EVALUATION OF INNOVATIVE SAFETY TREATMENTS

Volume 1: A Study of the Effectiveness of White Enforcement Lights

Prepared for

Florida Department of Transportation
State Safety Office

Contract Number B-D500
Financial Project I.D. 406865-1-B2-04
Evaluation of Innovative Safety Treatments
HNTB Project Number 40502-PL-003

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January 2008

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Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle EVALUATION OF INNOVATIVE SAFETY TREATMENTS A STUDY OF THE EFFECTIVENESS OF WHITE ENFORCEMENT LIGHTS		5. Report Date January 2008 6. Performing Organization Code
7. Author(s) Vivek Reddy, Mohamed Abdel-Aty, Satya Pinapaka		8. Performing Organization Report No. 40502-PL-003-001
9. Performing Organization Name and Address HNTB Corporation 6363 NW 6th Way, Suite 420 Fort Lauderdale, Florida 33309 University of Central Florida Dept. of Civil & Environmental Engineering Orlando, FL 32816		10. Work Unit No. (TRAIS) 11. Contract or Grant No. B-D500
12. Sponsoring Agency Name and Address Florida Department of Transportation 605 Suwannee Street, MS 30 Tallahassee, FL 32399		13. Type of Report and Period Covered Final, August 2006-January 2008 14. Sponsoring Agency Code
15. Supplementary Notes		

16. Abstract

The Florida Department of Transportation (FDOT) in cooperation with local engineering and enforcement agencies installed white enforcement lights at a number of intersections on the State Highway System in Hillsborough County to help police officers safely enforce red light violations. These lights were placed either above or below the signal head, so that they are visible from a complete circle of 360 degrees. Thus, a single officer positioned downstream from the intersection can safely observe the violation, stop the offending driver, and issue the citation. White lights can therefore potentially replace a police officer, reducing the required police manpower by half. This either could allow enforcement at more intersections or could increase enforcement hours at the same number of intersections. The increased enforcement could in turn help change driver behavior and reduce the number of red light violations and associated crashes.

This report documents the findings and conclusions of a study conducted to determine the effectiveness of white lights in reducing red light violations and associated crashes. The red light violation data collected at the study intersections before and after the installation of white lights indicates that the total number of violations (AM and PM hours combined) was reduced from 759 to 567. The one-tailed t-test indicated that the reduction in the number of violations is statistically significant at a 90% confidence level.

Crash frequencies and rates for the before and after periods were also compared. The analyses showed that while the average annual crash frequency of all crashes had increased from 828 to 860, the number of red light running crashes that occurred on the approaches equipped with white lights was reduced from 40.17 to 28. The one-tailed paired t-test indicated that the reduction was significant at a 95% confidence level. The analyses using the crash rates also indicated that the reduction in the crash rate for red light running crashes occurring on the approaches with white lights was statistically significant at a 95% confidence level.

The analyses conducted as part of this study show that better enforcement of red light compliance made possible by the installation of white lights has the potential to reduce red light violations and associated crashes. This is indicated by the analyses of a surrogate measure (number of red light violations) as well as a direct measure (crash frequency). Among the two measures, the variation in the number of red light running crashes between intersections was higher than the variation in the number of violations. Due to this higher variation, the results obtained from analyses of the crash data are less conclusive than the results obtained from analyses of the violation data. In other words, while the confidence level and the power of statistical tests are reasonable in the case of violation data, it is not the case with crash data. Therefore, it is recommended that crash data at additional intersections be collected and analyzed as it becomes available for conclusive evidence of the potential benefits of white lights in reducing red light running crashes.

17. Key Word	18. Distribution Statement
Safety, Red Light Violation, Enforcement, Crash, Red Light Running	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	46	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized.

ACKNOWLEDGMENTS

This research project was sponsored by the Florida Department of Transportation (FDOT). The research was conducted by Mr. Vivek Reddy of HNTB Corporation and Dr. Mohamed Abdel-Aty of the Department of Civil & Environmental Engineering, University of Central Florida. The researchers would like to acknowledge the support and guidance provided by the FDOT project manager, Mr. Patrick Brady. The researchers would also like to acknowledge the assistance of Mr. Peter Hsu of FDOT, several staff members from the Florida Department of Highway Safety & Motor Vehicles, and the Hillsborough County Sheriff's Office.

EXECUTIVE SUMMARY

The traffic violation "disregarding traffic signal," or "red light running" as it is commonly known, has been identified as a contributing cause for a significant number of crashes at signalized intersections. Crashes resulting from red light running frequently result in severe injuries and in some cases fatalities. In Florida, a total of 7,765 crashes occurred in 2004 due to motorists disregarding traffic signals, of which 96 were fatal crashes and 6,341 were injury crashes. While police departments across the state attempt to combat the problem of red light running, their effort is limited by the amount of manpower available. Safe enforcement of red light violations at a given intersection requires two officers -- one on the near side to observe the violation and another on the far side to pull over the violator and issue the citation. Enforcing red light violations with one officer is dangerous, both for the police officer and for other drivers on the cross street. Officers have to be on the same side of the light as the violator so that they can verify that the light was red. They then have to pursue the violator through the intersection, while the cross street has a green indication. This situation can lead to potential traffic conflicts and crashes.

The Florida Department of Transportation (FDOT) in cooperation with local engineering and enforcement agencies has installed white enforcement lights, hereafter referred to as "white lights," at a number of intersections on the State Highway System in Hillsborough County to help police officers safely enforce red light violations. The white lights were placed either above or below the signal head, so they are visible from a complete circle of 360 degrees. Thus, a single officer positioned downstream from the intersection can safely observe the violation, stop the offending driver, and issue the citation. White lights can therefore potentially replace a police officer, reducing the required police manpower by half. The remaining staff can be allocated to enforcement of additional intersections or increase enforcement hours at the same intersection. Increased enforcement could in turn help change driver behavior and reduce the number of red light violations and associated crashes. Also, using white lights is much safer for police officers and other drivers, as the officer does not have to pursue the violator through the intersection while the cross street has a green indication.

The goal of this research was to determine the effectiveness of white lights in reducing red light violations and associated crashes. The evaluation consisted of comparing the number of red light violations and red light running crashes before and after the installation of white lights. Statistical analyses were performed to test whether the observed differences were significant.

The red light violation data were collected on typical weekdays (Tuesday, Wednesday, or Thursday) at each of the study intersections during the morning peak hour (7:00 AM to 8:00 AM) and the

evening peak hour (5:00 PM to 6:00 PM). For the purpose of this study, any motorist that crossed the stop bar after the signal for the study approach turned red was considered a violator. Observers recorded the date, time of day, the movement of the red light violator (through or left turn) and the total number of such violations at each of the study intersections. The red light violation data prior to the installation of white lights (referred to as the before data) were collected during the five-month period from August 2003 through January 2004. The red light violation data after the installation of white lights (referred to as the after data) were collected during the three-month period from November 2004 through January 2005.

The crash data for each of the study intersections were obtained from the FDOT Crash Analysis Reporting System (CARS) for the years from 2000 to 2005. Since a majority of the white lights were installed in 2003 and 2004, the 36-month period from January 2000 through December 2002 was considered the before period. The 12-month period from January 2004 to December 2004 was considered the after period for those intersections where white lights were installed in 2003. For those intersections where white lights were installed in April/May 2004, the 12-month period from July 2004 to June 2005 was considered the after period. The white lights at the intersection of SR 60/Regency Mall were installed in 2002, therefore, the 24-month period from January 2000 to December 2001 was considered the before period and the 24-month period from January 2003 to December 2004 was considered the after period for this intersection. For the sake of comparison, the crash data were converted into an average annual frequency. The crash data retrieved from the CARS were reviewed to extract the data necessary for this study, such as the total of number of crashes, number of red light running crashes, average daily traffic, and crash rates for each of the study intersections.

A review of the referenced crash data indicates that an average of 828 crashes per year occurred during the before period at all of the study intersections combined, of which 56 crashes per year occurred due to motorists disregarding red signal indications. During the after period, an average of 860 crashes per year occurred at the study intersections, of which 52 crashes per year occurred due to motorists disregarding red signal indications. A further analysis of crash data, taking into account only the crashes occurring on the approaches with white lights was conducted. The results of this analysis indicate that the frequency of red light running crashes was reduced from an average of 40.17 crashes per year before the installation of white lights to 28 crashes per year after the installation of white lights. It is of particular interest to note that the frequency of red light running crashes decreased while the overall crash frequency at the same intersections increased during the study period. It is also worth mentioning that a review of the crash data for the entire Hillsborough County indicates an increasing trend in all crashes while the

increasing trend in red light running crashes stopped in 2002, the year that the FDOT and local agencies began installing white lights.

A review of red light citation data for Hillsborough County (obtained from the Department of Highway Safety and Motor Vehicles) indicates that the number of citations issued in 2004 and 2005 (an average of 24,551) were significantly higher as compared to the number of citations issued in years 2001 and 2002 (an average of 17,561). Based on this information, it appears that white lights installed in 2002 and 2003 helped in enforcement efforts and hence the increase in the number of red light citations issued. Researcher conversations with law enforcement officials from the Hillsborough County Sheriff's office indicate that officers are of the opinion that white lights made the task of red light enforcement simpler, easier, and safer.

The analyses conducted as part of this study show that better enforcement of red light compliance made possible by the installation of white lights has the potential to reduce red light violations and associated crashes. This is indicated by the analyses of a surrogate measure of effectiveness (number of red light violations) as well as a direct measure of effectiveness (crash frequency). Among the two measures, the variation across intersections in the number of red light running crashes was higher than the variation in the number of violations. Due to this higher variation, the results obtained from analyses of crash data are less conclusive than the results obtained from analysis of violation data. In other words, while the confidence level and the power of statistical tests are reasonable in the case of violation data, it is not the case with crash data. Therefore, it is recommended that crash data at additional intersections be collected and analyzed as it becomes available for conclusive evidence of the potential benefits of white lights in reducing red light running crashes.

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1. INTRODUCTION

The traffic violation "disregarding traffic signal," or "red light running" as it is commonly known, has been identified as a contributing cause for a significant number of crashes at signalized intersections. Crashes resulting from red light running normally are angle and left turn type and frequently result in severe injuries and in some cases fatalities. According to 2004 data from the National Highway Traffic Safety Administration (NHTSA), crashes caused by red light running resulted in as many as 854 fatalities and more than 168,000 injuries in the United States. In Florida, a total of 7,765 crashes occurred in 2004 due to motorists disregarding traffic signals, of which 96 were fatal crashes and 6,341 were injury crashes. While police departments across the country attempt to combat the problem of red light running, their efforts are limited by the amount of manpower available. Safe enforcement of red light violations at a given intersection requires two officers -- one on the near side to observe the violation and another on the far side to pull over the violator and issue the citation. Enforcing red light violations with one officer is dangerous, both for the police officer and for other drivers on the cross street. Officers have to be on the same side of the light as the violator so that they can verify that the light was red. They then have to pursue the violator through the intersection while the cross street has a green indication. This situation can lead to potential traffic conflicts and crashes.

The Florida Department of Transportation (FDOT) in cooperation with local engineering and enforcement agencies has installed white enforcement lights, hereafter referred to as "white lights," at a number of intersections on the State Highway System in Hillsborough County to help police officers safely enforce red light violations. The white light is placed either above or below the signal head (see Photo 1). It is wired in parallel with the red indication for the approach to be monitored such that it is illuminated at the same time as the red indication. The police officers must be trained to compare the actual red and white light correlation prior to working the intersection, so they can confirm that the lights are working properly.

The white light is visible from a complete circle of 360 degrees. Therefore, a single officer positioned downstream from the intersection can safely observe the violation, stop the offending driver, and issue the citation. White lights can therefore potentially replace a police officer, reducing the required police manpower by half. This could either allow enforcement at more intersections or could increase enforcement hours at the same number of intersections. Increased enforcement could in turn help change driver behavior and reduce the number of red light violations and associated crashes. Also, red light

enforcement using white lights is much safer for the officer and other drivers, since the officer does not have to pursue the violator through the intersection while the cross street has a green indication.

The objective of this study is to evaluate the impact of white enforcement lights on red light violations and associated crashes.

Photo 1: Typical Installation of a White Enforcement Light

2. EVALUATION METHODOLOGY

In order to determine the effectiveness of white lights, a before/after methodology was utilized. The impacts of white lights on traffic safety were evaluated in two ways, one by comparing the number of red light violations, a surrogate measure of safety, and the other by comparing the frequency of crashes, a direct measure of safety. One-tailed paired t-tests were used to test whether the changes in frequency of violations and crashes before and after the installation of white lights were significant. The formula for estimating the test statistic is as follows:

$$Test\ Statistic\ t = \frac{\bar{d}}{S_d / \sqrt{n}}$$

Where $\bar{d}$ and S_d represent the average and standard deviation of the differences in number of violations or crashes before and after the installation of white lights. The statistical test for significance is based on the hypothesis (i.e. null hypothesis) that the installation of white lights had no effect on the number of violations/crashes, while the alternate hypothesis is that the number of violations/crashes before the installation of white lights was greater than the number of violations/crashes after the installation of white lights.

Based on the test statistic, a p-value for the test may be obtained using appropriate statistical analysis software. A p-value of less than or equal to 0.05 indicates that there is sufficient evidence for rejecting the null hypothesis, thereby indicating a statistically significant reduction in violation/crash frequency at a 95% confidence level. If the p-value is between 0.05 and 0.10, then it would indicate a significant reduction in the number of violations/crashes at a 90% confidence level.

Surrogate Measure

Because white lights are essentially a law enforcement tool, the difference in the number of red light violations before and after the installation of white lights was used as a surrogate measure of effectiveness. For the purpose of this study, any motorist that crossed the stop bar after the signal for the study approach turned red was considered a violator. The red light violation data collected at 17 intersections listed in Table 1 before and after the installation of white lights were compared to determine the impact of white lights on red light violations.

Table 1: List of Intersections for Before/After Red Light Violation Data Comparison

Intersection	State Section	Mile Post	White Light Installation Date	City
Hillsborough Avenue (SR 600) at 40th Street	10030000	2.267	Aug-2003	Tampa
Adamo Drive (SR 60) at 50th Street	10110000	2.101	Aug-2003	Tampa
Florida Avenue (SR 685) at Waters Avenue	10020000	5.362	Aug-2003	Tampa
Busch Blvd (SR 580) at Nebraska Ave (SR 45)	10310000	3.320	Aug-2003	Tampa
Dale Mabry Highway (SR 573) at Gandy Boulevard	10180000	1.814	Aug-2003	Tampa
21st Street (SR 585) at 7th Avenue	10250101	0.784	Aug-2003	Tampa
Busch Boulevard (SR 580) at Florida Ave (SR 685)	10310000	2.817	Aug-2003	Tampa
Fowler Avenue (SR 582) at Nebraska Ave (SR 45)	10290000	0.505	Aug-2003	Tampa
Busch Boulevard (SR 580) at 56th Street	10310000	6.863	Jun-2003	Tampa
Fowler Avenue (SR 582) at 56th Street	10290000	4.019	Jun-2003	Tampa
SR 39 at SR 60	10070000	0.000	Apr-2004	Plant City
Parson Avenue at SR 60	10110000	9.425	Apr-2004	Brandon
SR 574 at Falkenburg Road	10340000	10.403	May-2004	Mango
US 301 at SR 574	10010000	24.800	May-2004	Riverview
Valrico Road at SR 60	10110000	11.447	Apr-2004	Valrico
Wheeler Street (SR 39) at Baker Street	10200000	0.102	Nov-2004	Plant City
Baker Street (SR 600) at Maryland Avenue	10030000	21.393	Nov-2004	Plant City

Direct Measure

Changes in the number of crashes and crash rates are generally used as direct measures of improvement in safety. To determine the impact of white lights on motorist safety, crash frequencies and rates for the before and after periods were compared for 25 intersections in Hillsborough County (see Table 2).

Table 2: List of Intersections for Before/After Crash Data Comparison

No.	Intersection	State Section	Mile Post	White Light Installation Date	City
1	Hillsborough Avenue (SR 600) at 40th Street	10030000	2.267	Aug-2003	Tampa
2	Adamo Drive (SR 60) at 50th Street	10110000	2.101	Aug-2003	Tampa
3	Florida Avenue (SR 685) at Waters Avenue	10020000	5.362	Aug-2003	Tampa
4	Busch Boulevard (SR 580) at Nebraska Avenue (SR 45)	10310000	3.320	Aug-2003	Tampa
5	Dale Mabry Highway (SR 573) at Gandy Boulevard	10180000	1.814	Aug-2003	Tampa
6	21st Street (SR 585) at 7th Avenue	10250101	0.784	Aug-2003	Tampa
7	Busch Boulevard (SR 580) at Florida Avenue (SR 685)	10310000	2.817	Aug-2003	Tampa
8	Fowler Avenue (SR 582) at Nebraska Avenue (SR 45)	10290000	0.505	Aug-2003	Tampa
9	Busch Boulevard (SR 580) at 56th Street	10310000	6.863	Jun-2003	Tampa
10	Fowler Avenue (SR 582) at 56th Street	10290000	4.019	Jun-2003	Tampa
11	SR 39 at SR 60	10070000	0.000	Apr-2004	Plant City
12	Parson Avenue at SR 60	10110000	9.425	Apr-2004	Brandon
13	SR 574 at Falkenburg Road	10340000	10.403	May-2004	Mango
14	US 301 at SR 574	10010000	24.800	May-2004	Riverview
15	Valrico Road at SR 60	10110000	11.447	Apr-2004	Valrico
16	US 301 at SR 60	10010000	22.505	Jul-2003	Brandon
17	Dale Mabry Highway at Ehrlich Road/Bearss Avenue	10160000	6.167	Aug-2003	Tampa
18	Falkenburg Road at SR 60	10110000	6.314	Jul-2003	Brandon
19	Florida Avenue (SR 685) at Fletcher Avenue	10020000	8.388	Aug-2003	Tampa
20	Florida Avenue (SR 685) at Bearss Avenue	10020000	9.682	Jul-2003	Tampa
21	Nebraska Avenue at Fletcher Avenue	10040000	8.196	Aug-2003	Tampa
22	Dale Mabry Highway at Waters Avenue	10160000	2.045	Jul-2003	Tampa
23	SR 60 at Lake Wood	10110000	7.929	Apr-2004	Brandon
24	SR 60 at Mt. Carmel	10110000	10.94	Apr-2004	Brandon
25	SR 60 at Regency/Brandon Mall	10110000	7.07	May-2002	Brandon

3. RED LIGHT VIOLATION DATA ANALYSIS

The red light violation data were collected on typical weekdays (Tuesday, Wednesday, or Thursday) during the morning peak hour (7:00 AM to 8:00 AM) and the evening peak hour (5:00 PM to 6:00 PM). For the purpose of this study, any motorist that crossed the stop bar after the signal for the study approach turned red was considered a violator. Observers recorded the date, time of day, the movement of the red light violator (through or left turn) and the total number of such violations at each of the study intersections. Before and after data at a given intersection were collected on the same day of week. For example, if the before data were collected on a Thursday, the after data were also collected on a Thursday.

The red light violation data prior to the installation of white lights (referred to as the before data) were collected at a total of 24 intersections during the six-month period from August 2003 through January 2004. The red light violation data after the installation of white lights (referred to as the after data) were collected during the three-month period from November 2004 through January 2005. The red light violation data collected before the installation of white lights is included in Appendix A, while the data collected after the installation of white lights is provided in Appendix B.

The red light violation data for the after period were collected only at 17 intersections, since some of the intersections originally scheduled for white light installation were not equipped with white lights at the time the researchers collected the after data. The red light violation data collected before and after the installation of white lights at 17 intersections listed in Table 3 were analyzed to determine the impact of white lights on red light violations. Red light violation data were not collected immediately after the installation of white lights. Because the hypothesis is that better enforcement will encourage drivers to change behavior as it relates to red light running, it was assumed that the impact of white lights would not be felt immediately but there would be a time lag. A time lag of at least six months (for a majority of the intersections) was assumed to be sufficient to be able to observe if there was a significant difference in driver behavior as it pertains to red light running.

Before/After Comparison of Red Light Violation Data

Table 3 shows the number of violations observed during morning and evening peak periods at each of the study intersections before and after the installation of white lights. The violation data are presented in a graphical form in Figure 1 (see Appendix C). As can be seen from this figure, the number

of violations reduced at a majority of the intersections, while some intersections experienced an increase in the number of violations. However, the total number of violations for all intersections combined reduced from 759 before the installation of white lights to 567 after the installation of white lights.

As can be seen from Table 3, two of the study intersections experienced more than 100 violations during peak hours. The maximum number of violations observed in one hour was 111, at the intersection of Busch Boulevard/56th Street.

Table 3: Before/After Comparison of Total Number of Red Light Violations

Study Intersection	Number of Red Light Violations (AM and PM Peak Hours Combined)	
	Before	After
Hillsborough Avenue (SR 600) at 40th Street	41	30
Adamo Drive (SR 60) at 50th Street	105	40
Florida Avenue (SR 685) at Waters Avenue	14	22
Busch Boulevard (SR 580) at Nebraska Avenue (SR 45)	51	49
Dale Mabry Highway (SR 573) at Gandy Boulevard	14	22
21st Street (SR 585) at 7th Avenue	24	47
Busch Boulevard (SR 580) at Florida Avenue (SR 685)	29	33
Fowler Avenue (SR 582) at Nebraska Avenue (SR 45)	16	32
Busch Boulevard (SR 580) at 56th Street	111	75
Fowler Avenue (SR 582) at 56th Street	79	22
Wheeler Street (SR 39) at Baker Street	5	11
Baker Street (SR 600) at Maryland Avenue	7	8
SR 39 at SR 60	43	19
Parson Avenue at SR 60	74	52
SR 574 at Falkenburg Road	64	42
US 301 at SR 574	48	32
Valrico Road at SR 60	34	31
Total	**759**	**567**

To determine whether the observed changes were statistically significant, a matched pair t-test was conducted with the number of violations at each intersection before and after the installation of white lights being the pairs. The null hypothesis for the test was that there was no difference between the number of red light violations before and after the installation of white lights. The one-tailed t-test resulted in a p-value of 0.037, which is less than 0.05. Hence, it may be concluded with a 95% confidence level that the number of violations was reduced after the installation of white lights.

Disaggregate Comparisons

The null hypothesis was tested at a microscopic level to further assess the impact of white lights on red light violations. The red light violation data was subdivided by time of day (morning or evening peak hour) and by movement (through or left-turn). The disaggregate analyses allow for a better comparison of the number of red light violations before and after the installation of white lights.

Morning Peak Hour

This section discusses the results of a comparative analysis of the red light violation data collected during the morning peak hour (7:00 AM to 8:00 AM) on a typical weekday.

Table 4 shows the number of violations observed during the morning peak hour before and after the installation of white lights. Some intersections experienced an increase, while the others experienced a reduction. However, the total number of violations (all intersections combined) decreased after the installation of white lights. At the intersection of Adamo Drive (SR 60)/50th Street, the number of violations was reduced drastically from 65 before the installation of white lights to 14 after the installation. Figure 2 represents the total number of violations at each of the 17 intersections observed during the before and after periods in a graphical form (see Appendix C).

A matched pair t-test was conducted to assess whether the reduction in the number of violations during the morning peak hour was statistically significant. Although the total number of violations decreased by 10%, the p-value for the one-tailed test of 0.33 indicates the null hypothesis of equal number of violations could not be rejected. While the insufficient evidence might be due to the limited sample size, the test indicates that the reduction in the number of violations during the morning peak hour is not statistically significant. During the morning peak hour, most drivers are likely to be driving under the pressure of arriving to work on time and as such, they tend to violate red signal indications.

Table 4: Before/After Comparison of Red Light Violations during the Morning Peak Period

Study Location	Number of Violations	
	Before	After
Hillsborough Avenue (SR 600) at 40th Street	18	11
Adamo Drive (SR 60) at 50th Street	65	14
Florida Avenue (SR 685) at Waters Avenue	9	14
Busch Boulevard (SR 580) at Nebraska Avenue (SR 45)	24	38
Dale Mabry Highway (SR 573) at Gandy Boulevard	5	6
21st Street (SR 585) at 7th Avenue	12	30
Busch Boulevard (SR 580) at Florida Avenue (SR 685)	14	19
Fowler Avenue (SR 582) at Nebraska Avenue (SR 45)	6	8
Busch Boulevard (SR 580) at 56th Street	21	20
Fowler Avenue (SR 582) at 56th Street	32	11
Wheeler Street (SR 39) at Baker Street	0	7
Baker Street (SR 600) at Maryland Avenue	3	4
SR 39 at SR 60	23	14
Parson Avenue at SR 60	30	23
SR 574 at Falkenburg Road	27	27
US 301 at SR 574	11	14
Valrico Road at SR 60	7	14
Total	**307**	**274**

Evening Peak Hour

This section presents the results of a comparative analysis of the number of red light violations observed during the evening peak hour (5:00 PM to 6:00 PM) at each of the study intersections before and after the installation of white lights (see Table 5). Twelve (12) out of the 17 intersections experienced a reduction in violations and four intersections experienced an increase. The reductions during the evening peak hour seem to be greater than the reductions during the morning peak hour. A matched pair t-test was conducted to test whether the changes observed in the number of violations during the evening peak hour were significant. The p-value for the one-tailed test was 0.06 and hence the null hypothesis of equal number of violations could be rejected with a 90% confidence level. While the reduction in the number of violations during the morning peak hour was not statistically significant, the reduction during the evening peak hour was statistically significant.

Table 5: Before/After Comparison of Red Light Violations during the Evening Peak Period

Study Location	Number of Violations	
	Before	After
Hillsborough Avenue (SR 600) at 40th Street	23	19
Adamo Drive (SR 60) at 50th Street	40	26
Florida Avenue (SR 685) at Waters Avenue	5	8
Busch Boulevard (SR 580) at Nebraska Avenue (SR 45)	27	11
Dale Mabry Highway (SR 573) at Gandy Boulevard	9	16
21st Street (SR 585) at 7th Avenue	12	17
Busch Boulevard (SR 580) at Florida Avenue (SR 685)	15	14
Fowler Avenue (SR 582) at Nebraska Avenue (SR 45)	10	24
Busch Boulevard (SR 580) at 56th Street	90	55
Fowler Avenue (SR 582) at 56th Street	47	11
Wheeler Street (SR 39) at Baker Street	5	4
Baker Street (SR 600) at Maryland Avenue	4	4
SR 39 at SR 60	20	5
Parson Avenue at SR 60	44	29
SR 574 at Falkenburg Road	37	15
US 301 at SR 574	37	18
Valrico Road at SR 60	27	17
Total	**452**	**293**

Analysis of Red Light Violation Data by Movement

A comparative analysis of the red light violation data by traffic movement (through or left-turn) was conducted to determine if there were any changes in red light running behavior depending on the movement. Table 6 shows the number of violations by motorists traveling in through and left turn lanes. A paired t-test conducted with the before and after red light violations by motorists traveling in through lanes indicates a p-value of 0.05. Therefore, it can be concluded with a 95% confidence level that the number of violations by motorists traveling in through lanes was reduced after the installation of white lights. The number of violations by motorists traveling in left-turn lanes was also reduced from 192 before the installation of white lights to 156 after the installation of white lights.

Table 6: Before/After Comparison of Red Light Violations by Motorists Traveling in Through and Left Turn Lanes

Study Location	Number of Violations by Motorists Traveling in Through Lanes		Number of Violations by Motorists Traveling in Left Turn Lanes	
	Before	After	Before	After
Hillsborough Avenue (SR 600) at 40th Street	41	30	0	0
Adamo Drive (SR 60) at 50th Street	105	40	0	0
Florida Avenue (SR 685) at Waters Avenue	14	22	0	0
Busch Boulevard (SR 580) at Nebraska Avenue (SR 45)	51	49	0	0
Dale Mabry Highway (SR 573) at Gandy Boulevard	14	22	0	0
21st Street (SR 585) at 7th Avenue	24	47	0	0
Busch Boulevard (SR 580) at Florida Avenue (SR 685)	17	15	12	18
Fowler Avenue (SR 582) at Nebraska Avenue (SR 45)	16	32	0	0
Busch Boulevard (SR 580) at 56th Street	51	27	60	48
Fowler Avenue (SR 582) at 56th Street	56	11	23	11
Wheeler Street (SR 39) at Baker Street	5	11	0	0
Baker Street (SR 600) at Maryland Avenue	7	8	0	0
SR 39 at SR 60	20	1	23	18
Parson Avenue at SR 60	40	18	34	34
SR 574 at Falkenburg Road	29	17	35	25
US 301 at SR 574	48	32	0	0
Valrico Road at SR 60	29	29	5	2
Total	**567**	**411**	**192**	**156**

Adequacy of the Sample Size

The observed average difference between the number of violations before and after the installation of white lights was 11.29. The standard deviation of the difference in the number of violations was 24.36. Based upon the mean, standard deviation, and the sample size of 17 study intersections, the power of the t-test can calculated as 0.73 with a 90% confidence level. While the power of statistical test is reasonable; it is not at a desirable level. A paired t-test with power 0.8 would have resulted in a sample

size requirement of 21. Therefore, it is suggested that red light violation data from more intersections be collected and analyzed to improve the power of this statistical test, thereby improving the confidence level in the results. Data from more intersections can be used for ascertaining the reduction in red light running during the morning peak hour and by left-turning vehicles.

4. CRASH DATA ANALYSIS

The crash data for each of the 25 study intersections were obtained from the FDOT Crash Analysis Reporting System (CARS) for the period from 2000 to 2005. Since white lights were installed in 2003 and 2004 at a majority of the study intersections, the 36-month period from January 2000 through December 2002 was considered the before period. The 12-month period from January 2004 to December 2004 was considered the after period for those intersections where white lights were installed in 2003. The 12-month period from July 2004 to June 2005 was considered the after period for those intersections where white lights were installed in April/May 2004. The white lights at the intersection of SR 60/Regency Mall were installed in 2002, therefore, the 24-month period from January 2000 to December 2001 was considered the before period, and the 24-month period from January 2003 to December 2004 was considered the after period for this intersection. For the sake of comparison, the crash data were converted into an average annual frequency. The crash data for the before period is included in Appendix D and the data for the after period is included in Appendix E.

The crash data for the before and after periods retrieved from the CARS were reviewed to extract the necessary data, such as the total of number of crashes, number of red light running crashes, average daily traffic, and crash rates for each of the study intersections. The crashes related to red light running were initially identified based on the contributing cause "disregarded traffic signal" as listed on the crash detail printout from the CARS. Then, copies of crash reports (completed by the investigating officer) for these crashes were reviewed to confirm the contributing cause, the direction of travel and to determine whether or not the crash occurred on the approach equipped with white lights. This information is summarized in crash data tables included in Appendices D and E.

A review of the crash data for the referenced period indicates that an average of 828 crashes per year occurred during the before period at all of the study intersections combined, of which an average of 56 crashes per year were due to motorists disregarding red signal indications. During the after period, an average of 860 crashes per year occurred at the study intersections, of which an average of 52 crashes per year occurred due to motorists disregarding red signal indications. It should be noted that the red light

running crashes mentioned above (56 during the before period, and 52 during the after period) represent the total red light running crashes occurring on all approaches. White lights were only installed on certain approaches and may therefore only affect crashes occurring on those approaches equipped with white lights. Therefore, a further analysis of crash data, taking into account only the crashes occurring on the approaches equipped with white lights was conducted. The results of this analysis indicate that the crash frequency of red light running crashes occurring on the approaches equipped with white lights was reduced from an average of 40.17 crashes per year before the installation of white lights to 28 crashes per year after the installation of white lights. It is of particular interest to note that the frequency of red light running crashes decreased while the overall crash frequency at the same intersections increased from 828 to 860 crashes per year. It is also worth mentioning that a review of crash data for the entire Hillsborough County indicates an increasing trend in all crashes while the increasing trend in red light running crashes stopped in 2002 (see Table 7), the year when the FDOT and local agencies began installing white lights. A review of the crash rates (based on the number of crashes and vehicle miles traveled in Hillsborough County) for before and after periods indicates an increasing trend for all crashes, while the crash rates for red light running crashes shows no significant changes. It is possible that aggressive enforcement with the use of white lights may have helped in keeping crashes rates for red light running crashes from increasing.

Before/After Comparisons and Statistical Analyses

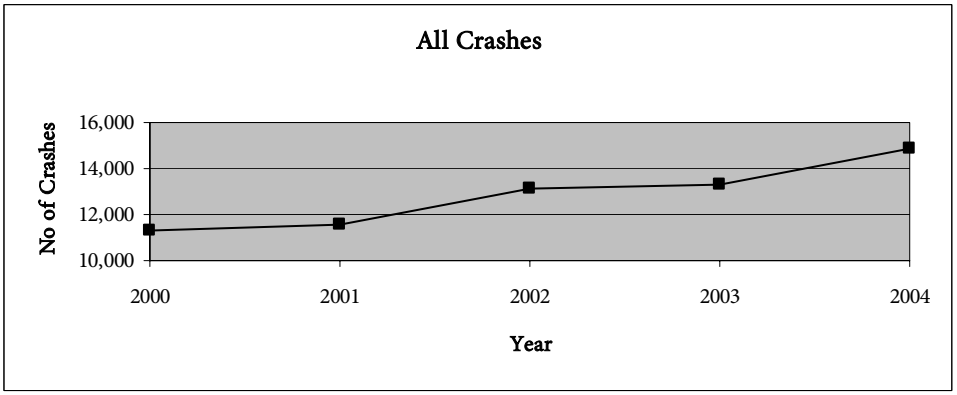
Statistical analyses were performed to determine if the observed changes in crash frequencies discussed above were statistically significant. The following sections summarize the results of the statistical analyses.

Before/After Comparison of Average Annual Frequency of All Crashes

Table 8 shows the average annual frequency of all crashes at each of the 25 study intersections. As can be seen from Table 8, the total number of crashes increased from 828 per year in the before period to 860 per year in the after period. The one-tailed paired t-test for the average annual frequency of crashes yielded a p-value of 0.24 indicating that the increase in the frequency of crashes is not statistically significant.

Table 7: Hillsborough County Crash Statistics

Year	All Crashes	Red Light Running Crashes	Percentage of Red Light Running Crashes	Crash Rates Based on All Crashes	Crash Rates Based on Red Light Running Crashes
2000	11,323	523	4.62	2.035	0.094
2001	11,576	545	4.71	1.955	0.092
2002	13,155	697	5.30	2.145	0.114
2003	13,325	648	4.86	2.088	0.102
2004	14,884	634	4.26	2.208	0.094



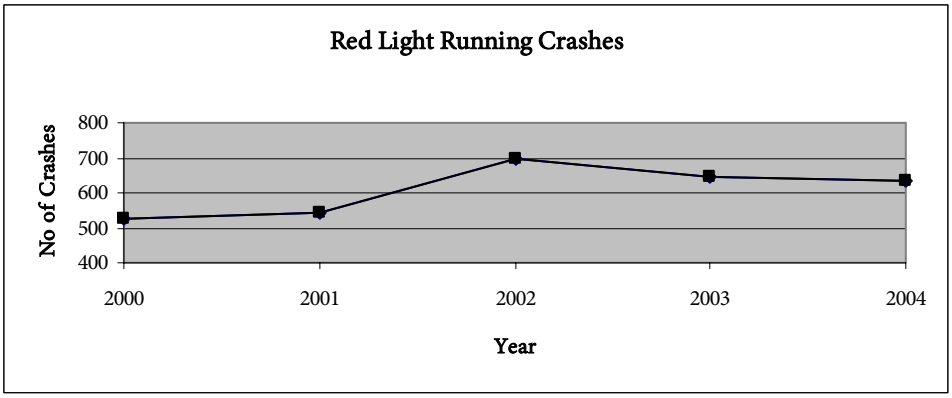


Table 8: Before/After Comparison of Average Annual Frequency of All Crashes

Study Intersection	Average Annual Frequency of All Crashes	
	Before	After
Hillsborough Avenue (SR 600) at 40th Street	59.00	60.00
Adamo Drive (SR 60) at 50th Street	36.67	28.00
Florida Avenue (SR 685) at Waters Avenue	35.67	34.00
Busch Boulevard (SR 580) at Nebraska Avenue (SR 45)	42.33	42.00
Dale Mabry Highway (SR 573) at Gandy Boulevard	40.33	48.00
21st Street (SR 585) at 7th Avenue	27.33	29.00
Busch Boulevard (SR 580) at Florida Avenue (SR 685)	40.00	22.00
Fowler Avenue (SR 582) at Nebraska Avenue (SR 45)	43.00	54.00
Busch Boulevard (SR 580) at 56th Street	20.67	25.00
Fowler Avenue (SR 582) at 56th Street	27.00	18.00
SR 39 at SR 60	30.00	27.00
Parson Avenue at SR 60	25.00	29.00
SR 574 at Falkenburg Road	23.00	16.00
US 301 at SR 574	20.33	25.00
Valrico Road at SR 60	23.33	35.00
US 301at SR 60	33.33	32.00
Dale Mabry Hwy at Ehrlich Rd/Bearss Avenue	39.00	48.00
Falkenburg Rd at SR 60	35.67	40.00
Florida Avenue (SR 685) at Fletcher Ave	25.67	28.00
Florida Avenue (SR 685) at Bearss Ave	15.00	29.00
Nebraska Avenue at Fletcher Avenue	49.33	39.00
Dale Mabry Highway at Waters Avenue	48.67	35.00
SR 60 at Lake Wood	24.00	35.00
SR 60 at Mt Carmel	15.00	29.00
SR 60 at Regency/Brandon Mall	49.00	53.00
Total	828.33	860.00

Before/After Comparison of Red Light Running Crashes on All Approaches

Table 9 shows the average annual frequency of red light running crashes (all approaches combined) at each of the study intersections. As can be seen from Table 9, no red light running crashes were reported at several intersections and some intersections experienced an increase in crash frequency. However, the total number of red light running crashes for all intersections combined reduced from 56 in the before period to 52.5 in the after period. One-tailed paired t-test resulted in a p-value of 0.34 indicating the reduction in the total number of red light running crashes (all approaches combined) is not statistically significant.

White lights are only installed on certain approaches of the study intersections (see Table 10) and can only affect crashes occurring on the approaches equipped with white lights. Therefore, the before and after frequencies of crashes occurring on the approaches with white lights were compared to better assess the impact of white lights on red light running crashes. The results of this comparative analysis are presented in the following sections.

Before/After Comparison of Red Light Running Crashes on Approaches with White Lights

The average annual frequency of red light running crashes occurring on the approaches equipped white lights was reduced from an average of 40.17 per year before the installation of white lights to 28 per year after the installation of white lights, which represents a 30% reduction. As can be seen from Table 11, no red light running crashes were reported at 11 intersections. The paired t-test for comparison resulted in a p-value of 0.05, which indicates that the reduction in the number of red light running crashes on the approaches equipped with white lights is statistically significant at a 95% confidence level.

Comparison of Before and After Crash Rates

Crash data were divided into the following four different groups for the purpose of comparing crash rates.

- Red light running crashes occurring on the approaches with white lights
- Red light running crashes occurring on the approaches without white lights
- Red light running crashes occurring on all approaches
- All crashes (all approaches combined)

Table 9: Before/After Comparison of the Average Annual Frequency of Red Light Running Crashes (All Approaches Combined)

Study Intersection	Average Annual Frequency of Red Light Running Crashes (All Approaches Combined)	
	Before	After
Hillsborough Avenue (SR 600) at 40th Street	1.67	4.00
Adamo Drive (SR 60) at 50th Street	1.67	2.00
Florida Avenue (SR 685) at Waters Avenue	2.67	4.00
Busch Boulevard (SR 580) at Nebraska Avenue (SR 45)	3.67	3.00
Dale Mabry Highway (SR 573) at Gandy Boulevard	0.67	0.00
21st Street (SR 585) at 7th Avenue	5.00	5.00
Busch Boulevard (SR 580) at Florida Avenue (SR 685)	2.33	1.00
Fowler Avenue (SR 582) at Nebraska Avenue (SR 45)	1.33	2.00
Busch Boulevard (SR 580) at 56th Street	1.33	3.00
Fowler Avenue (SR 582) at 56th Street	2.67	0.00
SR 39 at SR 60	3.33	4.00
Parson Avenue at SR 60	1.33	1.00
SR 574 at Falkenburg Road	1.33	0.00
US 301 at SR 574	1.00	3.00
Valrico Road at SR 60	0.67	0.00
US 301at SR 60	1.67	4.00
Dale Mabry Highway at Ehrlich Road/Bearss Avenue	2.33	4.00
Falkenburg Road at SR 60	1.67	0.00
Florida Avenue (SR 685) at Fletcher Avenue	2.00	0.00
Florida Avenue (SR 685) at Bearss Avenue	1.67	0.00
Nebraska Avenue at Fletcher Avenue	3.33	1.00
Dale Mabry Highway at Waters Avenue	3.67	0.00
SR 60 at Lake Wood	2.33	5.00
SR 60 at Mt. Carmel	1.67	3.00
SR 60 at Regency/Brandon Mall	5.00	3.50
Total	56.00	52.50

Table 10: Traffic Movements Equipped with White Lights by Intersection

Intersection	Traffic Movements Equipped with White Lights
Hillsborough Avenue (SR 600) at 40th Street	NB, SB, EB, WB
Adamo Drive (SR 60) at 50th Street	NB, SB, EB, WB
Florida Avenue (SR 685) at Waters Avenue	NB, SB, EB, WB
Busch Blvd (SR 580) at Nebraska Ave (SR 45)	NB, SB, EB, WB
Dale Mabry Highway (SR 573) at Gandy Boulevard	NB, SB, EB, WB
21st Street (SR 585) at 7th Avenue	SB
Busch Boulevard (SR 580) at Florida Ave (SR 685)	NB, NBLT, WB, WBLT
Fowler Avenue (SR 582) at Nebraska Ave (SR 45)	NB, WB
Busch Boulevard (SR 580) at 56th Street	NBLT, SBLT, EB, WB
Fowler Avenue (SR 582) at 56th Street	EB, EBLT, WB, WBLT
SR 39 at SR 60	NB, SB, EBLT, WBLT
Parson Avenue at SR 60	EB, EBLT, WB, WBLT
SR 574 at Falkenburg Road	NBLT, EB, WB, WBLT
US 301 at SR 574	NB, SB, EB, WB
Valrico Road at SR 60	EB, EBLT, WB, WBLT
US 301 at SR 60	NBLT, SBLT, EBLT, WBLT
Dale Mabry Highway at Ehrlich Road/Bearss Avenue	NBLT, SBLT, EBLT, WB
Falkenburg Road at SR 60	NB, SBLT, EB, WB
Florida Avenue (SR 685) at Fletcher Avenue	NBLT, SBLT, EB, WB
Florida Avenue (SR 685) at Bearss Avenue	NBLT, SBLT, EB, WB
Nebraska Avenue at Fletcher Avenue	NB, SB, EB, WB
Dale Mabry Highway at Waters Avenue	NB, NBLT, SB, EBLT
SR 60 at Lake Wood	NBLT, EB, EBLT, WB
SR 60 at Mt. Carmel	NB, SB, EB, WB
SR 60 at Regency/Brandon Mall	NBLT, SBLT, EB, WB

NB= Northbound Through; SB= Southbound Through; EB= Eastbound Through; WB= Westbound Through

NBLT= Northbound Left; SBLT= Southbound Left; EBLT= Eastbound Left; WBLT= Westbound Left

Table 11: Before/After Comparison of Average Annual Frequency of Red Light Running Crashes on the Approaches Equipped with White Lights

Study Location	Average Annual Frequency of Red light Running Crashes on Approaches With White Lights	
	Before	After
Hillsborough Avenue (SR 600) at 40th Street	1.67	3.00
Adamo Drive (SR 60) at 50th Street	1.33	2.00
Florida Avenue (SR 685) at Waters Avenue	2.67	4.00
Busch Boulevard (SR 580) at Nebraska Avenue (SR 45)	3.67	3.00
Dale Mabry Highway (SR 573) at Gandy Boulevard	0.67	0.00
21st Street (SR 585) at 7th Avenue	4.33	0.00
Busch Boulevard (SR 580) at Florida Avenue (SR 685)	0.67	1.00
Fowler Avenue (SR 582) at Nebraska Avenue (SR 45)	0.33	0.00
Busch Boulevard (SR 580) at 56th Street	1.00	2.00
Fowler Avenue (SR 582) at 56th Street	2.67	0.00
SR 39 at SR 60	3.33	1.00
Parson Avenue at SR 60	1.33	1.00
SR 574 at Falkenburg Road	0.67	0.00
US 301 at SR 574	1.00	1.00
Valrico Road at SR 60	0.67	0.00
US 301 at SR 60	0.33	0.00
Dale Mabry Highway at Ehrlich Rd/Bearss Avenue	0.33	2.00
Falkenburg Rd at SR 60	1.67	0.00
Florida Avenue (SR 685) at Fletcher Avenue	1.00	0.00
Florida Avenue (SR 685) at Bearss Avenue	0.67	0.00
Nebraska Avenue at Fletcher Avenue	3.00	1.00
Dale Mabry Highway at Waters Avenue	2.33	0.00
SR 60 at Lake Wood	1.67	3.00
SR 60 at Mt Carmel	1.67	2.00
SR 60 at Regency/Brandon Mall	1.50	2.00
Total	40.17	28.00

Crash rates (number of crashes per million vehicles) for the above mentioned four groups were calculated for the before and after periods. Then, the crash rates for the before period were compared with the crash rates for the after period within each group.

Crash rates for red light running crashes occurring on the approaches equipped with white lights were reduced from 0.0969 to 0.0513. There was an increase in the crash rate of red light running crashes on approaches without white lights from 0.0304 to 0.0515. The combined rate for all red light running crashes (all approaches combined) decreased from 0.1273 to 0.1028. Independent sample t-tests were performed between these three pairs of crash rates, which yielded p-values of 0.0231, 0.1530, and 0.2043 respectively. Therefore, it can concluded that the reduction in the rate of red light running crashes on the approaches equipped with white lights is statistically significant at a 95% confidence level. The increase in the rate of red light running crashes occurring on the approaches without white lights and the decrease in the rate of total red light running crashes are not statistically significant.

Additionally, paired t-tests were performed to test whether changes in crash rates at individual intersections were significant. Since each intersection is independent, this type of test is considered more powerful than the regular t-test performed on the average crash rates. The p-values for the difference in crash rates for crashes occurring on the approaches equipped with white lights, approaches without white lights, and the total red light running crashes (all approaches combined) were 0.0209, 0.1427, and 0.0952 respectively. These values indicate a significant reduction (at a 95% confidence level) in the red light running crash rates on the approaches equipped with white lights and no significant changes in red light running crashes on the approaches without white lights. The reduction in the rate of total red light running crashes was significant at a 90% confidence level.

The average crash rate (for all types of crashes) decreased from 1.811 to 1.740 crashes. The paired t-test indicates a p-value for the difference in crash rates (for all crashes) before and after the installation of white lights of 0.1896. Hence, the difference in crash rates before and after the installation of white lights is not statistically significant. It may be concluded that the installation of white lights on certain approaches led to reduction in red light running crash rates on those approaches without significantly affecting the overall crash rates.

Adequacy of the sample size

The observed average difference between the number of before and after red light running crashes on approaches equipped with white lights is 0.49. The standard deviation of the differences is 1.46. Based on the mean, standard deviation and the sample size of 25 intersections, the power of the test can be calculated as 0.64 with a 90% confidence level. A paired t-test with power 0.8 would have resulted in a sample size requirement of 41. Therefore, the sample size of 25 intersections is not sufficient based on a test with power 0.8. While the analysis conducted as part of this study indicates a reduction in the number of red light running crashes after the installation of white lights, it is recommended that crash data at additional intersections be collected and analyzed to improve the power of this statistical test, thereby improving the confidence level in the results.

5. RED LIGHT CITATION DATA

A review of red light citation data for Hillsborough County obtained from the Department of Highway Safety and Motor Vehicles (see Table 12) indicates that the number of citations issued in 2004 and 2005 (an average of 24,551) was significantly higher as compared to the number of citations issued in years 2001 and 2002 (an average of 17,561). Based on this information, it appears that white lights installed in 2002 and 2003 helped in enforcement efforts and increase the number of red light citations issued. Researcher conversations with law enforcement officials from the Hillsborough County Sheriff's office indicate that officers are of the opinion that white lights made the task of red light enforcement simpler, easier, and safer.

With white enforcement lights, a single police officer positioned at a downstream location can observe the violation, pull over the violator and issue the citation. Thus, the use of whites light potentially replaces a police officer, reducing the required manpower by half as compared to the traditional method of enforcing, which requires two officers. Therefore, with the use of white lights, the enforcement agencies are able to enforce more intersections with the same staff.

Table 12: Number of Red Light Citations Issued in Hillsborough County

Year	Number of citations issued by enforcement agency				
	FHP	City Police	Sheriff's office	Other Agencies	Total Citations
2001	1450	11349	4280	2	17081
2002	1341	10902	5796	2	18041
2003	1770	11268	6590	63	19691
2004	1795	15898	5511	104	23308
2005	2098	17902	5592	202	25794

6. CONCLUSIONS

The objective of this study was to examine the benefits of using white enforcement lights as a tool that allows for better enforcement of red light compliance at signalized intersections.

Two measures of effectiveness were evaluated in this study -- a surrogate measure (red light violations) and a direct measure (crash frequency).

The red light violation data collected at the study intersections before and after the installation of white lights were compared. According to the data collected during the morning and evening peak periods, the total number of violations (AM and PM hours combined) across 17 study intersections was reduced from 759 to 567. The one-tailed t-test indicated that the reduction in the number of violations is significant at a 90% confidence level.

The results from a paired t-test (with violations before and after the installation of white lights at every intersection being the pairs) also indicated statistically significant reduction in the total number of violations during the evening peak period (5:00 PM to 6:00 PM). Although the total number of violations was reduced during the morning peak period (7:00 AM to 8:00 AM), it was not a statistically significant reduction. The number of violations by vehicles traveling in through lanes was reduced significantly. In conclusion, it may be stated that the installation of white lights coupled with aggressive enforcement was able to significantly reduce the number of red light violations.

Crash frequencies and rates for the before and after periods were also compared to assess the benefits of white lights in terms of reducing red light running crashes. The analyses showed that while the

average annual crash frequency of all crashes had increased over time at the 25 study intersections, the number of red light running crashes (all approaches combined) was reduced. The reduction in the average annual frequency of red light running crashes was even more significant when the before and after comparisons were made using only the crash data for the approaches with white lights. The one-tailed paired t-test indicated a significant reduction (at a 95% confidence level) in the number of red light running crashes after the installation of white lights. The analyses using crash rates also indicated that while there was no significant change in the crash rate for all crashes, the reduction in the crash rate for red light running crashes occurring on the approaches with white lights was statistically significant at a 95% confidence level.

Also, it appears that white lights are helping in red light enforcement efforts as indicated by the increase in the number of red light citations issued after the installation of white lights.

7. RECOMMENDATIONS

The analyses conducted as part of this study show that better enforcement of red light compliance made possible by the installation of white lights has the potential to reduce red light violations and associated crashes. This is indicated by the analyses of a surrogate measure (number of violations) as well as a direct measure (crash frequency). Among the two measures, the variation between intersections in the number of red light running crashes was higher than the variation in the number of violations. Due to this higher variation, the results obtained from analyses of the crash data are less conclusive than the results obtained from analysis of violation data. In other words, while the confidence level and the power of statistical tests are reasonable in the case of violation data, it is not the case with crash data. Therefore, it is recommended that crash data at additional intersections be collected and analyzed as it becomes available for conclusive evidence of the potential benefits of white lights in reducing red light running crashes.

8. REFERENCES

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APPENDICES

APPENDIX A

Red Light Violation Data for Before Period

RED LIGHT VIOLATION DATA FOR BEFORE PERIOD

Location	City	Date Collected	Day	Time Period	NB	NBLT	SB	SBLT	EB	EBLT	WB	WBLT	Total
Hillsborough Avenue (SR 600) at 40th Street	Tampa	8/7/2003	Thursday	7:00 - 8:00 a.m.	0	-	8	-	3	-	7	-	18
		8/7/2003	Thursday	5:00 - 6:00 p.m.	4	-	1	-	6	-	12	-	23
Adamo Drive (SR 60) at 50th Street	Tampa	8/7/2003	Thursday	7:00 - 8:00 a.m.	30	-	18	-	5	-	12	-	65
		8/7/2003	Thursday	5:00 - 6:00 p.m.	18	-	9	-	11	-	2	-	40
Florida Avenue (SR 685) at Waters Avenue	Tampa	8/6/2003	Wednesday	7:00 - 8:00 a.m.	2	-	4	-	2	-	1	-	9
		8/6/2003	Wednesday	5:00 - 6:00 p.m.	4	-	0	-	0	-	1	-	5
Busch Boulevard (SR 580) at Nebraska Avenue (SR 45)	Tampa	8/6/2003	Wednesday	7:00 - 8:00 a.m.	7	-	9	-	7	-	1	-	24
		8/6/2003	Wednesday	5:00 - 6:00 p.m.	10	-	0	-	14	-	3	-	27
Dale Mabry Highway (SR 573) at Gandy Boulevard	Tampa	8/6/2003	Wednesday	7:00 - 8:00 a.m.	2	-	2	-	1	-	0	-	5
		8/6/2003	Wednesday	5:00 - 6:00 p.m.	4	-	3	-	2	-	0	-	9
21st Street (SR 585) at 7th Avenue	Tampa	8/7/2003	Thursday	7:00 - 8:00 a.m.	-	-	12	-	-	-	-	-	12
		8/7/2003	Thursday	5:00 - 6:00 p.m.	-	-	12	-	-	-	-	-	12
Busch Boulevard (SR 580) at Florida Avenue (SR 685)	Tampa	8/7/2003	Thursday	7:00 - 8:00 a.m.	0	1	-	-	-	-	6	7	14
		8/7/2003	Thursday	5:00 - 6:00 p.m.	2	1	-	-	-	-	9	3	15
Fowler Avenue (SR 582) at Nebraska Avenue (SR 45)	Tampa	8/7/2003	Thursday	7:00 - 8:00 a.m.	1	-	-	-	-	-	5	-	6
		8/7/2003	Thursday	5:00 - 6:00 p.m.	1	-	-	-	-	-	9	-	10
Busch Boulevard (SR 580) at 56th Street	Tampa	6/26/2003	Thursday	7:00 - 8:00 a.m.	-	8	-	2	3	-	8	-	21
		6/26/2003	Thursday	5:00 - 6:00 p.m.	-	39	-	11	35	-	5	-	90
Fowler Avenue (SR 582) at 56th Street	Tampa	6/26/2003	Thursday	7:00 - 8:00 a.m.	-	-	-	-	13	0	14	5	32
		6/26/2003	Thursday	5:00 - 6:00 p.m.	-	-	-	-	6	2	23	16	47
Wheeler Street (SR 39) at Baker Street	Plant City	8/13/2003	Wednesday	7:00 - 8:00 a.m.	0		0				0		0
		8/13/2003	Wednesday	5:00 - 6:00 p.m.	1		3				1		5
Baker Street (SR 600) at Maryland Avenue	Plant City	8/13/2003	Wednesday	7:00 - 8:00 a.m.	0		0		1		2		3
		8/13/2003	Wednesday	5:00 - 6:00 p.m.	1		0		3		0		4
SR 39 at SR 60	Plant City	1/7/2004	Wednesday	4:00 - 5:00 p.m.	1	0	6	7	1	3	4	1	23
		1/8/2004	Thursday	8:00 - 9:00 a.m.	0	0	1	2	3	9	4	1	20
Parson Avenue at SR 60	Brandon	1/6/2004	Tuesday	4:00 - 5:00 p.m.	5	3	1	4	5	2	4	6	30
		1/7/2004	Wednesday	8:00 - 9:00 a.m.	7	3	5	13	4	2	9	1	44
SR 574 at Falkenburg Road	Mango	1/15/2004	Thursday	4:00 - 5:00 p.m.	-	3	-	-	14	-	6	4	27
		1/15/2004	Wednesday	8:00 - 9:00 a.m.	-	0	-	-	2	-	7	28	37
US 301 at SR 574	Riverview	1/8/2004	Thursday	4:00 - 5:00 p.m.	0	-	1	-	2	-	8	-	11
		1/13/2004	Tuesday	8:00 - 9:00 a.m.	1	-	4	-	26	-	6	-	37
Valrico Road at SR 60	Valrico	1/13/2004	Tuesday	4:00 - 5:00 p.m.	-	-	-	-	4	1	2	-	7
		1/14/2004	Wednesday	8:25 - 9:25 a.m.	-	-	-	-	19	4	4	-	27

NOTES:

NB= Northbound Through; SB= Southbound Through; EB= Eastbound Through; WB= Westbound Through

NBLT= Northbound Left; SBLT= Southbound Left; EBLT= Eastbound Left; WBLT= Westbound Left

APPENDIX B

Red Light Violation Data for After Period

RED LIGHT VIOLATION DATA FOR AFTER PERIOD

Location	City	Date	Day	Time Period	NB	NBLT	SB	SBLT	EB	EBLT	WB	WBLT	Total
Hillsborough Avenue (SR 600) at 40th Street	Tampa	12/16/2004	Thursday	7:00 - 8:00 a.m.	3	-	0	-	1	-	7	-	11
		12/16/2004	Thursday	5:00 - 6:00 p.m.	2	-	4	-	4	-	9	-	19
Adamo Drive (SR 60) at 50th Street	Tampa	12/9/2004	Thursday	7:00 - 8:00 a.m.	5	-	4	-	1	-	4	-	14
		12/9/2004	Thursday	5:00 - 6:00 p.m.	10	-	12	-	3	-	1	-	26
Florida Avenue (SR 685) at Waters Avenue	Tampa	12/8/2004	Wednesday	7:00 - 8:00 a.m.	6	-	2	-	4	-	2	-	14
		12/8/2004	Wednesday	5:00 - 6:00 p.m.	4	-	1	-	2	-	1	-	8
Busch Boulevard (SR 580) at Nebraska Avenue (SR 45)	Tampa	11/17/2004	Wednesday	7:00 - 8:00 a.m.	10	-	15	-	4	-	9	-	38
		11/17/2004	Wednesday	5:00 - 6:00 p.m.	3	-	2	-	0	-	6	-	11
Dale Mabry Highway (SR 573) at Gandy Boulevard	Tampa	12/15/2004	Wednesday	7:00 - 8:00 a.m.	1	-	4	-	1	-	0	-	6
		12/15/2004	Wednesday	5:00 - 6:00 p.m.	7	-	1	-	4	-	4	-	16
21st Street (SR 585) at 7th Avenue	Tampa	12/2/2004	Thursday	7:00 - 8:00 a.m.	-	-	30	-	-	-	-	-	30
		12/2/2004	Thursday	5:00 - 6:00 p.m.	-	-	17	-	-	-	-	-	17
Busch Boulevard (SR 580) at Florida Avenue (SR 685)	Tampa	12/2/2004	Thursday	7:00 - 8:00 a.m.	1	1	-	-	-	-	7	10	19
		12/9/2004	Thursday	5:00 - 6:00 p.m.	3	1	-	-	-	-	4	6	14
Fowler Avenue (SR 582) at Nebraska Avenue (SR 45)	Tampa	12/2/2004	Thursday	7:00 - 8:00 a.m.	3	-	-	-	-	-	5	-	8
		12/2/2004	Thursday	5:00 - 6:00 p.m.	0	-	-	-	-	-	24	-	24
Busch Boulevard (SR 580) at 56th Street	Tampa	11/18/2004	Thursday	7:00 - 8:00 a.m.	-	14	-	0	1	-	5	-	20
		12/2/2004	Thursday	5:00 - 6:00 p.m.	-	30	-	4	10	-	11	-	55
Fowler Avenue (SR 582) at 56th Street	Tampa	11/18/2004	Thursday	7:00 - 8:00 a.m.	-	-	-	-	5	0	4	2	11
		11/18/2004	Thursday	5:00 - 6:00 p.m.	-	-	-	-	0	0	2	9	11
Wheeler Street (SR 39) at Baker Street	Plant City	12/8/2004	Wednesday	7:00 - 8:00 a.m.	2	-	3	-	-	-	2	-	7
		12/8/2004	Wednesday	5:00 - 6:00 p.m.	3	-	1	-	-	-	0	-	4
Baker Street (SR 600) at Maryland Avenue	Plant City	12/8/2004	Wednesday	7:00 - 8:00 a.m.	0	-	0	-	1	-	3	-	4
		12/8/2004	Wednesday	5:00 - 6:00 p.m.	0	-	0	-	4	-	0	-	4
SR 39 at SR 60	Plant City	12/8/2004	Wednesday	4:00 - 5:00 p.m.	0	1	0	7	1	5	0	0	14
		12/9/2004	Thursday	8:00 - 9:00 a.m.	0	2	0	1	0	2	0	0	5
Parson Avenue at SR 60	Brandon	12/14/2004	Tuesday	4:00 - 5:00 p.m.	2	1	0	2	2	4	5	7	23
		12/9/2004	Wednesday	8:00 - 9:00 a.m.	4	3	2	8	1	3	2	6	29
SR 574 at Falkenburg Road	Mango	12/16/2004	Thursday	4:00 - 5:00 p.m.	-	7	-	-	8	-	3	9	27
		12/15/2004	Wednesday	8:00 - 9:00 a.m.	-	4	-	-	2	-	4	5	15
US 301 at SR 574	Riverview	12/30/2004	Thursday	4:00 - 5:00 p.m.	4	-	4	-	3	-	3	-	14
		12/28/2004	Tuesday	8:00 - 9:00 a.m.	1	-	13	-	1	-	3	-	18
Valrico Road at SR 60	Valrico	12/28/2004	Tuesday	4:00 - 5:00 p.m.	-	-	-	-	10	1	3	-	14
		12/29/2004	Wednesday	8:25 - 9:25 a.m.	-	-	-	-	11	1	5	-	17

Notes:

NB= Northbound Through; SB= Southbound Through; EB= Eastbound Through; WB= Westbound Through

NBLT= Northbound Left; SBLT= Southbound Left; EBLT= Eastbound Left; WBLT= Westbound Left

APPENDIX C

Graphical Comparison of Before/After Red Light Violation Data

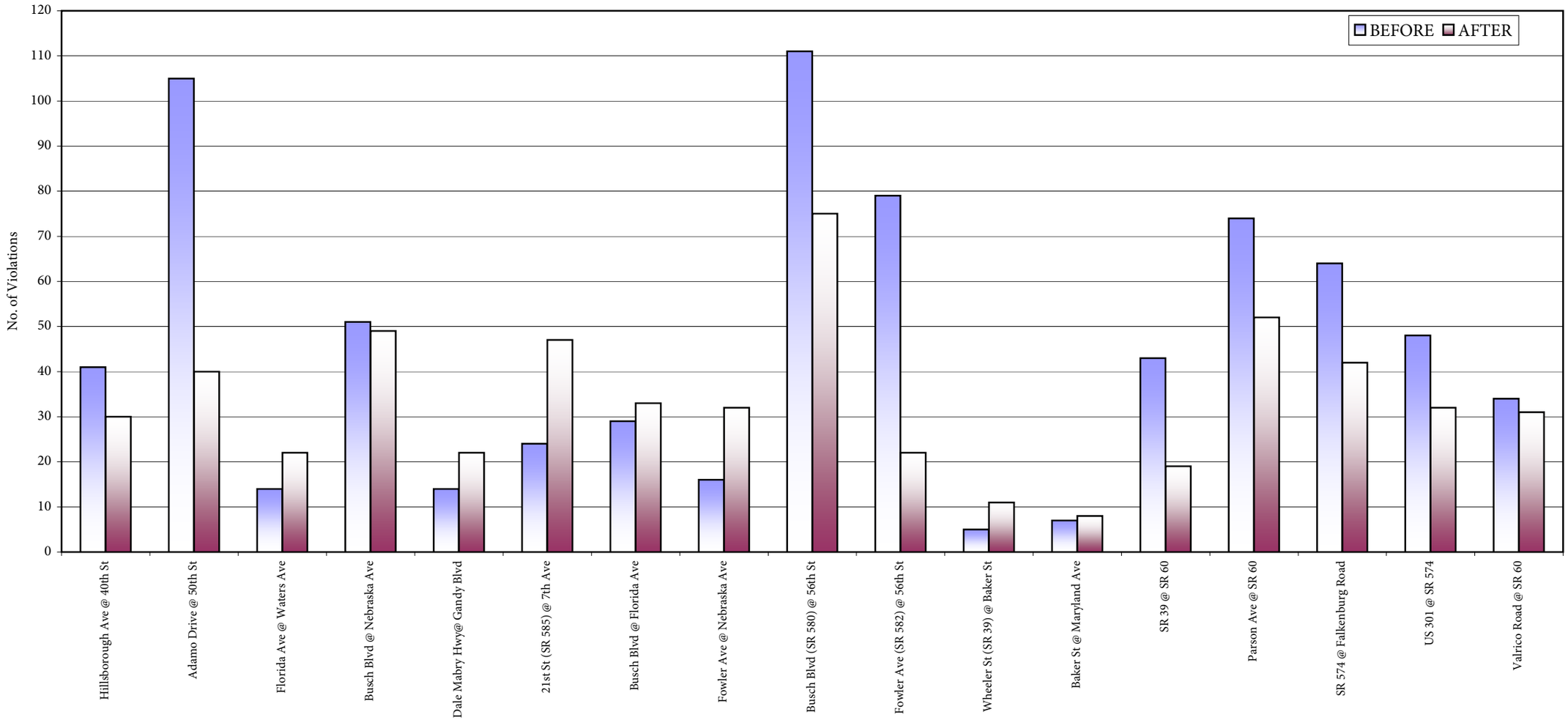

Figure 1: Before/ After Comparison of the Total Number of Red Light Violations (AM and PM Peak Hours Combined)

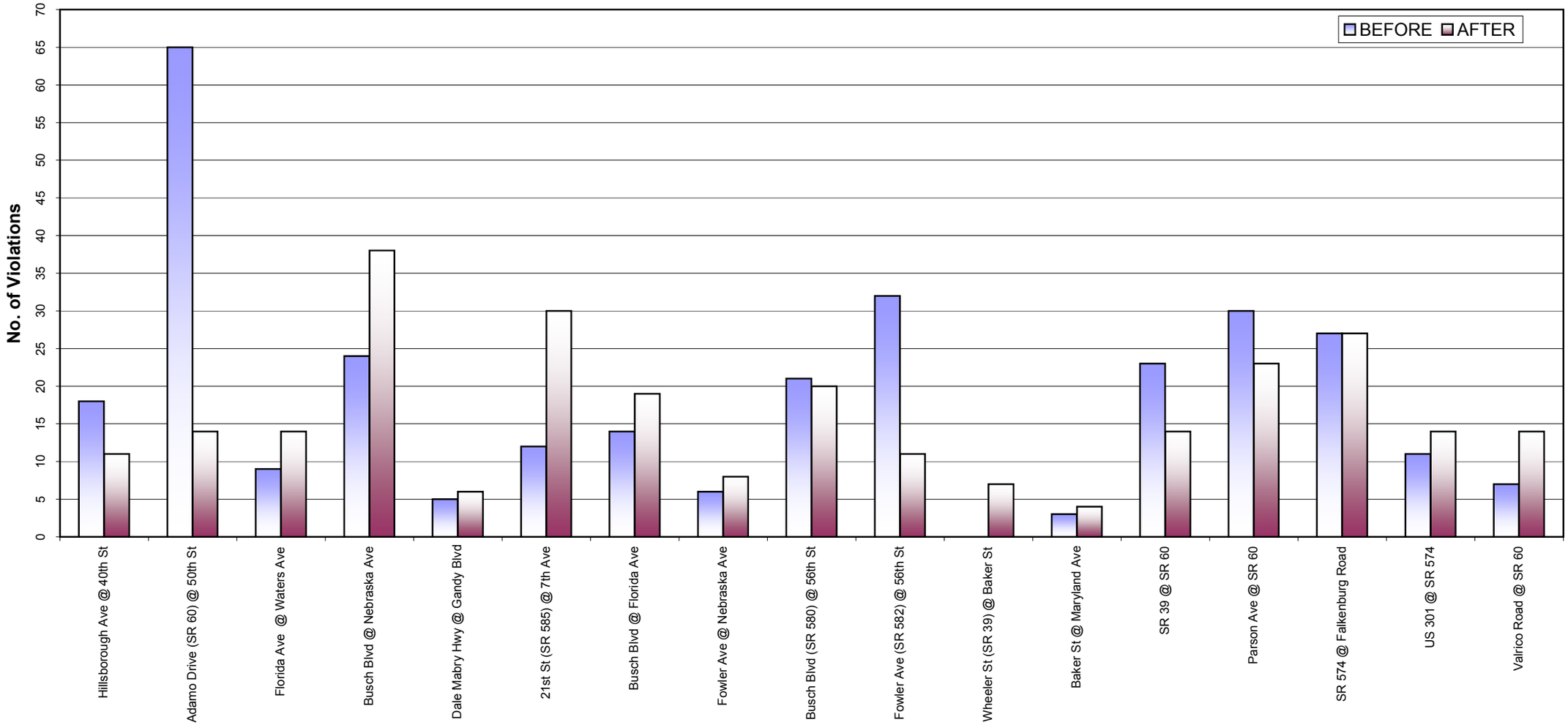

Figure 2: Comparison of Before/After Red Light Violations During the Morning Peak Period

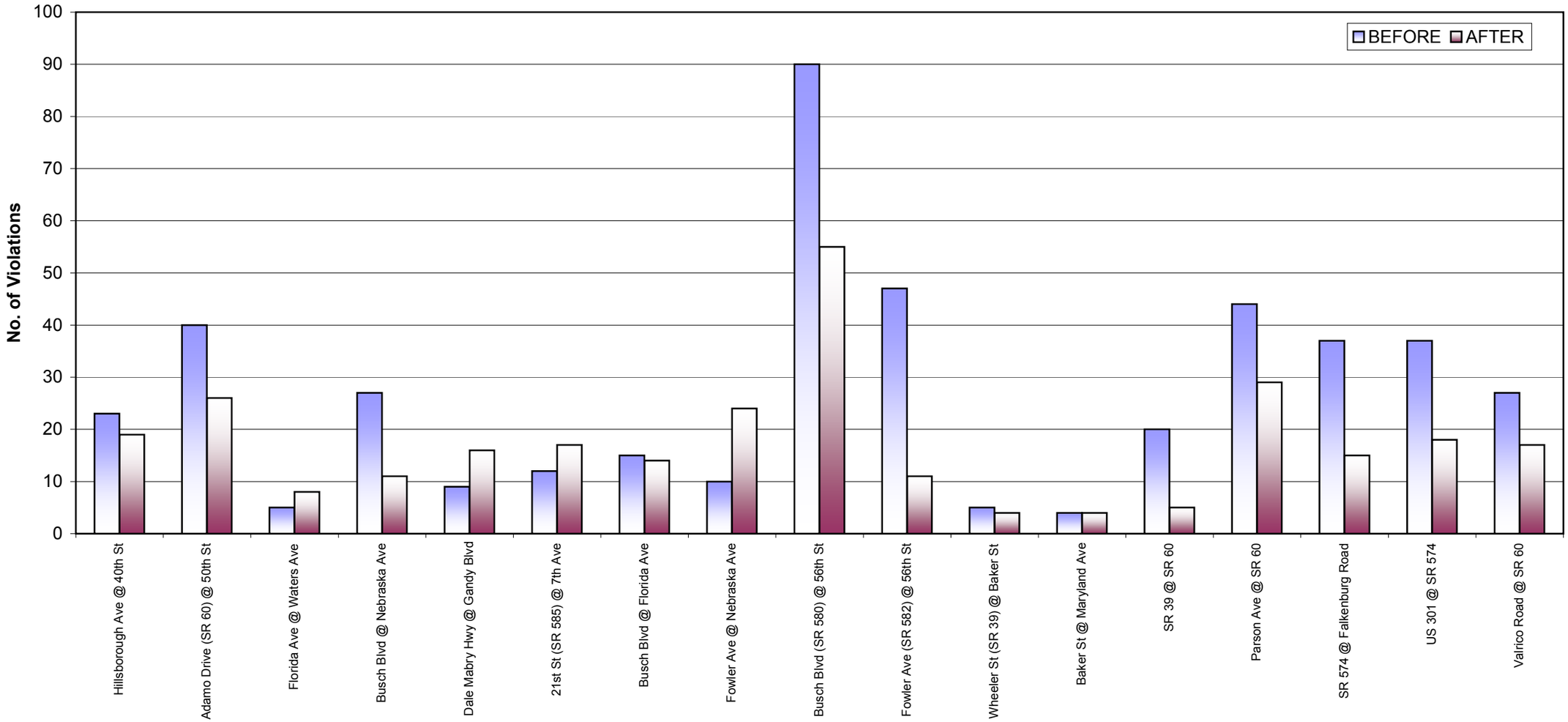

Figure 3: Comparison of Before/After Violations During the Evening Peak Period

APPENDIX D

Crash Data for Before Period

Crash Data for Before Period by Intersection

Location	State Section	Mile Post	White Light Installation Date	White Light Installation Direction	City	Study Period		Red Light Running Crashes		Total Red Light Running Crashes (All Approaches)	Annual Average Red Light Running Crashes		Annual Average Red Light Running Crashes (All Approaches)	All Crashes	Annual Average (All Crashes)	% of Red Light Running Crashes Compared to All Crashes	ADT	Crash Rate (Based on Total Crashes)	Crash Rate (Based on Red Light Running Crashes)
						No. of Months	From/To	White Light Approaches	Non-White Light Approaches		White Light Approaches	Non-White Light Approaches							
Hillsborough Avenue (SR 600) at 40th Street	10030000	2.267	Aug-03	NB, SB, EB, WB	Tampa	36 Months	Jan 00 to Dec 02	5.00	0.00	5.00	1.67	0.00	**1.67**	177	59.00	2.82%	42,000	3.845	0.109
Adamo Drive (SR 60) at 50th Street	10110000	2.101	Aug-03	NB, SB, EB, WB	Tampa	36 Months	Jan 00 to Dec 02	4.00	1.00	5.00	1.33	0.33	**1.67**	110	36.67	4.55%	71,167	1.398	0.064
Florida Avenue (SR 685) at Waters Avenue	10020000	5.362	Aug-03	NB, SB, EB, WB	Tampa	36 Months	Jan 00 to Dec 02	8.00	0.00	8.00	2.67	0.00	**2.67**	107	35.67	7.48%	48,667	2.006	0.150
Busch Boulevard (SR 580) at Nebraska Avenue (SR 45)	10310000	3.320	Aug-03	NB, SB, EB, WB	Tampa	36 Months	Jan 00 to Dec 02	11.00	0.00	11.00	3.67	0.00	**3.67**	127	42.33	8.66%	71,333	1.624	0.141
Dale Mabry Highway (SR 573) at Gandy Boulevard	10180000	1.814	Aug-03	NB, SB, EB, WB	Tampa	36 Months	Jan 00 to Dec 02	2.00	0.00	2.00	0.67	0.00	**0.67**	121	40.33	1.65%	33,167	3.412	0.055
21st Street (SR 585) at 7th Avenue	10250101	0.784	Aug-03	SB	Tampa	36 Months	Jan 00 to Dec 02	13.00	2.00	15.00	4.33	0.67	**5.00**	82	27.33	18.29%	27,000	2.771	0.507
Busch Boulevard (SR 580) at Florida Avenue (SR 685)	10310000	2.817	Aug-03	NB, NBLT, WB, WBLT	Tampa	36 Months	Jan 00 to Dec 02	2.00	5.00	7.00	0.67	1.67	**2.33**	120	40.00	5.83%	79,833	1.371	0.080
Fowler Avenue (SR 582) at Nebraska Avenue (SR 45)	10290000	0.505	Aug-03	NB, WB	Tampa	36 Months	Jan 00 to Dec 02	1.00	3.00	4.00	0.33	1.00	**1.33**	129	43.00	3.10%	78,500	1.499	0.047
Busch Boulevard (SR 580) at 56th Street	10310000	6.863	Jun-03	NBLT, SBLT, EB, WB	Tampa	36 Months	Jan 00 to Dec 02	3.00	1.00	4.00	1.00	0.33	**1.33**	62	20.67	6.45%	45,833	1.254	0.080
Fowler Avenue (SR 582) at 56th Street	10290000	4.019	Jun-03	EB, EBLT, WB, WBLT	Tampa	36 Months	Jan 00 to Dec 02	8.00	0.00	8.00	2.67	0.00	**2.67**	81	27.00	9.88%	55,167	1.34	0.132
SR 39 at SR 60	10070000	0.000	Apr-04	NB, SB, EBLT, WBLT	Plant City	36 Months	Jan 00 to Dec 02	10.00	0.00	10.00	3.33	0.00	**3.33**	90	30.00	11.11%	35,383	2.322	0.258
Parson Avenue at SR 60	10110000	9.425	Apr-04	EB, EBLT, WB, WBLT	Brandon	36 Months	Jan 00 to Dec 02	4.00	0.00	4.00	1.33	0.00	**1.33**	75	25.00	5.33%	63,833	1.073	0.057
SR 574 at Falkenburg Road	10340000	10.403	May-04	NBLT, EB, WB, WBLT	Mango	36 Months	Jan 00 to Dec 02	2.00	2.00	4.00	0.67	0.67	**1.33**	69	23.00	5.80%	61,000	1.032	0.060
US 301 at SR 574	10010000	24.800	May-04	NB, SB, EB, WB	Riverview	36 Months	Jan 00 to Dec 02	3.00	0.00	3.00	1.00	0.00	**1.00**	61	20.33	4.92%	54,000	1.048	0.051
Valrico Road at SR 60	10110000	11.447	Apr-04	EB, EBLT, WB, WBLT	Valrico	36 Months	Jan 00 to Dec 02	2.00	0.00	2.00	0.67	0.00	**0.67**	70	23.33	2.86%	38,917	1.642	0.047
US 301at SR 60	10010000	22.505	Jul-03	NBLT, SBLT, EBLT, WBLT	Brandon	36 Months	Jan 00 to Dec 02	1.00	4.00	5.00	0.33	1.33	**1.67**	100	33.33	5.00%	82,000	1.113	0.056
Dale Mabry Highway at Ehrlich Rd/Bearss Avenue	10160000	6.167	Aug-03	NBLT, SBLT, EBLT, WB	Tampa	36 Months	Jan 00 to Dec 02	1.00	6.00	7.00	0.33	2.00	**2.33**	117	39.00	5.98%	64,167	1.665	0.100
Falkenburg Road at SR 60	10110000	6.314	Jul-03	NB, SBLT, EB, WB	Brandon	36 Months	Jan 00 to Dec 02	5.00	0.00	5.00	1.67	0.00	**1.67**	107	35.67	4.67%	55,833	1.75	0.082
Florida Avenue (SR 685) at Fletcher Avenue	10020000	8.388	Aug-03	NBLT, SBLT, EB, WB	Tampa	36 Months	Jan 00 to Dec 02	3.00	3.00	6.00	1.00	1.00	**2.00**	77	25.67	7.79%	24,883	2.826	0.220
Florida Avenue (SR 685) at Bearss Avenue	10020000	9.682	Jul-03	NBLT, SBLT, EB, WB	Tampa	36 Months	Jan 00 to Dec 02	2.00	3.00	5.00	0.67	1.00	**1.67**	45	15.00	11.11%	32,167	1.276	0.142
Nebraska Avenue at Fletcher Avenue	10040000	8.196	Aug-03	NB, SB, EB, WB	Tampa	36 Months	Jan 00 to Dec 02	9.00	1.00	10.00	3.00	0.33	**3.33**	148	49.33	6.76%	35,250	3.831	0.259
Dale Mabry Highway at Waters Avenue	10160000	2.045	Jul-03	NB, NBLT, SB, EBLT	Tampa	36 Months	Jan 00 to Dec 02	7.00	4.00	11.00	2.33	1.33	**3.67**	146	48.67	7.53%	77,833	1.713	0.129
SR 60 at Lake Wood	10110000	7.929	Apr-04	NBLT, EB, EBLT, WB	Brandon	36 Months	Jan 00 to Dec 02	5.00	2.00	7.00	1.67	0.67	**2.33**	72	24.00	9.72%	73,500	0.894	0.087
SR 60 at Mt. Carmel	10110000	10.94	Apr-04	NB, SB, EB, WB	Brandon	36 Months	Jan 00 to Dec 02	5.00	0.00	5.00	1.67	0.00	**1.67**	45	15.00	11.11%	43,167	0.952	0.106
*SR 60 at Regency/Brandon Mall	10110000	7.07	May-02	NBLT, SBLT, EB, WB	Brandon	24 Months	Jan 00 to Dec 01	3.00	7.00	10.00	1.50	3.50	**5.00**	98	49.00	10.20%	82,750	1.622	0.166
TOTAL								119.00	44.00	163.00	40.17	15.83	**56.00**	2436	828.33	6.69%	1,377,350	1.811	0.127

* Since White Lights were installed in 2002, only two years (2000-2001) of available crash data was used.

APPENDIX E

Crash Data for After Period

Crash Data for After Period by Intersection

Location	State Section	Mile Post	White Light Installation Date	White Light Installation Direction	City	Study Period		Red Light Running Crashes		Total Red Light Running Crashes (All Approaches)	Annual Average Red Light Running Crashes		Annual Average Red Light Running Crashes (All Approaches)	All Crashes	Annual Average (All Crashes)	% of Red Light Running Crashes Compared to All Crashes	ADT	Crash Rate (Based on Total Crashes)	Crash Rate (Based on Red Light Running Crashes)
						No. of Months	From/To	White Light Approaches	Non-White Light Approaches		White Light Approaches	Non-White Light Approaches							
Hillsborough Avenue (SR 600) at 40th Street	10030000	2.267	Aug-03	NB, SB, EB, WB	Tampa	12 Months	Jan 04 to Dec 04	3	1	4	3	1	4.0	60	60	6.67%	49,000	3.346	0.224
Adamo Drive (SR 60) at 50th Street	10110000	2.101	Aug-03	NB, SB, EB, WB	Tampa	12 Months	Jan 04 to Dec 04	2	0	2	2	0	2.0	28	28	7.14%	78,000	0.981	0.070
Florida Avenue (SR 685) at Waters Avenue	10020000	5.362	Aug-03	NB, SB, EB, WB	Tampa	12 Months	Jan 04 to Dec 04	4	0	4	4	0	4.0	34	34	11.76%	58,000	1.602	0.189
Busch Boulevard (SR 580) at Nebraska Avenue (SR 45)	10310000	3.320	Aug-03	NB, SB, EB, WB	Tampa	12 Months	Jan 04 to Dec 04	3	0	3	3	0	3.0	42	42	7.14%	73,000	1.572	0.113
Dale Mabry Highway (SR 573) at Gandy Boulevard	10180000	1.814	Aug-03	NB, SB, EB, WB	Tampa	12 Months	Jan 04 to Dec 04	0	0	0	0	0	0.0	48	48	0.00%	42,000	3.123	0.000
21st Street (SR 585) at 7th Avenue	10250101	0.784	Aug-03	SB	Tampa	12 Months	Jan 04 to Dec 04	0	5	5	0	5	5.0	29	29	17.24%	32,000	2.476	0.428
Busch Boulevard (SR 580) at Florida Avenue (SR 685)	10310000	2.817	Aug-03	NB, NBLT, WB, WBLT	Tampa	12 Months	Jan 04 to Dec 04	1	0	1	1	0	1.0	22	22	4.55%	82,000	0.733	0.033
Fowler Avenue (SR 582) at Nebraska Avenue (SR 45)	10290000	0.505	Aug-03	NB, WB	Tampa	12 Months	Jan 04 to Dec 04	0	2	2	0	2	2.0	54	54	3.70%	78,000	1.892	0.070
Busch Boulevard (SR 580) at 56th Street	10310000	6.863	Jun-03	NBLT, SBLT, EB, WB	Tampa	12 Months	Jan 04 to Dec 04	2	1	3	2	1	3.0	25	25	12.00%	44,000	1.552	0.187
Fowler Avenue (SR 582) at 56th Street	10290000	4.019	Jun-03	EB, EBLT, WB, WBLT	Tampa	12 Months	Jan 04 to Dec 04	0	0	0	0	0	0.0	18	18	0.00%	57,500	0.855	0.000
SR 39 at SR 60	10070000	0.000	Apr-04	NB, SB, EBLT, WBLT	Plant City	12 Months	July 04 to Jun 05	1	3	4	1	3	4.0	27	27	14.81%	37,850	1.954	0.290
Parson Avenue at SR 60	10110000	9.425	Apr-04	EB, EBLT, WB, WBLT	Brandon	12 Months	July 04 to Jun 05	1	0	1	1	0	1.0	29	29	3.45%	68,750	1.155	0.040
SR 574 at Falkenburg Road	10340000	10.403	May-04	NBLT, EB, WB, WBLT	Mango	12 Months	July 04 to Jun 05	0	0	0	0	0	0.0	16	16	0.00%	64,000	0.685	0.000
US 301 at SR 574	10010000	24.800	May-04	NB, SB, EB, WB	Riverview	12 Months	July 04 to Jun 05	1	2	3	1	2	3.0	25	25	12.00%	62,000	1.105	0.133
Valrico Road at SR 60	10110000	11.447	Apr-04	EB, EBLT, WB, WBLT	Valrico	12 Months	July 04 to Jun 05	0	0	0	0	0	0.0	35	35	0.00%	45,500	2.107	0.000
US 301at SR 60	10010000	22.505	Jul-03	NBLT, SBLT, EBLT, WBLT	Brandon	12 Months	Jan 04 to Dec 04	0	4	4	0	4	4.0	32	32	12.50%	93,750	0.935	0.117
Dale Mabry Highway at Ehrlich Rd/Bearss Avenue	10160000	6.167	Aug-03	NBLT, SBLT, EBLT, WB	Tampa	12 Months	Jan 04 to Dec 04	2	2	4	2	2	4.0	48	48	8.33%	65,000	2.023	0.169
Falkenburg Road at SR 60	10110000	6.314	Jul-03	NB, SBLT, EB, WB	Brandon	12 Months	Jan 04 to Dec 04	0	0	0	0	0	0.0	40	40	0.00%	73,500	1.491	0.000
Florida Avenue (SR 685) at Fletcher Avenue	10020000	8.388	Aug-03	NBLT, SBLT, EB, WB	Tampa	12 Months	Jan 04 to Dec 04	0	0	0	0	0	0.0	28	28	0.00%	26,615	2.880	0.000
Florida Avenue (SR 685) at Bearss Avenue	10020000	9.682	Jul-03	NBLT, SBLT, EB, WB	Tampa	12 Months	Jan 04 to Dec 04	0	0	0	0	0	0.0	29	29	0.00%	37,750	2.099	0.000
Nebraska Avenue at Fletcher Avenue	10040000	8.196	Aug-03	NB, SB, EB, WB	Tampa	12 Months	Jan 04 to Dec 04	1	0	1	1	0	1.0	39	39	2.56%	32,000	3.33	0.086
Dale Mabry Highway at Waters Avenue	10160000	2.045	Jul-03	NB, NBLT, SB, EBLT	Tampa	12 Months	Jan 04 to Dec 04	0	0	0	0	0	0.0	35	35	0.00%	72,500	1.322	0.000
SR 60 at Lake Wood	10110000	7.929	Apr-04	NBLT, EB, EBLT, WB	Brandon	12 Months	July 04 to Jun 05	3	2	5	3	2	5.0	35	35	14.29%	80,000	1.198	0.171
SR 60 at Mt. Carmel	10110000	10.94	Apr-04	NB, SB, EB, WB	Brandon	12 Months	July 04 to Jun 05	2	1	3	2	1	3.0	29	29	10.34%	53,250	1.492	0.154
SR 60 at Regency/Brandon Mall	10110000	7.07	May-02	NBLT, SBLT, EB, WB	Brandon	24 Months	Jan 03 to Dec 04	4	3	7	2.0	1.5	3.5	106	53	6.60%	91,500	1.586	0.105
TOTAL								**30**	**26**	**56**	**28**	**24.5**	**52.5**	**913**	**860**	**6.13%**	1,497,465	1.740	0.103