EVALUATION OF INNOVATIVE SAFETY TREATMENTS

Final Report

Prepared for

Florida Department of Transportation
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The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the State of Florida Department of Transportation.

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16. Abstract

Although the Florida Department of Transportation has made many efforts to reduce the number, rate, and severity of traffic crashes, Florida is still one of the highest highway fatality rate states in the nation. In 2006, 3,365 persons were killed on the state's streets and roads. In an effort to enhance highway safety, FDOT has been refocusing its efforts by implementing new and innovative treatments to achieve its safety objectives. An evaluation is required to determine if these innovative treatments are effective in reducing crashes and fatalities. As such, the FDOT has established the "Evaluation of Innovative Safety Treatments" contract for the purpose of evaluating new and innovative traffic control devices and design features. A total of six innovative safety treatments were evaluated as part of this project. The following is a summary findings and recommendations from each of the following six evaluation studies conducted as part of this research project.

Temporary Rumble Strips: The use of temporary rumble strips in advance of construction work zones significantly reduced vehicular speeds once motorists encountered temporary rumble strips. Therefore, the use of temporary rumble strips prior to a construction work zone may be a practical countermeasure to reduce speeds through the work zone, thereby improving safety for both the motorist and the construction worker.

White Enforcement Lights at Signalized Intersections: The results of this study show that better enforcement of red light compliance made possible by the installation of white enforcement lights has the potential to reduce red light violations and associated crashes. The reduction in the number of red light violations and the reduction in red light running crashes were significant at 90% and 95% confidence levels, respectively.

Motorist Awareness System (MAS): The MAS was effective in reducing vehicular speeds through construction work zones. Targeted enforcement resulted in additional speed reductions. The MAS was also found to decrease the proportion of speeding motorists.

Tyregrip High Friction Surface System: The Tyregrip treatment was effective in increasing the friction between the roadway and vehicle tires. The treatment was also effective in assisting motorists in maintaining their lane position under wet pavement conditions. In addition, drivers tended to slow down when traveling over the section of the ramp treated with Tyregrip surface.

Countdown Pedestrian Signals: The results of this study indicate that countdown pedestrian signals seem to be effective in increasing the percentage of successful crossings and decreasing the percentage of pedestrians who initiate crossing during the flashing "Don't Walk" indication. However, the percentage of pedestrians entering during the steady "Don't Walk" indication increased at some locations. Since the results are based on only eight intersections, further research is recommended to confirm the findings from this study.

In-roadway Lights: The use of in-roadway lights reduced vehicular speeds, but did not have a substantial impact on crashes. The before and after crash frequencies were statistically similar at a 95% confidence level, although there was an increase in crashes during the after period. Additional traffic safety measures may need to be implemented at the study intersection to further reduce travel speeds and associated potential for crashes.

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Executive Summary

The ability to travel safely is the public's highest expectation of a transportation system, and it is an important aspect of Floridians' quality of life. Safely transporting people and products is the number one goal of the Florida Department of Transportation (FDOT). Although FDOT has made many efforts to reduce the number, rate, and severity of traffic crashes, Florida's highway fatality rate has been higher than the national average. The state's fatality rate in 2006 was 1.65 per 100 million vehicle miles traveled (VMT), a 4.7 % decrease from 2005, however it is still well above the national average of 1.45 per 100 million VMT. In 2006, 3,365 persons were killed on the state's streets and roads.

In an effort to enhance highway safety, in May 2001, FDOT adopted the improvement of transportation safety as a strategic objective. FDOT views this objective as a revitalization of its responsibility to improve the quality of life for Florida residents and visitors by enhancing transportation safety. An important part of this effort was the development of the first FDOT Strategic Highway Safety Plan in 2003. As a follow-up to this initial effort, FDOT worked diligently with many transportation and safety partners in developing the Florida Strategic Highway Safety Plan (SHSP) in 2006. The SHSP contains implementation strategies to help meet the SHSP's goal of improving the safety of Florida's surface transportation system by achieving a 5% annual reduction in the rate of fatalities and serious injuries beginning in 2007.

FDOT has been refocusing its efforts by implementing new and innovative treatments to achieve the above mentioned safety objectives. An evaluation is required to determine if these innovative treatments are effective in reducing crashes. The objective of this project was to evaluate new and innovative safety treatments to determine their impact on crashes and/or other surrogate measures. The following six different innovative treatments were evaluated as part of this project:

Temporary Rumble Strips in advance of Work Zones

The Florida Department of Transportation District 1 office utilized temporary rumble strips on the approach to work zone areas on State Road 31 to alert motorists of lane closures associated with a milling/resurfacing project (FM No. 193750), from the Lee/Charlotte County line to the Charlotte/Desoto County line. Rumble strips are cuts or ridges formed in the pavement that cause vibrations and make a rumbling sound when driven over. The ability of rumble strips to alert drivers of unusual or hazardous conditions makes them ideal candidates for use on the approach to a highway work zone.

Temporary rumble strips used as part of this project are made from a highly durable composite material with an adhesive backing that allows them to easily adhere to the roadway. These rumble strips can be installed and removed more easily than traditional rumble strips. In addition to ease-of-use, temporary rumble strips are brightly colored, which is another advantage over traditional rumble strips. Thus, temporary rumble strips provide motorists with three different types of warnings alerting them to the approaching work zone: a physical vibration, an auditory rumble sound, and a visual cue. In addition to making drivers more alert, it is anticipated that temporary rumble strips will also encourage drivers to slow down as they approach work zones.

White Enforcement Lights at Signalized Intersections

The Florida Department of Transportation in cooperation with local engineering and enforcement agencies has 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 and thus reduce the potential for crashes associated with red light running.

Motorist Awareness System in advance of Work Zones

In an effort to make work zones safer, the Florida Department of Transportation has developed a new Maintenance of Traffic (MOT) system for work zone traffic control, referred to as Motorist Awareness System (MAS). In addition to traffic control and warning devices used with standard MOT plans, the MAS uses portable changeable message signs, radar speed display units, and regulatory speed limit signs (with flashers) to alert motorists of work zone activities such as lane closures and reduced speed limits. Active enforcement is a critical element of the MAS. Thus, the MAS is intended to reduce travel speeds through work zones.

The MAS was implemented as part of construction projects on two segments of Florida interstate highways I-10 and I-95. These segments are a suburban section of I-10 in Baker County, from US 90 to Columbia County line, and a rural section of I-95 in Flagler County from the Volusia/Flagler County line to the Flagler/St. John County line.

Tyregrip High Friction Surface System

The Florida Department of Transportation District 4 Traffic Operations office in consultation with the FDOT District 4 Maintenance office, the FDOT Central office, and the Federal Highway Administration (FHWA) has installed the Tyregrip high friction surfacing system to help reduce the potential for run-off-road crashes along the on-ramp to northbound I-75 from eastbound Royal Palm Boulevard located in the City of Weston, Broward County, Florida. The Tyregrip system was installed on a 300-foot section of the ramp, just upstream of the gore area between I-75 and the ramp, where the majority of the crashes occurred. This particular ramp was chosen as a candidate based on its crash history with 12 run-off-road crashes in the three-year period from 2002 to 2004. Eighty-three percent of these crashes occurred under wet road surface conditions.

Countdown Pedestrian Signals

The Florida Department of Transportation, the Broward County Traffic Engineering Division and the City of Boca Raton replaced traditional pedestrian signals at several intersections located in the South Florida area (Broward and Palm Beach Counties) with countdown pedestrian signals. The countdown pedestrian signal is comprised of the same three indications as the conventional pedestrian signal. The flashing "Don't Walk" indication, however, is complemented by an illuminated number indicating the number of seconds before the steady "Don't Walk" indication will be illuminated. The signal head counts down the seconds of what would traditionally be the flashing "Don't Walk" interval and thus provides feedback to pedestrians on the time remaining in their crossing. By advising the pedestrian of the remaining seconds before the "Don't Walk" indication will be illuminated, the pedestrian can make a decision on his or her ability to safely cross the street in the available time. As such, countdown signals are expected to improve compliance with pedestrian indications and enhance pedestrian safety.

In-roadway Lights

In an effort to reduce the frequency of crashes at the intersection of southbound I-95 off-ramp and westbound State Road 84 (SR 84), the FDOT District 4 Traffic Operations Office installed a series of in-roadway lights along the off-ramp. The purpose of the in-roadway lighting system was to alert motorists to the approaching sharp right turn at SR 84, so that drivers would reduce their speeds in order to negotiate the turn safely. The in-roadway lights were linked with a speed detection system, which would illuminate the lights when the approaching vehicle's speed was detected to be greater than the pre-set speed of 50 mph. The in-roadway lights were operated in such a way that they create a 'strobing' effect towards the approaching driver to give the motorist the perception that he/she is speeding. The 'strobe' effect starts at the beginning of each group of lights, and progresses with each unit in the group illuminating until all are illuminated, then off, and starting the sequence over again. As such, in-roadway lights are expected to reduce travel speeds. It is anticipated that the reduction in vehicular speeds would reduce the potential for crashes.

In order to determine the effectiveness of the safety treatments described above, either a comparative parallel or a before/after evaluation methodology was utilized. In the before/after evaluation, data are compared for conditions before and after the installation of the treatment at the study location. The after condition refers to the location and time where the treatment has been applied and the before condition refers to the location and time prior to the installation of the treatment. In the comparative parallel evaluation study, data are compared for test and control conditions. A test condition refers to a site where the treatment was applied and a control condition refers to a site that did not utilize the treatment. Various measures of effectiveness (MOEs) were compared to determine the impact of innovative treatments. The following sections provide a description of the MOEs that were used as part of this study.

Observed changes in the number of crashes or crash rates are generally used as a direct measure of changes in traffic safety. Crash frequencies for the before and after periods can be compared to determine the impact of a safety treatment. Some of the innovative treatments discussed above were installed less than a year ago. Consequently, sufficient crash data for the after period were not available. Therefore, surrogate measures of safety (such as changes in average speed, red light violations, compliance with pedestrian signals) were used to quantify the impacts of the treatment. The measures of effectiveness (MOEs) used in the evaluation studies conducted as part of this project were as follows:

- Change in crash frequency
- Change in average speed
- Change in speed distribution
- Change in the proportion of speeding vehicles
- Change in the percentage of vehicles whose wheels crossed the yellow or white edge line
- Change in the proportion of compliance with pedestrian signals

It should be noted that not all MOEs listed above apply to all evaluation studies. Depending on the nature of the treatment being studied, one or more of the MOEs listed above were used. Statistical analysis was performed to determine if the changes in the measures of effectiveness are attributable to the use of the treatment or simply due to chance. Statistical tests that were performed to test the effectiveness of the innovative safety treatments were as follows:

- Kolmogorov-Smirnov and Shapiro-Wilk Tests – to determine if the data are normally distributed.

- Student's t-Test – to determine if the differences between the mean speeds are statistically significant.
- z-Test – to determine if the differences between the proportions of vehicles traveling over the speed limit are statistically significant.
- Poisson Test of Significance: to determine if differences in the before and after crash frequencies are significant.
- Z-scores for skewness and kurtosis with the Kolmogorov-Smirnov Test: to determine if there are changes in the speed distributions for the before and after periods.
- Analysis of Variance (ANOVA): to determine if differences in mean speeds are statistically significant.
- F-test: to determine if differences in the variance of the mean speed are different.

The following is a summary of findings and recommendations based on the results of the evaluation studies conducted as part of this project:

Temporary Rumble Strips in advance of Work Zones

The use of temporary rumble strips in advance of construction work zones significantly reduced vehicular speeds once motorists encountered the temporary rumble strips. Therefore, the use of temporary rumble strips prior to a construction work zone may be a practical countermeasure to reduce vehicular speeds through the work zone, thereby improving safety for both the motorist and the construction worker.

White Enforcement Lights at Signalized Intersections

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). The reduction in the number of red light violations and the reduction in the crash rate for red light running crashes occurring on the approaches with white lights were statistically significant.

Between 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 the analysis of crash data are less conclusive than the results obtained from the 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.

Tyregrip High Friction Surface System

The Tyregrip friction surface treatment was effective in increasing the friction between the roadway and vehicle tires. The treatment was also effective in assisting motorists in maintaining their lane position under wet pavement conditions. In addition, drivers tended to slow down when traveling over the treated section of the ramp. It appears that the use of Tyregrip may be a practical countermeasure for improving safety at locations that are prone to run-off-road crashes, particularly sharp curves and entry/exit ramps.

Motorist Awareness System (MAS) in advance of Work Zones

The MAS was effective in reducing vehicular speeds through construction work zones. Targeted enforcement resulted in additional speed reductions. The MAS decreased the proportion of motorists traveling over the posted speed limit. Based on these findings, the use of MAS appears to be a practical countermeasure to reduce vehicular speeds through the work zone.

Countdown Pedestrian Signals

Pedestrian countdown signals seem to be effective in increasing the percentage of successful crossings and decreasing the percentage of pedestrians who initiate crossing during the flashing "Don't Walk" indication. However, the percentage of pedestrians entering during the steady "Don't Walk" indication increased at some locations. Since the results are based on only eight intersections, further research is recommended to confirm the findings from this study. In addition, it is recommended that the frequency and rate of pedestrian crashes at the study intersections be examined once sufficient crash data for the after period become available to quantify the impacts of countdown signals on pedestrian safety.

In-roadway Lights

The use of in-roadway lights reduced vehicular speeds, but did not have a substantial impact on crashes at the study intersection. It should be noted that in-roadway lights were not working continuously throughout the study period. The system was not 100% functional due to erratic operation of the loop detector card caused by lightening strikes and/or other reasons. The before and after crash frequencies were statistically similar at a 95% confidence level, although there was an increase in crashes during the after period. Additional traffic safety measures may need to be implemented at the study intersection to further reduce travel speeds and associated potential for crashes.

In summary, the innovative treatments evaluated as part of this research positively impacted driver behavior related to speeding, red light violation, and pedestrian compliance with the flashing "Don't Walk" signal indication. The results of this research also indicate that the Tyregrip friction surface has the potential to reduce run-off-road crashes. Better enforcement made possible by white enforcement lights has the potential to reduce crashes associated with red light running. Sufficient after crash data were not available to determine the impact of countdown pedestrian signals and Tyregrip friction surface on crashes. Therefore, several surrogate measures were evaluated to document the effectiveness of these innovative treatments. It is recommended that before and after crash data are compared as it become available to determine the impact of countdown pedestrian signals and Tyregrip surface treatment on crashes and to further verify the impact of white enforcement lights on red light running crashes.

The Evaluation of Innovative Safety Treatments research should be considered as a long-term initiative by the Department. The results of this research benefit the Department in a number of ways. First, the research helps evaluate the effectiveness of innovative treatments, so the Department can decide whether or not to continue to implement the innovative treatment. The Department may choose to implement those treatments having the greatest impact on safety on a statewide basis. As such, the research supports the Department's efforts towards improving safety by continuously looking for new and innovative ways to achieve the Department's number one goal of providing a safer transportation system. In addition, this research provides support for improvements to current design, construction, and/or maintenance standards. For example, the use of the Motorist Awareness System combined with enforcement and the use of temporary rumble strips in advance of work zones can be considered as potential enhancements to MOT standards to alert motorists of lane closures, reduced speed limits and other activities associated with work zones.

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1.0 INTRODUCTION

The ability to travel safely is the public's highest expectation of a transportation system, and it is an important aspect of Floridians' quality of life. Safely transporting people and products is the number one goal of the Florida Department of Transportation (FDOT). Although FDOT has made many efforts to reduce the number, rate, and severity of traffic crashes, Florida is still one of the states with high fatality rates in the nation. The state's fatality rate in 2006 was 1.65 per 100 million vehicle miles traveled (VMT), a 4.7 % decrease from 2005, however it is still well above the national average of 1.45 per 100 million VMT. In 2006, 3,365 persons were killed on the state's streets and roads. Florida's weather, demographics, and social elements foster a highly mobile population that is increasing by approximately half-a-million people annually. In addition, millions of tourists visit Florida from other states and nations. With this ever-growing number of people traveling on Florida's roads, safer roadways have become an important issue in the economics of Florida.

In an effort to enhance highway safety, in May 2001, FDOT adopted the improvement of transportation safety as a strategic objective. FDOT views this objective as a revitalization of its responsibility to improve the quality of life for Florida residents and visitors by enhancing transportation safety. An important part of this effort was the development of the first FDOT Strategic Highway Safety Plan in 2003 by a multi-disciplinary team of FDOT transportation professionals. This Plan provided direction to focus resources where opportunities for safety improvements are greatest. As a follow-up to this initial effort, FDOT worked diligently with many transportation and safety partners, including the Florida Department of Highway Safety and Motor Vehicles, Florida Highway Patrol, Metropolitan Planning Organization Advisory Council and citizens, in developing the Florida Strategic Highway Safety Plan (SHSP) in 2006. The SHSP contains implementation strategies and a plan for measuring and monitoring progress.

The following Vision, Mission, and Goal statements were developed by the SHSP Steering Committee (1).

VISION: To provide a safer surface transportation system for residents, businesses, and visitors.

MISSION: The State of Florida, utilizing engineering, enforcement, education, and emergency management will focus resources where opportunities for safety improvements are greatest.

GOAL: To improve the safety of Florida's surface transportation system by achieving a 5% annual reduction in the rate of fatalities and serious injuries beginning in 2007.

FDOT has been refocusing its efforts by implementing new and innovative treatments to achieve the above mentioned safety objectives. An evaluation is required to determine if these innovative treatments are effective in reducing crashes and fatalities. As such, the State Safety Office of FDOT proposed the "Evaluation of Innovative Safety Treatments" research for the purpose of evaluating new and innovative traffic control devices and design features.

2.0 OBJECTIVES

The objective of this project was to conduct evaluation studies of new and innovative safety treatments implemented by FDOT or other agencies in Florida to determine their impact on crashes and/or other surrogate measures. The results of this research can help identify those treatments that had a positive impact on safety, so the Department may choose to implement them on a statewide basis. The following specific tasks were completed for each of the evaluation studies conducted as part of this project.

- Identification of an Innovative Treatment
- Preparation of an Evaluation Plan
- Review and Approval of Evaluation Plan by the Department
- Before Period Data Collection
- Implementation of the Identified Treatment
- After Period Data Collection
- Analysis of Before/After Data
- Statistical Analysis
- Preparation of Report to Document the Effectiveness of the Innovative Treatment

The following section discusses these tasks in greater detail.

Identification of Innovative Treatments

The research team worked closely with the FDOT Project Manager, district safety engineers and local government agencies in identifying the following innovative treatments:

- Temporary Rumble Strips in advance of Work Zones
- White Enforcement Lights at Signalized Intersections
- Motorist Awareness System in advance of Work Zones

- Tyregrip High Friction Surface System on an on-ramp to I-75
- Countdown Pedestrian Signals
- In-roadway Lights on an off-ramp from I-95
- Special Pavement Marking and Signing for Bicycle Detection at Signalized Intersections

Preparation of Evaluation Plans

Based upon the type of treatment, the research team identified motorist and/or pedestrian behaviors that would be expected to be affected by the treatment. For example, a safety treatment intended to cause motorists to reduce speeds should have some effect on motorist behavior as related to their speed; but, it might also have other effects, including avoidance, sudden braking, or other conflicts or unsafe actions. These potential behaviors were identified prior to the data collection process, so that they could be monitored in the field. The research team developed an evaluation plan for each of the above listed innovative treatments to define the elements of work to be performed, a work schedule, and a project budget for FDOT review and approval.

FDOT Review and Approval of the Evaluation Plan

The research team submitted evaluation plans to the FDOT Project Manager for review and comments. Based on the review comments, the evaluation plans were revised and then resubmitted for final approval. The Plans were used as the basis for the Task Work Orders issued by the FDOT Project Manager.

Before Period Data Collection

Upon the receipt of the Notice to Proceed from the Department, the research team collected necessary data as described in the evaluation plan for each of the studies.

Implementation of the Innovative Treatment

The research team coordinated with implementing agencies and their contractors regarding time frames for implementation of the treatment, so appropriate schedules were developed for before and after data collection activities.

After Period Data Collection

At the appropriate time as established in the study methodology, the research team conducted speed and shoulder encroachment studies, and collected crash data and pedestrian/motorist behavior data as described in the evaluation plan for each of the studies. In some cases, the research teams were not able to collect data as originally scheduled due to delays in construction schedules and due to hurricanes. As such, schedules for research studies had to be extended.

Analyze Data Collected

Data collected before and after the installation of innovative treatments were analyzed to quantify changes in the measures of effectiveness, such as differences in crash frequency/rate, mean speed, speed distribution, proportion of speeding vehicles, proportion of vehicles encroaching the shoulder, proportion of pedestrian compliance with signals, and other surrogate measures. Then actual results were compared with expected results.

Statistical Analysis

Statistical tests were conducted to determine whether the changes observed in the measures of effectiveness are attributable to the treatment or simply due to chance.

Prepare Report to Document the Effectiveness of the Innovative Treatment

A report documenting the study results, findings and recommendations for each of the evaluation studies was prepared as a separate volume as follows.

- Volume 1, A Study of the Effectiveness of White Enforcement Lights
- Volume 2, A Study of the Effectiveness of Temporary Rumble Strips
- Volume 3, A Study of the Effectiveness of the Tyregrip High Friction Surface System
- Volume 4, A Study of the Effectiveness of the Motorist Awareness System
- Volume 5, A Study of the Effectiveness of Countdown Pedestrian Signals
- Volume 6, A Study of the Effectiveness of In-roadway Lights

3.0 STUDY METHODOLOGY

In most cases, the study sites were selected by FDOT based on the number of crashes or other known problems. Therefore, a before and after with control group evaluation plan could not be used since that evaluation design depends on random selection of treatment and control groups prior to the implementation of the treatment. Therefore, a comparative parallel or a before/after evaluation methodology was utilized to determine the effectiveness of the treatments discussed above.

Measures of Effectiveness

Observed changes in the number of crashes or crash rates are generally used as a direct measure of changes in traffic safety. Crash frequencies for the before and after periods can be compared to determine the impact of a safety treatment. Some of the innovative treatments discussed above were installed less than a year ago. Consequently, sufficient crash data for the after period were not available. Therefore, surrogate measures of safety (such as changes in average speed, red light violations, compliance with pedestrian signals) were instead utilized to quantify the impacts of the treatment. The proposed measures of effectiveness (MOEs) used in the evaluation studies conducted as part of this project were as follows:

- Change in crash frequency
- Change in average speed
- Change in speed distribution
- Change in the proportion of speeding vehicles
- Change in the percentage of vehicles encroaching the shoulder
- Change in the proportion of compliance with pedestrian signals

Statistical significance of the changes observed in the measures of effectiveness was evaluated to determine if the changes are attributable to the use of the treatment or simply due to chance. Statistical tests that were performed to test the effectiveness of the innovative treatments were as follows:

- Kolmogorov-Smirnov and Shapiro-Wilk Tests – to determine if the data are normally distributed.
- Student's t-Test – to determine if the differences between the mean speeds are statistically significant.
- z-Test – to determine if the differences between the proportions of vehicles traveling over the speed limit are statistically significant.
- Poisson Test of Significance: to determine if differences in the before and after crash frequencies are significant.
- Z-scores for skewness and kurtosis with the Kolmogorov-Smirnov Test: to determine if there are changes in the speed distributions for the before and after periods.
- Analysis of Variance (ANOVA): to determine if differences in mean speeds are statistically significant.
- F-test: to determine if differences in the variance of the mean speed are different.

4.0 OVERVIEW OF THE WHITE ENFORCEMENT LIGHT EVALUATION STUDY

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 (see Table 1) to help police officers safely enforce red light compliance and thus reduce the potential for crashes associated with red light violations.

The white lights were placed either above or below the signal head (see Photograph 4), 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.

Table 1: Study Intersections for White Enforcement Light Evaluation

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

Photograph 1: Typical Installation of a White Enforcement Light

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.

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 the before and after periods were obtained from the FDOT Crash Analysis Reporting System (CARS) for the years from 2000 to 2005. 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) 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 with 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 analysis of a surrogate measure of effectiveness (number of red light violations) as well as a direct measure of effectiveness (crash frequency). Between 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 the analysis of crash data are less conclusive than the results obtained from the 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. For further details, please refer to the attached Volume 1.

5.0 OVERVIEW OF THE TEMPORARY RUMBLE STRIP EVALUATION STUDY

In an effort to improve safety in work zones, the Florida Department of Transportation District 1 office utilized temporary rumble strips on the approach to work zone areas on State Road 31 to alert motorists of lane closures associated with a milling/resurfacing project (FM No. 193750), from the Lee/Charlotte County line to the Charlotte/Desoto County line (see Figure 1). This segment of SR 31 is a north/south, two-lane, rural highway with paved shoulders on both sides of the roadway. The speed limit along the entire study segment of SR 31 is 60 miles per hour.

Rumble strips are cuts or ridges formed in the pavement that cause vibrations and make a rumbling sound when driven over. Rumble strips are widely used across the United States to warn drivers of a change in traffic pattern or unusual roadway conditions. For instance, they are frequently used on the shoulder of high-speed roadways to alert potentially errant drivers that they are leaving the traveled way.

Rumble strips are also frequently used on the approach to an unusual roadway condition, such as a sharp curve or an unexpected stop condition.

The ability of rumble strips to alert drivers of unusual or hazardous conditions makes them ideal candidates for use on the approach to a highway work zone. However, the traditional rumble strips are not easy to install or to remove, making them impractical for use in a temporary situation like a highway work zone. In recent years, however, manufacturers have developed temporary rumble strips, made from a highly durable composite material with an adhesive backing that allows them to easily adhere to the roadway (see Photographs 2 and 3). Temporary rumble strips can be installed and removed more easily than traditional rumble strips. In addition to ease-of-use, temporary rumble strips are brightly colored, which is another advantage over traditional rumble strips. Thus, temporary rumble strips provide motorists with three different types of warnings alerting them to the approaching work zone: a physical vibration, an auditory rumble sound, and a visual cue. In addition to making drivers more alert, it is anticipated that temporary rumble strips will also encourage drivers to slow down as they approach work zones.

Four sets of rumble strips were installed in advance of the work zone, in each travel direction. The rumble strips were four inches wide and were installed in four sets of six strips per set (see Photograph 4). The first set was located 100 feet past the first (1500 feet) construction warning sign. The second, third, and fourth sets were installed at 500 feet, 250 feet, and 100 feet downstream of the previous sets, respectively (see Figure 3). The rumble strips were installed perpendicular to the travel direction of northbound and southbound traffic.

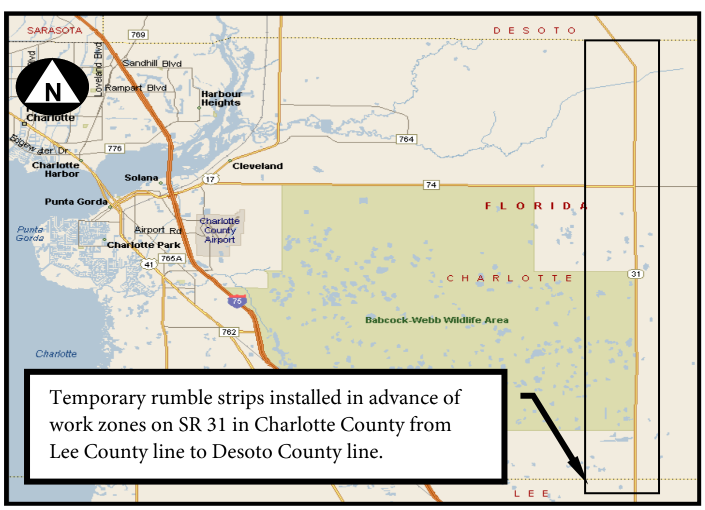
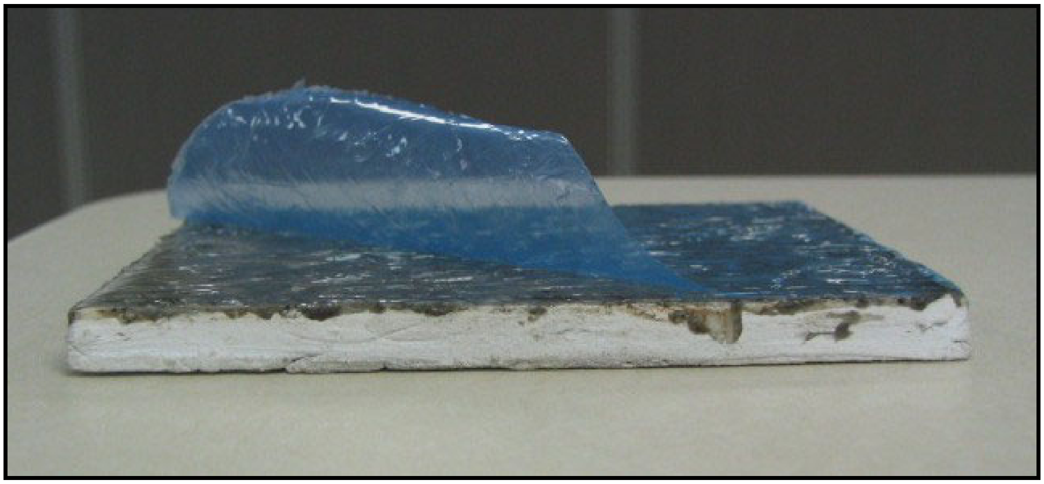


Figure 1. Project location map

Photograph 2. Sectional view of temporary rumble strip



Photograph 3. Adhesive backing on temporary rumble strip

Photograph 4: Typical installation of temporary rumble strips (6 strips per set)

The Maintenance of Traffic (MOT) plans for the control (without rumble strips) and test (with rumble strips) conditions are shown in Figures 2 and 3, respectively. The MOT plans shown in these figures were derived from Index 603 of the 2004 FDOT Design Standards for Design, Construction, Maintenance and Operations on the State Highway System (2).

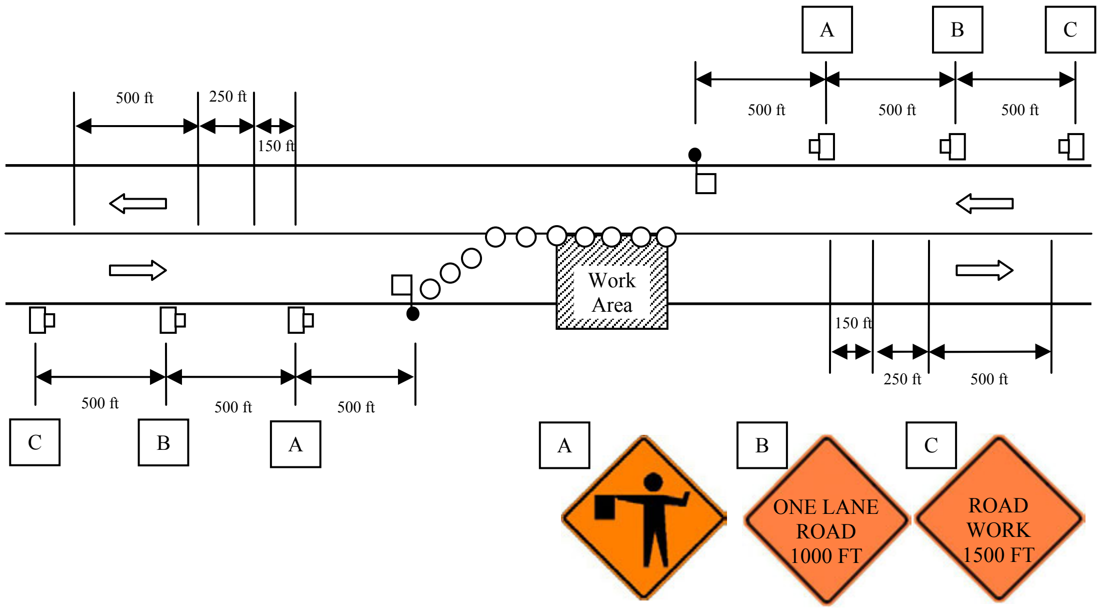


Figure 2. MOT Plan for Control Condition

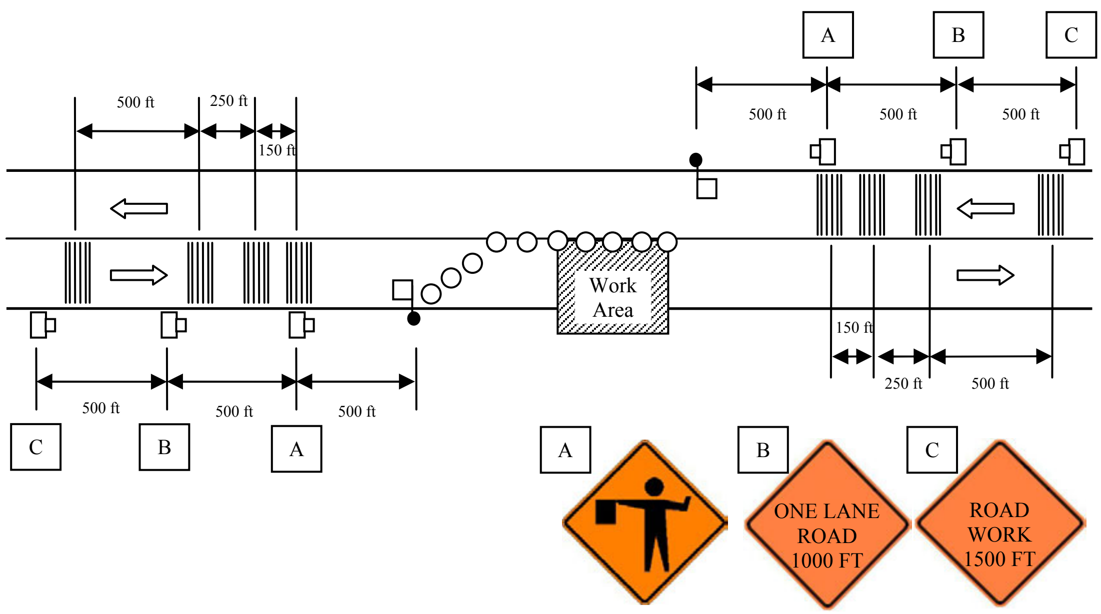


Figure 3. MOT Plan for Test Condition

The goal of this research was to determine the effectiveness of temporary rumble strips in reducing travel speeds approaching highway work zones. The effectiveness of the temporary rumble strips was determined through a field experiment conducted on SR 31 at various test (with temporary rumble strips) and control (without temporary rumble strips) locations.

Speed data were collected for the control condition (without rumble strips) during the second week of June 2006 and the third week of July 2006, during which time researchers conducted 19 speed studies at different times of the day (Noon and Evening periods) and for various days of the week. The contractor began to apply the temporary rumble strips as a part of setting up the Maintenance of Traffic (MOT) each day starting the fourth week of July 2006. Once again, speed data for the test (with rumble strips) condition were collected at different times of the day and for various days of the week over a two-week period, during the fourth week of July 2006 and the first week of August 2006. A total of 25 speed studies were conducted for the test condition. Speed data were collected at two locations under each condition (with and without rumble strips):

- About 4,000 feet upstream from the first warning sign. This location was selected to obtain travel speeds that are not influenced by signs/devices associated with the work zone or the slow moving/stopped traffic associated with lane closures.
- Just prior to the final warning sign or about 600 feet upstream from the flagging station. Since this location is in the midst of a series of rumble strips, the travel speeds measured at this location reflect speeds of vehicles that encountered three of the four sets of rumble strips.

A comparison was made between the speeds of vehicles traveling through construction work zones with and without temporary rumble strips. Changes in travel speed were evaluated in several ways, such as changes in mean speed, speed distribution and the proportion of speeding motorists (the percentage of motorists driving above the 60 mph speed limit). The statistical significance of the changes observed in the measures of effectiveness was evaluated to determine whether the changes are attributable to the use of temporary rumble strips or simply due to chance. The following is a summary of findings:

- For the Noon and Evening periods at the 600-foot upstream location, the speed distributions for the test condition (with rumble strips) were significantly different than those for the control condition (without rumble strips). The speed distributions for each of the periods indicated a greater proportion of higher speeds at the control locations (without rumble strips) as compared to the test locations (with rumble strips) where a greater proportion of lower speeds were found.

- For the Noon and Evening periods at the 600-foot upstream location, the mean speeds at test locations (with rumble strips) were significantly different at the 95% confidence level than those observed at control locations (without rumble strips). During the Noon period, the mean travel speed at the test locations with rumble strips was 36.28 miles per hour (mph) as compared to 45.17 mph at the control locations without rumble strips. During the evening period, the mean speed for the test locations with rumble strips was 35.79 mph as compared to 44.34 mph for the control locations without rumble strips. This indicates that the installation of rumble strips reduced the mean speed by approximately 9 mph.
- For the Noon and Evening periods at the 4,000-foot upstream location, the mean speeds and the speed distributions were not different at the 95% confidence level. This indicates that motorists maintained similar speeds at an upstream location when they did not encounter rumble strips. This observation also indicates that travel speeds approaching work zones, at a 4,000-foot upstream location, were similar under both the test and control conditions.
- In general, a majority of motorists slowed their vehicles in response to construction warning signs, flagmen and rumble strips.

In summary, the use of temporary rumble strips in advance of construction work zones reduced vehicular speeds once motorists encountered the temporary rumble strips. Therefore, the use of temporary rumble strips prior to a construction work zone may be a practical countermeasure to reduce vehicular speeds through the work zone, thereby improving safety for both the motorist and the construction worker. For additional details, please refer to the attached Volume 2.

6.0 OVERVIEW OF THE TYREGRIP EVALUATION STUDY

The Florida Department of Transportation (FDOT) District 4 Traffic Operations Office in consultation with the FDOT Central office and the Federal Highway Administration (FHWA) has installed the Tyregrip high friction surfacing system to help reduce the potential for run-off-road crashes along the on-ramp to northbound I-75 from eastbound Royal Palm Boulevard (see Figure 4). This ramp is located in the City of Weston, Broward County, Florida.

Based on the information received from the manufacturer, "the Tyregrip high friction surfacing system consists of a highly modified exothermic epoxy resin two-part binder usually top dressed with a calcined bauxite with a PSV (Polished Stone Value) of 70%+. This gives the system long lasting durability and skid resistance properties on both wet and dry pavement conditions."

The Tyregrip system was installed on a 300-foot section of the ramp, just upstream of the gore area between I-75 and the ramp, where the majority of the crashes occurred. The subject ramp is a one-lane loop ramp with an advisory speed of 25 mph. Curve warning signs and chevron signs exist in advance of the study section of the ramp. This particular ramp was chosen as a candidate based on its crash history with12 run-off-road crashes in the three-year period from 2002 to 2004. Eighty-three percent of these crashes occurred under wet road surface conditions.

In order to evaluate the effectiveness of the Tyregrip treatment, a before and after methodology was utilized. The after condition refers to the location and time where the Tyregrip has been applied and the before condition refers to the location and time prior to the installation of the Tyregrip. The Tyregrip treatment was applied on May 15, 2006. The effectiveness of the Tyregrip surface was evaluated from a materials perspective and from a safety perspective by using various types of data as discussed below.

Friction Factor

A before and after comparison of friction numbers was conducted to determine if skid numbers for the study section of the ramp after the treatment are significantly higher than the skid numbers before the treatment. Skid numbers are a measure of the amount of friction between the roadway and a standardized tire under wet road conditions. Skid tests were performed by the FDOT Materials Testing office for the study section of the ramp before and after the treatment on April 11, 2006 and May 23, 2006, respectively. A locked wheel tester under designation ASTM E-274 was used to evaluate the surface in terms of friction. As can be seen from Table 2, the friction number was much higher after application of the Tyregrip treatment, as expected.

Table 2. Friction (FN_{40R}) Test Results

Friction Number at 40 MPH (FN_{40R})	Test Date	Pavement Surface Treatment	Time Period
35	04/11/06	FC-5	Before
104	05/23/06	Tyregrip	After

Crash Frequency

Crash data were obtained from the Florida Department of Transportation Crash Analysis Reporting System (CARS). Table 3 provides before/after crash statistics for the section of the ramp where the Tyregrip was applied. Over the four-year and four-month period (January 2002 to April 2006) prior to the installation of the Tyregrip, the treated section experienced an average of 2.54 crashes per year. In the 12 month period (June 2006 to June 2007) immediately following the installation the section experienced two crashes. Since the Tyregrip was installed in May 2006, sufficient crash data were not available to determine a statistically significant difference in crash frequency or rate. Due to the crash data limitations, surrogate measures of safety were evaluated to obtain a better understanding of the effects of the Tyregrip treatment. Explanations of these surrogate measures are presented in the following paragraphs.

Table 3. Before/After Crash Statistics

Year	Before Treatment (January 2002- April 2006)	After Treatment (June 2006 – June 2007)
2002	3	N/A
2003	1	N/A0
2004	5	N/A
2005	2	N/A
2006	0	2
Total	11	2

Vehicle Speeds

Vehicle speed is one of the factors that affect the amount of friction needed to keep a vehicle on the roadway. Since the study intentionally varies the amount of friction available while the other two factors (radius of curvature and superelevation) are held constant, it is important to know if there are any changes in vehicle speeds after the installation of the Tyregrip surface. Consequently, spot speed studies were performed and vehicle speeds prior to and after the installation of the treatment were compared. Specific MOEs for the speed comparison were the shape of the speed distributions (variability), the mean of the speed distributions, and the proportion of vehicles traveling over the advisory speed limit.

Spot speed studies were performed using a radar gun within the study section before and after the installation of the Tyregrip at different times of the day (morning, mid-day and evening peak hours). Researchers collected speed data during rainy and dry conditions, so that the impact of Tyregrip on travel speeds can be evaluated for both wet and dry conditions. A total of five speed studies were conducted in early May of 2006 prior to the application of the Tyregrip treatment. The researchers began data collection activities for the after period in July 2006 and concluded in September 2007. Once again, speed data were collected at different times of the day and for various days of the week during this period, resulting in a total of nine speed studies for the after period.

The mean speeds decreased by an average of 3.72 miles per hour under dry pavement conditions after the application of the Tyregrip treatment (see Table 4). Under wet conditions, the mean speeds also decreased by an average of 2.62 miles per hour after the application of the Tyregrip treatment. The increased frictional forces created by the Tyregrip treatment make it possible for drivers to travel at higher speeds while maintaining their lane position. However, it appears that drivers are reducing their speeds, possibly due to texture difference in pavement and potential additional noise created by the Tyregrip surface.

Table 4. Mann-Whitney U Test Results for Mean Vehicle Speeds

Pavement Condition	Period	Sample Size	Mean Speed (mph)	Mean Rank	Mann-Whitney U	Z-statistic	Z-critical	Conclusion
Dry	Before	291	28.13	814.23	33981.5	-17.769	+/- 1.96	Speeds Lower After Treatment
	After	786	24.41	436.29				
Wet	Before	199	24.41	167.77	6414.5	-5.027	+/- 1.96	Speeds Lower After Treatment
	After	100	21.79	114.65				

The proportion of speeding drivers decreased after the Tyregrip surface treatment had been applied under both wet and dry pavement conditions. The variance of the travel speeds also decreased following the Tyregrip treatment. These findings indicate that there were fewer drivers traveling over the speed limit after the Tyregrip treatment.

Shoulder Encroachments

The proportion of vehicles encroaching either the outer or inner shoulder was examined prior to and following the application of the Tyregrip. The proposed MOE for this comparison is the percentage of vehicles whose wheels crossed the yellow or white edge line on the ramp. The number of vehicles whose wheels crossed the edge lines on the ramp were collected at the same spot before and after the treatment was applied. Observers recorded the date and time of day, the total number of vehicles and the number of vehicles that crossed the pavement edge lines. Data were collected during dry and wet conditions to determine if there are any changes in shoulder encroachments under dry and wet conditions.

Encroachment data were collected for the before condition (without Tyregrip) in May 2006, during which time researchers conducted six studies at different times of the day and for various days of the week. The researchers began data collection activities for the after condition (with Tyregrip) in July 2006 and completed in September 2007. A total of 10 studies were conducted during the after period.

Table 5 shows that the proportion of drivers encroaching the shoulder decreased significantly after the installation of the Tyregrip under wet pavement conditions, while no significant difference was found under dry conditions.

Table 5. Z-test Results for Proportion of Encroaching Vehicles

Pavement Condition	Period	Sample Size	Vehicles Encroaching	Proportion	Group Proportion	Z-statistic	Z-critical	Conclusion
Dry	Before	2924	389	0.13	0.14	-1.07	+/- 1.96	No Statistically Significant Difference
	After	6268	921	0.15				
Wet	Before	1961	564	0.29	0.22	12.34	+/- 1.96	Encroachments Decreased After Treatment
	After	1722	232	0.13				

Overall, the Tyregrip treatment was effective in increasing the friction between the roadway and vehicle tires. The treatment was also effective in assisting motorists in maintaining their lane position under wet pavement conditions. In addition, drivers tended to slow down when traveling over the treated section of the ramp. It appears that the use of Tyregrip may be a practical countermeasure for improving safety at locations that are prone to run-off-road crashes, particularly sharp curves and entry/exit ramps. For additional details, please refer to the attached Volume 3.

7.0 OVERVIEW OF THE MOTORIST AWARENESS SYTEM EVALUATION STUDY

Speeding is a common occurrence in highway work zones. The hazards associated with maintaining traffic are elevated when drivers do not obey reduced work zone speed limits. Although highway work zones are either marked for a reduced speed limit or are covered by a statewide law, driver adherence to such reduced speed limits in work zones is minimal at best. In 2005, the State of Florida experienced 137 fatalities from 4,136 crashes occurred in highway work zones. While construction workers are exposed to heightened risk in work zones, 90% of those killed in highway work zones in Florida are motorists or pedestrians. Speeding and inattentive driving are some of the factors that cause work zone crashes. Drivers need to be alert and travel at a slower speed to be able to safely negotiate often unexpected situations in the work zone. This is due to many factors including abrupt changes in horizontal or vertical alignment, slow moving vehicles leaving/entering the traffic stream from the construction area, and a reduced clear recovery area.

In an effort to make work zones safer, the Florida Department of Transportation (FDOT) has developed a new Maintenance of Traffic (MOT) system for work zone traffic control, referred to as Motorist Awareness System (MAS). In addition to traffic control and warning devices used with standard MOT plans, the MAS uses portable changeable message signs, radar speed display units, and regulatory speed limit signs (with flashers) to alert motorists of work zone activities such as lane closures and reduced speed limits. The radar speed display unit displays individual vehicle speed as compared to the speed limit and as such provides feedback to motorists. In addition, active enforcement is a critical element of the MAS. Thus, the MAS is intended to reduce travel speeds through work zones.

The MAS was implemented as part of construction projects on two segments of Florida interstate highways I-10 and I-95. These segments are a suburban section of I-10 in Baker County, from US 90 to Columbia County line, and a rural section of I-95 in Flagler County from the Volusia/Flagler County line to the Flagler/St. John County line . Both I-10 and I-95 are four lane-divided freeways with 70 mph posted speed limits, though I-95 has three travel lanes in one direction at some locations.

The effectiveness of the MAS was determined through a field experiment conducted on I-10 and I-95 at various test (condition with the MAS) and control (condition without the MAS) locations in combination with targeted speed enforcement. This experiment consisted of a number of observations related to travel speeds approaching and within the work zones along the study segments of I-10 and I-95. Speed studies were conducted at three different locations within each work zone to assess changes in the speed profiles through the work zone: (1) prior to the work zone, (2) in the middle of the work zone, and (3) near the end of the work zone.

Speed data were collected for the control condition (without MAS) along I-95 between June 2005 and May 2007, during which time researchers conducted 48 speed studies at different times of the day and for various days of the week. The contractor began to apply the MAS as a part of setting up the MOT each day starting the second week of August 2005. The researchers began data collection for the test condition (with MAS) in the second week of August 2005 and concluded studies in May 2007. Once again, speed data for the test condition were collected during this period at different times of the day and for various days of the week, with a total of 63 speed studies conducted for the test condition. Similar speed data were collected for the control and test conditions on I-10 between May 2007 and July 2007, during which time researchers conducted an additional 68 speed studies at different times of the day and for various days of the week.

Speed data from the following three scenarios were compared to determine the effect of the MAS on work zone travel speeds.

- Standard Maintenance of Traffic (MOT)
- Motorist Awareness System (MAS) without police enforcement
- MAS with police enforcement

The effectiveness of the MAS was evaluated in several ways including changes in mean speed, 85th percentile speed, and the characteristics of the speed distribution. In addition, the proportion of motorists driving above the posted speed limit under different MOT scenarios was also compared.

A number of statistical tests were conducted in order to better understand whether the changes observed in the measures of effectiveness are attributable to the use of the MAS or simply due to chance. A summary of the findings is as follows:

- Travel speeds, both the mean and 85th percentile speeds, were consistently lower at the locations within the work zones where the MAS was utilized in comparison to the standard MOT. The implementation of the MAS along I-10 reduced average speeds by an average of 1.5 miles per hour in comparison to standard MOT. Combining MAS with enforcement resulted in additional reduction in mean speeds by 3 to 4 miles per hour in comparison to standard MOT.

- The combination of the MAS with enforcement was also shown to decrease speeds in comparison to the standard MOT with enforcement along I-95. In general, speeds within the work zone were reduced by an average of 4 to 5 miles per hour.
- The variability of travel speeds along I-10 within the work zone was decreased when MAS was utilized.
- The proportions of drivers speeding within and near the end of the work zones were also substantially reduced when the MAS was utilized in comparison to the standard MOT under all scenarios. Further, combining MAS with enforcement produced more pronounced reductions both within and near the end of the work zone.

Overall, the MAS was effective in reducing vehicular speeds through construction work zones. Targeted enforcement resulted in additional speed reductions. The MAS decreased the proportion of motorists traveling over the posted speed limit. The use of MAS may be a practical countermeasure to reduce vehicular speeds through the work zone, thereby improving safety for both the motorist and the construction worker. For additional details on this study, please refer to the attached Volume 4.

8.0 OVERVIEW OF THE COUNTDOWN PEDESTRIAN SIGNAL EVALUATION STUDY

Approximately 500 pedestrians are killed and 8,000 are injured in traffic crashes every year in Florida. A combination of pedestrian and driver actions contribute to pedestrian crashes. Common driver actions associated with pedestrian crashes include failure to yield to pedestrians, inattention, and speeding. Such pedestrian actions include crossing the street at inappropriate locations or violating the flashing “Don’t Walk” and steady “Don’t Walk” indications.

The various indications on traditional pedestrian signal heads (“Walk,” flashing “Don’t Walk,” and steady “Don’t Walk”) are not universally understood. While the “Walk” indication is straightforward, the flashing “Don’t Walk” is misinterpreted by a significant portion of the pedestrian population. The steady “Don’t Walk” and flashing “Don’t Walk” are frequently confused. Some pedestrians think that the flashing “Don’t Walk” indication means that they should quickly complete their crossing or even return to the sidewalk. Given that the flashing and steady “Don’t Walk” intervals dominate the typical cycle, pedestrians who are unclear on what each indication means may become impatient and cross contrary to the pedestrian indication, thus increasing the potential for pedestrian-vehicular conflicts and crashes.

In recent years, several innovative pedestrian safety treatments have been developed and implemented in various cities throughout the United States to improve pedestrian safety by raising motorist awareness and providing feedback to pedestrians. Such treatments include illuminated pushbuttons, animated eye displays, in-pavement lighting and countdown pedestrian signals.

The countdown pedestrian signal is comprised of the same three indications as the conventional pedestrian signal. The flashing “Don’t Walk” indication, however, is complemented by an illuminated number indicating the number of seconds before the steady “Don’t Walk” indication will be illuminated. The signal head counts down the seconds of what would traditionally be the flashing “Don’t Walk” interval and thus provides feedback to pedestrians on the time remaining in their crossing. By advising the pedestrian of the remaining seconds before the “Don’t Walk” indication will be illuminated, the pedestrian can make a decision on his or her ability to safely cross the street in the available time. As such, the countdown signals are expected to improve compliance with pedestrian indications and enhance pedestrian safety.

The Florida Department of Transportation (FDOT), the Broward County Traffic Engineering Division and the City of Boca Raton replaced traditional pedestrian signals at several intersections located in the South Florida area (Broward and Palm Beach Counties) with countdown pedestrian signals (see Photograph 5). The study intersections represent a variety of land use characteristics, traffic circulation patterns and levels of pedestrian activities. A majority of the study locations are large intersections with multi-lane approaches and the average daily traffic volumes range from 19,000 to 65,000 vehicles/day. The pedestrian crossing distances range from 38 feet to 131 feet.

Photograph 5. Typical Installation of Countdown Pedestrian Signal

The primary purpose of this study was to determine the effectiveness of countdown pedestrian signals by comparing crash data and pedestrian behavior data collected at each of the study intersections before and after the installation of countdown pedestrian signals.

Since sufficient crash data for the after period were not available, several surrogate measures (percentage of pedestrians initiating crossing during "Walk", flashing "Don't Walk" and steady "Don't Walk" indications, and the percentage of successful crossings) were utilized to quantify the impacts of the countdown pedestrian signals. Pedestrian behavior data were collected before and after the installation of countdown signals at different times of the day and for various days of the week. Between June 2006 and October 2007, a total of 58 studies were conducted, of which 36 were conducted before the installation of countdown signals and 22 were conducted after the installation of countdown signals. A total of 3,734 pedestrian movements (2,479 in the before period and 1,255 in the after period) were observed at the study intersections.

Several statistical tests were conducted to determine whether the changes observed in the measures of effectiveness are attributable to the installation of the countdown signals. A summary of the findings is as follows:

- Overall, the results of the study show that there was a slight increase in the percentage of pedestrian compliance with the "Walk" indication from 55.03% to 56.33%. However, the increase was not statistically significant. The analysis by intersection indicates that the percentage of pedestrian compliance at three of the study intersections significantly increased, while three of the study intersections experienced reduced compliance rates.
- The countdown signals significantly reduced the proportion of pedestrians crossing during the flashing "Don't Walk" indication from 13.70% during the before period to 8.13% during the after period. The countdown pedestrian signals provide feedback to pedestrians on the time remaining to cross. Pedestrians appear to use this information to assess their ability to cross the street and consequently, appeared to make better decisions on whether or not to initiate crossing, as indicated by the smaller proportion of pedestrians crossing during the "Don't Walk" phase.
- The percentage of pedestrians entering the crosswalk during the steady "Don't Walk" interval increased from 31.26% to 35.54% (all intersections combined). The analysis by intersection indicates that the proportion of pedestrians crossing during the steady "Don't Walk" phase

decreased at one intersection and increased at three intersections. Field observations revealed that pedestrians generally crossed during the steady "Don't Walk" indication when gaps were present in the oncoming traffic or began crossing early, often during the side street left-turn phase, especially at major intersections. In addition, other factors such as the size of intersection, the availability of gaps in oncoming traffic, whether or not the clearance intervals are adequate, and type of pedestrian activity may influence pedestrian behavior related to crossing during the steady "Don't Walk" indication. Further research is warranted to verify the reasons for this pedestrian behavior.

- The percentage of successful crossings (all intersections combined) increased significantly, from 56.15% to 63.27%. The analysis by intersection indicates that the proportion of successful crossings significantly increased at three intersections and decreased at one intersection. It appears that pedestrians are able to more easily assess their likelihood of a successful crossing due to the countdown timers and it is likely that pedestrians might have quickened their steps as they saw the remaining time winding down.
- Sufficient data were not available at the time of this report that would allow for an assessment of the impact of the countdown signals on driver behavior, specifically in regard to red light running and associated crashes. As crash data for the after period becomes available, these particular issues can be addressed by comparing crash rates between the before and after periods. Previous research has shown that countdown signals had no significant impacts on vehicular traffic.

Overall, the pedestrian countdown signals seem to be effective in increasing the percentage of successful crossings and decreasing the percentage of pedestrians who initiate crossing during the flashing "Don't Walk" indication. However, the percentage of pedestrians entering during the steady "Don't Walk" indication increased at some locations. Since the results are based on only eight intersections, further research is recommended to confirm the findings from this study. In addition, it is recommended that the frequency and rate of pedestrian crashes at the study intersections be examined once sufficient crash data for the after period become available to quantify the impacts of countdown signals on pedestrian safety. For additional details on this study, please refer to the attached Volume 5.

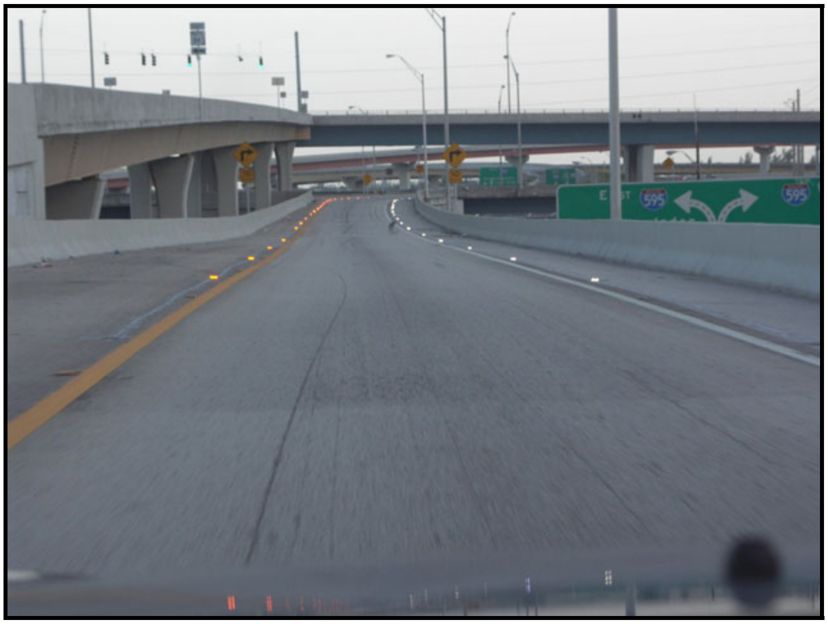
9.0 OVERVIEW OF THE IN-ROADWAY LIGHT EVALUATION STUDY

The Nation's freeway systems are generally built to the highest mobility and safety standards. The wider lanes, sufficient lateral clearances and appropriate geometric characteristics are provided on freeways to achieve higher levels of service. Such features, however, promote faster driving behavior in motorists. Although speeding on freeways during uncongested time periods are common occurrences, safety is not often compromised. However, the freeway connection to other roadways, at interchanges, presents a set of challenges to motorists. Interchanges often require drivers to reduce their speed significantly due to horizontal curves, grades and traffic control measures that are distinctly different from normal freeway conditions. Some drivers under such circumstances fail to reduce their speed sufficiently to be able to safely negotiate through this change in driving environment, which sometimes leads to serious crashes.

The intersection of southbound I-95 off-ramp and westbound State Road 84 is a T-intersection located in Fort Lauderdale, Florida. The exit ramp is relatively long, approximately 2,000 feet in length. As such, drivers tend to travel at a relatively high speed even after exiting the interstate. The exit ramp consists of one-lane and operates as a free-flow right-turn-only lane, which then merges with westbound SR 84. The turning radius for this right turn is very small requiring drivers to slow down to 10 miles per hour.

A total of 41 crashes occurred at this intersection during the three-year period from 2001 to 2003. A majority of these crashes (71%) involved southbound vehicles from the off-ramp and westbound vehicles traveling in the rightmost through lane. Based on crash history at this location, it appears that some southbound drivers on this exit ramp approach the intersection of SR 84 at a high rate of speed, often misjudge the ramp geometry, miss the merge lane due to the wide turn associated with excessive speed and encroach into the path of oncoming westbound traffic on SR 84 or travel straight into the barrier wall located on the south side of SR 84.

In an effort to reduce the frequency of crashes at this intersection, the Florida Department of Transportation District 4 Traffic Operations Office installed (in November 2004) a series of in-roadway lights along the off-ramp (see Photograph 6). The intention was to alert motorists to the approaching sharp right turn at SR 84, so that drivers would reduce their speeds in order to negotiate the turn safely. The in-roadway lights were linked with a speed detection system, which would illuminate the lights when the approaching vehicle's speed was detected to be greater than the pre-set speed of 50 mph. The in-roadway lights were operated in such a way that they create a ‘strobing’ effect towards the approaching driver to give the motorist the perception that he/she is speeding. The ‘strobe’ effect starts at the beginning of each group of lights, and progresses with each unit in the group illuminating until all are illuminated, then off, and starting the sequence over again. As such, in-roadway lights are expected to reduce travel speeds. It is anticipated that the reduction in vehicular speeds would reduce the potential for crashes.



Photograph 6. In-roadway lights along the Southbound I-95 off-ramp to Westbound SR 84

The goal of this research was to determine the effectiveness of in-roadway lights in reducing travel speeds and associated crash frequency and severity. A before and after evaluation plan was utilized to determine the effectiveness of in-roadway lights. The Measures of Effectiveness (MOEs) for the before and after evaluation study were as follows:

- Change in crash frequency
- Change in average speed
- Change in speed distribution

Crash data were collected for a three-year before period (2001, 2002 and 2003) and a three-year after period (2004, 2005 and 2006). The before period specifically began on January 1, 2001 and continued through December 31, 2003. The after period began on December 1, 2004 and continued through August 10, 2006. During the after period, Hurricane Wilma interrupted the performance of the in-roadway lights between October of 2005 and March of 2006. Therefore, crash data for this period were not considered in the analysis.

Speed data were collected at four locations (200, 500, 600 and 900 feet north of SR 84) along the ramp during the before condition (without in-roadway lights) and after condition (with in-roadway lights). A total of 76 speed studies were conducted during four different time periods (AM, Noon, PM and Evening). Forty-four studies (44) were conducted during the before condition and thirty-two (32) were conducted during the after condition.

Several statistical tests were conducted to determine whether the changes observed in the measures of effectiveness (mean speed, speed distribution and crash frequency) are attributable to the installation of the in-roadway lights. A summary of the findings is as follows:

- There was an increase in crashes during the after period. However, the total crash frequencies for the before condition (without in-roadway lights) and the after condition (with in-roadway lights) were not significantly different at a 95% confidence level.
- For the AM and Noon periods at the 600-foot location, the speed distributions for the before condition were significantly different from those for the after condition. This indicates that the in-roadway lights positively impacted travel speeds.
- For the AM, Noon, PM and Evening periods at the 600-foot speed study location, the mean speeds between the before and after conditions were significantly different at a 95% confidence level. Overall, the travel speeds were lower (by 2 to 7 mph based on time of day) during the after condition than those observed during the before condition. This indicates that the installation of in-roadway lights reduced the overall speed.
- The mean speeds for the AM, Noon, PM and Evening periods at the 200-foot location were significantly lower (by 2 to 4 mph) at a 95% confidence level in the after condition. This indicates that motorists reduced their speeds in response to the in-roadway lights.
- The mean speeds for the Noon, PM and Evening periods at the 500-foot location were significantly lower (by 2 to 3 mph) at a 95% confidence level in the after condition, while the AM period mean speed was similar.
- For the 900-foot speed study location, the Noon, PM and Evening period mean speeds between the before and after conditions were similar at a 95% confidence level, which means

that speeds prior to approaching the study area were similar. Therefore, the reductions in speed at 200-foot and 500-foot locations can be attributed to in-roadway lights.

In summary, the use of in-roadway lights reduced vehicular speeds by 2 to 7 mph, but did not have a substantial impact on crashes at the study intersection. Additional traffic safety measures may need to be implemented at the study intersection to further reduce travel speeds and associated potential for crashes. It should be noted that the in-roadway lights were not working continuously throughout the study period. The system was not 100% functional due to erratic operation of the loop detector card caused by lightening strikes and/or other reasons. For additional details on this study, please refer to the attached Volume 6.

10.0 OVERVIEW OF THE BICYCLE DETECTION EVALUATION STUDY

Vehicle detectors at signalized intersections in the City of Orlando are able to detect a bicycle if the bicyclist stops his/her bicycle directly on the detector, but only a few bicyclists appear to know where to place their bike in order to be detected. If bicyclists do not stop their bicycle properly on the detector, they will not receive a green indication. As such, some bicyclists may get impatient and disregard the traffic signal or run the red light. Disobeying red lights is a contributing cause of bicyclist/motorist crashes and accounts for about 8% of adult cyclist crashes.

In an effort to improve bicycle detection at signalized intersections, the City of Orlando installed special pavement markings to guide bicyclists to properly place their bicycles on the detector in order to be detected. As a supplement to the pavement markings, signs were also placed at the curb or on mast arms (see Photograph 7). A total of 100 intersection approaches were prioritized based on several factors including roadway functional classification, traffic volume on major and minor streets, and number of bicycle crashes. The first 25 locations from the priority list were then selected for application of this treatment (see Table 6).

Photograph 7. Typical Installation of Bike Loop Detection Markings and Signs

Table 6: Study Sites for Bicycle Detection Treatment

No.	Intersection	Approach
1	Mercado Avenue /Lake Underhill Drive	Northbound
2	Mercado Avenue /Lake Underhill Drive	Southbound
3	Oxalis Drive / Lake Underhill Drive	Northbound
4	Oxalis Drive /Lake Underhill Drive	Southbound
5	La Costa Drive /Semoran Blvd (SR 436)	Eastbound
6	La Costa Drive /Semoran Blvd (SR 436)	Westbound
7	Delaney Avenue /Michigan Street	Northbound
8	Delaney Avenue/ Michigan Street	Southbound
9	Mills Avenue /Anderson Street	Northbound
10	Mills Avenue /Anderson Street	Southbound
11	Formosa Drive /Princeton Street	Northbound
12	Formosa Drive /Princeton Street	Southbound
13	Winter Park Road /Corrine Drive	Northbound
14	Winter Park Road /Corrine Drive	Southbound
15	Virginia Drive /Mills Avenue	Eastbound
16	Virginia Drive /Mills Avenue	Westbound
17	Dartmouth Street/Edgewater Drive	Eastbound
18	Dartmouth Street/Edgewater Drive	Westbound
19	Carrier Drive /Universal Blvd.	Eastbound
20	Carrier Drive /Universal Blvd.	Westbound
21	Orange Center Blvd. /John Young Parkway	Eastbound
22	Orange Center Blvd. /John Young Parkway	Westbound
23	S Goldwyn Ave. (Lake Park)/ Columbia Street	Northbound
24	S Goldwyn Ave. (Lake Park) /Columbia Street	Southbound
25	Amaros Avenue /Columbia Street	Northbound
26	Amaros Avenue /Columbia Street	Southbound

A before/after methodology was proposed to determine the impact of this treatment on bicyclist behavior and crashes. Since the number of crashes involving bicycles was relatively low (ranging from 0 to

2 crashes), it would be difficult to detect significant changes in the crash frequency. Therefore, the following MOEs were proposed for this study.

- Number of violations by bicyclists before and after installation of the treatment.
- The proportion of bicyclists who stop at the proper location before and after the installation of the treatment. This MOE seems to be the most promising since it is directly associated with pavement marking and signing treatment for bicycle detection.

The research team collected the bicycle traffic data at study intersections located in December 2003, prior to the installation of the treatment (see Table 7).

Table 7: Data Collection Schedule for Before Period

Locations	Intersection	Approach	Data Collection Date
1	Mercado Avenue/Lake Underhill Drive	Northbound	December 13, 2003
2	Mercado Avenue/Lake Underhill Drive	Southbound	December 13, 2003
3	Oxalis Drive/Lake Underhill Drive	Northbound	December 13, 2003
4	Oxalis Drive/Lake Underhill Drive	Southbound	December 13, 2003
5	La Costa Drive/Semoran Blvd. (SR 436)	Eastbound	December 13, 2003
6	La Costa Drive/Semoran Blvd. (SR 436)	Westbound	December 13, 2003
7	Delaney Avenue/Michigan Street	Northbound	December 6, 2003
8	Delaney Avenue/Michigan Street	Southbound	December 6, 2003
9	Mills Avenue/Anderson Street	Northbound	December 6, 2003
10	Mills Avenue/Anderson Street	Southbound	December 6, 2003
11	Formosa Drive/Princeton Street	Northbound	December 6, 2003
12	Formosa Drive/Princeton Street	Southbound	December 6, 2003
13	Winter Park Road/Corrine Drive	Northbound	December 6, 2003
14	Winter Park Road/Corrine Drive	Southbound	December 6, 2003
15	Virginia Drive/Mills Avenue	Eastbound	December 6, 2003
16	Virginia Drive/Mills Avenue	Westbound	December 6, 2003
17	Dartmouth Street/Edgewater Drive	Eastbound	December 6, 2003
18	Dartmouth Street/Edgewater Drive	Westbound	December 6, 2003
19	Carrier Drive/Universal Blvd	Eastbound	December 4, 2003
20	Carrier Drive/Universal Blvd	Westbound	December 4, 2003
21	Orange Center Blvd./John Young Pkwy	Eastbound	December 4, 2003
22	Orange Center Blvd./John Young Pkwy	Westbound	December 4, 2003
23	S Goldwyn Ave. (Lake Park)/Columbia St	Northbound	December 4, 2003
24	S Goldwyn Ave. (Lake Park)/Columbia St	Southbound	December 4, 2003
25	Amaros Avenue/Columbia Street	Northbound	December 6, 2003
26	Amaros Avenue/Columbia Street	Southbound	December 6, 2003

Table 8: Summary of Data Collected for Before Period

	LOCATIONS																									
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Total number of bicycles approached:	2	1	20	6	2	2	1	1	8	2	4	2	12	17	5	15	0	1	1	3	48	53	6	5	--	3
Total number of bicycles using the sidewalk:	--	--	6	--	--	1	--	--	6	1	--	--	2	9	5	2	0	1	--	--	25	36	2	3	--	1
Total number of bicycles using the sidewalk on the opposite side:	--	--	--	4	--	--	--	--	--	--	--	--	--	--	--	--	0	--	--	--	--	--	--	--	--	--
Total number of bicycles using the sidewalk going opposite direction:	--	1	11	2	1	--	1	--	--	1	--	--	2	3	--	1	0	--	1	2	22	16	2	2	--	
Total number of bicycles using the bicycle lane:	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0	--	--	--	--	--	--	--	--	--
Total number of bicycles using the travel lane:	2	--	3	--	1	1	--	1	2	--	4	2	8	5	--	12	0	--	--	1	1	1	2	--	1	2
Total number of bicycles properly stopped on the detector:	--	--	--	--	--	1	--	--	--	--	--	1	5	--	--	1	0	--	--	--	--	--	1	--	--	--
Total number of bicycles not-properly stopped on the detector:	--	--	3	--	--	--	--	1	1	--	4	1	1	--	--	2	0	--	--	--	1	--	--	--	--	--
Total number of bicycles that went with traffic without stopping:	2	--	5	3	--	--	--	--	2	--	--	--	4	11	1	11	0	--	--	1	24	34	3	2	1	--
Total number of bicycles that waited for a green signal:	--	--	8	--	--	1	--	--	4	1	4	1	6	2	1	--	0	1	--	--	2	--	--	--	--	--
Total number of bicycles that ran the red light signal:	--	--	4	--	--	--	--	--	2	--	--	1	--	1	3	3	0	--	--	--	--	3	1	1	--	--

Location	Intersection	Location	Intersection
1	Mercado Avenue - Lake Underhill Drive	14	Winter Park Road - Corrine Drive
2	Mercado Avenue - Lake Underhill Drive	15	Virginia Drive and Mills Avenue
3	Oxalis Drive - Lake Underhill Drive	16	Virginia Drive and Mills Avenue
4	Oxalis Drive - Lake Underhill Drive	17	Dartmouth Street - Edgewater Drive
5	La Costa Drive - Semoran Blvd (SR 436)	18	Dartmouth Street - Edgewater Drive
6	La Costa Drive - Semoran Blvd (SR 436)	19	Carrier Drive - Universal Blvd
7	Delaney Avenue - Michigan Street	20	Carrier Drive - Universal Blvd
8	Delaney Avenue - Michigan Street	21	Orange Center Blvd - John Young Pkwy
9	Mills Avenue - Anderson Street	22	Orange Center Blvd - John Young Pkwy
10	Mills Avenue - Anderson Street	23	S Goldwyn Ave (Lake Park) @ Columbia St
11	Formosa Drive - Princeton Street	24	S Goldwyn Ave (Lake Park) @ Columbia St
12	Formosa Drive - Princeton Street	25	Amaros Avenue - Columbia Street
13	Winter Park Road - Corrine Drive	26	Amaros Avenue - Columbia Street

As can be seen in Table 8, the bicycle volume at the study sites was relatively low, ranging from 1 to 53 in twenty four hour period, of which only a few bicyclists (less than 3 at most locations) used travel lanes. A majority of bicyclists were observed using the sidewalk. As such, they do not wait for a green traffic signal indication.

The pavement and signing treatment was implemented by the City of Orlando during the period from December 2003 to January 2004. However, the pavement markings were incorrectly placed on vehicle detection loops. As such, the treatment was not working as intended due to incorrect placement. In addition, Hurricanes Francis and Jeanne damaged the bicycle loop signs and interrupted the performance of the treatment. Therefore, researchers were not able to collect the after data as originally scheduled.

Researchers contacted the City of Orlando several times regarding the reinstallation of bicycle loop markings/signs, and were told by the City staff that they were unable to refurbish the bicycle loop markings and signs due to other priorities (such as hurricane restoration work) until September/October 2006. A field review was conducted in April 2007 to verify whether the pavement markings and signs were correctly placed and to observe bicyclist behavior. This field review indicated that some of the markings were incorrectly placed. Also, bicycle traffic was not observed at many of the study sites during the field review. Since the before data were collected in December, researchers scheduled the after data collection activities for December 2007 to ensure the before and after data were obtained under similar conditions. However, since the research project had to be completed by the end of November 2007, the research team was not able to collect the after data. As such, the research team was unable to complete this evaluation study.

11.0 CONCLUSIONS

The objective of this project was to evaluate new/innovative safety treatments implemented by FDOT or other local government agencies to determine their impact on crashes and/or other surrogate measures. Evaluation studies were conducted to determine the effectiveness of the following innovative safety treatments.

- Temporary Rumble Strips in advance of Work Zones
- White Enforcement Lights at Signalized Intersections
- Motorist Awareness System in advance of Work Zones

- Tyregrip High Friction Surface System on an on-ramp to I-75
- Countdown Pedestrian Signals
- In-roadway Lights along an off-ramp from I-95

The following is a summary of findings and recommendations based on the results of the evaluation studies conducted as part of this project:

Temporary Rumble Strips in advance of Work Zones

The use of temporary rumble strips in advance of construction work zones reduced vehicular speeds once motorists encountered the temporary rumble strips. Therefore, the use of temporary rumble strips prior to a construction work zone may be a practical countermeasure to reduce vehicular speeds through the work zone, thereby improving safety for both the motorist and the construction worker.

White Enforcement Lights at Signalized Intersections

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 analysis of a surrogate measure of effectiveness (number of red light violations) as well as a direct measure of effectiveness (crash frequency). Between 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 the analysis of crash data are less conclusive than the results obtained from the 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.

Tyregrip High Friction Surface System

The Tyregrip friction surface treatment was effective in increasing the friction between the roadway and vehicle tires. The treatment was also effective in assisting motorists in maintaining their lane position under wet pavement conditions. In addition, drivers tended to slow down when traveling over the treated section of the ramp. It appears that the use of Tyregrip may be a practical countermeasure for improving safety at locations that are prone to run-off-road crashes, particularly sharp curves and entry/exit ramps.

Motorist Awareness System (MAS) in advance of Work Zones

The MAS was effective at reducing vehicular speeds through construction work zones. The MAS combined with targeted enforcement resulted in additional speed reductions. The MAS decreased the proportion of motorists traveling over the posted speed limit. Based on these findings, the use of MAS appears to be a practical countermeasure to reduce vehicular speeds through the work zone, thereby improving safety for both the motorist and the construction worker.

Countdown Pedestrian Signals

Pedestrian countdown signals seem to be effective in increasing the percentage of successful crossings and decreasing the percentage of pedestrians who initiate crossing during the flashing "Don't Walk" indication. However, the percentage of pedestrians entering during the steady "Don't Walk" indication increased at some locations. Since the results are based on only eight intersections, further research is recommended to confirm the findings from this study. In addition, it is recommended that the frequency and rate of pedestrian crashes at the study intersections be examined once sufficient crash data for the after period become available to quantify the impacts of countdown signals on pedestrian safety.

In-roadway Lights

The use of in-roadway lights reduced vehicular speeds, but did not have a substantial impact on crashes at the study intersection. It should be noted that the in-roadway lights were not working continuously throughout the study period. The system was not 100% functional due to erratic operation of the loop detector card caused by lightening strikes and/or other reasons. Additional traffic safety measures may need to be implemented at the study intersection to further reduce travel speeds and associated potential for crashes.

In summary, the innovative treatments evaluated as part of this research were found to positively impact driver behavior related to speeding and red light violation; and pedestrian compliance with the flashing "Don't Walk" signal indication. The results of this research also indicate that the Tyregrip friction surface has the potential to reduce run-off-road crashes. Better enforcement made possible by white enforcement lights has the potential to reduce crashes associated with red light running. Sufficient after crash data were not available to determine the impact of countdown pedestrian signals and Tyregrip treatment on crashes. Therefore, several surrogate measures were evaluated to document the effectiveness of these innovative treatments. It is recommended that before and after crash data are compared as it become available to determine the impact of countdown pedestrian signals and Tyregrip surface treatment on crashes and to further verify the impact of white enforcement lights on red light running crashes.

It is suggested that the Department consider the "Evaluation of Innovative Safety Treatments" research as a long-term initiative. The results of this research benefit the Department in a number of ways. First, the research helps evaluate the effectiveness of innovative treatments, so the Department can decide whether or not to continue to implement the innovative treatment. The Department may choose to implement those treatments having the greatest impact on safety on a statewide basis. As such, the research supports the Department's efforts towards improving safety by continuously looking for new and innovative ways to achieve the Department's number one goal of providing a safer transportation system. In addition, this research provides support for improvements to current design, construction, and/or maintenance standards. For example, the use of the Motorist Awareness System combined with enforcement and the use of temporary rumble strips in advance of work zones can be considered as potential enhancements to MOT standards to alert motorists of lane closures, reduced speed limits and other activities associated with work zones.

If the Department were to undertake this research again, the research duration should be longer than 36 months. Delays in treatment implementation schedules impacted this research. Longer durations would allow sufficient time for implementation of the treatment and to collect adequate after data needed for a meaningful and statistically valid study.

12.0 REFERENCES

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