the MASO-EB has the highest RLV on Saturday. The lowest RLV was recorded on Sunday (see Figure F6).

Valley and Avenida de Mesilla – Southbound (VAAM-SB): Like many other camera sites, the VAAM-SB has experienced the most RLV on Friday and the least on Sunday (see Figure F7).

Valley and Avenida de Mesilla – Northbound (VAAM-NB): The two most RLV occurred on Wednesdays and Fridays, whereas the least on Sunday (see Figure F8).

3.2.1.4 Time Elapsed Since the Red Light Signal (sec.)

Next, we review the monthly average RLV by elapsed time (sec.) since the red light onset (see Figures 3-7 and 3-8). This elapsed time is recorded to the nearest 0.1 second. The STOP at the City of Las Cruces has captured vehicles crossing intersections after the red light was initiated, from 0.1 second (minimum elapsed time to activate the enforcement camera). Figure 3-7 shows that 56% of the RLV in the City of Las Cruces occurred within 1 second after the onset of the red light. The influence of the "dilemma zone" is probably one of the major reasons for such a high percentage of the RLV. It is also observed, however, that 28% of the RLV occurred more than 3 seconds after the red light signal. A combination of shorter signal timing cycle and high traffic volume might have created many dilemma zones that caused indecisive drivers to violate the red light. Some drivers might be intentionally violating the traffic law, however, there could be other drivers, especially seniors, who might not react to the light change quick enough to stop their vehicles. Note that we separated the red light violators into four groups according to the elapsed time since the red light signal: (1) up to 1 second; (2) 1.1 to 2 seconds; (3) 2.1 to 3 seconds; and (4) more than 3 seconds.

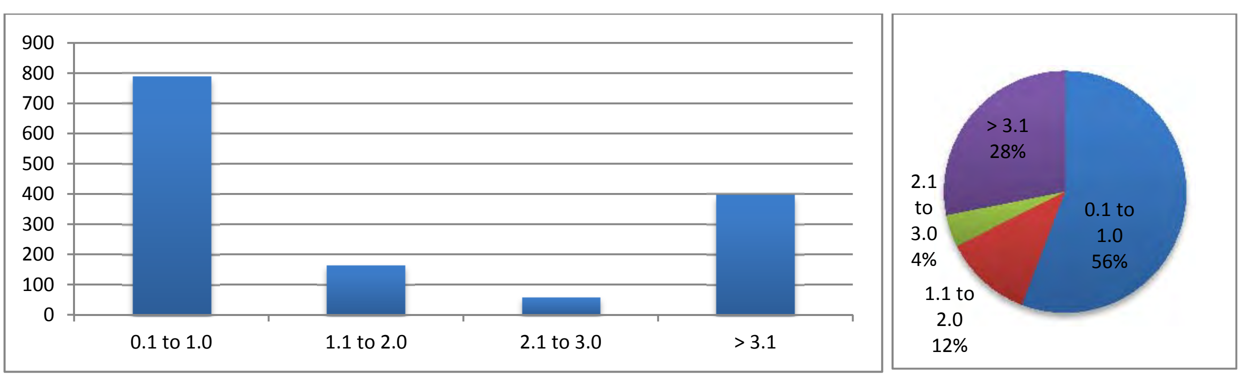


Figure 3-7. Red-light violations by elapsed time since the red light signal (all camera sites)

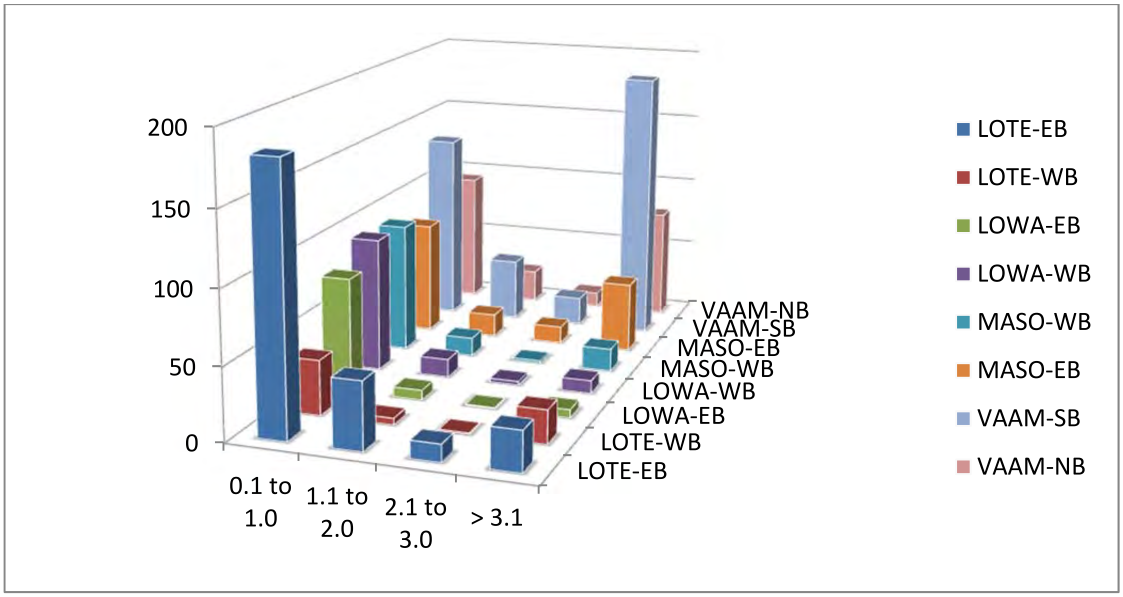


Figure 3-8. Red-light violations by elapsed time since the red light signal

Appendix G also illustrates the distribution of the RLV records by elapsed time from onset of red signal until time of violation at each individual intersection (see Figures G1 through G8).

Lohman and Telshor Intersection -Eastbound (LOTE-EB): More than 67% of the violations occurred within 1 second and 85% within 2 seconds after the onset of the red light. We may also notice that more than 10% of the RLV occurred more than 3 seconds after the red light signal (see Figure G1).

Main and Solano – Westbound (MASO-WB): Similar to the LOWA-WB, more than 74% of the violations occurred within 1 second and 85% within 2 seconds respectively after the onset of the red light. Almost 12% of the RLV occurred more than 3 seconds after the red light (see Figure G5).

Main and Solano – Eastbound (MASO-EB): About 50% of the violations occurred within 1 second and 60% within 2 seconds respectively after the onset of the red light. Nearly 30% of the RLV was recorded more than 3 seconds after the red light signal (see Figure G6)

Valley and Avenida de Mesilla – Southbound (VAAM-SB): Unlike many other camera sites, the VAAM-SB recorded nearly 50% of the RLV more than 3 seconds after the red light onset. Only 35% and 46% of the violations occurred within 1 second and within 2 seconds respectively after the onset of the red light (see Figure G7).

Valley and Avenida de Mesilla – Northbound (VAAM-NB): Similar to the VAAM-NB, the high rates of the RLV (38%) were recorded after 3 seconds of red light onset. About 46% of the violations occurred within 1 second and 57% within 2 seconds respectively (see Figure G8).

3.2.1.5 Different Lanes of the Intersection

Next, we review the RLV by different lanes of the intersection. The lanes are numbered from the inside (center) to the outside (curb) (see Table 3-2). Note that the right turn lanes at the LOTE intersection are not included in our study since they aren't monitored due to the road width. Figures H1 through H8 in Appendix H illustrates the percentage distribution of the RLV records by different lanes of the intersection. In the graphs, the blue, red, green, and purple bars represent left turn, thru, right turn, and both thru & right turn lanes, respectively.

Table 3-2. Different Lanes of the Intersection

Camera Sites	Lane #1	Lane #2	Lane #3	Lane #4
LOTE-EB	Inside left turn	Outside left turn	Inside thru	Outside thru
LOTE-WB	Inside left turn	Outside left turn	Inside thru	Outside thru
LOWA-EB	Left turn	Inside thru	Middle thru	Outside thru & right turn
LOWA-WB	Left turn	Inside thru	Middle thru	Outside thru & right turn
MASO-WB*	Left turn	Inside thru	Outside thru & right turn	–
MASO-EB*	Left turn	Inside thru	Outside thru	Right turn
VAAM-SB*	Left turn	Inside thru	Outside thru	Right turn
VAAM-NB	Left turn	Inside thru	Outside thru	Right turn

Lohman and Telshor – Eastbound (LOTE-EB): About 87% of the RLV occurred on the left turn lanes, while the rest of the RLV on the thru lanes. At the LOTE-EB, the right turn lane is not included in our study (see Figure H1).

Lohman and Telshor – Westbound (LOTE-WB): About 70% of the RLV was recorded on the left turn lanes, whereas 30% of the violations occurred on the thru lanes. Note that the outmost two lanes at LOTE-WB are not included in our study (see Figure H2).

Lohman and Walnut – Eastbound (LOWA-EB): Compared to those from the LOTE intersection, a majority of the RLV occurred on the thru lanes. Including 17% which belong to the thru & right turn lane, 93% of the RLV was recorded on the thru lanes. Only about 7% of the RLV occurred on the left turn lane (see Figure H3).

Lohman and Walnut – Westbound (LOWA-WB): Like LOWA-EB, a lot more RLV occurred on the thru lanes. Including 36% from the thru & right turn lane, 81% of the RLV occurred on the thru lanes. About 19% of the RLV recorded on the left turn lane (see Figure H4).

Main and Solano – Westbound (MASO-WB): Like LOWA intersection, a lot more red light violators ran the red light on the thru lanes than the left turn lane. Only 26% of the RLV occurred on the left turn lane (see Figure H5).

Main and Solano – Eastbound (MASO-EB): About 15%, 66%, and 19% of the RLV occurred on the left turn, thru, and thru & right turn lanes, respectively (see Figure H6)

Valley and Avenida de Mesilla – Southbound (VAAM-SB): Unlike many other camera sites, a majority of the RLV at the VAAM-SB occurred on the right turn lane (81%) (see Figure H7).

Valley and Avenida de Mesilla – Northbound (VAAM-NB): Similar to the VAAM-SB, 64% of the red light violators ran the red light on the right turn lane (see Figure H8).

3.2.2 Statistical Analysis

3.2.2.1. Monthly Red-light Violation Trends

In section 3.2.1.1, it is observed that, after the camera deactivation, the MASO-WB, MASO-EB, and VAAM-SB camera sites experienced an upward trend in the monthly average red-light violations. The LOWA-WB intersection also experienced a upward trend. It is also noticed that there weren't any upward or downward trends at the LOTE-EB, LOTE-WB, LOWA-EB, and VAAM-NB interesections. (Actually, there were slight upward trends at the LOWA-EB and the VAAM-NB, but they are negligible). Most of these findings are supported by the statistical analysis (see Table 3-3).

Table 3-3. Statistical Analysis on Red-light Violation Trends

Intersection	P value	Trend
LOTE-EB	0.970	Flat
LOTE-WB	0.951	Flat
LOWA-EB	0.881	Flat
LOWA-WB	0.000	Upward
MASO-WB*	0.026	Upward
MASO-EB*	0.002	Upward
VAAM-SB*	0.697	Flat
VAAM-NB	0.552	Flat

Next, we use the Kruskal-Wallis test to compare yearly trends of the red-light violations (RLV) during the three year study period at each individual camera site. Note that only five out of the eight camera sites were used in the statistical test. In conducting the analysis, the RLV data was grouped into three periods, namely, the first, the second, and the third year of the STOP operation. The test results show that there weren't any upward or downward trends at the LOTE-EB, LOTE-WB, and VAAM-NB interesections during the three year study period. However, the LOWA-WB intersection experienced a significant upward trend. The statistical test results also show that the LOWA-EB intersection had a downward trend until the second year and then began the upward trend (see Table 3-4). The Mann-Whitney test was also used to prove if there is a significant difference on the RLV between the second and the third year. The test results are very similar to the one from the Kruskal-Wallis test (see Table 3-4).

Table 3-4. Statistical Analysis on Yearly Red-light Violation Trends

Intersection	3 year study period (Year 1 vs. Year 2 vs. Year 3)		2 year study period (Year 2 vs. Year 3)	
	P value	Decision	P value	Decision
LOTE-EB	0.704	No Change	0.507	No Change
LOTE-WB	0.792	No Change	0.817	No Change
LOWA-EB	0.001	Increase (3rd year)	0.000	Increase
LOWA-WB	0.000	Increase	0.000	Increase
VAAM-NB	0.474	No Change	0.773	No Change

3.2.2.2 Different Times of the Day

The trend analysis in section 3.2.1.2 implies that a majority of the red-light violations (RLV) occurred during the daytime. This finding is supported by the statistical analysis. The statistical test results of the monthly average RLV also show that there is a significant difference between each time period at all of the different camera sites (see Table 3-5). Note that the RLV data was grouped into four time periods, namely (1) 0:00 to 5:59, (2) 6:00 to 11:59, (3) 12:00 to 17:59, and (4) 18:00 to 23:59.

Table 3-5. Statistical Analysis on Different Times of the Day

Time periods	0:00 – 5:59	6:00 – 11:59	12:00 – 17:59	18:00 – 23:59
P value	0.000	0.000	0.000	0.000

3.2.2.3 The Days of the Week

According to the trend analysis in section 3.2.1.3, the highest RLV at the six camera sites (i.e., LOTE-EB, LOTE-WB, LOWA-EB, LOWA-WB, MASO-WB, and VAAM-SB) occurred on Friday, whereas the lowest RLV occurred on Sunday.

Table 3-6. Statistical Analysis on the Days of the Week

Camera sites	Mon	Tue	Wed	Thu	Fri	Sat	Sun	P value
LOTE-EB					X		X	0.000
LOTE-WB								0.085
LOWA-EB					X		X	0.018
LOWA-WB					X		X	0.000
MASO-WB							X	0.002
MASO-EB							X	0.056
VAAM-SB							X	0.012
VAAM-NB					X		X	0.000

The statistical test results of the monthly average RLV show that Friday and Sunday are significantly different from the other days of the week. The test results also show that there aren't any significant differences between Monday, Tuesday, Wednesday, Thursday, and Saturday (see Table 3-6). In the table, 'X' indicates that there is a significant difference from the other days of the week.

3.2.2.4 Time Elapsed Since the Red Light Signal (sec.)

The trend analysis in section 3.2.1.4 implies that the highest volume of the red-light violations (RLV) occurred within 1 second after the onset of the red light signal, and the second highest volume of the RLV occurred more than 3 seconds after the red light signal. This finding is supported by the statistical analysis. The statistical test results of the monthly average RLV also show that there is a significant difference between each time interval at all of the different camera sites (see Table 3-7).

Table 3-7. Statistical Analysis on Red-light violations by elapsed time since the red light signal

Time into Red (sec.)	0.1 to 1.0	1.1 to 2.0	2.1 to 3.0	> 3.1
P value	0.000	0.000	0.000	0.000

3.2.2.5 Different Lanes of the Intersection

Violation counts in each lane of the intersection are highly influenced by traffic volume in each lane, and also different lanes have different behaviors at each intersection; for example, most of the red-light violations at the LOTE intersection belong to the left-turn lanes. At the LOWA intersection, the thru-lanes have higher violation rates, whereas the most red-light violations at the VAAM intersection occurred in the right turn lanes. Unfortunately, however, since there is no information available on the traffic volume in each lane of the intersections, we didn't implement any statistical analyses for lane comparisons.

4. SPEEDING VIOLATION DATA ANALYSIS

The speeding data was obtained from the City of Las Cruces Police Department. The provided data covers five camera sites at three intersections, i.e., LOTE-EB, LOTE-WB, LOWA-EB, LOWA-WB, and VAAM-NB. The given study periods are 24 months (May 2010 – April 2012). Three other cameras sites, i.e., MASO-WB, MASO-EB and VAAM-SB, were not included in this study since their cameras were no longer operable since May 2010, and as a result, there is no information available on the speeding violation. The posted speed limit (PSL) is 35mph at LOTE, LOWA, and MASO intersections. The PSL at VAAD intersection is 40mph. However, the trigger speed (or the threshold speed) for all cameras in town is set to 10mph and over, which means that speeding of 1-9mph over the speed limit will not result in a violation citation. In conducting the analysis, the speeds of violating vehicles were subtracted from corresponding PSLs at each intersection, and the resulting speeding records are grouped into two categories: 1) Under the threshold speed, i.e., speed detected is 1-9mph over the PSL; 2) Over the threshold speed, i.e., speed detected is higher than or equal to 10mph over the PSL. The record log of the violation data includes the speeding violation count based on by date when the violation occurred, camera site of each intersection, different lanes of the intersection, and the average speed of the vehicle at the time of the violation.

4.1 Methodology

To study the speeding violations and related factors, we implement the same methodology that was used for the red-light violation analysis. That is, two levels of data analysis were conducted – one is using trend analysis and the other is using statistical analysis. Readers are referred to Section 3.1 for detailed information of it.

4.2 Results and Discussion

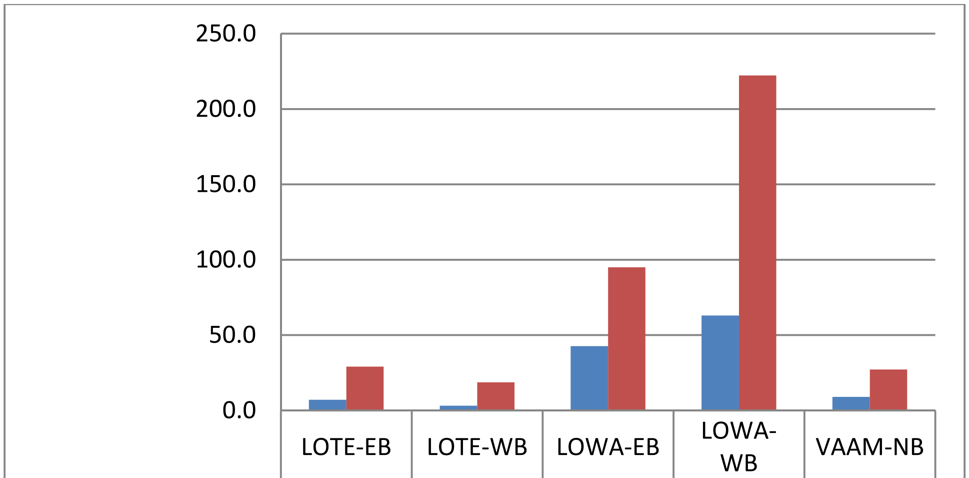
4.2.1 Trend Analysis

Trend analysis fits a general trend model to time series data and is often used to provide forecasts. In this section, we use the linear trend line which is a best-fit straight line and it shows that speeding violations are increasing or decreasing at a steady rate.

4.2.1.1 Monthly Speeding Violation Trends

There were 12,400 speeding violation records at the five camera sites during the study period (i.e., May 2010 – April 2012). Figure 4-1 shows the monthly average values of the violation records at each camera site. The LOWA-WB experienced the highest monthly average violation counts of 285.3 with 78% of actual violation citation rate, whereas the LOTE-WB recorded the lowest number of 21.8 per month with 86% of the acutal citation rate.

We review the monthly trends of the speeding violations at the camera sites, which are illustrated in Figures 4-2 and 4-3. That is, the monthly average counts of vehicles with 1-9mph over the PSL are depicted in Figure 4-2, whereas Figure 4-3 shows the monthly average counts of vehicles with higher than or equal to 10mph over the PSL.



	LOTE-EB	LOTE-WB	LOWA-EB	LOWA-WB	VAAM-NB
1-9mph over PSL	7.1	3.1	42.7	63.0	9.0
≥ 10mph over PSL	29.1	18.6	95.0	222.3	27.2

Figure 4-1. Monthly average number of the speeding violations

To show clearer behaviors at each camera site, a set of graphs are included in Appendix I (see Figures I1 through I5). In the graph, the blue dashed line shows a linear trend based on the vehicle counts with 1-9mph over the PSL. The red dashed trend line was drawn based on the one with higher than or equal to 10mph over the PSL.

Lohman and Telshor – Eastbound (LOTE-EB): The graph shows the speeding violation counts at LOTE-EB camera site since May 2010 (see Figures 4-2, 4-3, and I1). There were upward spikes on the speeding violation citations count in July 2010 and March 2011. Overall, a slightly downward trend is observed for both speed violation categories.

Lohman and Telshor – Westbound (LOTE-WB): Similar to LOTE-EB, overall, a slightly downward trend is observed. The highest violation citation count of 43 was recorded in May 2010 (see Figures 4-2, 4-3, and I2).

Lohman and Walnut – Eastbound (LOWA-EB): Compared to the LOTE intersection, the LOWA-EB camera site experienced a lot more violation citation counts during the study period. The citation counts were very fluctuating and the highest count of 147 was recorded in November 2010. Overall, a downward trend is observed (see Figures 4-2, 4-3, and I3).

Lohman and Walnut – Westbound (LOWA-WB): During the study period, LOWA-WB recorded the highest violation counts among all camera sites. Similar to the LOWA-EB, the pattern over time at the LOWA-WB camera site is jagged. The recorded values of the violation citation counts were varied from 108 (February 2011) to 368 (September 2010). Overall, a downward trend is observed as well (see Figures 4-2, 4-3, and I4).

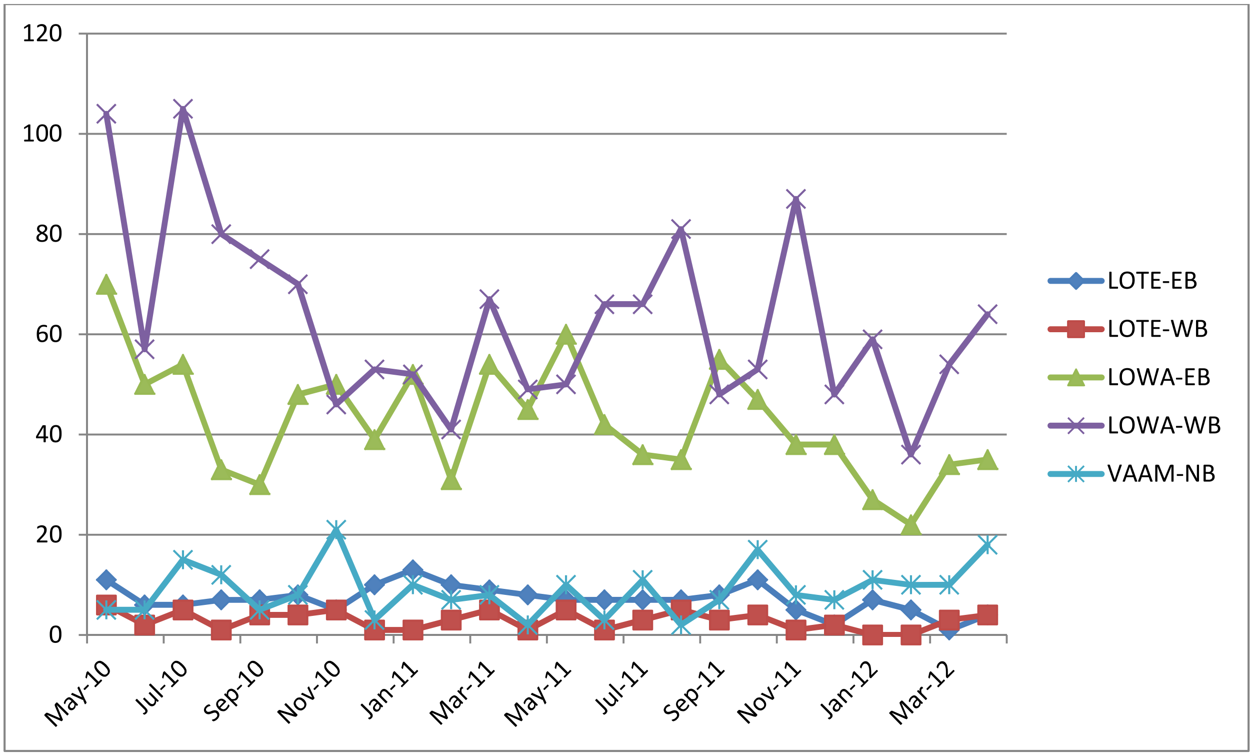


Figure 4-2. Monthly speeding violation trends (1-9mph over PSL)

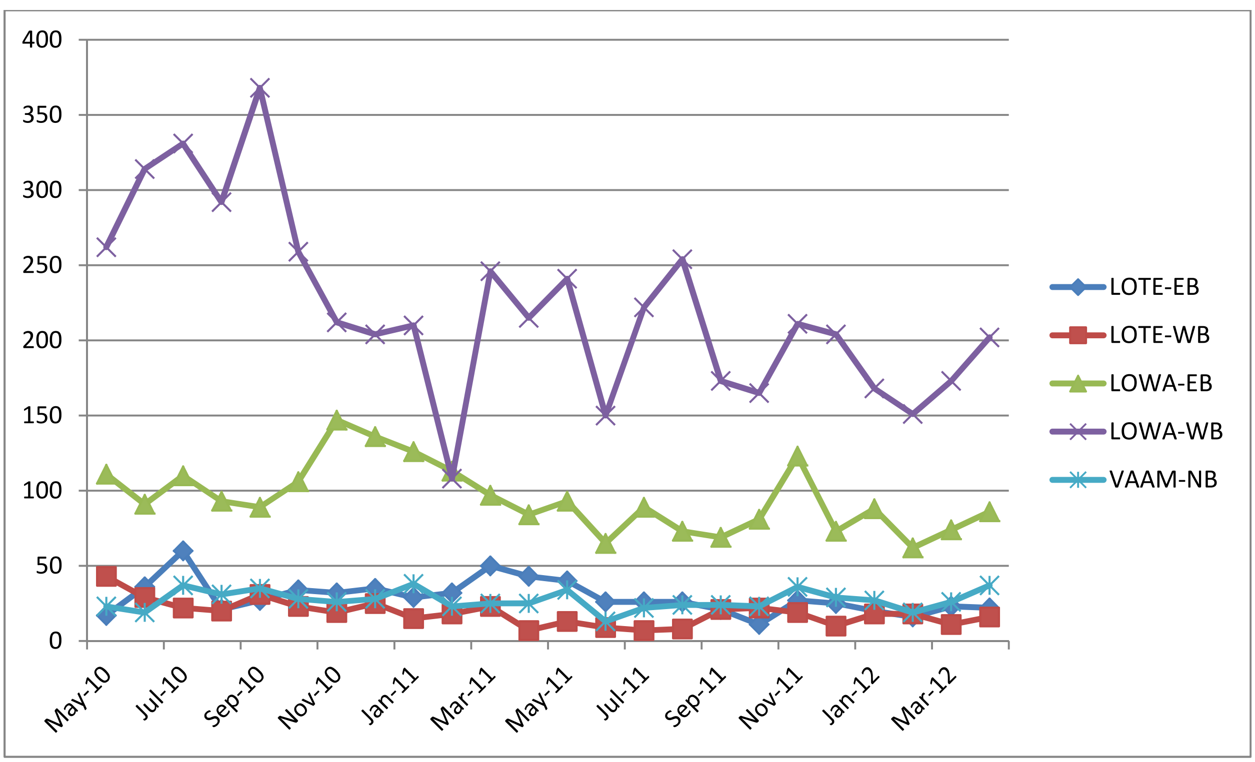


Figure 4-3. Monthly Speeding violation trends (≥ 10mph over PSL)

Valley and Avenida de Mesilla – Northbound (VAAM-NB): In comparison with the other camera sites, a somewhat flat trend is observed at the VAAM-NB. The highest violation citation count of 38 was recorded in January 2011 (see Figures 4-2, 4-3, and I5).

4.2.1.2 Monthly Average Speed of Vehicle at Time of Violation

Next, we review the monthly average speed of the vehicles at the time of the violation. The monthly average speed of vehicles with 1-9mph over the PSL are depicted in Figure 4-4, whereas Figure 4-5 shows the monthly average speed for vehicles with higher than or equal to 10mph over the PSL. To show clearer behaviors at each camera site, a set of graphs are included in Appendix J (see Figures J1 through J5). Below are interpretations based on the monthly average speed trends of the vehicles which received the violation citation (see Figure 4-5):

Lohman and Telshor – Eastbound (LOTE-EB): At LOTE-EB, the monthly average speeds fluctuated between 46mph and 48mph. Overall, however, a flat trend was observed (see Figure J1).

Lohman and Telshor – Westbound (LOTE-WB): Similar to the LOTE-EB, the pattern at the LOWA-WB camera site was jagged. The monthly average speeds were fluctuated between 46mph and 49.3mph. Overall, a flat trend was observed (see Figure J2).

Lohman and Walnut – Eastbound (LOWA-EB): The monthly average speeds were varied between 46.6mph and 47.9mph, which are a lot more stable than those of LOTE intersection. Overall, a flat trend was observed (see Figure J3).

Lohman and Walnut – Westbound (LOWA-WB): The monthly average speeds at the LOWA-WB are even more stable than those of the LOWA-EB. Overall, a flat trend was observed (see Figure J4).

Valley and Avenida de Mesilla – Northbound (VAAM-NB): Like the LOTE intersection, the pattern at the VAAM-NB camera site was jagged. The monthly average speeds were fluctuated between 50.2mph and 52.9mph. Unlike other camera sites, overall, a slightly upward trend was observed (see Figure J5).

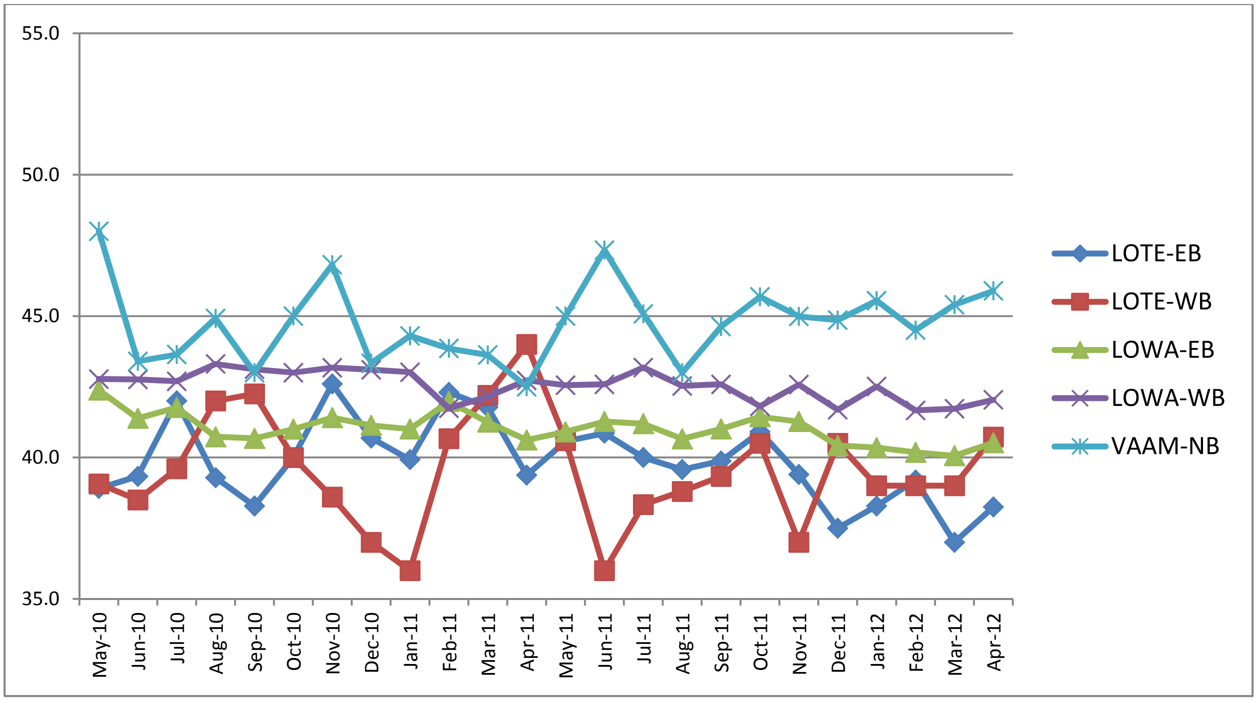


Figure 4-4. Monthly Average Speed of Vehicle (1-9mph over PSL) at Time of Violation

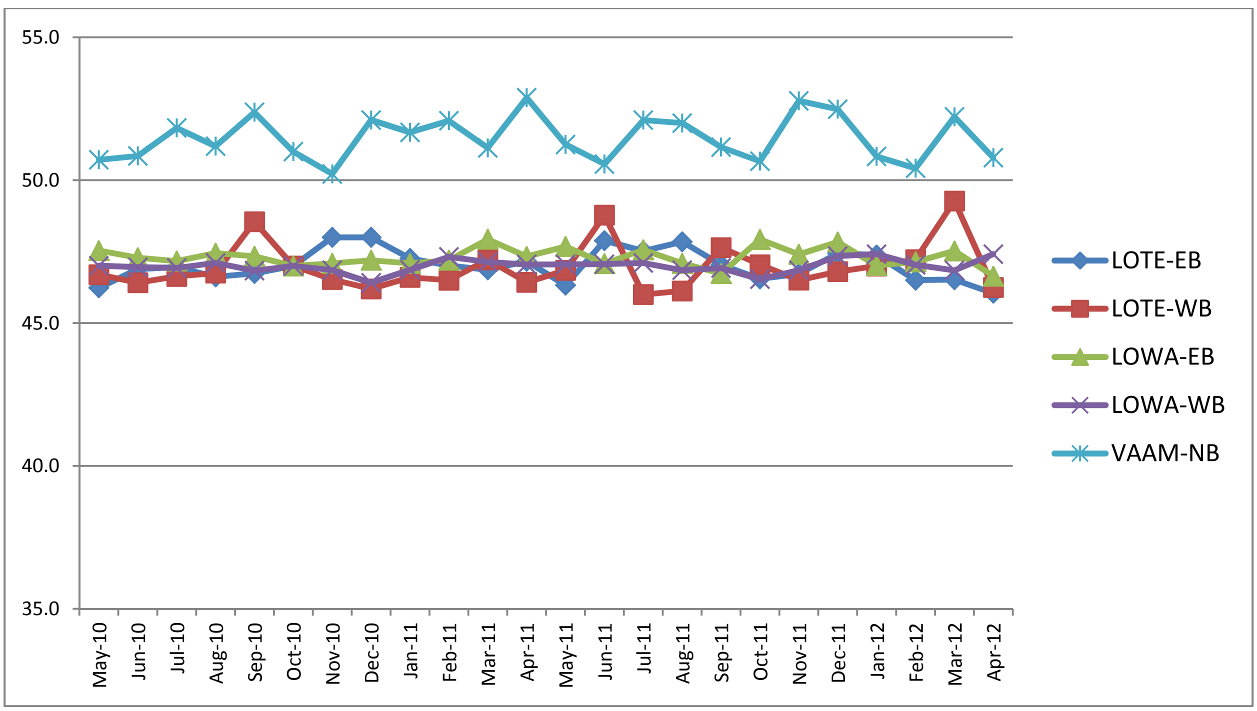


Figure 4-5. Monthly Average Speed of Vehicle (≥ 10mph over PSL) at Time of Violation

4.2.1.3 Monthly Speeding Violations by Different Lanes of the Intersection

Next, we review the speeding violations by different lanes of the intersection. Figures K1 through K5 illustrates the monthly speeding violation counts at each camera sites by different lanes of the intersection. Below are again interpretations based on the monthly average speed trends of the vehicles which received the violation citation:

Lohman and Telshor – Eastbound (LOTE-EB): At the LOTE-EB camera site, 73% of the speeding violation citations occurred in lane #4 and 23% in lane #3. In lane #4, an upward trend is observed during the first year of the study period, followed by a downward trend during the second year. Overall, however, a downward trend is observed at both lanes (see Figure K1). Note that the number of the speeding violations at both lanes #1 and #2 of the LOTE-EB camera site is very small, making it negligible.

Lohman and Telshor – Westbound (LOTE-WB): The trend over time at LOTE-WB camera site is a downward (see Figure K2). Similar to the LOTE-EB, the number of speeding violations at both lanes #1 and #2 of this camera site is negligible.

Lohman and Walnut – Eastbound (LOWA-EB): The percentage of speeding violations in lanes #2, #3 and #4 are 42%, 43% and 15%, respectively. Both lanes #2 and #3 show a downward trend on the monthly speeding violations, while lane #4 shows a slightly upward trend (see Figure K3).

Lohman and Walnut – Westbound (LOWA-WB): The LOWA-WB camera site recorded the highest speeding violation rate among the five camera sites. More than 3,700 (i.e., 53%) speeding violation citations are recorded in lane #3 of LOWA-WB. Lanes #2 and #4 count for 35% and 12% of the monthly speeding violations, respectively. Lane #3 shows a significant downward trend, whereas a slightly downward trend is observed in both lanes #2 and #4. Note that the speeding violation counts for the lane #2 from November 2010 through February 2011 are almost zero. The reason for this is a road closure due to road construction works during this period (see Figure K4).

Valley and Avenida de Mesilla – Northbound (VAAM-NB): Both lanes #2 and #3 of the VAAM-NB camera site show almost a flat trend on the monthly speeding violation citations (see Figure K5). Note that the number of speeding violations at both lanes #1 and #4 of this camera site is very small which is negligible.

4.2.2 Statistical Analysis

Statistical analyses are conducted to prove if there is a reliable significant difference in speeding violation trends after the launch of the STOP.

4.2.2.1. Monthly Speeding Violation Trends

In section 4.2.1.1, it is observed that, during the given study periods (May 2010 – April 2012), both LOWA-WB and LOWA-EB camera sites experienced a significant downward trend on the average monthly speeding violations. Also, slightly downward trends are observed at the LOTE-EB and LOTE-WB camera sites, but they are negligible. The VAAM camera site shows a flat trend, overall. All of these findings are supported by the statistical analysis (see last column in Table 4-1).

Table 4-1. Statistical Analysis on Speeding Violation Trends

Intersection	Overall Speeding Violation		1-9mph over PSL		≥ 10mph over PSL	
	P value	Trend	P value	Trend	P value	Trend
LOTE-EB	0.006	Downward	0.024	Downward	0.028	Downward
LOTE-WB	0.002	Downward	0.536	Flat	0.002	Downward
LOWA-EB	0.001	Downward	0.013	Downward	0.008	Downward
LOWA-WB	0.001	Downward	0.042	Downward	0.000	Downward
VAAM-NB	0.825	Flat	0.437	Flat	0.782	Flat

Next, we use the Mann-Whitney test to compare yearly trends of the speeding violations at each individual camera site. In conducting the analysis, the speeding violation data was grouped into two periods, namely the first 12-months and the next 12-months of the 24-months study period. For the actual speeding violation citations count, the statistical test results show that there weren't any significant differences between the first 12-months and the next 12-months of the study period at the VAAM-NB camera site. However, all of the othercamera sites experienced a significant decrease during the second 12-months period (see last column in Table 4-2).

Table 4-2. Statistical Analysis on Yearly Speeding Violation Trends

Intersection	Overall Speeding Violation		1-9mph over PSL		≥ 10mph over PSL	
	P value	Decision	P value	Decision	P value	Decision
LOTE-EB	0.0054	Decrease	0.0463	Decrease	0.0085	Decrease
LOTE-WB	0.0071	Decrease	0.9195	No Change	0.0093	Decrease
LOWA-EB	0.0020	Decrease	0.1935	No Change	0.0013	Decrease
LOWA-WB	0.0303	Decrease	0.5251	No Change	0.0110	Decrease
VAAM-NB	1.0000	No Change	0.4504	No Change	0.4519	No Change

4.2.2.2 Monthly Average Speed of Vehicle at Time of Violation

According to the trend analysis in section 4.2.1.2, there weren't any significant upward or downward trends on average speed of vehicles at time of violation at the five camera sites. Actually, there was a slightly upward trend at the VAAM-NB, but they were negligible. All of these findings are supported by the statistical analysis (see last column in Table 4-3).

Table 4-3. Statistical Analysis on Violators' Monthly Average Speed Trends

Intersection	Overall Speeding Violation		1-9mph over PSL		≥ 10mph over PSL	
	P value	Trend	P value	Trend	P value	Trend
LOTE-EB	0.867	Flat	0.045	Downward	0.670	Flat
LOTE-WB	0.812	Flat	0.709	Flat	0.386	Flat
LOWA-EB	0.213	Flat	0.001	Downward	0.792	Flat
LOWA-WB	0.278	Flat	0.000	Downward	0.228	Flat
VAAM-NB	0.602	Flat	0.546	Flat	0.75	Flat

The Mann-Whitney test was also used to prove if there is a significant difference on the monthly average speeds between two periods, i.e., the first 12-months and the next 12-months of the 24-months study period. The test result also shows that there aren't any meaningful differences on the speeds between the two periods at any of the camera intersections (see last column in Table 4-4).

Table 4-4. Statistical Analysis on Violators' Yearly Average Speed Trends

Intersection	Overall Speeding Violation		1-9mph over PSL		≥ 10mph over PSL	
	P value	Decision	P value	Decision	P value	Decision
LOTE-EB	0.7075	No Change	0.1570	No Change	0.6650	No Change
LOTE-WB	0.8399	No Change	0.3116	No Change	0.3555	No Change
LOWA-EB	0.1410	No Change	0.0531	No Change	0.0940	No Change
LOWA-WB	0.3123	No Change	0.0073	Decrease	0.6236	No Change
VAAM-NB	0.6236	No Change	0.0605	No Change	0.7950	No Change

4.2.2.3 Monthly Speeding Violations by Different Lanes of the Intersection

According to the statistical test results, downward trends are observed at LOTE-EB lane #3, LOTE-WB lane #4, LOWA-EB lanes #2 and #3, and LOWA-WB lanes #3 and #4. All of the other lanes at each camera site experienced a flat trend (see Table 4-5). Most of these results are consisitent with those from the trend analysis.

Table 4-5. Statistical Analysis on Speeding by Different Lanes of the Intersections

Intersection	Lane #1		Lane #2		Lane #3		Lane #4	
	P value	Trend	P value	Trend	P value	Trend	P value	Trend
LOTE-EB	–	–	–	–	0.006	Downward	0.110	Flat
LOTE-WB	–	–	–	–	0.059	Flat	0.000	Downward
LOWA-EB	–	–	0.000	Downward	0.000	Downward	0.277	Flat
LOWA-WB	–	–	0.527	Flat	0.000	Downward	0.002	Downward
VAAM-NB	–	–	0.738	Flat	0.470	Flat	–	–

5. PRELIMINARY CONCLUSIONS

The following preliminary conclusions can be made:

- The trend analysis of the signalized intersections shows some changes in the crash rates at certain intersections for certain accident types. Even though some of findings from the crash data are encouraging, not all the results from the trend analysis are supported by the statistical analysis.
- Descriptive statistics suggest that the program has a positive impact on the traffic safety at the LOTE camera intersection. The introduction of the STOP at the LOTE intersection reduces the total crash rates, mainly due to the reduction on the rear-end crash rates and the property-damage only crash rates.
- The Lohman & Walnut intersection experienced an overall, negative impact. After the STOP operation, there were significant increases in every category of the crashes. The Main & Solano intersection also experienced an overall, negative impact as a result of the STOP operation. After the camera was installed, the trend has an upward spike after which the rates remain steady until the deactivation, when they trend downward quickly indicating a negative effect made by installing the camera.
- The VAAM camera intersection showed a mixture in reduction and incremental rates. However, we cannot make a solid conclusion on the camera effect at the Valley & Avenida de Mesilla intersection. This is because the northbound camera is still operable while southbound camera had deactivated and thus, was no longer operable since May 2010.
- Even though there weren't any STOP operations, the statistical tests show significant reductions in the crash rates at certain control intersections for certain crash types.
- The highest volume of the red-light violations occurred during the daytime with two peak hours at 12 pm and 4pm, and the highest red-light violations occurred on Friday.
- A majority of the red-light violations occurred within 1 second after the onset of the red-light signal, whereas the second highest volume of the red-light violations occurred more than 3 seconds after the red-light signal.
- Red-light violation did not decrease in any of eight camera sites since starting the STOP program.
- Significant decrease in speeding violation has been observed in 4 of 5 camera sites during the two years of study period. LOTE-EB, LOTE-WB, LOWA-EB and LOWA-WB showed downward trend since May 2010.
- The LOWA-WB experienced the highest monthly average speeding violation counts whereas the LOTE-WB recorded the lowest number. Both LOWA-WB and LOWA-EB camera sites experienced a significant downward trend on the average monthly speeding violations. Also, slightly downward trends are observed at the LOTE-EB and LOTE-WB camera sites. The VAAM camera site shows a flat trend, overall.
- There aren't any significant changes on the monthly average speed of the vehicles at the time of the violations.

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.
- Compiling the red-light violation data to date, and updating the red-light violation analyses.
- Compiling the speeding violation data to date, and updating the speeding violation analyses.
- 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

	# 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	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	1.90	2.36	2.12	2.19	2.12	-41.7	-6.3	-17.9	56.3	-17.0

Table A2. Average 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	0.81	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	0.99	0.79	0.97	-33.3	83.3	15.4	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	0.27	0.63	0.46	0.53	0.45	-66.7	-33.3	-46.2	20.0	-42.2

Table A3. Average 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	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	1.52	1.34	1.53	1.58	1.49	-30.0	-5.6	-8.0	125.0	-5.5

Table A4. Average PDO 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	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	1.41	1.57	1.39	2.01	1.56	-42.2	-13.0	-27.6	109.1	-16.7

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	0.38	0.63	0.73	0.18	0.49	-53.3	-11.1	10.0	-60.0	-28.2

Table A6. 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	3.31	4.72	5.04	2.89	3.99	-49.2	-11.8	-3.8	-8.3	-24.1

Table A7. Average Severity Index Rates for Angle Crash 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	1.68	1.57	1.92	1.14	1.61	-	-	-	-	-
2005	0.76	3.38	1.39	1.40	1.73	-54.8	115.0	-27.6	23.1	7.5
2006	0.76	3.93	2.59	1.49	2.08	-54.8	150.0	34.5	30.8	29.0
2007	1.63	2.28	1.46	0.53	1.51	-3.2	45.0	-24.1	-53.8	-6.5
2008	1.36	1.89	1.86	1.23	1.58	-19.4	20.0	-3.4	7.7	-2.2
2009	0.65	1.18	2.78	0.53	1.30	-61.3	-25.0	44.8	-53.8	-19.4
2010	0.87	1.41	2.12	1.93	1.53	-48.4	-10.0	10.3	69.2	-5.4
2011	0.49	0.94	1.26	0.88	0.87	-71.0	-40.0	-34.5	-23.1	-46.2

Table A8. Average Severity Index Rates for Rear-end Crash 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	4.12	3.62	3.25	1.40	3.24	-	-	-	-	-
2005	4.50	3.06	3.58	3.07	3.69	9.2	-15.2	10.2	118.8	13.9
2006	4.61	3.46	4.58	4.12	4.35	11.8	-4.3	40.8	193.8	34.2
2007	5.91	2.51	4.64	2.80	4.22	43.4	-30.4	42.9	100.0	29.9
2008	3.53	1.89	3.05	4.64	3.47	-14.5	-47.8	-6.1	231.3	7.0
2009	4.83	3.77	5.50	2.19	4.25	17.1	4.3	69.4	56.3	31.0
2010	3.74	2.59	3.85	3.50	3.50	-9.2	-28.3	18.4	150.0	8.0
2011	2.71	3.06	3.65	1.93	2.88	-34.2	-15.2	12.2	37.5	-11.2

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	2.04	1.67	1.77	1.74	1.66	1.10	1.65	19.0	0.0	-4.2	38.5	-16.7	-11.8	1.7
2011	2.69	4.01	2.84	0.96	1.66	1.62	2.36	57.1	140.9	54.2	-23.1	-16.7	29.4	45.5

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	0.65	1.29	1.23	0.29	0.75	0.29	0.77	14.3	466.7	60.0	50.0	0.0	33.3	67.6

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	2.04	2.58	1.46	0.58	0.83	1.32	1.52	108.3	78.9	35.7	-33.3	0.0	28.6	44.9

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	1.63	3.64	2.15	0.48	1.08	1.32	1.79	81.8	182.4	55.6	-16.7	-13.3	80.0	72.7

Table B5. Average Injury 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	0.73	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	1.06	0.23	0.54	0.48	0.58	0.29	0.52	44.4	-40.0	16.7	-16.7	-22.2	-33.3	-4.9

Table B6. Average Severity Index Rates at Control Intersections

	Severity Index per 1 million vehicles							% Changes in Severity Index per 1 million vehicles						
Year	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	6.93	4.77	4.84	2.89	3.99	2.79	4.40	51.8	50.0	31.3	-16.7	-20.0	-5.0	16.3

Table B7. Average Severity Index Rates for Angle Crash at Control Intersections

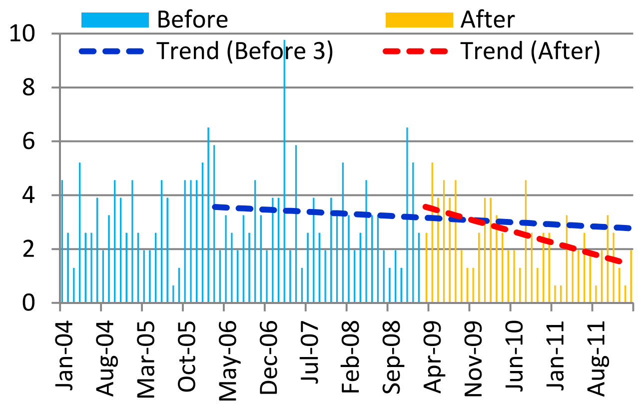
	Severity Index per 1 million vehicles							% Changes in Severity Index per 1 million vehicles						
Year	ELMA	PIMA	PIVA	SOMI	SOSP	VAAD	Ave.	ELMA	PIMA	PIVA	SOMI	SOSP	VAAD	Ave.
2004	1.55	0.83	1.08	0.19	1.74	0.51	0.99	-	-	-	-	-	-	-
2005	0.49	0.76	1.77	1.64	0.66	1.32	1.10	-68.4	-9.1	64.3	750.0	-61.9	157.1	10.8
2006	0.98	0.98	1.54	0.87	1.99	0.44	1.13	-36.8	18.2	42.9	350.0	14.3	-14.3	13.5
2007	0.16	1.29	0.85	0.96	0.91	0.66	0.81	-89.5	54.5	-21.4	400.0	-47.6	28.6	-18.9
2008	3.59	0.53	1.00	0.77	0.91	0.22	1.15	131.6	-36.4	-7.1	300.0	-47.6	-57.1	16.2
2009	2.53	1.59	1.08	2.41	1.25	0.37	1.49	63.2	90.9	0.0	1150.0	-28.6	-28.6	50.0
2010	1.06	0.61	1.92	0.58	1.08	0.15	0.90	-31.6	-27.3	78.6	200.0	-38.1	-71.4	-9.5
2011	1.30	1.51	1.69	0.29	1.74	0.88	1.26	-15.8	81.8	57.1	50.0	0.0	71.4	27.0

Table B8. Average Severity Index Rates for Rear-end Crash at Control Intersections

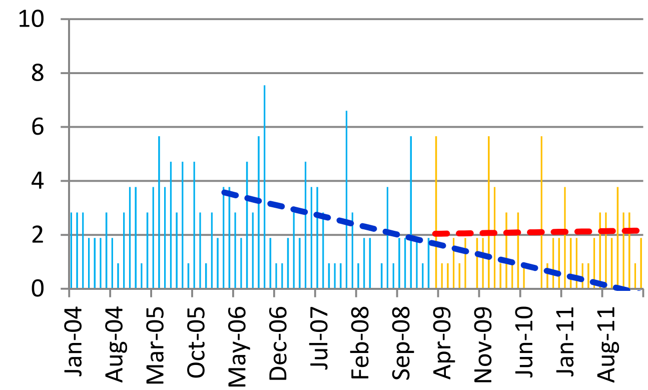
	Severity Index per 1 million vehicles							% Changes in Severity Index per 1 million vehicles						
Year	ELMA	PIMA	PIVA	SOMI	SOSP	VAAD	Ave.	ELMA	PIMA	PIVA	SOMI	SOSP	VAAD	Ave.
2004	2.61	2.35	2.61	3.18	2.49	2.42	2.59	-	-	-	-	-	-	-
2005	2.69	2.88	2.31	1.16	1.08	1.91	2.04	3.1	22.6	-11.8	-63.6	-56.7	-21.2	-21.2
2006	3.42	3.03	1.69	0.29	3.24	3.75	2.64	31.3	29.0	-35.3	-90.9	30.0	54.5	2.1
2007	5.79	2.50	2.23	1.45	1.58	1.91	2.60	121.9	6.5	-14.7	-54.5	-36.7	-21.2	0.5
2008	4.48	2.12	2.38	2.03	0.17	1.98	2.20	71.9	-9.7	-8.8	-36.4	-93.3	-18.2	-15.0
2009	4.81	2.50	2.77	2.70	1.50	3.01	2.89	84.4	6.5	5.9	-15.2	-40.0	24.2	11.4
2010	3.26	1.67	1.61	1.45	2.08	1.54	1.93	25.0	-29.0	-38.2	-54.5	-16.7	-36.4	-25.4
2011	5.62	3.11	2.69	2.12	1.83	1.91	2.90	115.6	32.3	2.9	-33.3	-26.7	-21.2	11.9

APPENDIX C

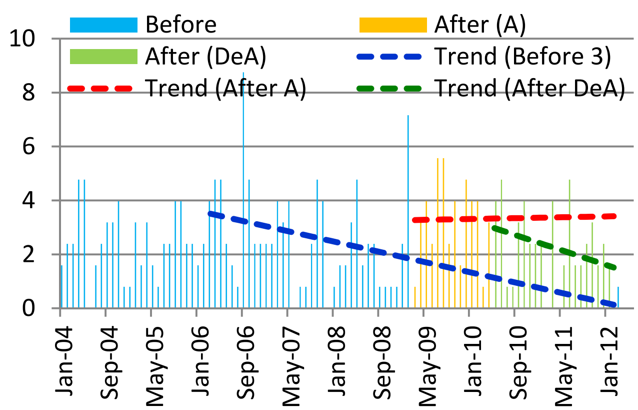
Monthly Crash Trends



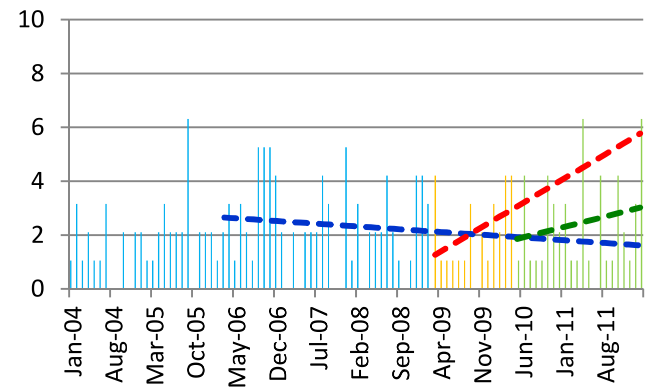
(a) LOTE



(b) LOWA

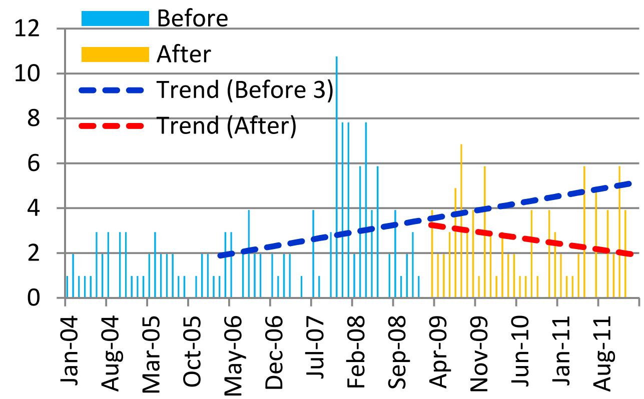


(c) MASO

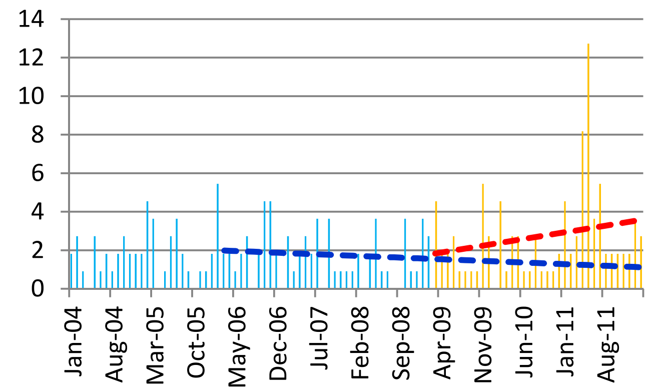


(d) VAAM

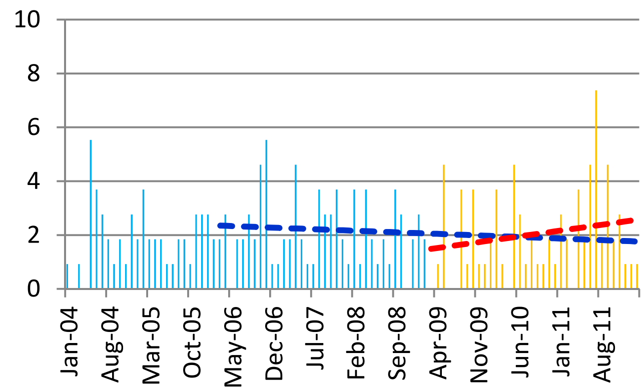
Figure C1. Total Crash Rate at Camera Intersections



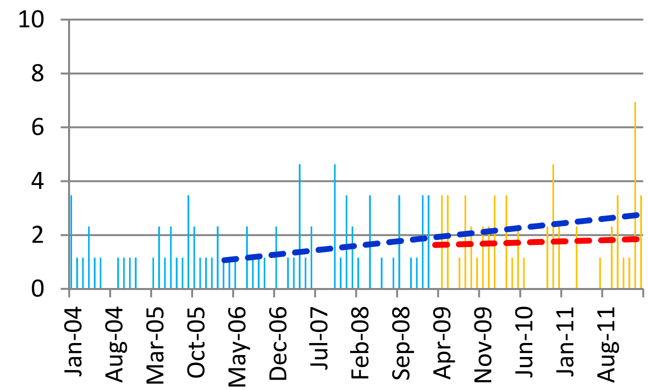
(a) ELMA



(b) PIMA

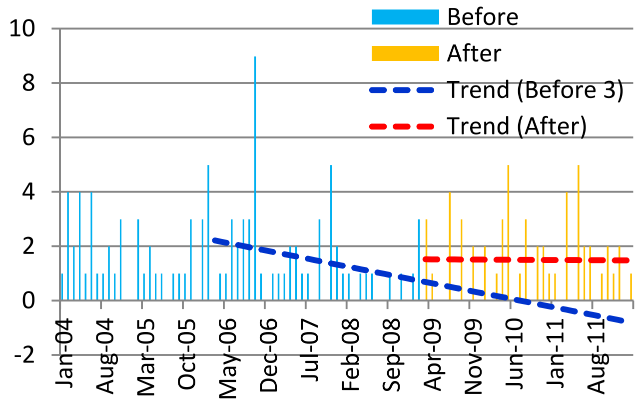


(c) PIVA

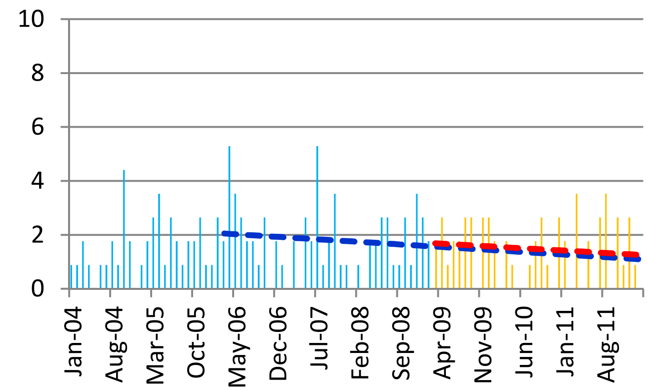


(d) SOMI

Figure C2. Total Crash Rate at Control Intersections

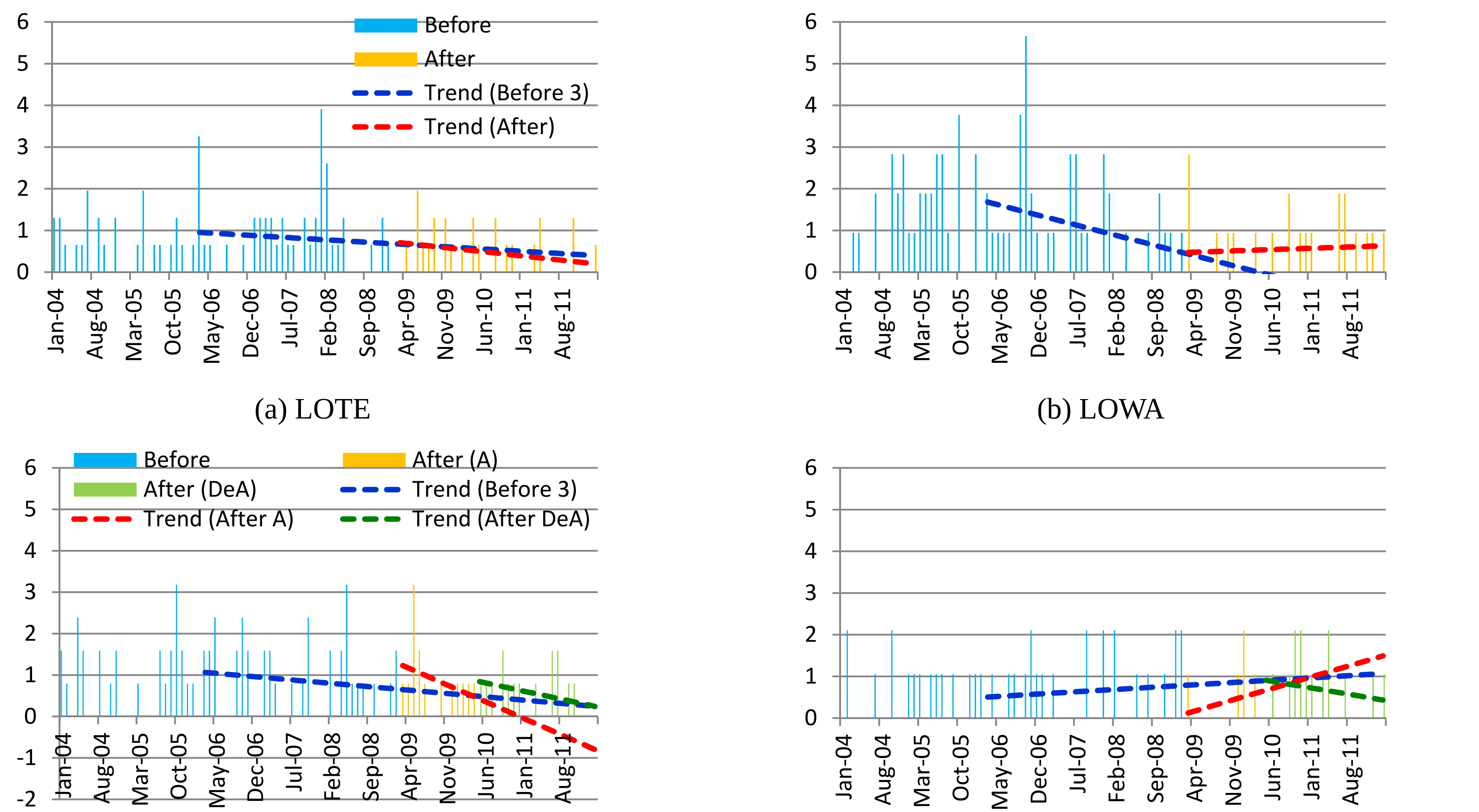


(e) SOSP



(f) VAAD

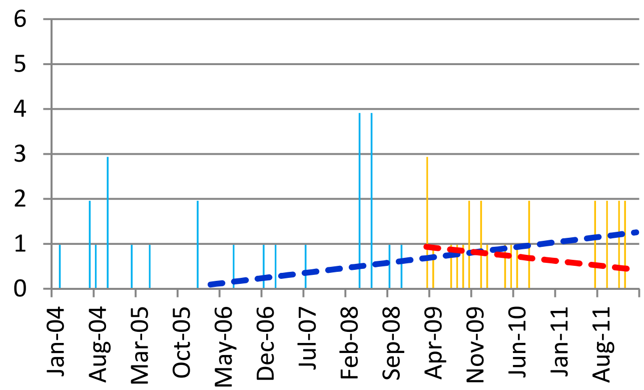
Figure C2. Total Crash Rate at Control Intersections ***(continued)***



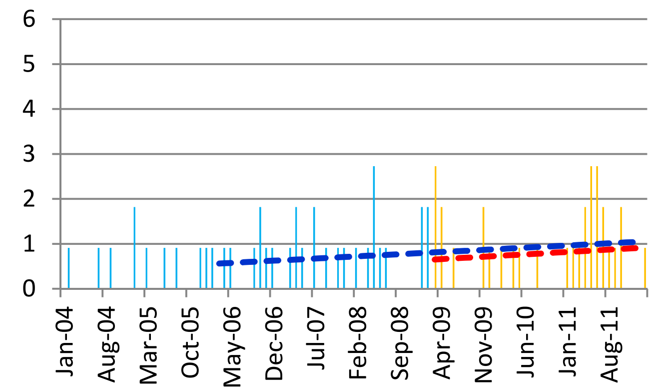
(a) LOTE (b) LOWA

(c) MASO (d) VAAM

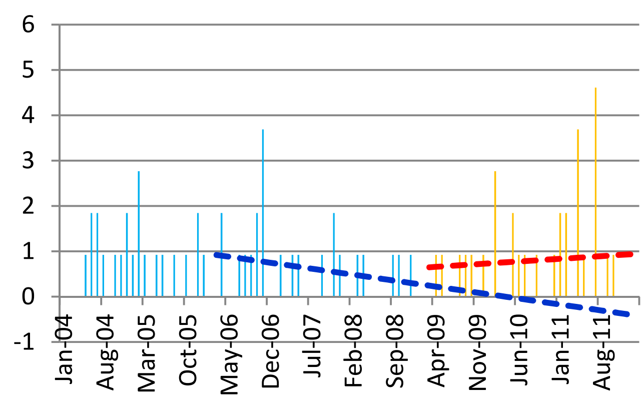
Figure C3. Angle Crash rate at Camera Intersections



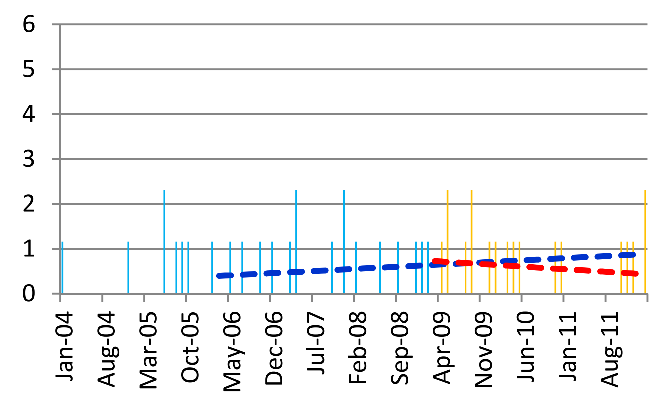
(a) ELMA



(b) PIMA

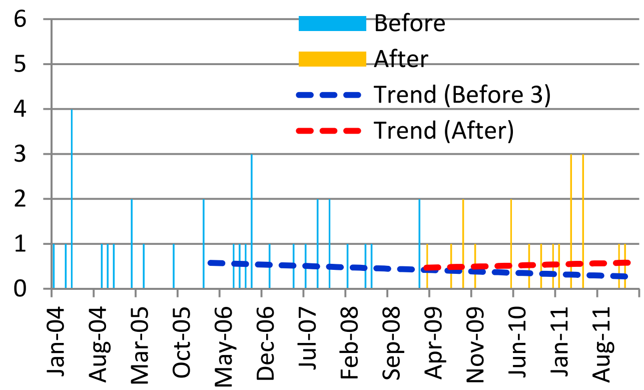


(c) PIVA

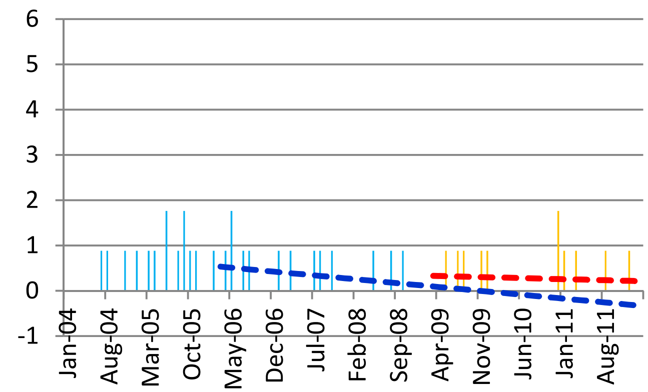


(d) SOMI

Figure C4. Angle collisions rate at Control Intersections



(e) SOSP



(f) VAAD

Figure C4. Angle collisions rate at Control Intersection ***(Continued)***

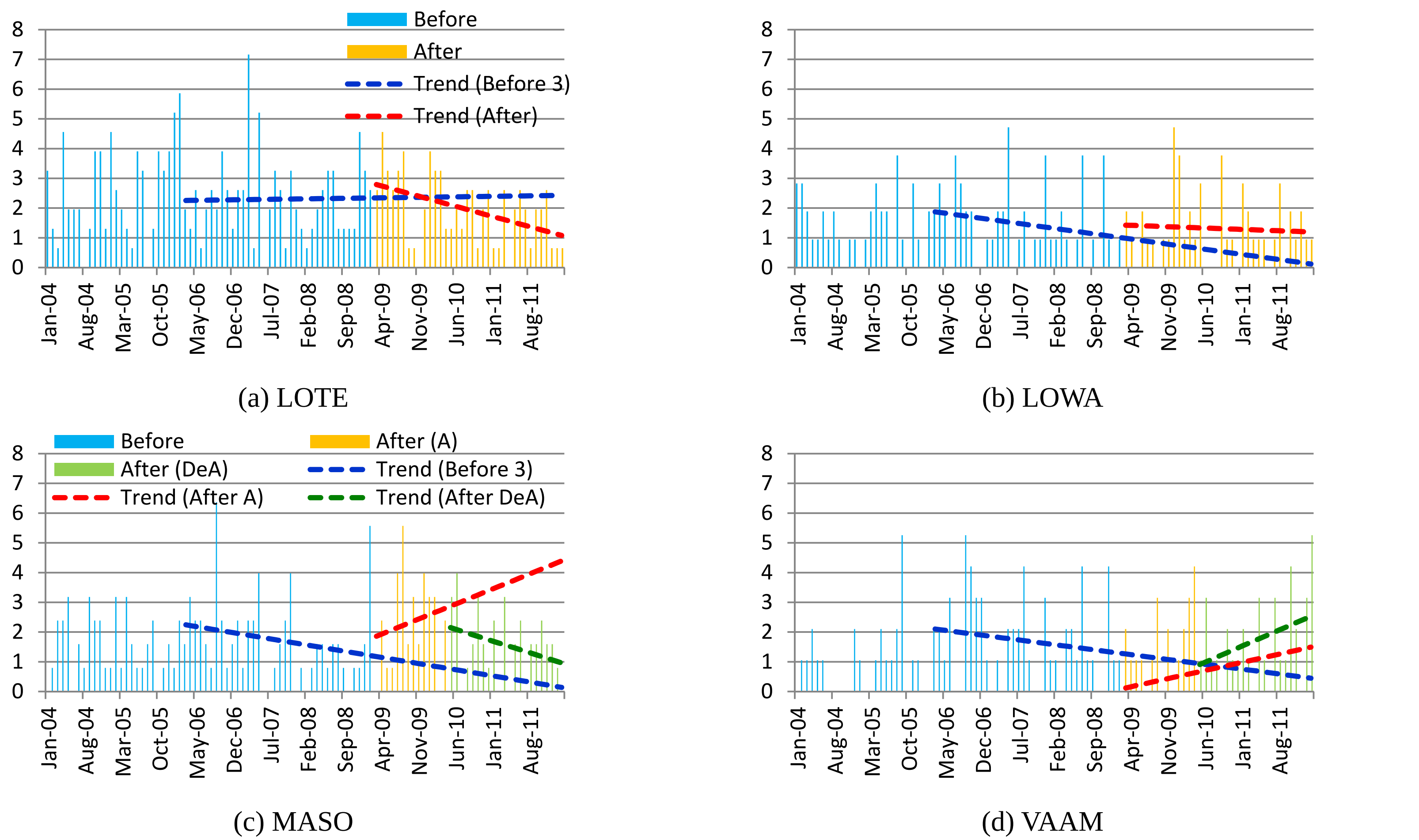
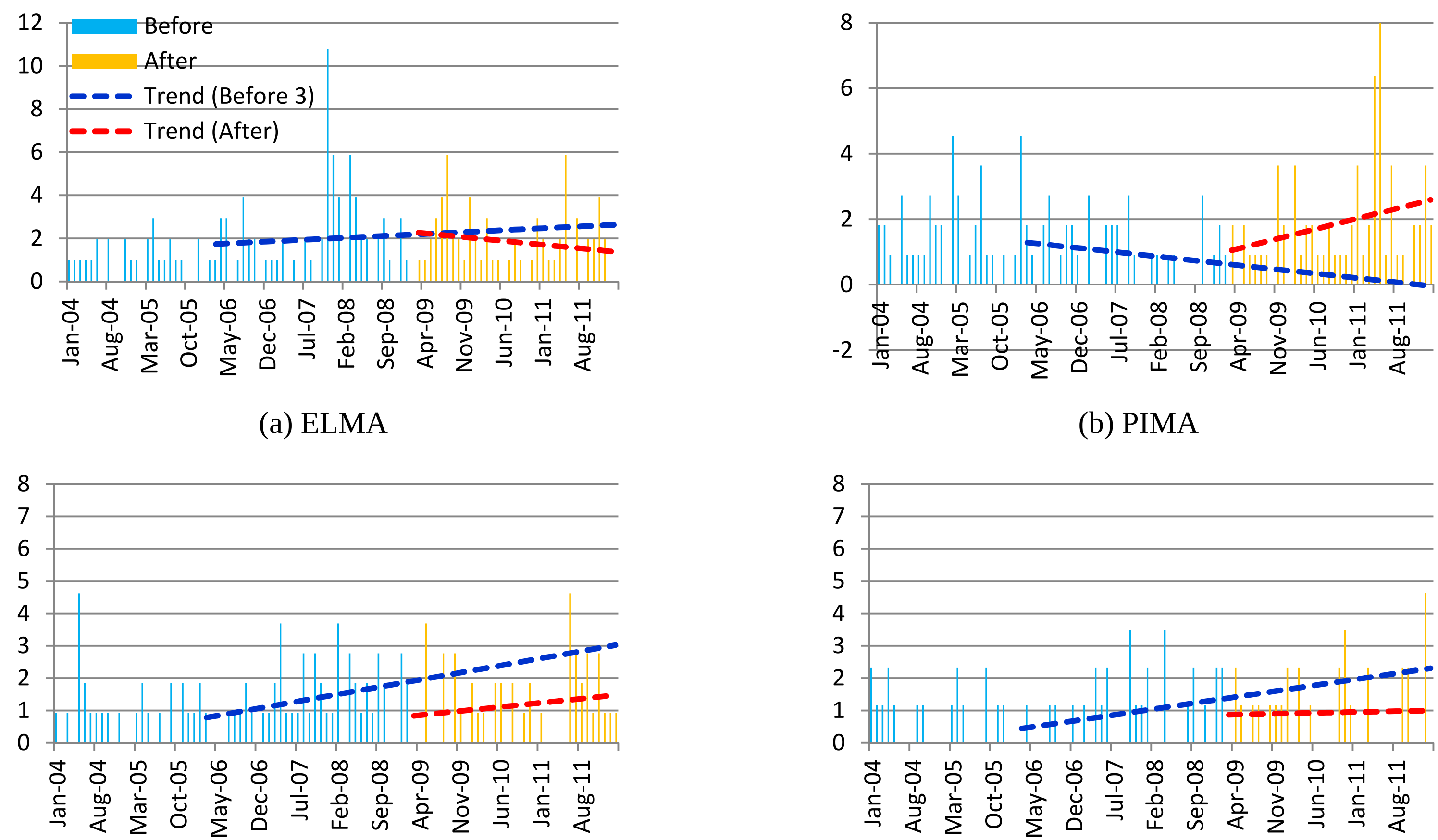


Figure C5. Rear-end Crash rate at Camera Intersections



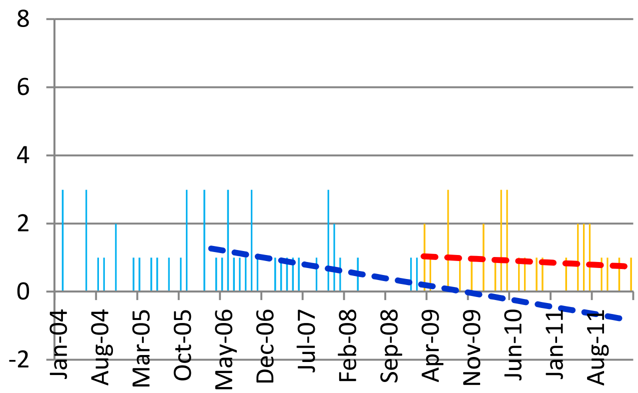
(a) ELMA

(b) PIMA

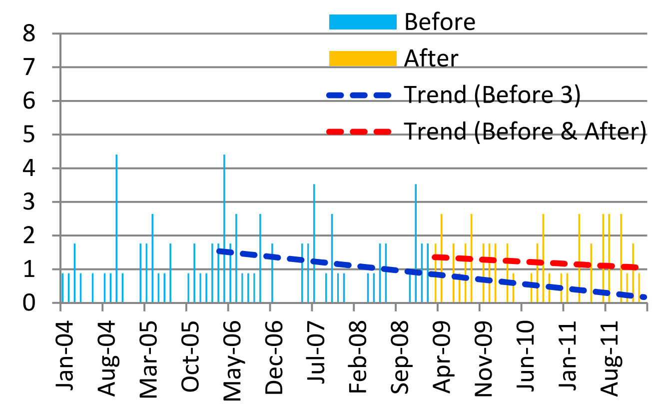
(c) PIVA

(d) SOMI

Figure C6. Rear-end collisions rate at Control Intersections

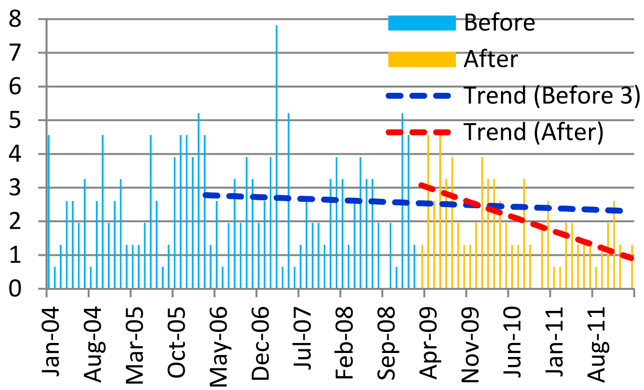


(e) SOSP

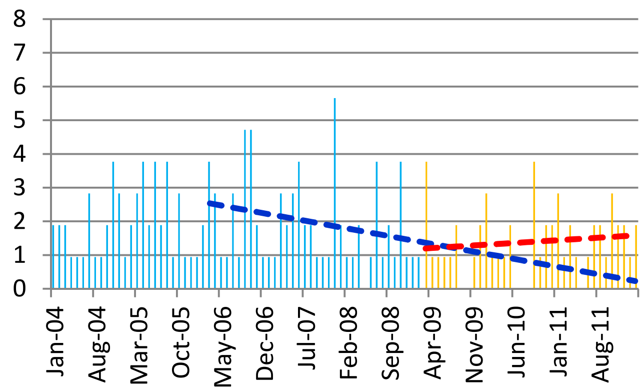


(f) VAAD

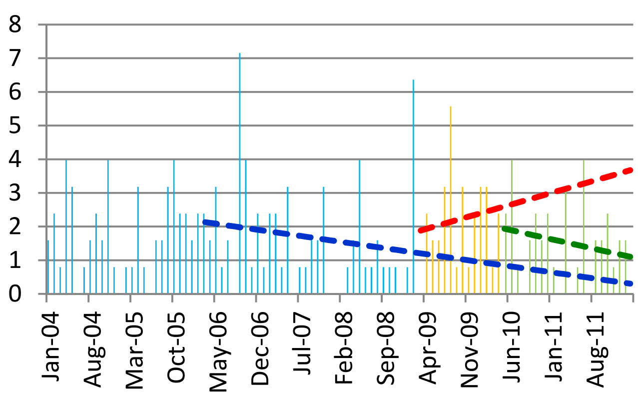
Figure C6. Rear-end collisions rate at Control Intersections ***(continued)***



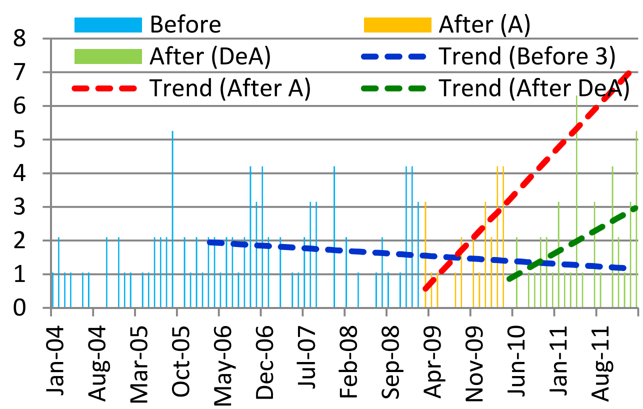
(a) LOTE



(b) LOWA

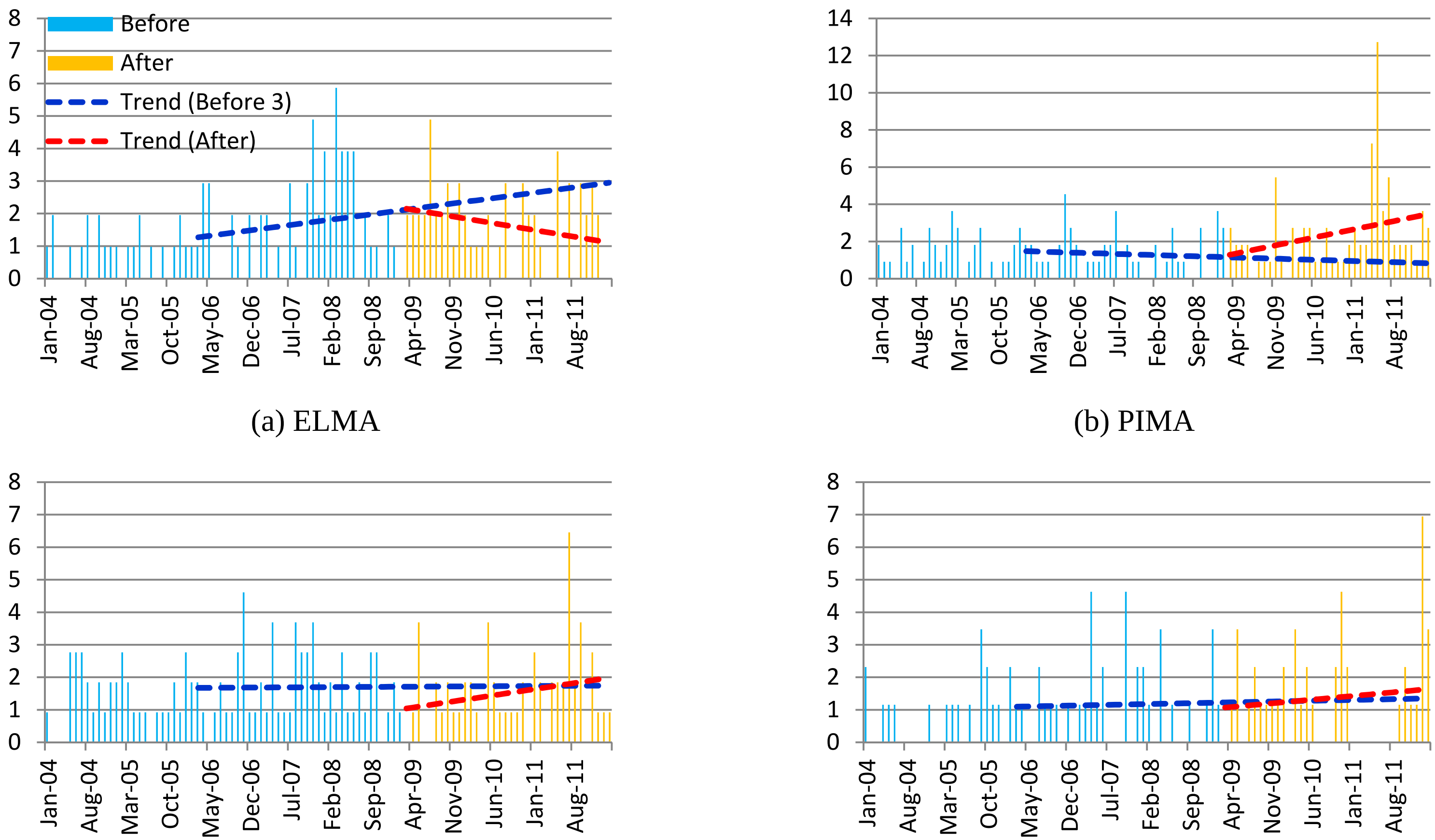


(c) MASO



(d) VAAM

Figure C7. Property-Damage-Only Crash rate at Camera Intersections



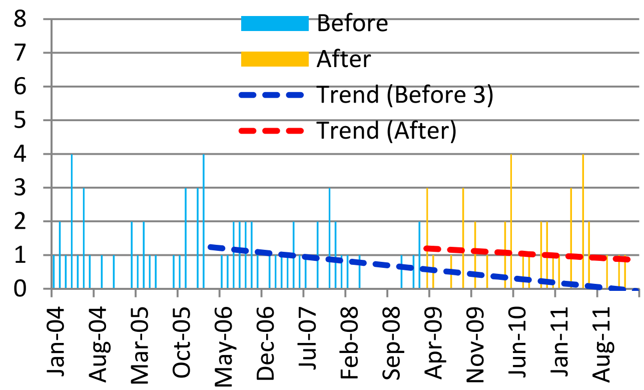
(a) ELMA

(b) PIMA

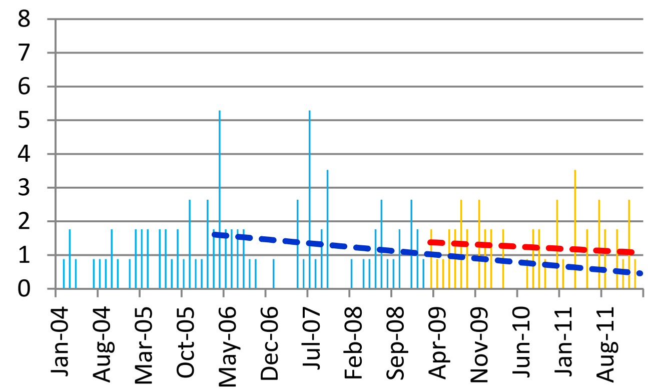
(c) PIVA

(d) SOMI

Figure C8. Property-Damage-Only collisions rate at Control Intersections

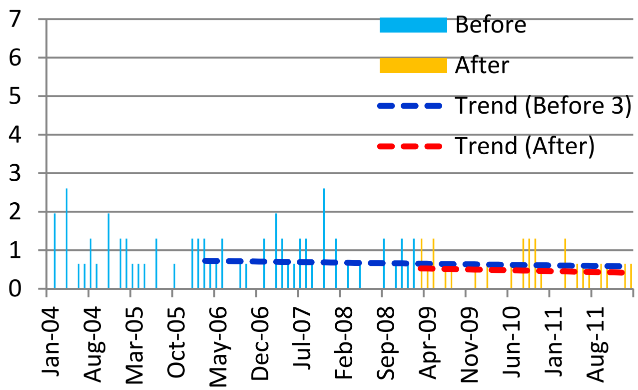


(e) SOSP

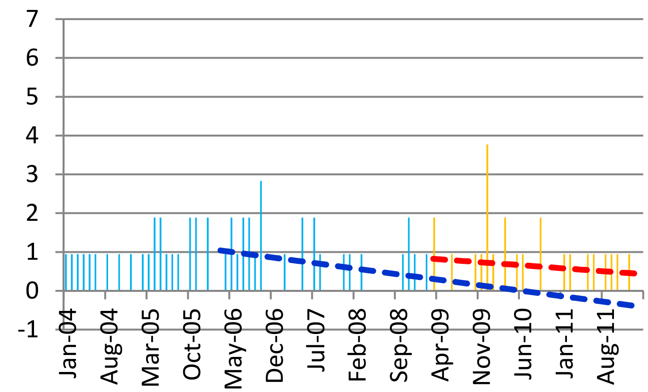


(f) VAAD

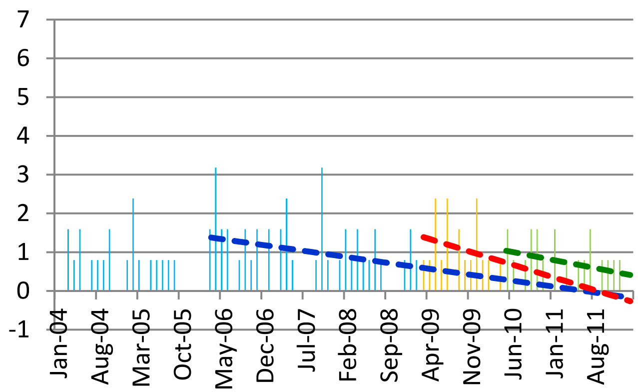
Figure C8. Property-Damage-Only collisions rate at Control Intersections ***(continued)***



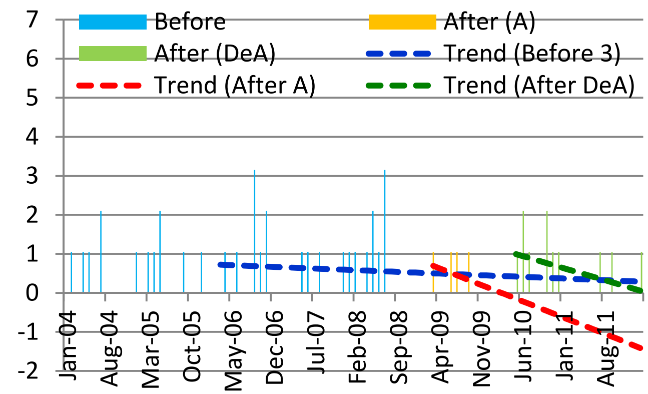
(a) LOTE



(b) LOWA

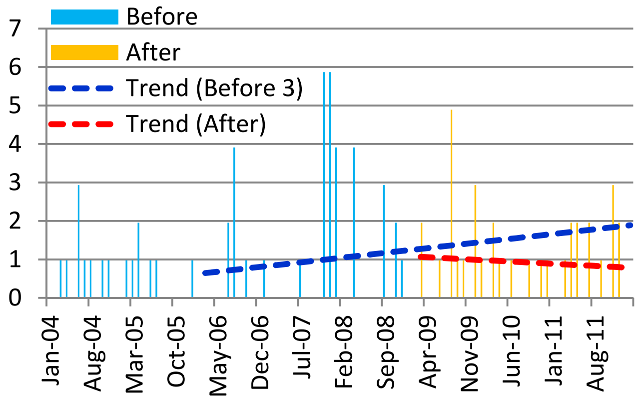


(c) MASO

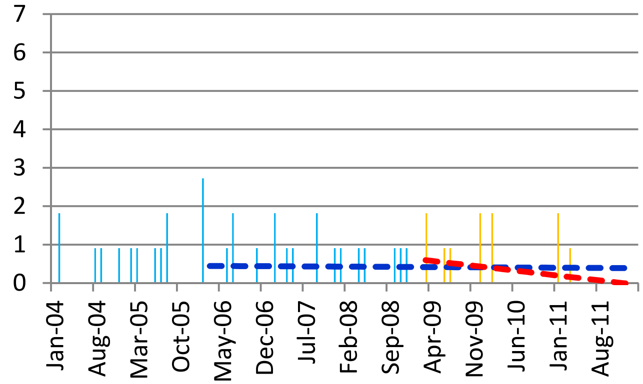


(d) VAAM

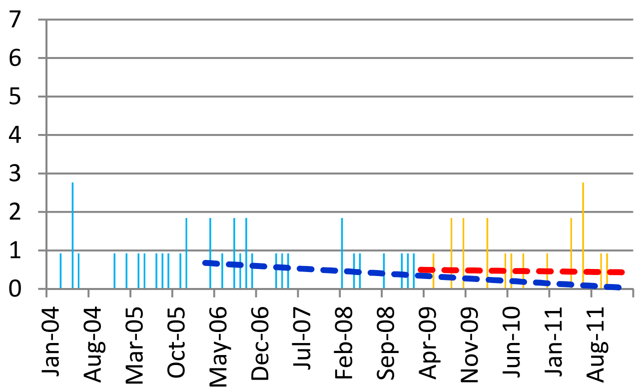
Figure C9. Injury Crash rate at Camera Intersections



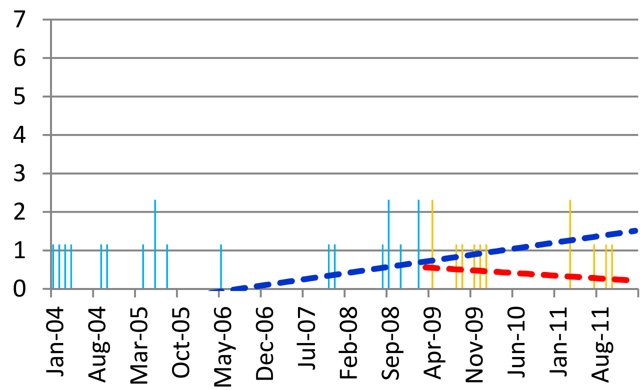
(a) ELMA



(b) PIMA

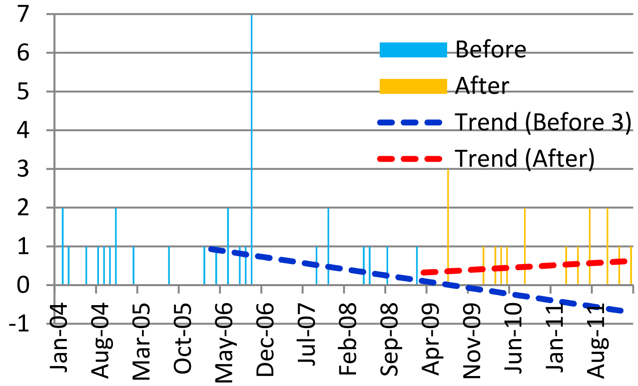


(c) PIVA

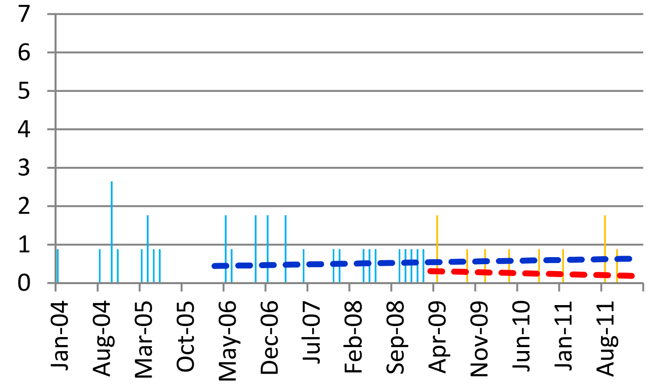


(d) SOMI

Figure C10. Injury Crash rate at Control Intersections

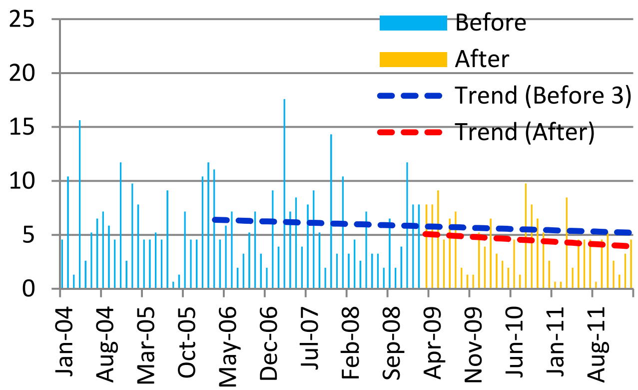


(e) SOSP

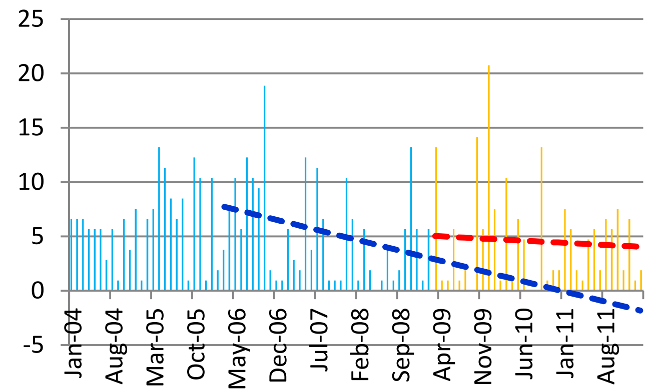


(f) VAAD

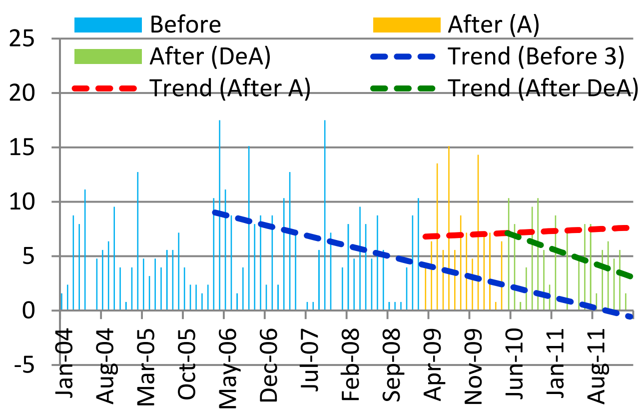
Figure C10. Injury Crash rate at Control Intersections ***(continued)***



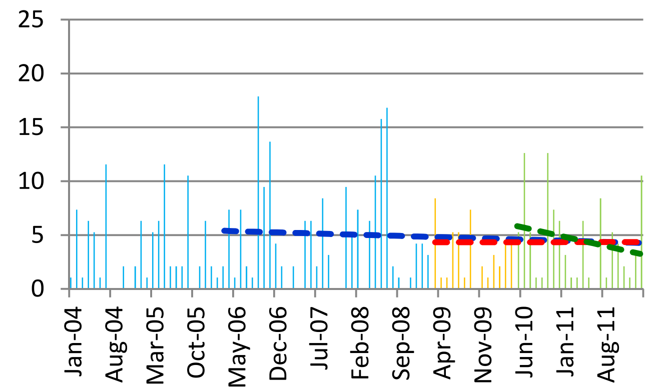
(a) LOTE



(b) LOWA

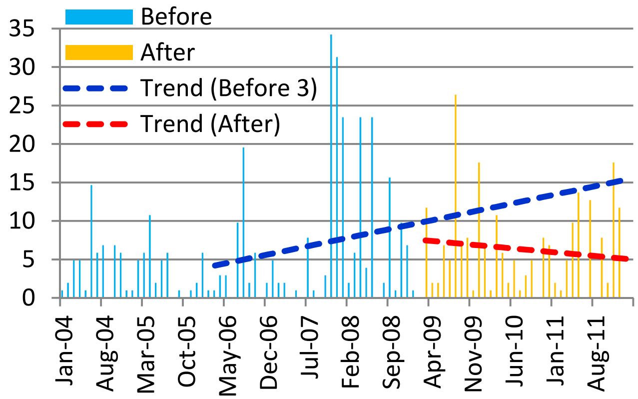


(c) MASO

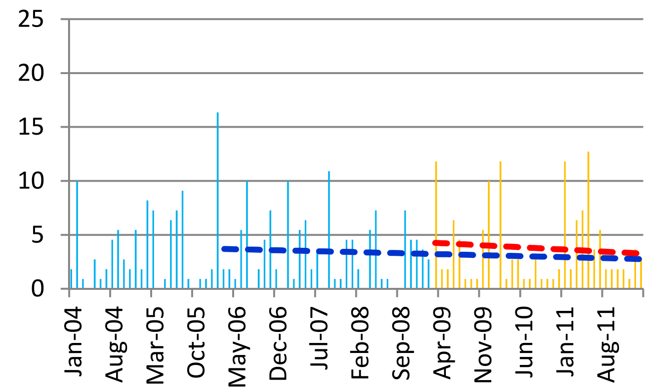


(d) VAAM

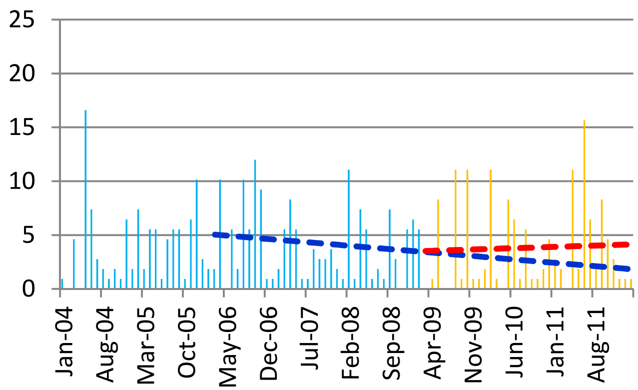
Figure C11. Severity Index at Camera Intersections



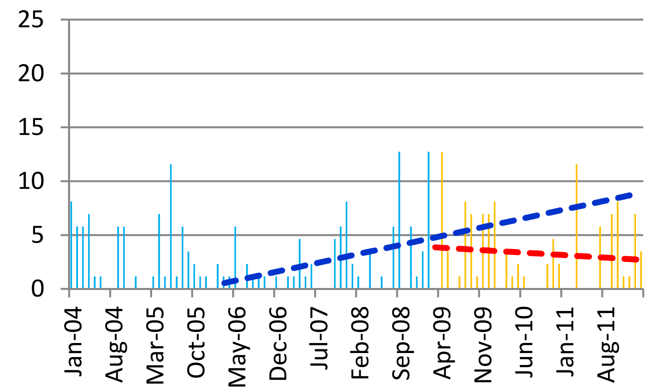
(a) ELMA



(b) PIMA

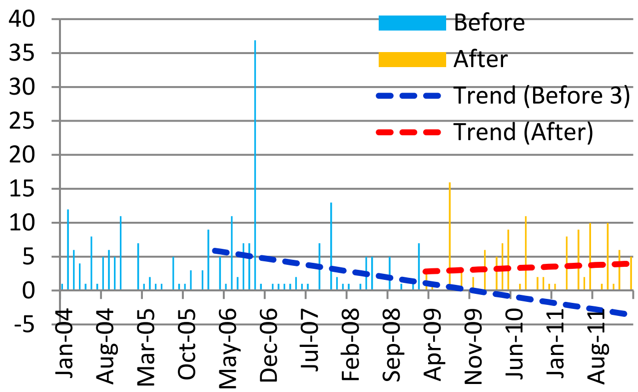


(c) PIVA

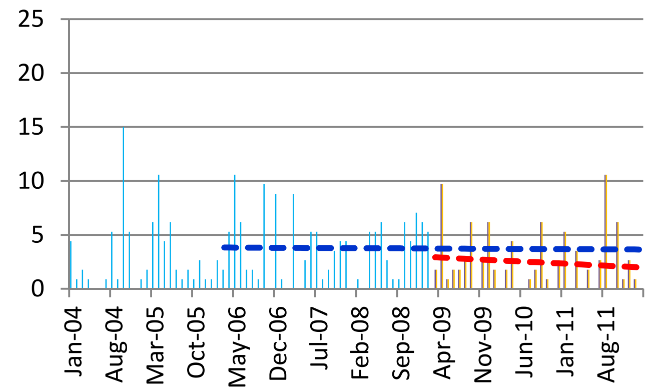


(d) SOMI

Figure C12. Severity Index rate at Control Intersections

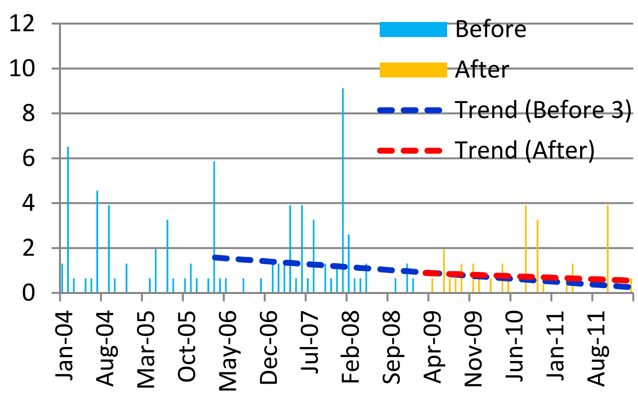


(e) SOSP

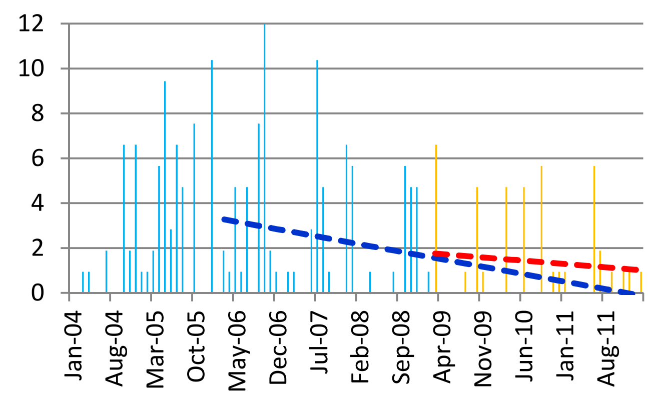


(f) VAAD

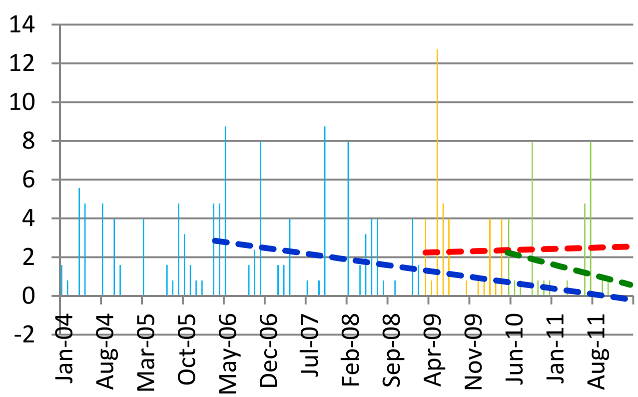
Figure C12. Severity Index rate at Control Intersections ***(continued)***



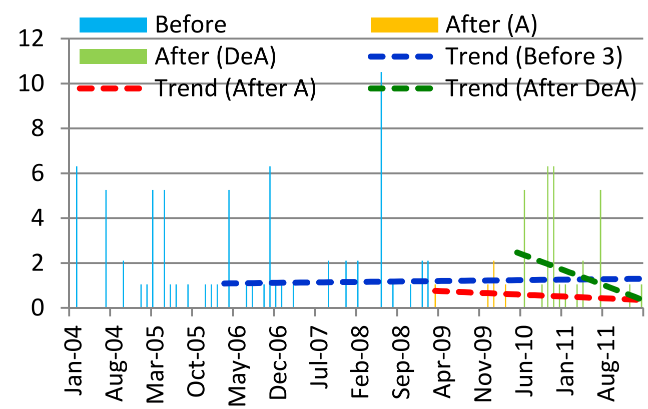
(a) LOTE



(b) LOWA

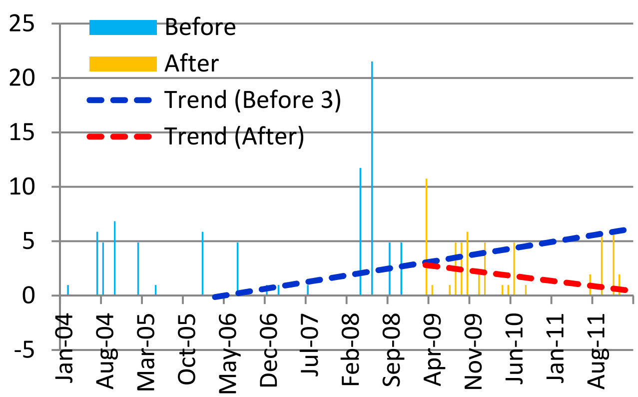


(c) MASO

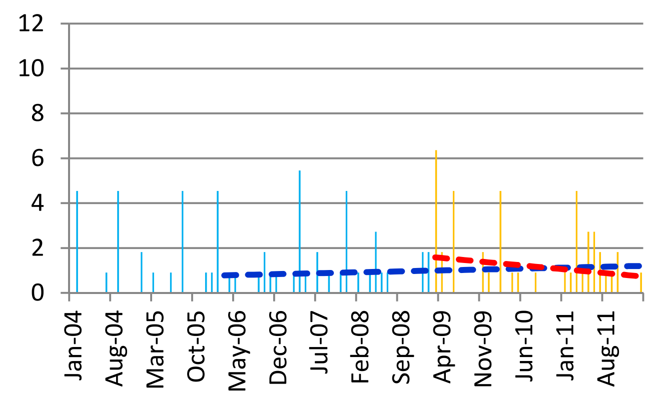


(d) VAAM

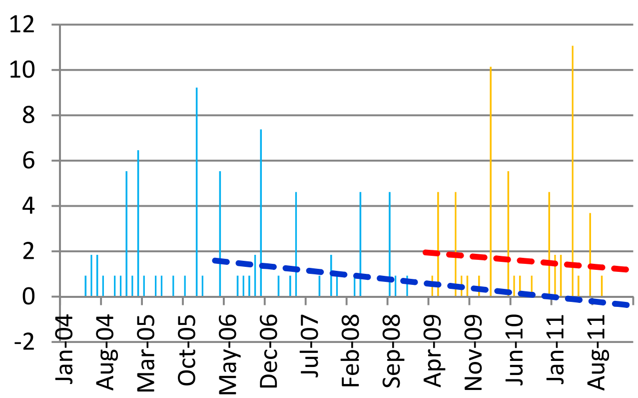
Figure C13. Severity Index rate for Angle Crash at Camera Intersections



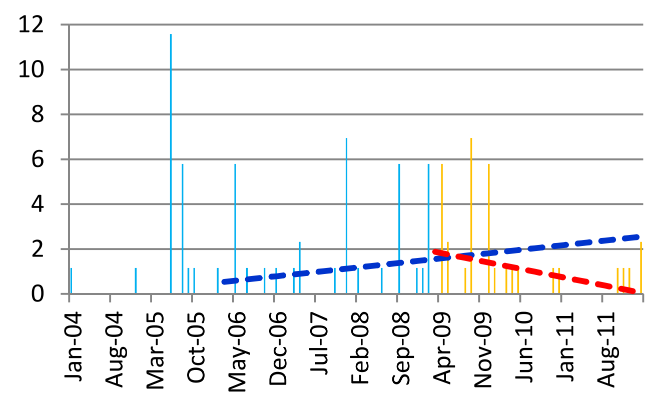
(a) ELMA



(b) PIMA

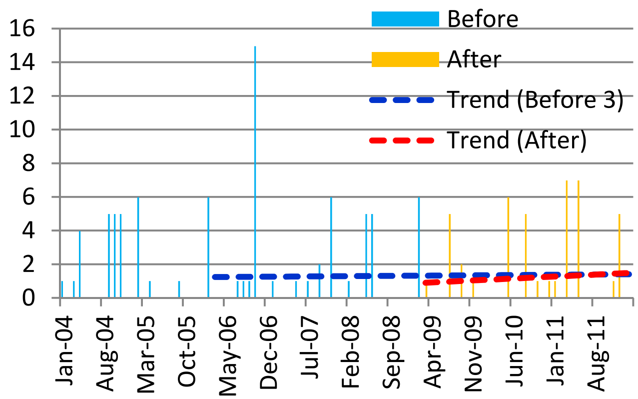


(c) PIVA

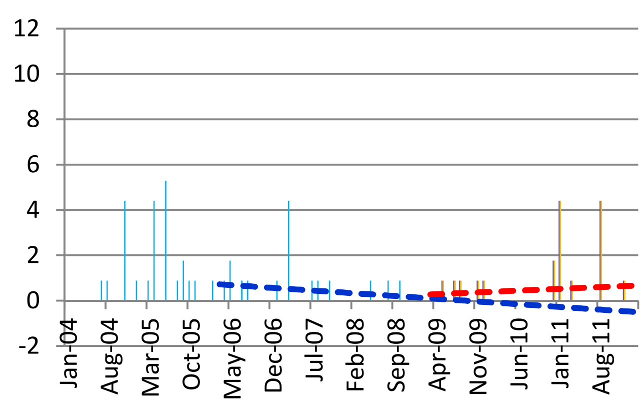


(d) SOMI

Figure C14. Severity Index rate for Angle Crash at Control Intersections

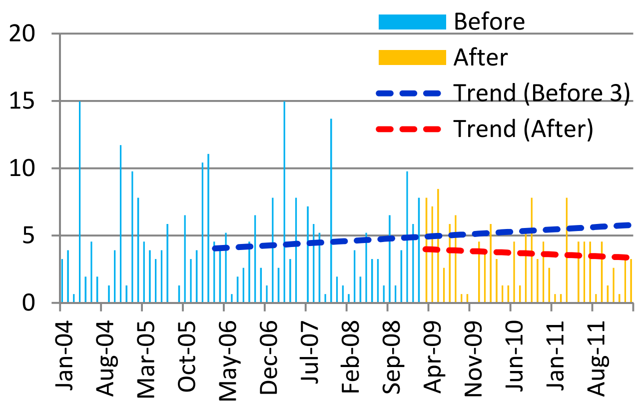


(e) SOSP

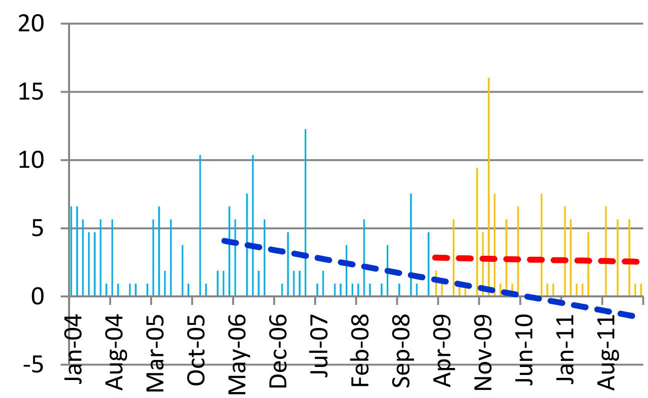


(f) VAAD

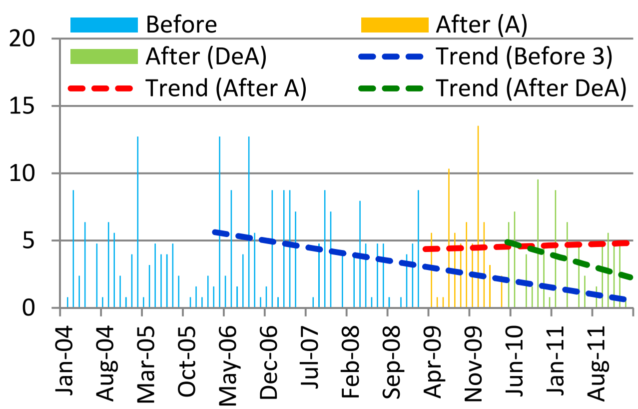
Figure C14. Severity Index rate for Angle Crash at Control Intersections ***(continued)***



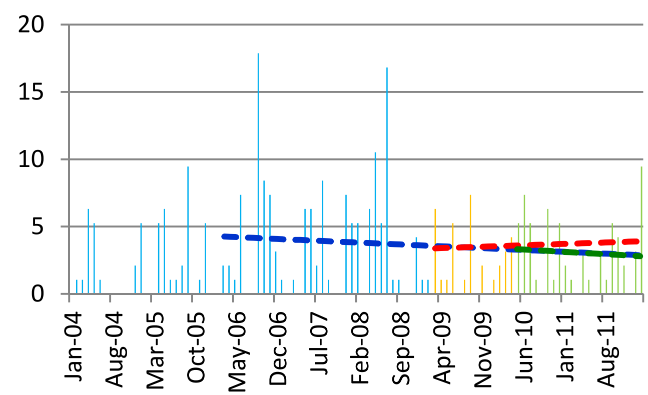
(a) LOTE



(b) LOWA



(c) MASO



(d) VAAM

Figure C15. Severity Index rate for Rear-end Crash at Camera Intersections

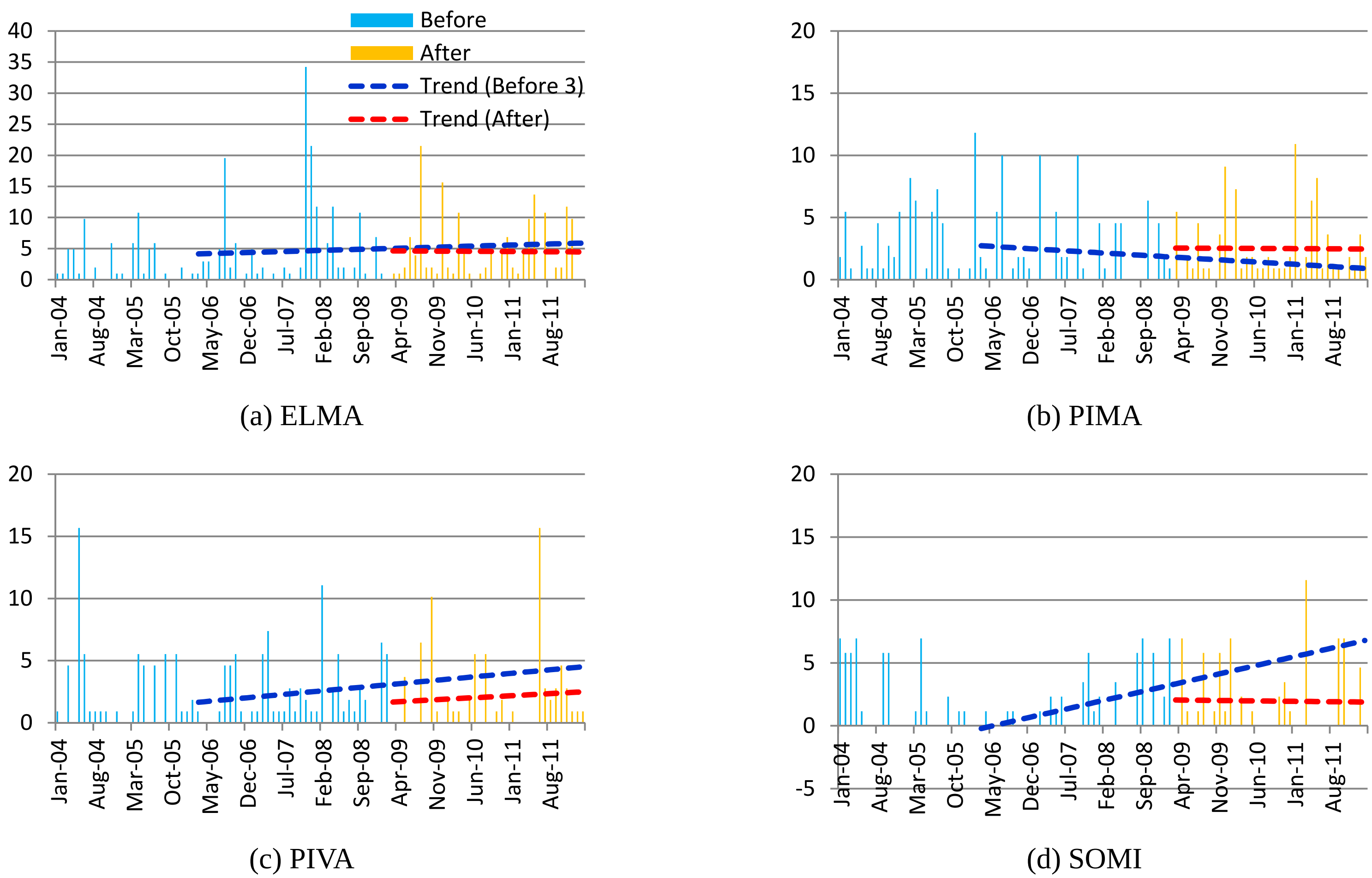
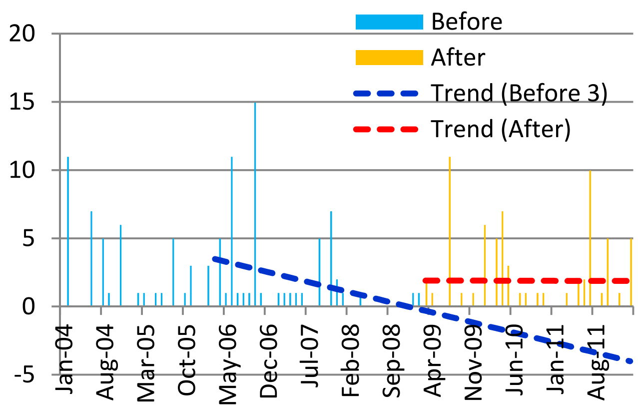
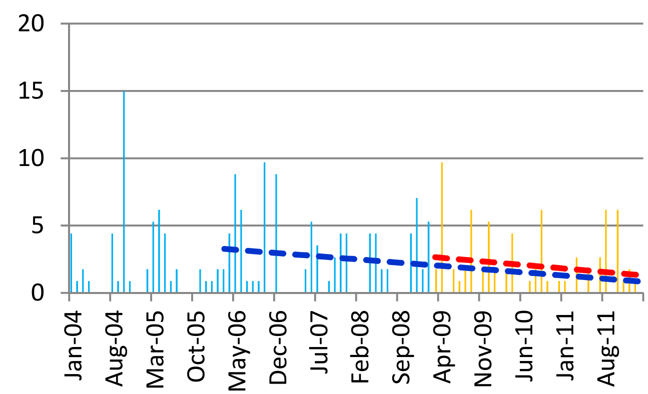


Figure C16. Severity Index rate for Rear-end Crash at Control Intersections



(e) SOSP



(f) VAAD

Figure C16. Severity Index rate for Rear-end Crash at Control Intersections ***(continued)***

APPENDIX D

Monthly Red-light Violations and Trends

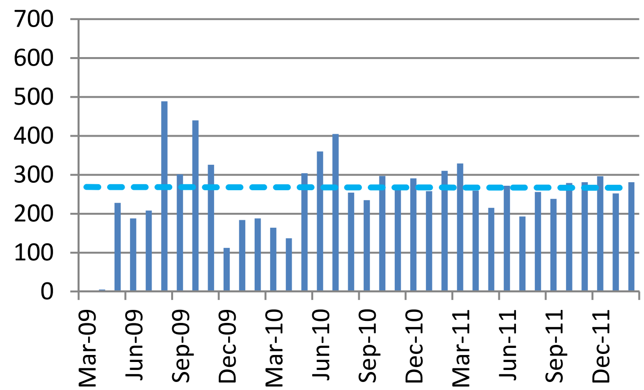


Figure D1. LOTE-EB

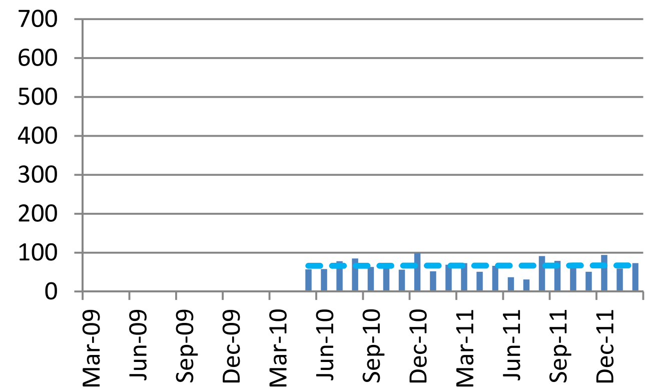


Figure D2. LOTE-WB

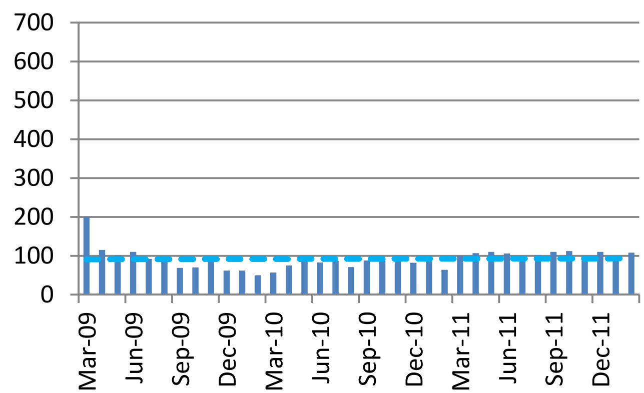


Figure D3. LOWA-EB

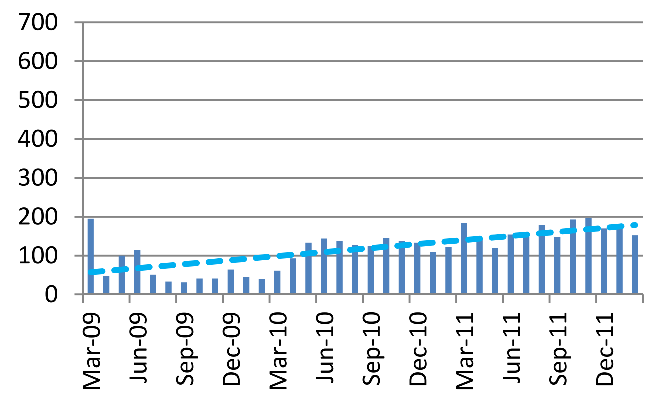


Figure D4. LOWA2-WB

Monthly Red-light Violations and Trends

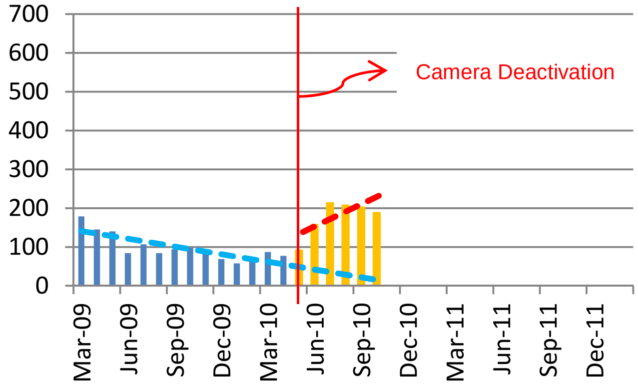


Figure D5. MASO1-WB

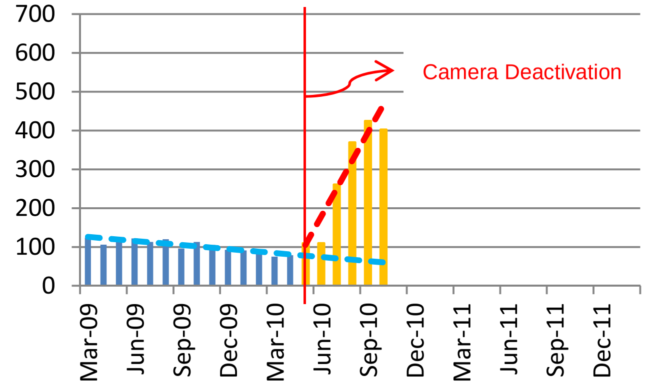


Figure D6. MASO-EB

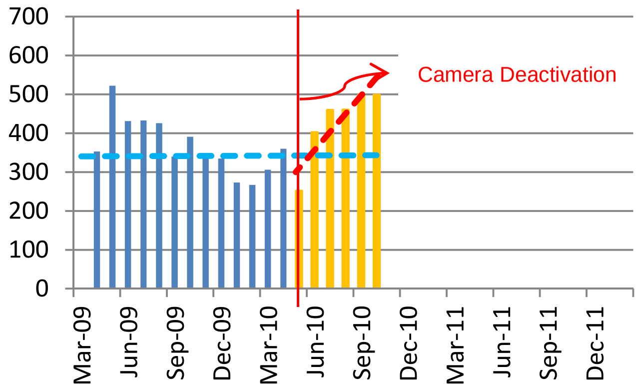


Figure D7. VAAM-SB

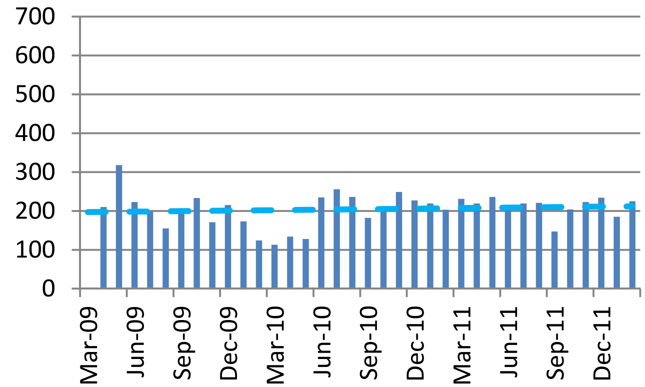


Figure D8. VAAM-NB

Monthly Red-light Violations and Trends

APPENDIX E

Red-light Violations based on Different Times of the Day

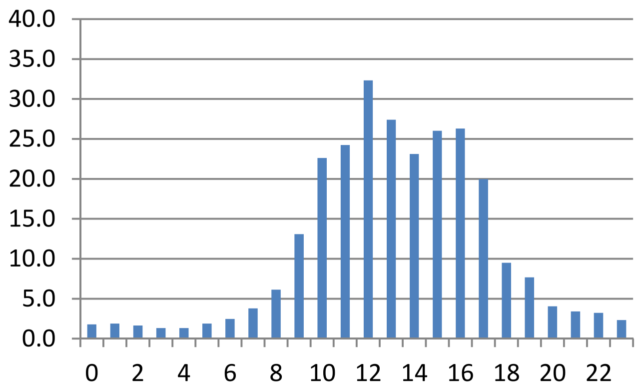


Figure E1. LOTE-EB

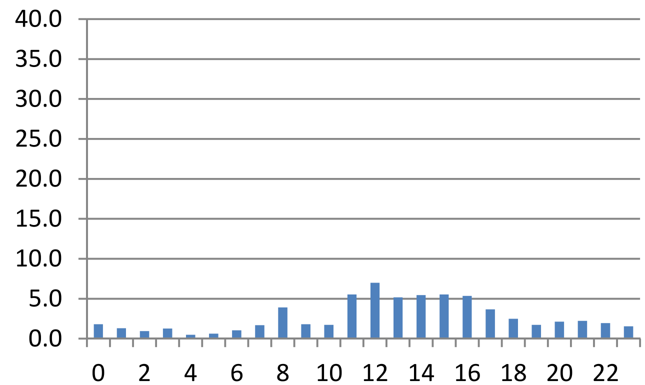


Figure E2. LOTE-WB

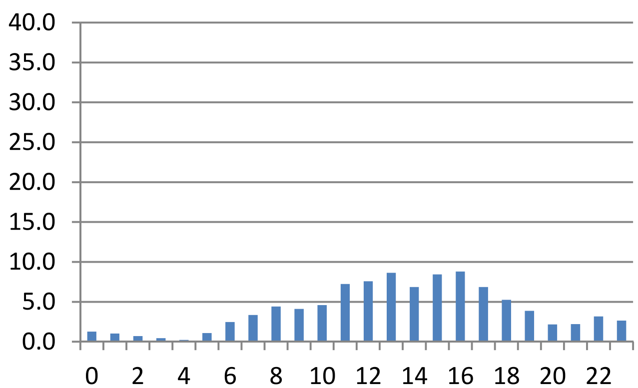


Figure E3. LOWA-EB

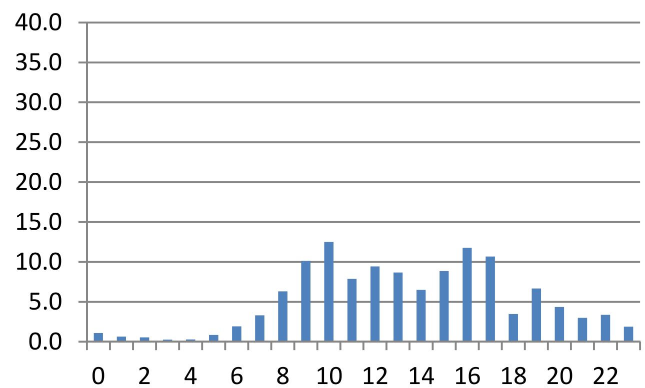


Figure E4. LOWA-WB

Red-light Violations based on Different Times of the Day

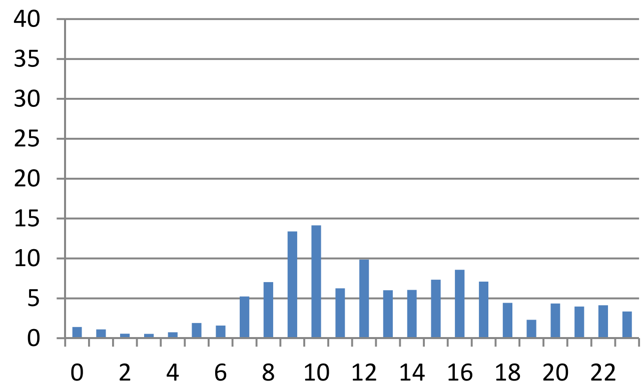


Figure E5. MASO-WB

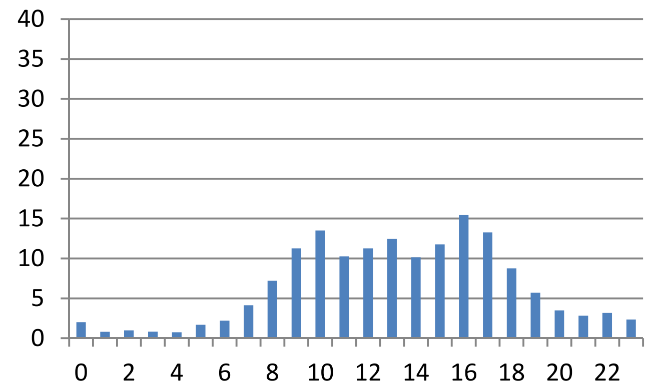


Figure E6. MASO-EB

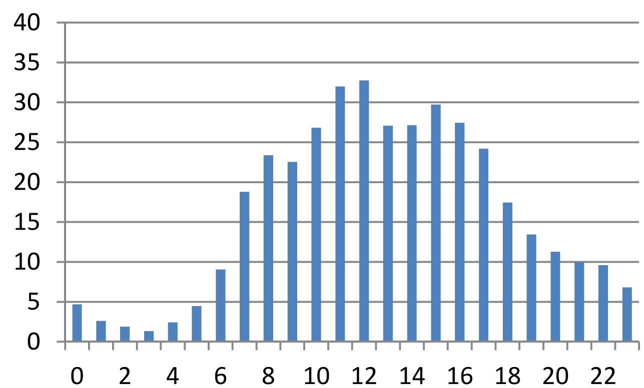


Figure E7. VAAM-SB

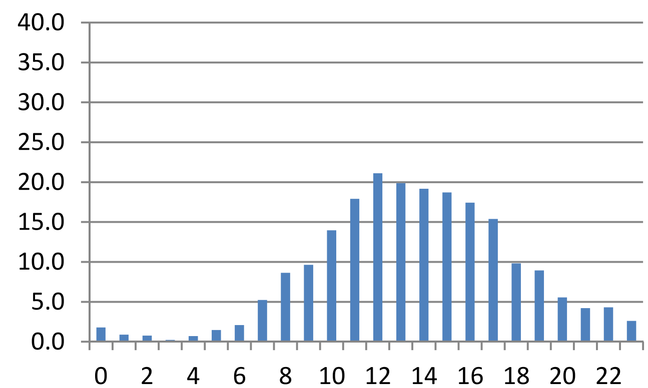


Figure E8. VAAM-NB

Red-light Violations based on Different Times of the Day

APPENDIX F

Red-light Violations based on the Days of the Week

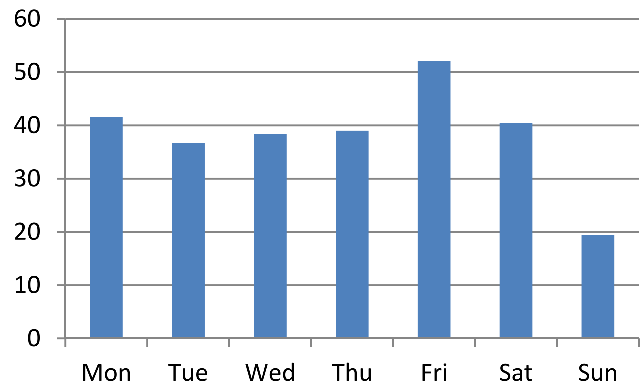


Figure F1. LOTE-EB

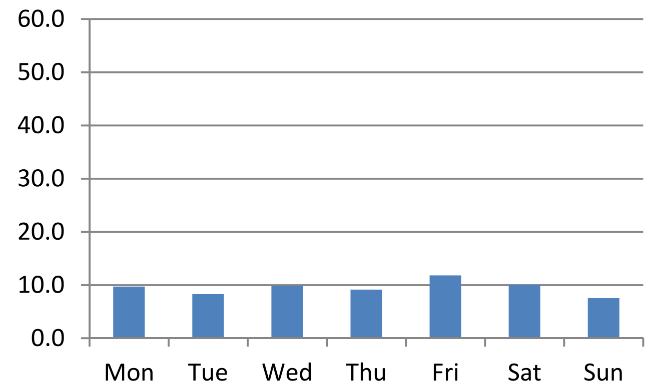


Figure F2. LOTE-WB

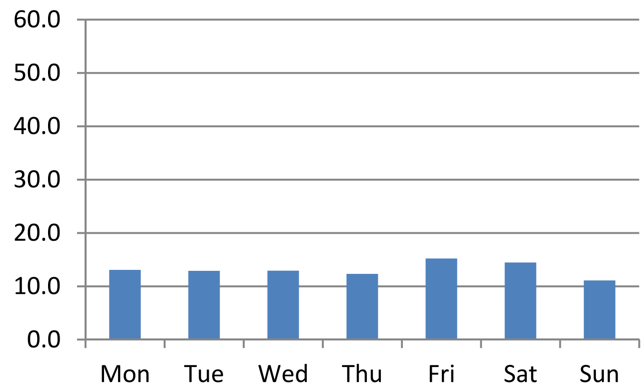


Figure F3. LOWA-EB

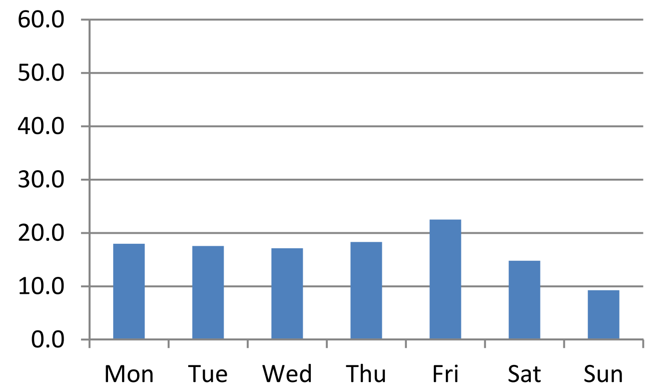


Figure F4. LOWA-WB

Red-light Violations based on the Days of the Week

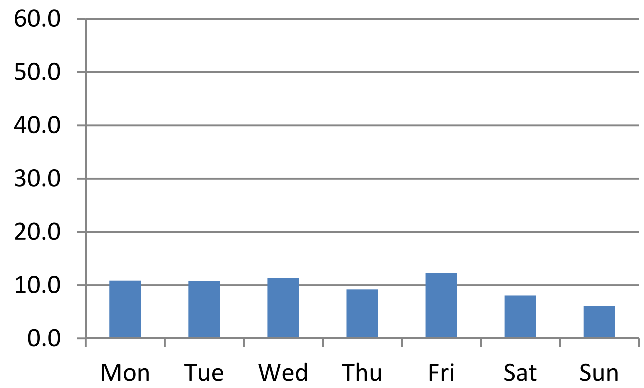


Figure F5. MASO-WB

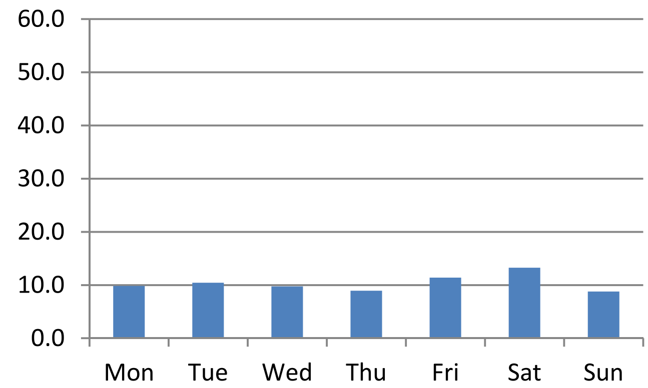


Figure F6. MASO-EB

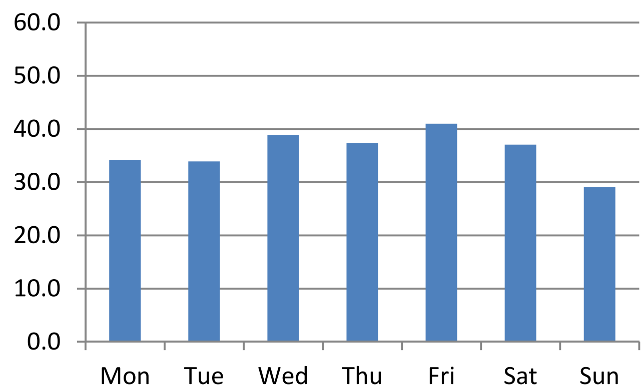


Figure F7. VAAM-SB

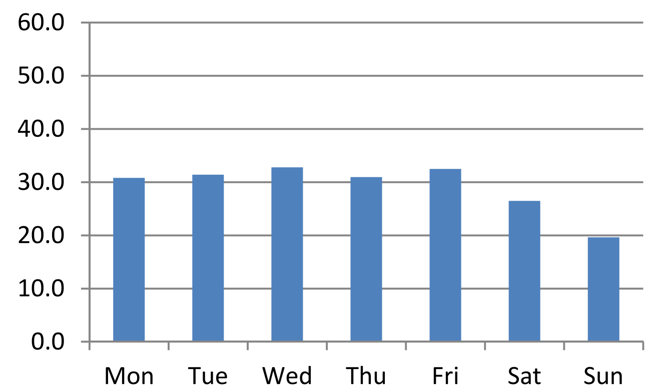


Figure F8. VAAM-NB

Red-light Violations based on the Days of the Week

APPENDIX G

Red-light Violations by Elapsed Time (sec.) since the Red Light

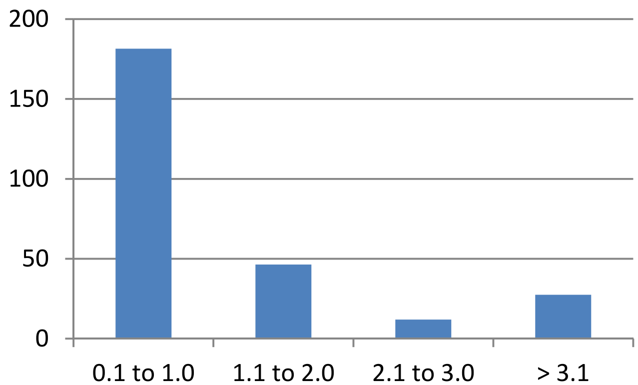


Figure G1. MASO-WB

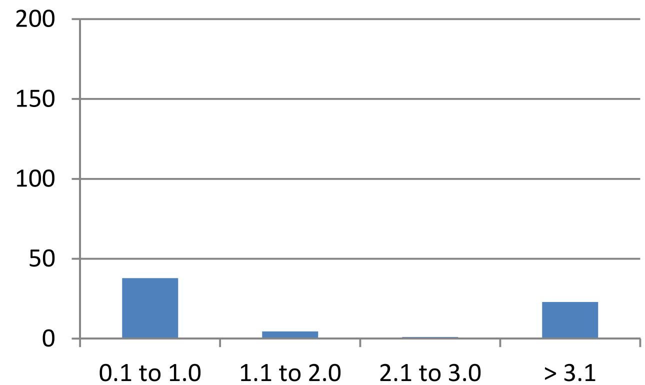


Figure G2. MASO-EB

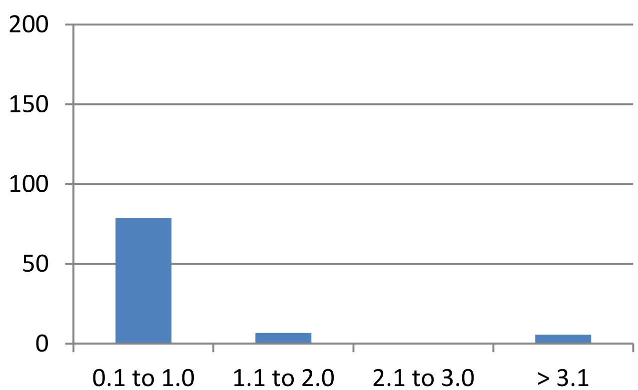


Figure G3. VAAM-SB

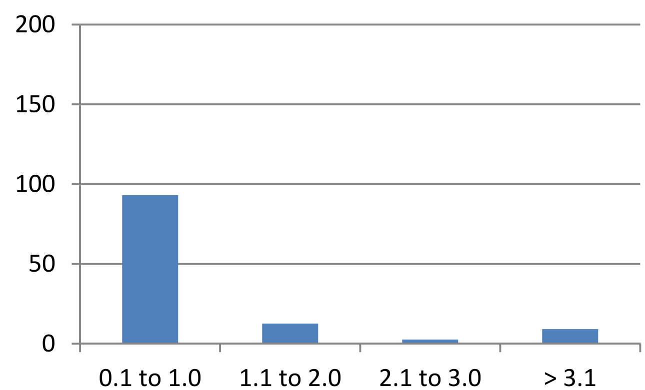


Figure G4. VAAM-NB

Red-light Violations by Elapsed Time (sec.) since the Red Light

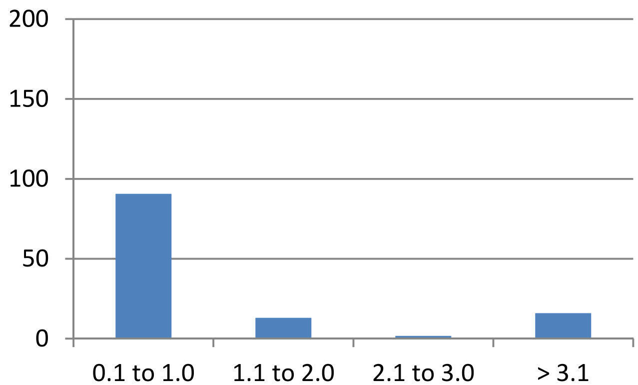


Figure G5. MASO-WB

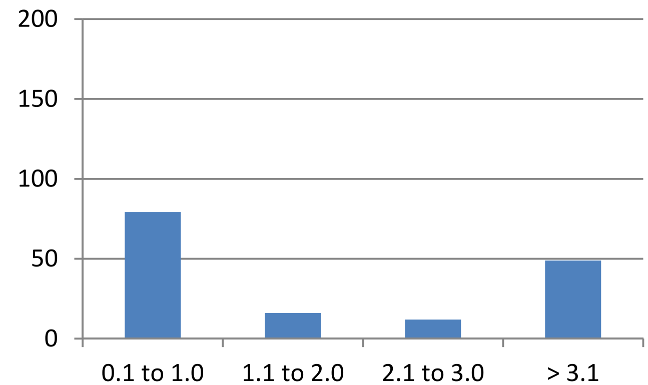


Figure G6. MASO-EB

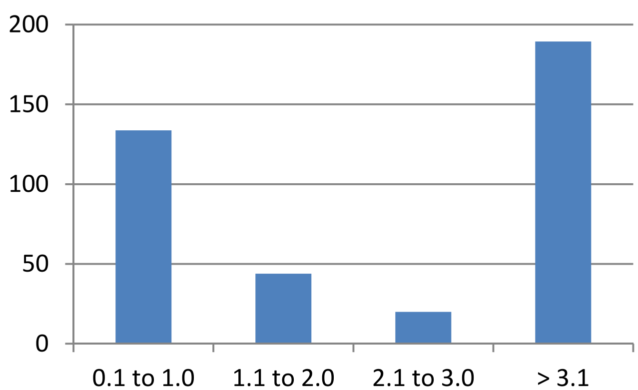


Figure G7. VAAM-SB

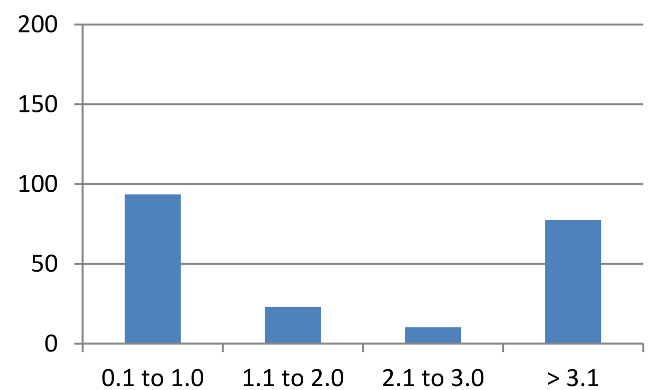


Figure G8. VAAM-NB

Red-light Violations by Elapsed Time (sec.) since the Red Light

APPENDIX H

Red-light Violations by Different Lanes of the Intersection

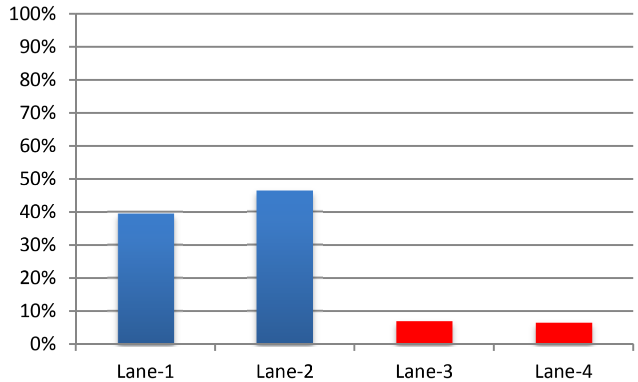


Figure H1. LOTE-EB

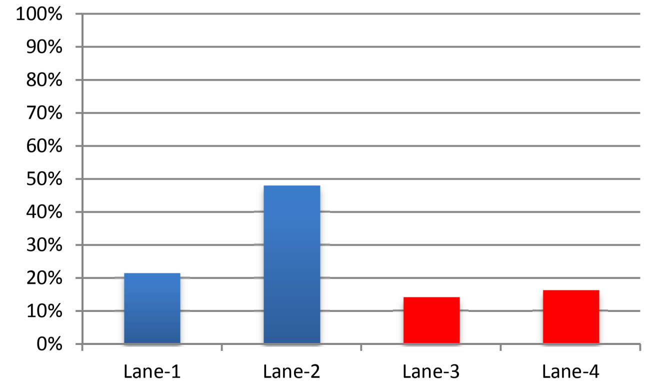


Figure H2. LOTE-WB

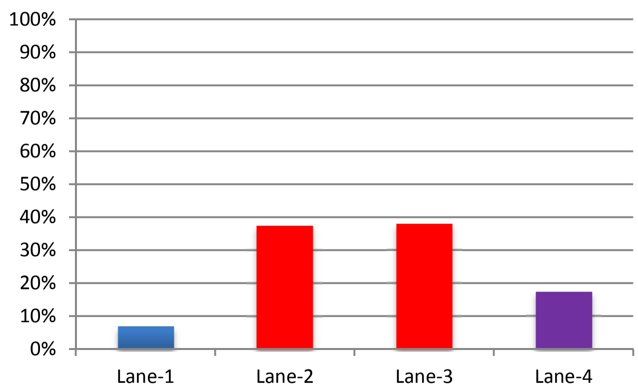


Figure H3. LOWA-EB

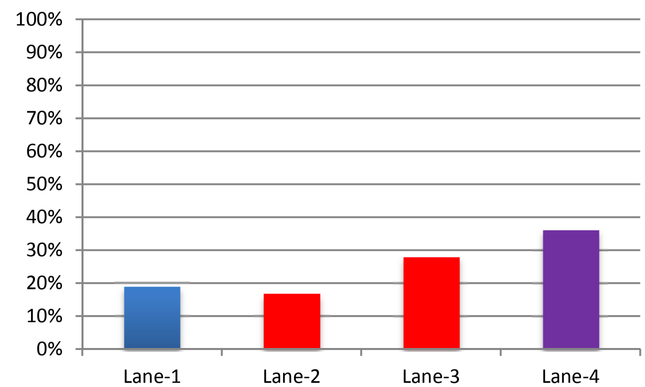


Figure H4. LOWA-WB

Red-light Violations by Different Lanes of the Intersection

● Left Turn Lane ● Thru Lane ● Right Turn Lane ● Thru & Right Turn Lane

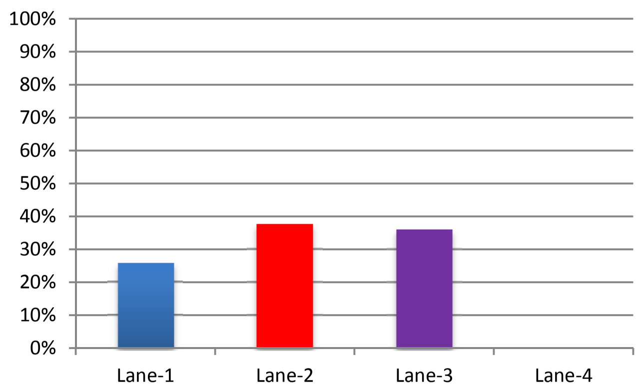


Figure H5. MASO-WB

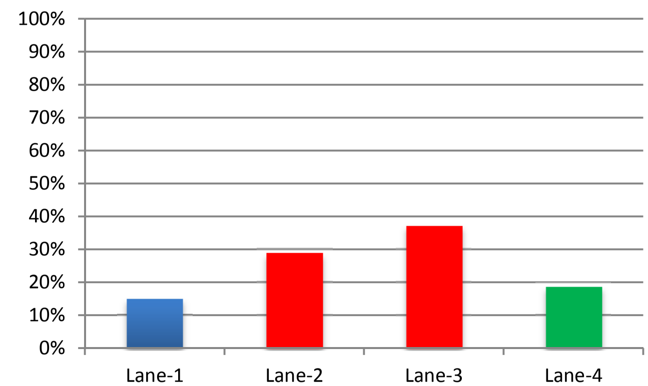


Figure H6. MASO-EB

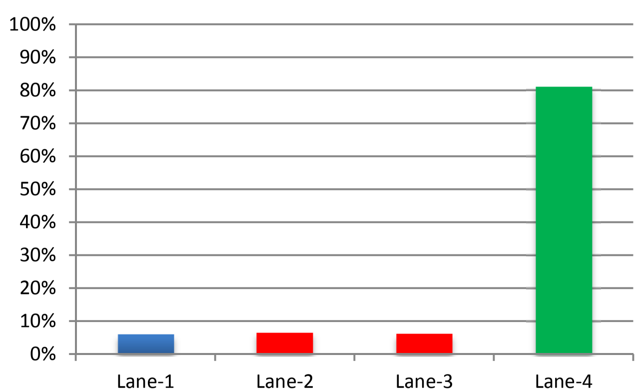


Figure H7. VAAM-SB

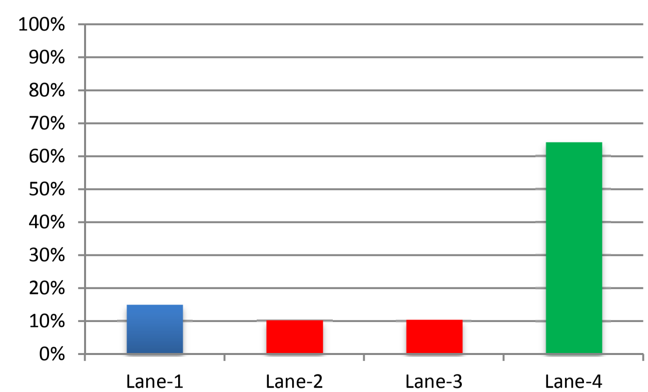


Figure H8. VAAM-NB

Red-light Violations by Different Lanes of the Intersection

● Left Turn Lane ● Thru Lane ● Right Turn Lane ● Thru & Right Turn Lane

APPENDIX I

Monthly Average Number of Speeding Violations

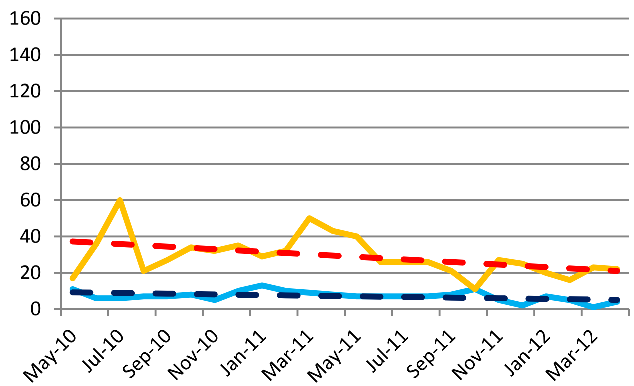


Figure I1. LOTE-EB

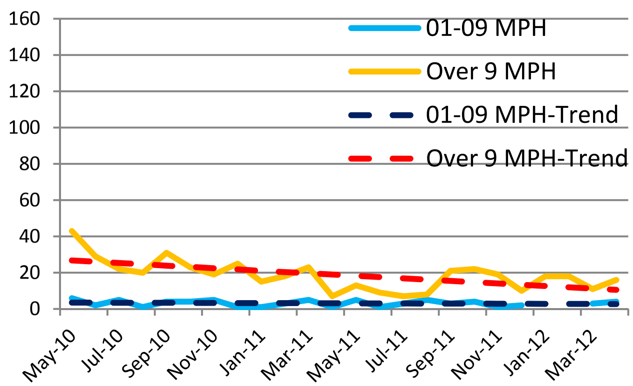


Figure I2. LOTE-WB

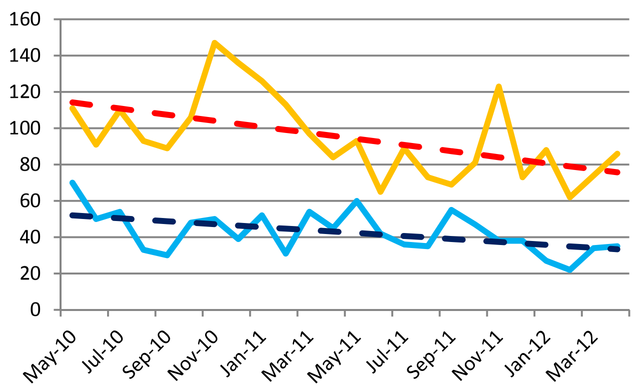


Figure I3. LOWA-EB

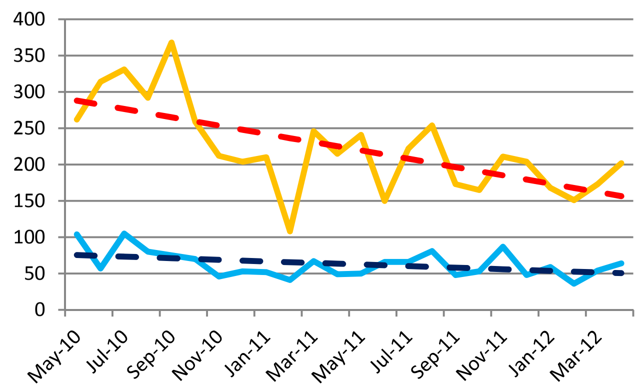


Figure I4. LOWA-WB

Monthly Average Number of Speeding Violations

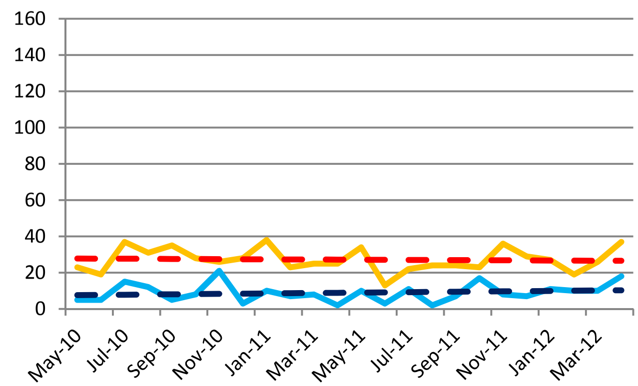


Figure I5. VAAM-NB

Monthly Average Number of Speeding Violations

01-09 MPH — Over 9 MPH — 01-09 MPH-Trend — Over 9 MPH-Trend

APPENDIX J

Monthly Average Speed of Vehicle at Time of Violation

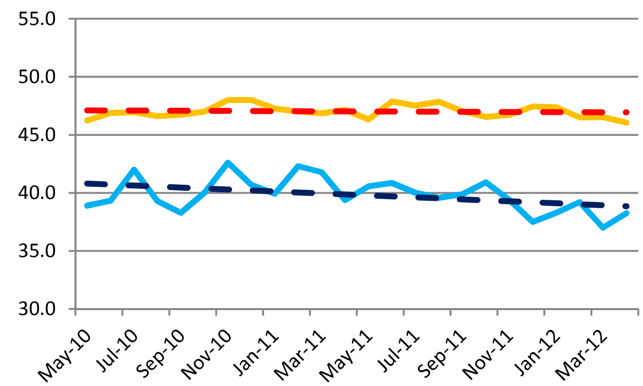


Figure J1. LOTE-EB

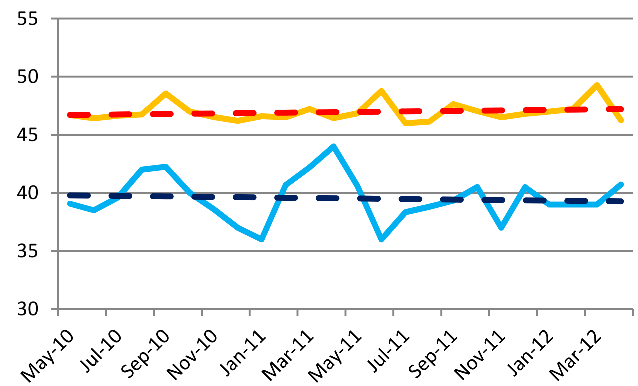


Figure J2. LOTE-WB

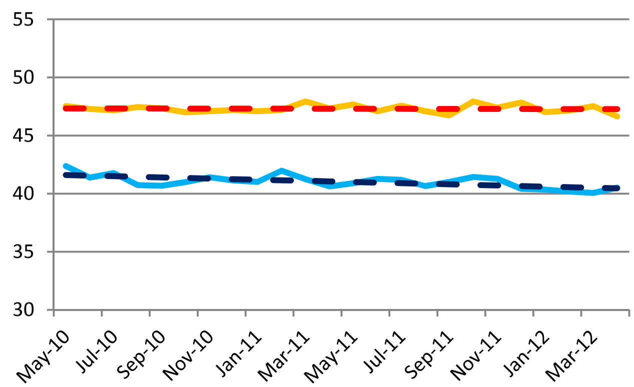


Figure J3. LOWA-EB

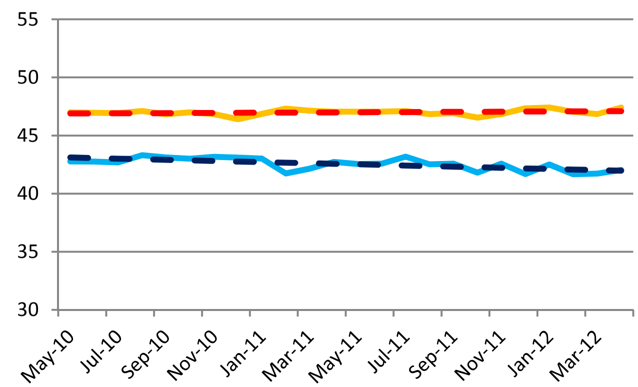


Figure J4. LOWA-WB

Monthly Average Speed of Vehicle at Time of Violation

Monthly Ave. Speed for 0-9 MPH — Trend for 0-9 MPH — Monthly Ave. Speed for Over 9 MPH — Trend for Over 9 MPH

Monthly Average Speed of Vehicle at Time of Violation

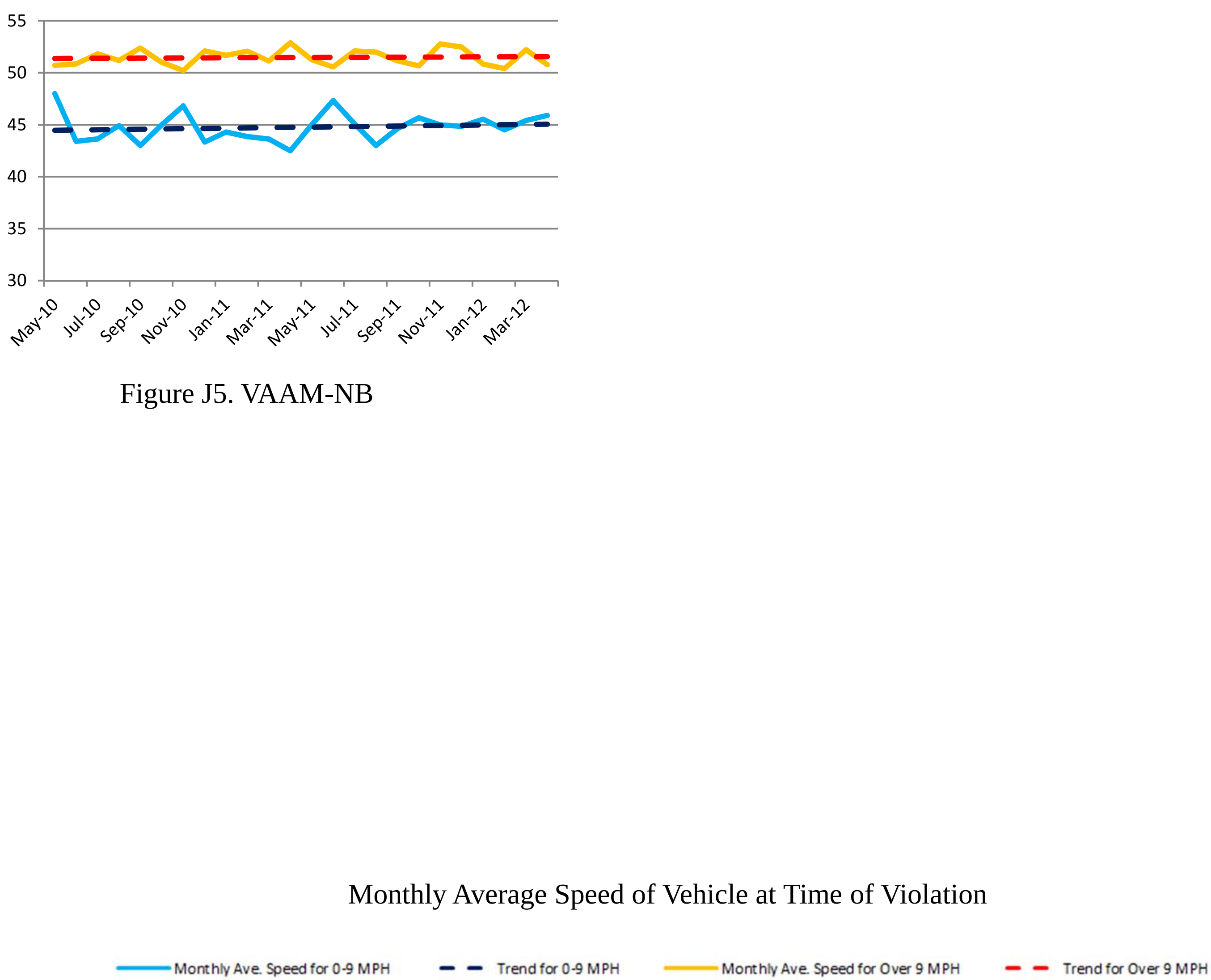


Figure J5. VAAM-NB

APPENDIX K

Monthly Speeding Violations by Different Lanes of the Intersection

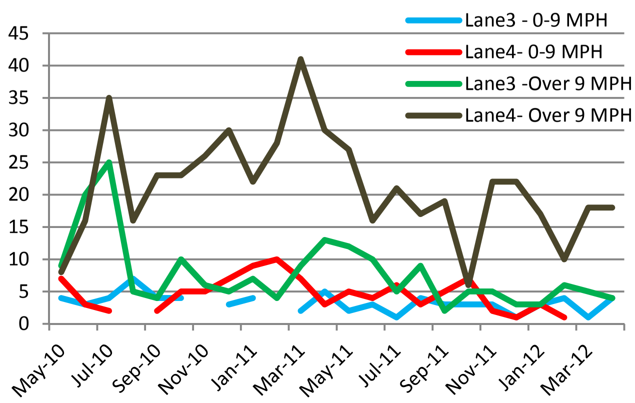


Figure K1. LOTE-EB

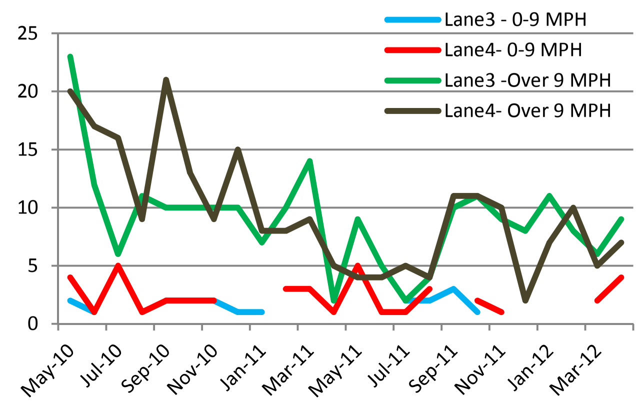


Figure K2. LOTE-WB

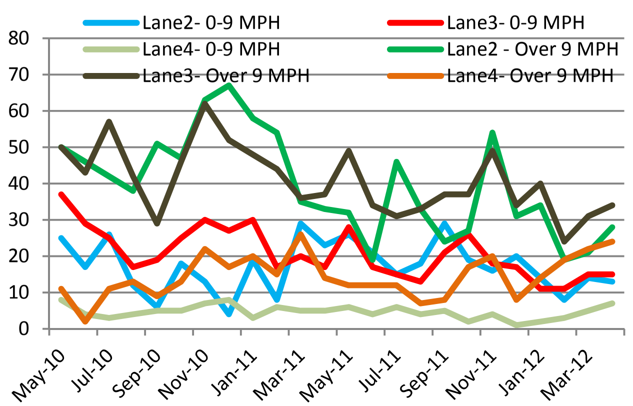


Figure K3. LOWA-EB

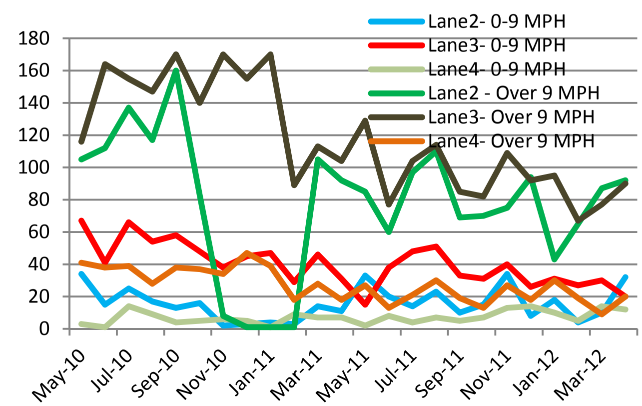


Figure K4. LOWA-WB

Monthly Speeding Violations by Different Lanes of the Intersection

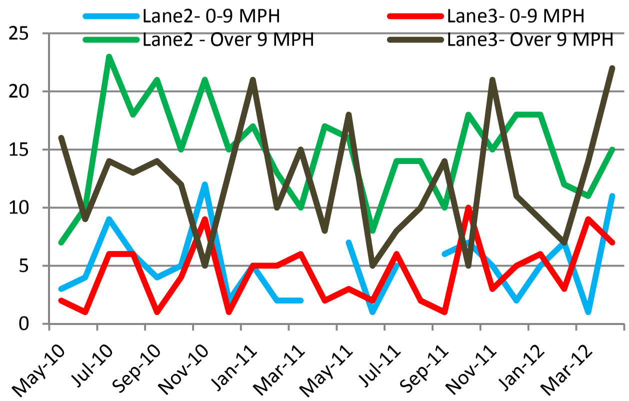


Figure K5. VAAM-NB

Monthly Speeding Violations by Different Lanes of the Intersection

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