BD-548-26

Traffic & Rural Intersection Monitoring with a Solar-based Infrared Wireless System

Phase 2 Final Report

Long Term Effect and Justification for Further Analysis

Submitted to
The Florida Department of Transportation
Research Center
605 Suwannee Street, MS 30
Tallahassee, FL 32399

Chris R. Birosak
ITS Program Manager
District One, Florida Department of Transportation

Submitted by
Dr. Amr Oloufa (PI)
Dr. Yasser Hosni (CO-PI)

College of Engineering and Computer Science
University of Central Florida
4000 Central Florida Blvd.
Orland, FL 32816

May 2008

Disclaimer

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."

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle	5. Report Date
Traffic & Rural Intersection Monitoring with a Solar-based Infrared Wireless System	May 2008
	6. Performing Organization Code UCF
7. Author(s) Dr. Amr A. Oloufa, P.E.	8. Performing Organization Report No.
9. Performing Organization Name and Address University of Central Florida Center for Advanced Transportation Simulation Systems (CATSS) P.O. Box 162450, Orlando, FL 32816-2450	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. BD-548-26
12. Sponsoring Agency Name and Address Florida Department of Transportation 605 Suwannee Street, MS 30 Tallahassee, FL 32399	13. Type of Report and Period Covered Final Report
	14. Sponsoring Agency Code FDOT

15. Supplementary Notes

16. Abstract

In this study we analyze the effectiveness of an experimental Dynamic Speed Monitoring (DSM) system that was installed in the summer of 2007 at the southbound entry loop ramp at the US 27/ US 192 trumpet interchange in Polk County, Florida. The analysis aimed at assessing the effect of installing the DSM system, both on the long and short terms, on vehicles' approach speed, at a point 250 feet in advance of the southbound entry ramp curve (also the detection zone of the DSM system radar). Vehicular speeds were recorded at different time intervals, including before and after the DSM installation.

Short term results showed that after the DSM installation there was a significant average speed reduction of 3.58 mph and an increase in speed compliance of 22.27%.

The Long term data (insufficient period) has shown a continued average speed reduction of 2.31 mph, and, perhaps more importantly a continued reduction in the number of vehicles traveling well past the cautionary speed limit (6.8%).

It is important to note that the district has made some improvements to the curve during the long term evaluation period which upsets the analysis, as it makes it impossible to isolate the contributions of those improvements on the DSM system performance. Such may render the results inconclusive and warrant further additional long term studies. Hence, it is strongly recommended that a long term study for much longer duration (9 months at least) be conducted. Such study would render higher confidence in measuring the long term effect.

17. Key Words	18. Distribution Statement
Dynamic Speed Sign, Intersection Monitoring, Speed Compliance, Remote Operation, Wireless Systems, Solar powered.	No restriction. This document is available to the public from the sponsoring agency at the website http://www.fta.dot.gov.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	33	

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

Executive Summary

In this study we analyze the effectiveness of an experimental Dynamic Speed Monitoring (DSM) system that was developed and installed in the summer of 2007 at the southbound entry loop ramp at the US 27/ US 192 trumpet interchange in Polk County, Florida. The analysis aimed at assessing the effect of installing the DSM system, both on the long and short terms, on vehicles' approach speed, at a point 250 feet in advance of the southbound entry ramp curve (also the detection zone of the DSM system radar). Vehicular speeds were recorded at different time intervals, including before and after the DSM installation.

Short term results showed that after the DSM installation there was a significant average speed reduction of 3.58 mph and an increase in speed compliance of 22.27%.

The long term data (insufficient period) has shown a continued average speed reduction of 2.31 mph, and, perhaps more importantly a continued reduction in the number of vehicles traveling well past the cautionary speed limit (6.8%).

It is important to note that the district has made some improvements to the curve during the long term evaluation period which upsets the analysis, as it makes it impossible to isolate the contributions of those improvements on the DSM system performance. Such may render the results inconclusive and warrant further additional long term studies. Hence, it is strongly recommended that a long term study for much longer duration (9 months at least) be conducted. Such study would render higher confidence in measuring the long term effect.

Table of Contents

List of Figures

List of Tables

Chapter 1: Introduction

In this study we analyze the effectiveness of a Solar-based Dynamic Speed Monitoring (DSM) systems that was developed and installed in the summer of 2007 at the southbound entry loop ramp at the US 27/ US 192 trumpet interchange in Polk County, Florida. There has been a relatively high incidence of accidents at that site. The geometry of the southbound entry ramp coupled with high approach speeds are two of the contributing factors.

It is believed that the DSM system may lead to an overall reduction in approach speed and increase in percentage of speed limit compliance, which can possibly lower the frequency of vehicular off-tracking.

The analysis, which is aimed at assessing the effect of installing the DSM, included the collection of approach speed data, at a point 250 feet in advance of the southbound entry ramp curve (also the detection zone of the DSM system radar). The approach speed data was gathered at different points in time. Such data was to be compared with the first set of data that was collected during the months of May and June 2007, before the use of the DSM system. The second set of data was collected in July 2007, after the DSM system has been put in use. A third set of data was collected 6 months later, in January 2008, to monitor the long term effect of the DSM system.

In this report we are analyzing all speed data sets: before and after installing the DSM system for the short term, and the long term. To have a more accurate indication of a possible change in vehicular behavior detailed analyses were performed that consider daytime/nighttime, weekdays/weekends, rain effect, and others. For each analysis, hypothesis tests were performed that include significant differences in the mean speed, variance, percentage of vehicles obeying the advisory sign, percentage of vehicles obeying 5 miles above the advisory sign, and the percentage of vehicles obeying 10 miles above the advisory sign.

Chapter 2: Approach Speed Analysis for the Entire Data Set

Table 1 presents before and after long term data and statistical parameters for the approach speeds for the entire data set. Table 3 and Table 4 present the summary of the hypothesis test results.

The data reveal that the average speed decreased by 3.58 mph, the variance by 3.34 and the speed limit compliance increased by 22.27 % after installing the DSM system. The long term data show that, 6 months following the use of DSM system, the average speed went down by a further 2.31 mph and the speed limit compliance increased by a further 6.80 %. However, the variance seems to have significantly increased. Figure 1 provides a frequency graph for different speed bins and Figure 2 provides the cumulative frequency. The 85th percentile speed has been reduced by 4 mph after the use of the DSM system and has been reduced by another 4 mph on the long term.

In order to mitigate the effect of external factors, for before and after data analysis, days including rainfall have been isolated and replaced by other similar days of the week with no rainfall. Historical rainfall data was used by accessing the Weather Underground (1) website to identify the days with high precipitation. For the long term data no signific0ant precipitation has been documented except for the morning of January 23rd 2008. Table 2 shows that by removing that day from the calculations the results yielded no signification difference.

Table 1: Before - After - Long Term for Entire* Data Set Summary

Speed Bins (mph)	Before Vehicle Frequency		After Vehicle Frequency		Long Term Vehicle Frequency	
	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency
1 to 30	0.001	48	0.001	61	0.012	81
31 to 32	0.000	17	0.002	70	0.004	25
33 to 35	0.002	65	0.006	251	0.014	97
36 to 38	0.004	165	0.015	604	0.034	240
39 to 41	0.013	485	0.033	1345	0.068	474
42 to 44	0.030	1174	0.076	3086	0.111	777
45 to 47	0.067	2582	0.127	5200	0.157	1105
48 to 50	0.129	4954	0.201	8199	0.198	1388
51 to 53	0.174	6684	0.197	8038	0.162	1139
54 to 56	0.207	7991	0.173	7054	0.124	869
57 to 59	0.164	6310	0.094	3853	0.068	475
60 to 62	0.114	4406	0.045	1853	0.031	219
63 to 65	0.053	2025	0.018	731	0.011	80
66 to 68	0.025	949	0.007	294	0.004	27
69 to 147	0.017	660	0.004	181	0.003	22
Total	**1.00**	**38515**	**1.00**	**40820**	**1.00**	**7018**
Average Speed (mph)	**---**	**54.63**	**---**	**51.05**	**---**	**48.74**
Variance	**---**	**41.29**	**---**	**37.95**	**---**	**51.95**
Coefficient of Variance	**---**	**0.12**	**---**	**0.12**	**---**	**---**
% Obeying Speed Limit	**---**	**55.95**	**---**	**78.22**	**---**	**85.02**
% Obeying Speed Limit + 5 Mph	**---**	**83.74**	**---**	**94.44**	**---**	**96.38**
% Obeying Speed Limit + 10 Mph	**---**	**95.82**	**---**	**98.84**	**---**	**99.30**
85th Percentile (mph)	**---**	**61.00**	**---**	**57.00**	**---**	**53.00**

* Entire data set includes both short and long term data

Table 2: Long Term analysis for Entire Data Set Summary not including Rainfall Days

Total Count	**6928**
Average Speed (mph)	**48.80**
Variance	**51.62**
Coefficient of Variance	**---**
% Obeying Speed Limit	**83.80**
% Obeying Speed Limit + 5 Mph	**95.11**
% Obeying Speed Limit + 10 Mph	**98.02**
85th Percentile (mph)	**53.00**

Table 3: Before and After Approach Speeds Entire Data Set Hypothesis Tests Summary

Hypothesis Test	Alternate Hypothesis	Parameter Change	Significant?
Mean	μ (b) - μ (a) > 0	-3.58 mph	Yes
Variance	σ^2 (b) / σ^2 (a) > 0	-3.34	Yes
% Obeying Speed Limit	P (b) - P (a) < 0	22.27%	Yes
% Obeying Speed Limit + 5 Mph	P (b) - P (a) < 0	10.70%	Yes
% Obeying Speed Limit + 10 Mph	P (b) - P (a) < 0	3.01%	Yes

Table 4: After and Long Term Approach Speeds Entire Data Set Hypothesis Tests Summary

Hypothesis Test	Alternate Hypothesis	Parameter Change	Significant?
Mean	μ (b) - μ (a) > 0	-2.31 mph	Yes
Variance	σ^2 (b) / σ^2 (a) > 0	14	No (*increased*)
% Obeying Speed Limit	P (b) - P (a) < 0	6.80%	Yes
% Obeying Speed Limit + 5 Mph	P (b) - P (a) < 0	1.94%	Yes
% Obeying Speed Limit + 10 Mph	P (b) - P (a) < 0	0.46%	No

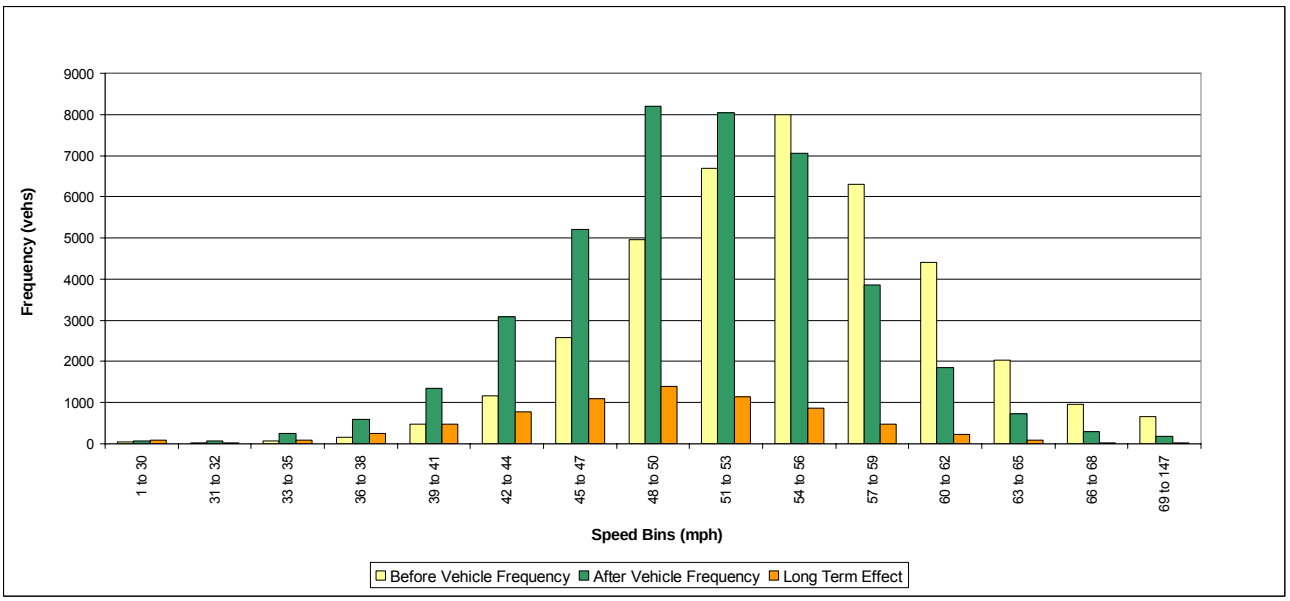

Figure 1: Before - After - Long Term Approach Speeds - Entire Data Set Graph

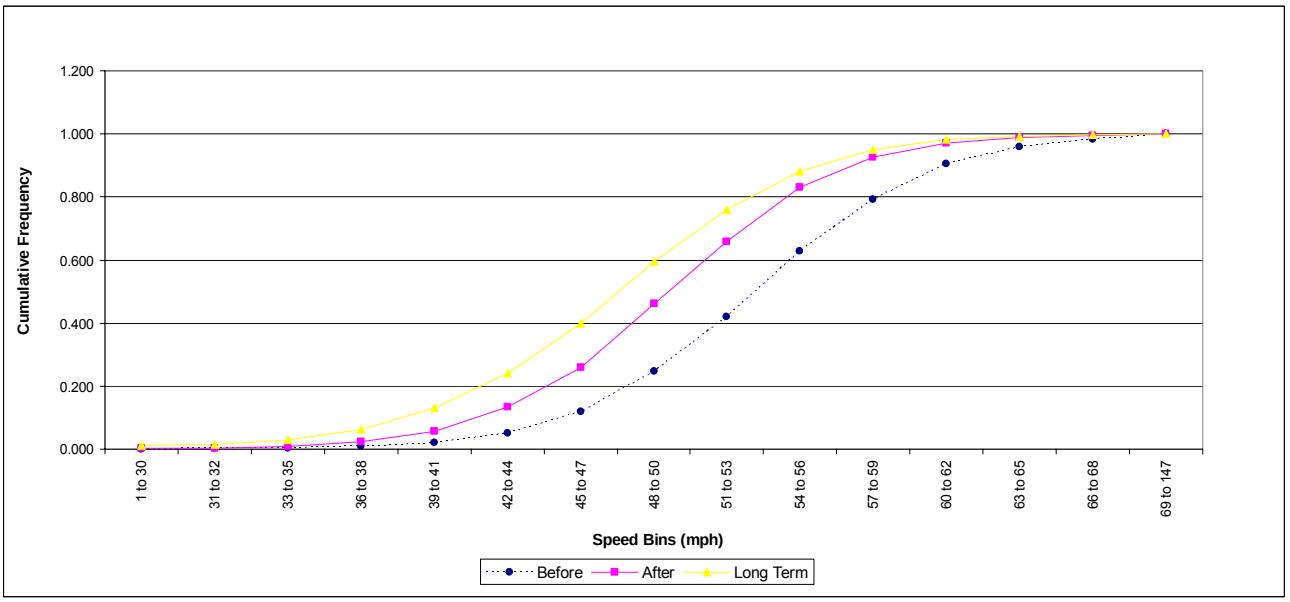

Figure 2: Before - After - Long Term Approach Speeds - Entire Data Set Cumulative Distributions

As illustrated in Figure 2, after using the DSM system there was a general shift in the proportion for vehicles from higher to lower speed bins (speed ranges). The long term data show a further general shift to even lower speed bins.

Chapter 3: Approach Speed Analysis for Daytime and Nighttime Data

Similar analysis was performed but by differentiating the daylight conditions and night effect on the data. Table 5 presents before, after and long term data and statistical parameters for the approach speeds including separate daytime and nighttime data sets. Table 6 and Table 7 present the summary of the hypothesis tests results. The data reveal that the average speed decreased by 3.56 mph during daytime and 3.64 mph during nighttime, while the speed limit compliance increased by 23.60% and 19.67% after for daytime and nighttime respectively after installing the DSM system. The long term data show that, 6 months following the use of DSM system, the average speed went down by 1.00 mph during daytime and 2.32 mph during the nighttime, while the speed limit compliance increased by 3.79% for the daytime and 5.38% for the nighttime. The long term drop in compliance was less on the long term. However, there is no evidence that the compliance level is reverting back to initial conditions. The variance seems to have significantly decreased immediately after the use of the DSM system but it increased again on the long term. Figure 3 provides a frequency graph for different speed bins and Figure 4 provides the cumulative frequency during daylight conditions, and Figures 5 and 6 are the same but for the night. The 85^{th} percentile speed has been consistently reduced during daylight conditions and nighttime after the use of the DSM system and on the long term.

Table 5: Before - After - Long Term Daytime and Nighttime Data Set Summary

Speed Bins (mph)	Before Vehicle Frequency		After Vehicle Frequency		Long Term Vehicle Frequency	
	Daytime	Nighttime	Daytime	Nighttime	Daytime	Nighttime
1 to 30	33	15	25.000	36	10	71
31 to 32	10	7	38.000	32	4	21
33 to 35	41	24	133.000	118	13	84
36 to 38	93	72	337.000	267	46	194
39 to 41	284	201	756.000	589	106	368
42 to 44	712	462	1901.000	1185	197	580
45 to 47	1609	973	3300.000	1900	361	744
48 to 50	3012	1942	5376.000	2823	517	871
51 to 53	4298	2386	5553.000	2485	447	692
54 to 56	5298	2693	5102.000	1952	361	508
57 to 59	4475	1835	2846.000	1007	220	255
60 to 62	3263	1143	1383.000	470	114	105
63 to 65	1503	522	536.000	195	38	42
66 to 68	738	211	226.000	68	13	14
69 to 147	491	169	124.000	57	14	8
Total	**25860**	**12655**	**27636**	**13184**	**2461**	**4557**
Average Speed (mph)	**55.06**	**53.75**	**51.50**	**50.11**	**50.50**	**47.79**
Variance	**41.41**	**39.90**	**36.53**	**39.62**	**41.65**	**54.95**
Coefficient of Variance	**0.12**	**0.12**	**0.12**	**0.13**	**---**	**---**
% Obeying Speed Limit	**52.66**	**62.66**	**76.26**	**82.33**	**80.05**	**87.71**
% Obeying Speed Limit + 5 Mph	**81.86**	**87.59**	**93.89**	**95.59**	**94.88**	**97.19**
% Obeying Speed Limit + 10 Mph	**95.25**	**97.00**	**98.73**	**99.05**	**98.90**	**99.52**
85^{th} Percentile (mph)	**61.00**	**60.00**	**57.00**	**56.00**	**54.27**	**51.98**

Table 6: Before and After Daytime and Nighttime Hypothesis Tests Summary

Hypothesis Test	Alternate Hypothesis	Parameter Change		Significant?	
		Daytime	Nighttime	Daytime	Nighttime
Mean	μ (b) - μ (a) > 0	-3.56	-3.64	Yes	Yes
Variance	σ^2 (b) / σ^2 (a) > 0	-4.87	-0.28	Yes	Yes
% Obeying Speed Limit	P (b) - P (a) < 0	23.60%	19.67%	Yes	Yes
% Obeying Speed Limit + 5 Mph	P (b) - P (a) < 0	12.03%	8.00%	Yes	Yes
% Obeying Speed Limit + 10 Mph	P (b) - P (a) < 0	3.49%	2.06%	Yes	Yes

Table 7: After and Long Term Daytime and Nighttime Hypothesis Tests Summary

Hypothesis Test	Alternate Hypothesis	Parameter Change		Significant?	
		Daytime	Nighttime	Daytime	Nighttime
Mean	μ (b) - μ (a) > 0	-1.00	-2.32	Yes	Yes
Variance	σ^2 (b) / σ^2 (a) > 0	5.11	15.34	No (increased)	No (increased)
% Obeying Speed Limit	P (b) - P (a) < 0	3.79	5.38	Yes	Yes
% Obeying Speed Limit + 5 Mph	P (b) - P (a) < 0	0.99	1.60	Yes	Yes
% Obeying Speed Limit + 10 Mph	P (b) - P (a) < 0	0.17	0.47	Yes	No

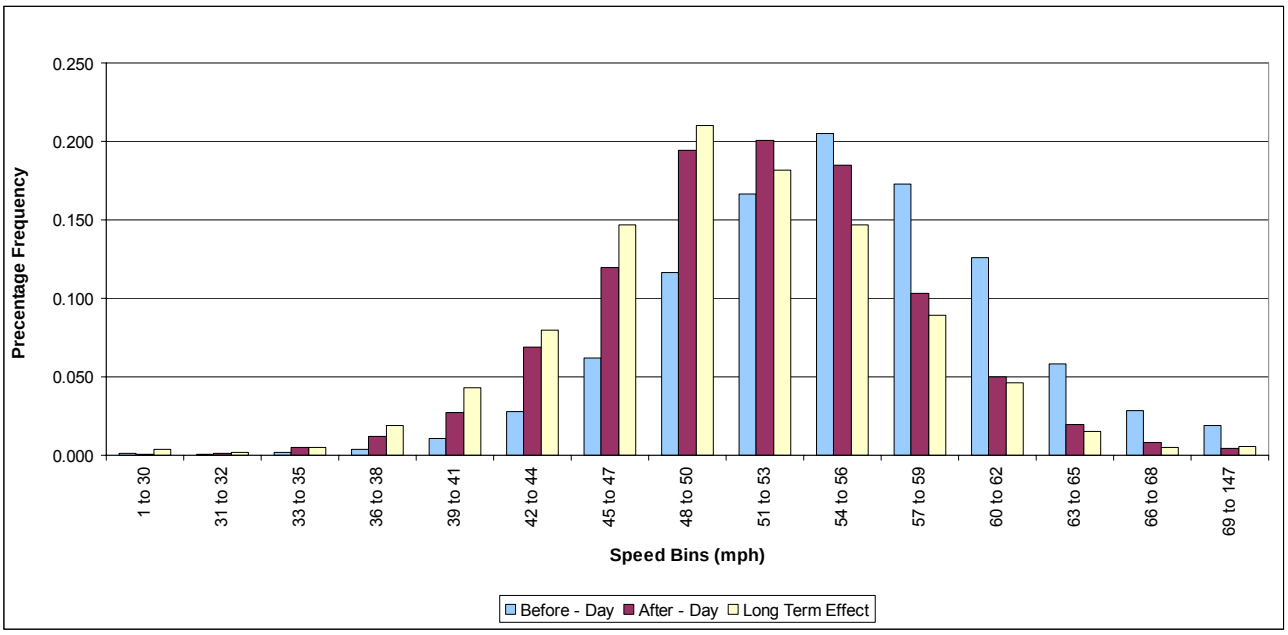

Figure 3: Before - After - Long Term Approach Speeds – Daytime Data Set Graph

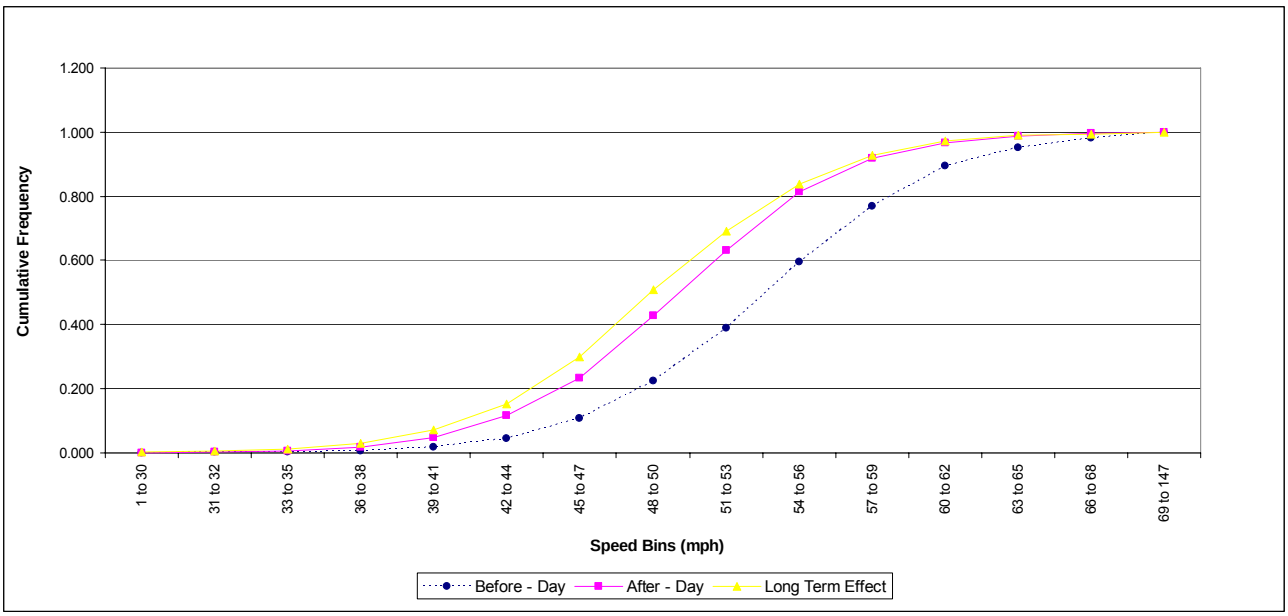

Figure 4: Before - After - Long Term Approach Speeds – Daytime Data Set Cumulative Distributions

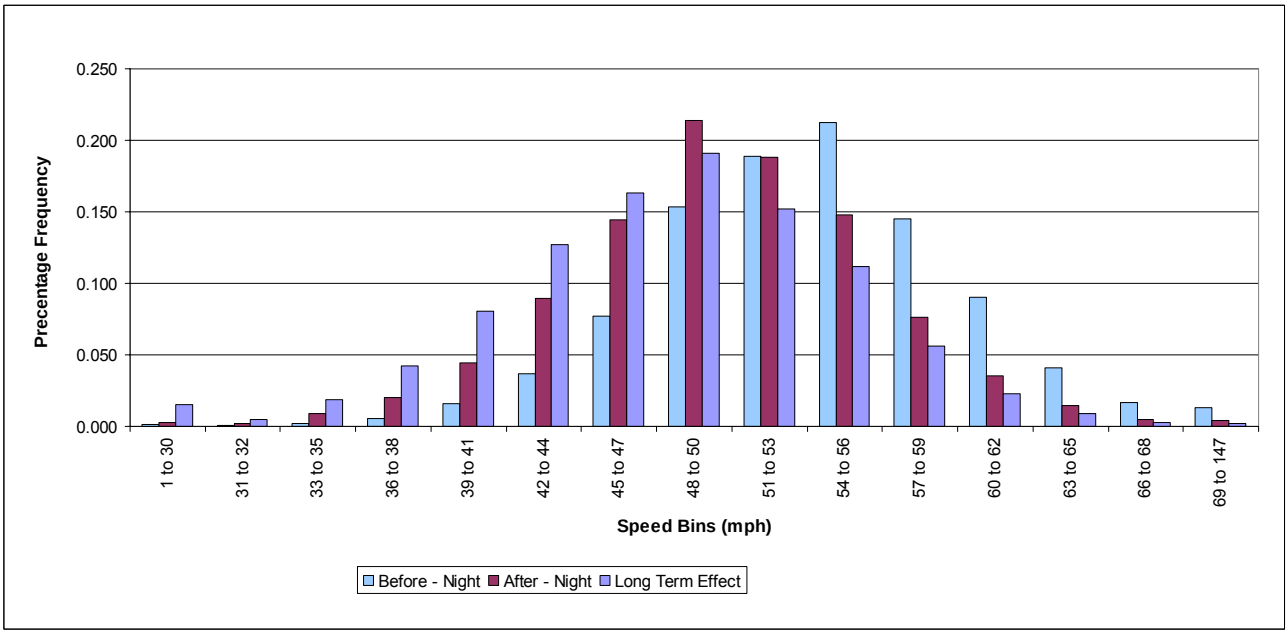

Figure 5: Before - After - Long Term Approach Speeds – Nighttime Data Set Graph

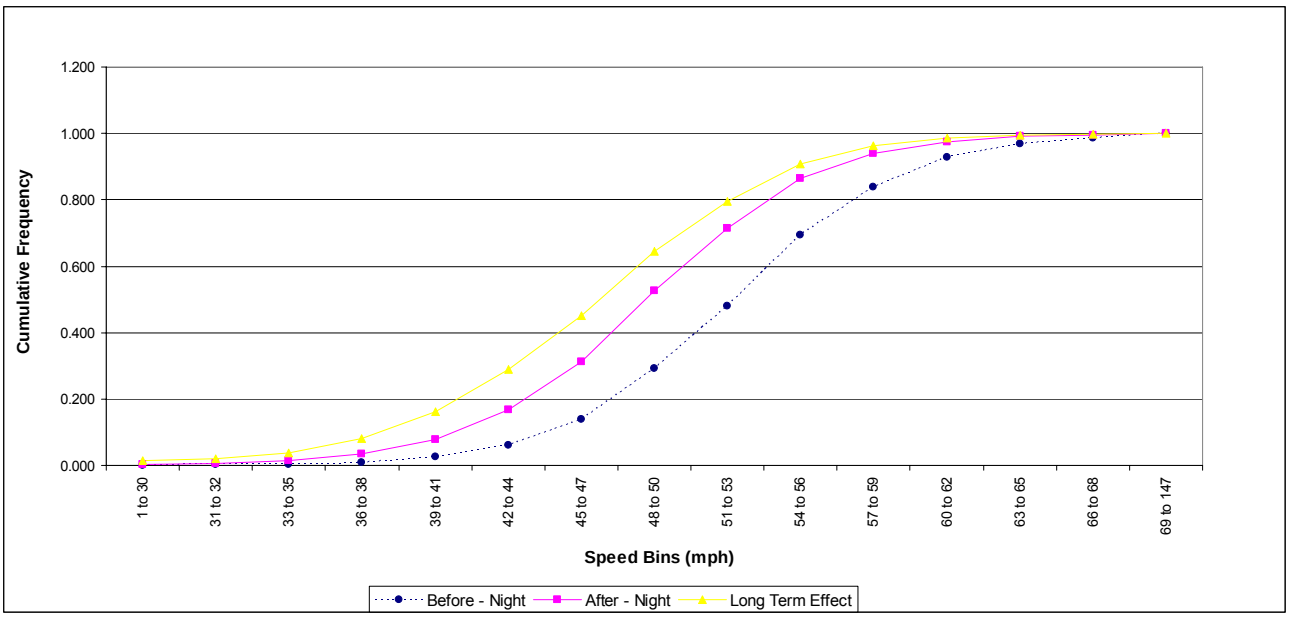

Figure 6: Before - After - Long Term Approach Speeds – Nighttime Data Set Cumulative Distributions

As illustrated in Figure 4 and Figure 6, after using the DSM system there was a general shift in the proportion for vehicles from higher to lower speed bins. The long term data show a further general shift to even lower speed bins, however it appears to be more significant during the nighttime.

Chapter 4: Approach Speed Analysis for Weekdays and Weekends Data

The same analysis was performed but by differentiating the Weekdays and Weekends effect on the data. Table 1-8 presents before, after and long term data and statistical parameters for the approach speeds for the weekdays data sets and Table 9 for the weekend data sets. Table 1-10 shows that there was no major difference between the general behavior of the data between weekdays and weekends. The average speeds, speed limit compliances, and 85^{th} speed percentile appear to be diminishing, for both weekdays and weekends, after the use of the DSM system and decreases further more on the long term. However, similar to the prior data analysis for the entire set, the variance decreases after the use of the DSM system and increases back again on the long term (after 6 months).

Figure 7 provides a frequency graph for different speed bins and Figure 8 provides the cumulative frequency during weekdays, and Figures 9 and 10 are the same but for the weekends. There is no apparent difference in the behavior of the curves between weekdays and weekends.

Table 8: Before - After - Long Term for Weekdays Data Set Summary

Speed Bins (mph)	Before Vehicle Frequency		After Vehicle Frequency		Long Term Vehicle Frequency	
	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency
1 to 30	0.001	22	0.002	36	0.012	48
31 to 32	0.000	9	0.002	37	0.003	10
33 to 35	0.002	33	0.006	149	0.014	56
36 to 38	0.005	86	0.014	343	0.031	123
39 to 41	0.013	242	0.033	775	0.063	249
42 to 44	0.031	585	0.074	1771	0.106	421
45 to 47	0.068	1276	0.125	2974	0.148	588
48 to 50	0.125	2331	0.198	4713	0.197	784
51 to 53	0.174	3248	0.197	4703	0.165	655
54 to 56	0.208	3881	0.174	4139	0.132	524
57 to 59	0.163	3046	0.098	2328	0.074	294
60 to 62	0.114	2135	0.046	1106	0.035	140
63 to 65	0.054	1008	0.020	475	0.013	52
66 to 68	0.025	467	0.008	182	0.005	20
69 to 147	0.017	311	0.004	101	0.003	13
Total	**1.00**	**18680**	**1.00**	**23832**	**1.00**	**3977**
Average Speed (mph)	**---**	**54.63**	**---**	**51.16**	**---**	**49.09**
Variance	**---**	**40.88**	**---**	**38.02**	**---**	**53.50**
Coefficient of Variance	**---**	**0.12**	**---**	**0.12**	**---**	**---**
% Obeying Speed Limit	**---**	**56.00**	**---**	**77.43**	**---**	**83.56**
% Obeying Speed Limit + 5 Mph	**---**	**83.60**	**---**	**94.08**	**---**	**95.83**
% Obeying Speed Limit + 10 Mph	**---**	**95.84**	**---**	**98.81**	**---**	**99.17**
85th Percentile (mph)	**---**	**61**	**---**	**58**	**---**	**53.00**

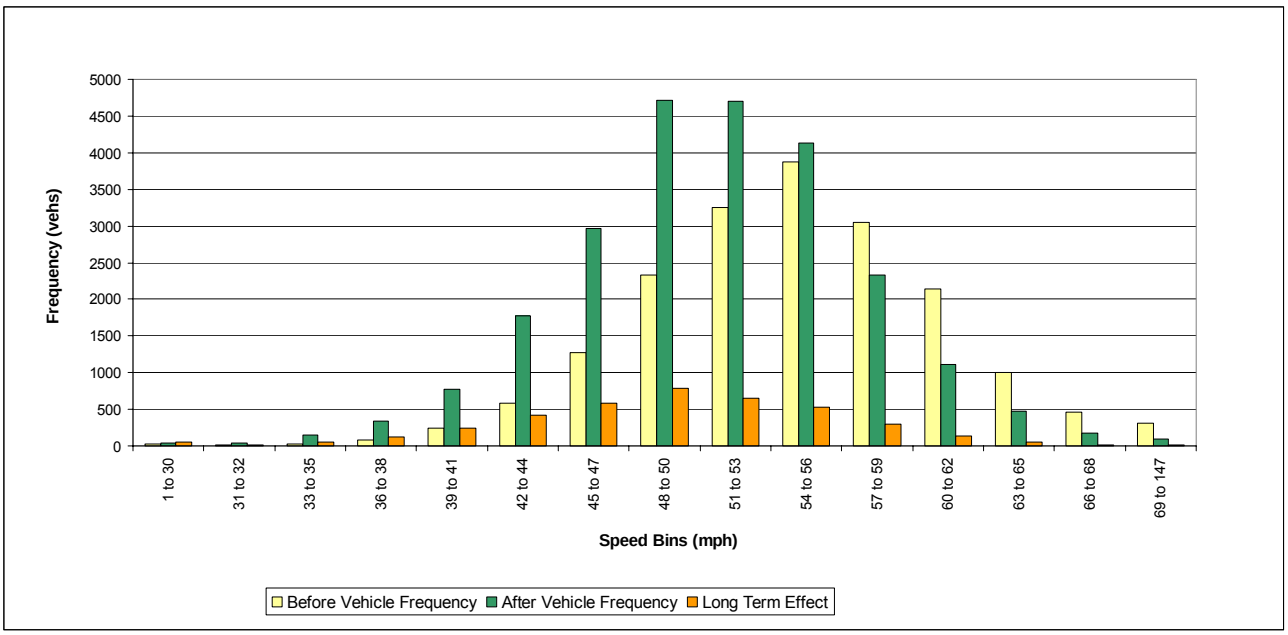

Figure 7: Before - After - Long Term Approach Speeds –Weekdays Data Set Data Set Graph

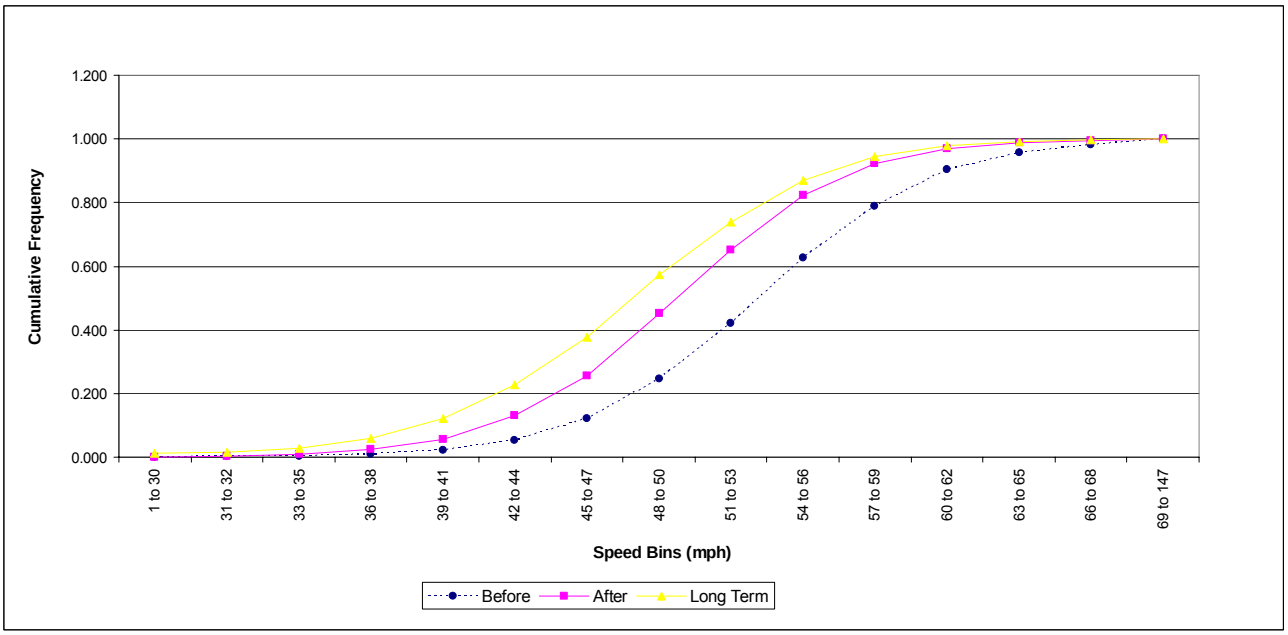

Figure 8: Before - After - Long Term Approach Speeds – Weekdays Data Set Cumulative Distributions

Table 9: Before - After - Long Term for Weekends Data Set Summary

Speed Bins (mph)	Before Vehicle Frequency		After Vehicle Frequency		Long Term Vehicle Frequency	
	Proportion of Total	Frequency	Proportion of Total	Frequency	Proportion of Total	Frequency
1 to 30	0.002	19	0.001	15	0.011	33
31 to 32	0.000	3	0.002	22	0.005	15
33 to 35	0.001	18	0.006	70	0.013	41
36 to 38	0.003	40	0.016	174	0.038	117
39 to 41	0.011	130	0.034	371	0.074	225
42 to 44	0.028	338	0.075	814	0.117	356
45 to 47	0.065	786	0.130	1410	0.170	517
48 to 50	0.134	1627	0.203	2213	0.199	604
51 to 53	0.177	2140	0.198	2155	0.159	484
54 to 56	0.209	2528	0.169	1838	0.113	345
57 to 59	0.165	2000	0.091	986	0.060	181
60 to 62	0.115	1389	0.047	507	0.026	79
63 to 65	0.051	620	0.017	182	0.009	28
66 to 68	0.022	270	0.007	75	0.002	7
69 to 147	0.017	204	0.005	50	0.003	9
Total	**1.00**	**12112**	**1.00**	**10882**	**1.00**	**3041**
Average Speed (mph)	**---**	**54.64**	**---**	**50.95**	**---**	**48.28**
Variance	**---**	**39.86**	**---**	**37.20**	**---**	**49.56**
Coefficient of Variance	**---**	**0.12**	**---**	**0.12**	**---**	**---**
% Obeying Speed Limit	**---**	**55.94**	**---**	**79.00**	**---**	**86.95**
% Obeying Speed Limit + 5 Mph	**---**	**84.21**	**---**	**94.55**	**---**	**97.11**
% Obeying Speed Limit + 10 Mph	**---**	**96.09**	**---**	**98.85**	**---**	**99.47**
85th Percentile (mph)	**---**	**61.00**	**---**	**58.00**	**---**	**53.00**

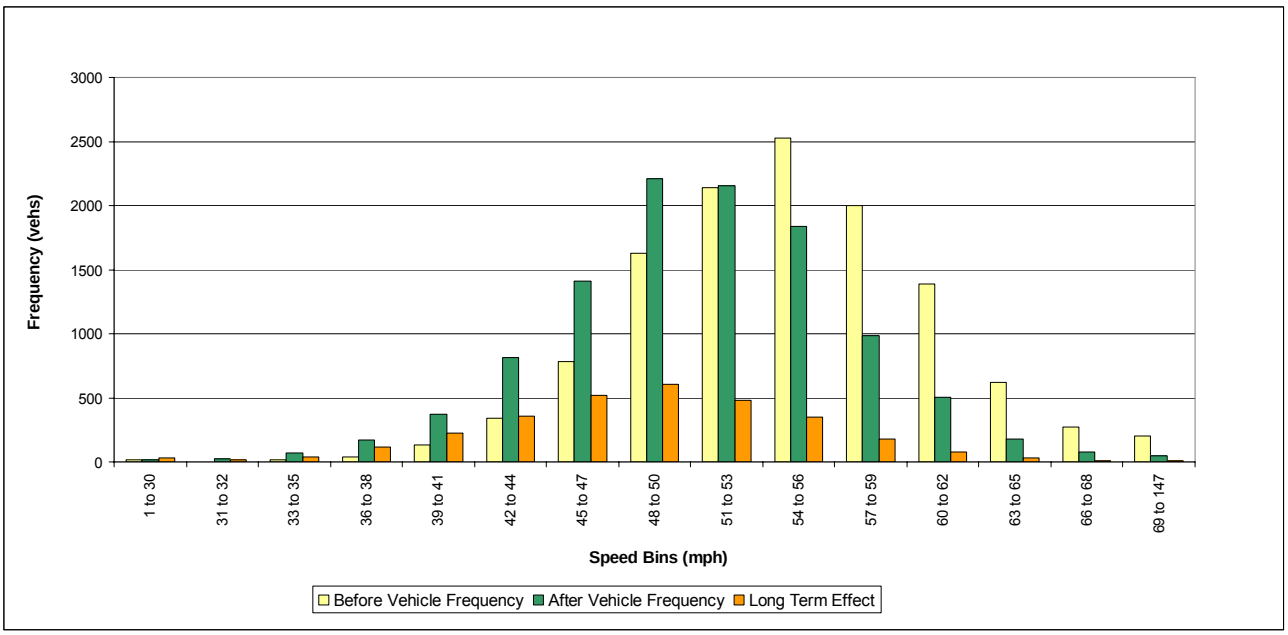

Figure 9: Before - After - Long Term Approach Speeds –Weekends Data Set Data Set Graph

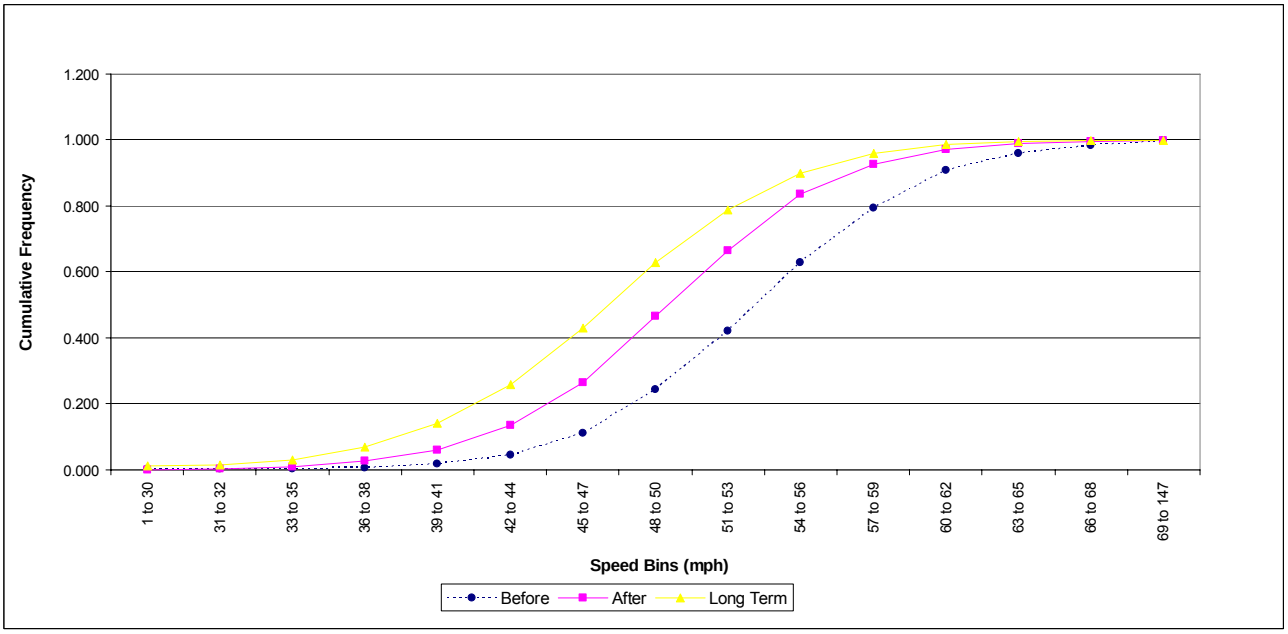

Figure 10: Before - After - Long Term Approach Speeds – Weekends Data Set Cumulative Distributions

Table 10: Summary of Parameters Difference for Weekdays and Weekends

Parameters Difference	Weekdays		Weekends	
	Before and After	After and Long Term	Before and After	After and Long Term
Means	-3.46	-2.07	-3.69	-2.67
Variance	-2.85	15.48	-2.66	12.36
% Obeying Speed Limit	21.43	6.12	23.07	7.94
% Obeying Speed Limit + 5 Mph	10.48	1.75	10.34	2.56
% Obeying Speed Limit + 10 Mph	2.98	0.36	2.76	0.62
85^{th} Speed Percentile	-3.00	-5.00	-3.00	-5.00

Chapter 5: Average speed for every hour of the day

As shown in Tables 11 and 12, the average speeds for every hour of the day have been analyzed for the entire long term data set. The data analysis has been considered for weekdays and weekends. The plots illustrated in Figure 10 show that the average speeds were at a peak during the hours of 2pm to 4pm and at their lowest during the hours of 7pm to 8pm. Figure 11 shows that the overall average speeds on weekends tend to be higher then the general data, whereas on the Weekdays they tend to be lower.

Table 11: Average Speed for Each Hour of the Day for Long Term Data Set (a)

	Hours of the Day	hr-0	hr-1	hr-2	hr-3	hr-4	hr-5	hr-6	hr-7	hr-8	hr-9	hr-10	hr-11	hr-12
General	Speed x (Vehicle count)	18048	13898	11281	9020	8059	11536	20734	25812	8095	7631	7891	8124	14566
	Vehicle Count	372	281	228	186	166	233	425	517	162	151	157	163	287
	Avg. Speed per hour	**48.5**	**49.5**	**49.5**	**48.5**	**48.5**	**49.5**	**48.8**	**49.9**	**50.0**	**50.5**	**50.3**	**49.8**	**50.8**
Weekdays	Speed x (Vehicle count)	13997	10527	8407	6662	5851	8055	14640	18529	6227	7580	7891	7732	7111
	Vehicle Count	288	212	169	134	120	162	300	374	125	150	157	155	137
	Avg. Speed per hour	**48.6**	**49.7**	**49.7**	**49.7**	**48.8**	**49.7**	**48.8**	**49.5**	**49.8**	**50.5**	**50.3**	**49.9**	**51.9**
Weekends	Speed x (Vehicle count)	4051	3371	2874	2358	2208	3481	6094	7283	1868	51	0	392	7455
	Vehicle Count	84	69	59	52	46	71	125	143	37	1	0	8	150
	Avg. Speed per hour	**48.2**	**48.9**	**48.7**	**45.3**	**48.0**	**49.0**	**48.8**	**50.9**	**50.5**	**51.0**	**50.0**	**49.0**	**49.7**

Table 12: Average Speed for Each Hour of the Day for Long Term Data Set (b)

	Hours of the Day	hr-13	hr-14	hr-15	hr-16	hr-17	hr-18	hr-19	hr-20	hr-21	hr-22	hr-23	Total
General	Speed x (Vehicle count)	14404	15198	9497	9009	10717	13541	17941	18739	21152	23346	23823	342062
	Vehicle Count	283	293	185	180	219	290	400	414	450	486	490	7018
	Avg. Speed per hour	**50.9**	**51.9**	**51.3**	**50.1**	**48.9**	**46.7**	**44.9**	**45.3**	**47.0**	**48.0**	**48.6**	**48.7**
Weekdays	Speed x (Vehicle count)	6991	8262	1179	873	2315	5856	7990	7938	9108	10654	10869	195244
	Vehicle Count	135	158	22	17	50	123	173	173	196	221	226	3977
	Avg. Speed per hour	**51.8**	**52.3**	**53.6**	**51.4**	**46.3**	**47.6**	**46.2**	**45.9**	**46.5**	**48.2**	**48.1**	**49.09**
Weekends	Speed x (Vehicle count)	7413	6936	8318	8136	8402	7685	9951	10801	12044	12692	12954	146818
	Vehicle Count	148	135	163	163	169	167	227	241	254	265	264	3041
	Avg. Speed per hour	**50.1**	**51.4**	**51.0**	**49.9**	**49.7**	**46.0**	**43.8**	**44.8**	**47.4**	**47.9**	**49.1**	**48.3**

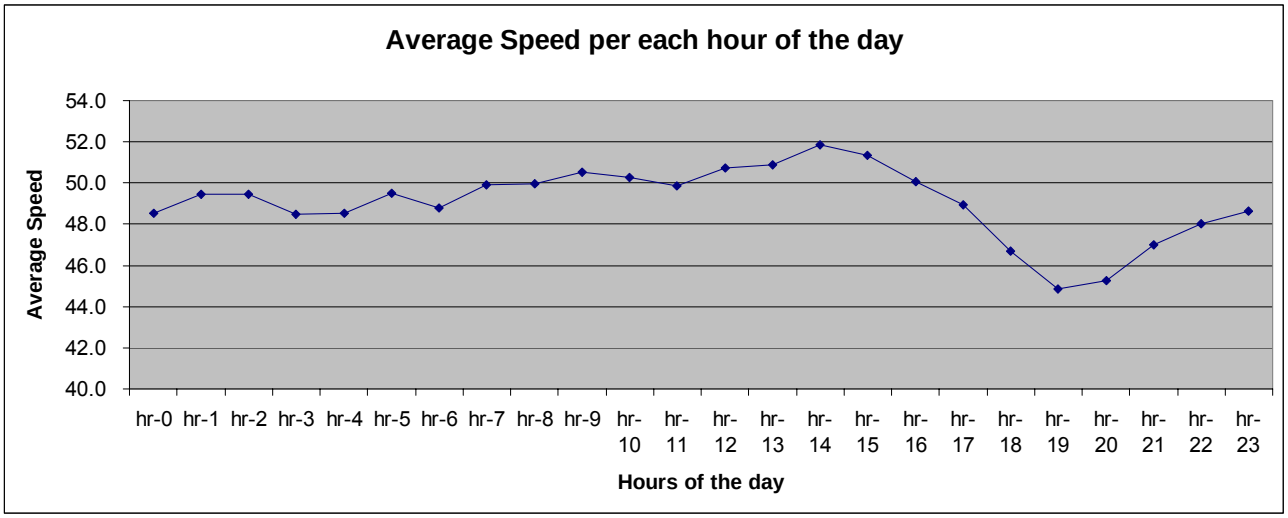

Figure 11: Average Speed for Each Hour of the Day for Long Term Data Set

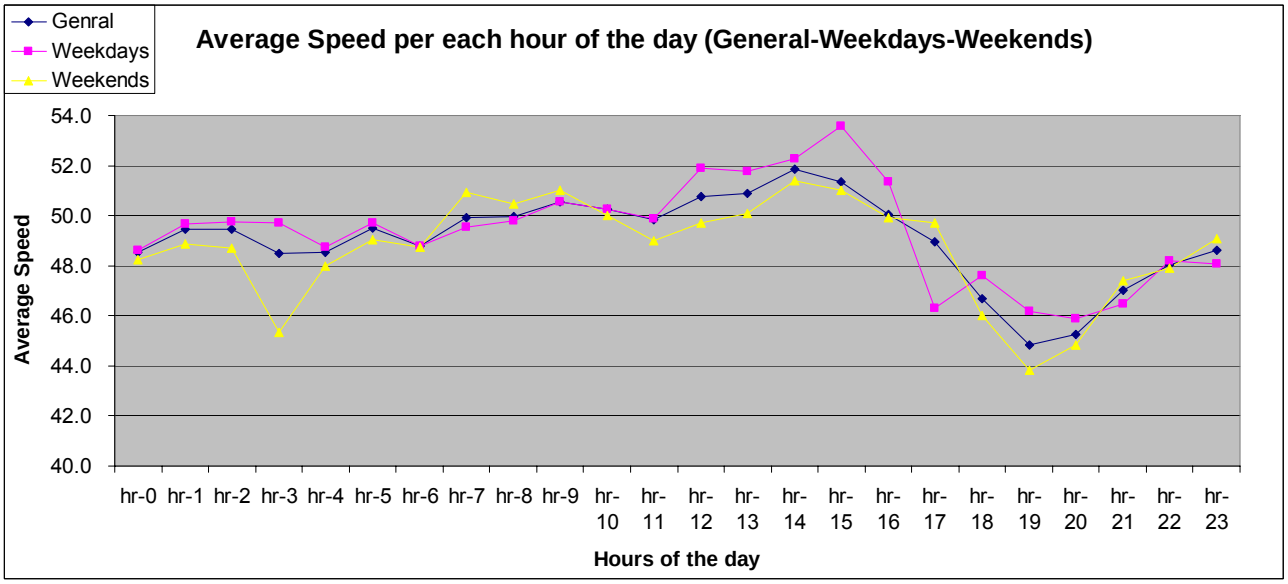

Figure 12: Average Speed for Each Hour of the Day for Long Term Data Set Including Weekdays and Weekends

Chapter 6: Conclusion

The analyses for the approach speeds before, after and on the long term have been performed for various data sets including the entire data set, daytime/nighttime and weekdays/weekends. Most of the results show that the average speeds, speed limit compliances, and 85th speed percentile diminish after the use of the DSM system and decrease further more on the long term. However, the variances appeared to decrease after the use of the DSM system and increase back again on the long term (after 6 months). The root cause for that may be the fact that only 10 days worth of data where available for long term analysis. In addition, construction/maintenance work may have taken place during some of those days. From the data analyses we can say that, in general, there is no evidence that the average speeds, speed limit compliances, or the 85th speed percentile have increased or returned to the original status before installing the DSM system.

For reasons cited above – short duration (10 days data) and improvements introduced, it is strongly recommended that a long term study for much longer duration (9 months at least) be conducted. Such study would render higher confidence in measuring the long term effect. If proven effective, such solar powered systems can be propagated throughout the State for similar operational characteristics.

If a longer-term study is approved as proposed in the paragraph above, the researchers propose that data collection proceed as follows:

1. Collect and analyze speed data while sign is bagged to determine if average and approach speeds are affected when the sign is not operational.
2. Collect and analyze long term speed data to confirm earlier findings under consistent operational conditions.
3. Select and deploy equipment that is on the State's approved APL list. This will enable the FDOT the immediate deployment of the DSM system once results proved valuable.

APPENDIX

Detailed Hypothesis Analysis

HYPOTHESIS TEST FOR A DIFFERENCE IN MEANS - APPROACH SPEED DATA

To determine if the mean speed decreased after DSM installation ***(short term).***

Ho: $Mean_{(before)} - Mean_{(after)} = 0$ **Ha: $Mean_{(before)} - Mean_{(after)} > 0$**

Reject Ho if t test statistic > Critical statistic; 95% significance level

1. Difference in Means - Entire Approach Data Set

$N_{(Before)}$ =	38,515	$N_{(After)}$ =	40,820
Mean Before =	54.631	Mean After =	51.049
Variance Before =	41.286	Variance After =	37.949
t test Statistic =	80.066	Deg. of Free, υ =	78545
Critical Statistic =	1.645		

Hence: Reject Ho - Conclude Mean Speed Reduction is Significant

2. Difference in Means - Daytime Approach Data Set

$N_{(Before)}$ =	25,860	$N_{(After)}$ =	27,636
Mean Before =	55.060	Mean After =	51.496
Variance Before =	41.406	Variance After =	36.534
t test Statistic =	65.924	Deg. of Free, υ =	52621
Critical Statistic =	1.645		

Hence: Reject Ho - Conclude Mean Speed Reduction is Significant

3. Difference in Means - Nighttime Approach Data Set

$N_{(Before)}$ =	12,655	$N_{(After)}$ =	13,184
Mean Before =	53.753	Mean After =	50.11
Variance Before =	39.895	Variance After =	39.62
t test Statistic =	46.416	Deg. of Free, υ =	25786
Critical Statistic =	1.645		

Hence: Reject Ho - Conclude Mean Speed Reduction is Significant

*To determine if the mean speed decreased after DSM installation in the **(long term).***

Ho: $Mean_{(before)} - Mean_{(after)} = 0$ **Ha: $Mean_{(before)} - Mean_{(after)} > 0$**

Reject Ho if t test statistic > Critical statistic; 95% significance level

1. Difference in Means - Entire Approach Data Set

$N_{(Before)}$ =	40,820		$N_{(After)}$ =	7,018	
Mean Before	=	51.049	Mean After	=	48.740
Variance Before	=	37.949	Variance After	=	51.620
t test Statistic	=	25.363	Deg. of Free, υ	=	8879
Critical Statistic	=	1.645			

Hence: Reject Ho - Conclude Mean Speed Reduction is Significant

2. Difference in Means - Daytime Approach Data Set

$N_{(Before)}$ =	27,636		$N_{(After)}$ =	2,461	
Mean Before	=	51.496	Mean After	=	50.500
Variance Before	=	36.534	Variance After	=	41.650
t test Statistic	=	7.374	Deg. of Free, υ	=	2858
Critical Statistic	=	1.645			

Hence: Reject Ho - Conclude Mean Speed Reduction is Significant

3. Difference in Means - Nighttime Approach Data Set

$N_{(Before)}$ =	13,184		$N_{(After)}$ =	4,557	
Mean Before	=	50.111	Mean After	=	47.79
Variance Before	=	39.618	Variance After	=	54.95
t test Statistic	=	18.908	Deg. of Free, υ	=	6960
Critical Statistic	=	1.645			

Hence: Reject Ho - Conclude Mean Speed Reduction is Significant

HYPOTHESIS TEST FOR A DIFFERENCE IN VARIANCE - APPROACH SPEED DATA

To determine if the speed variance decreased after DSM installation ***(short term).***

Ho: Variance$_{(before)}$ - Variance$_{(after)}$ = 0 **Ha: Variance$_{(before)}$ - Variance$_{(after)}$ > 0**

Reject Ho if Fstatistic > Critical statistic; 95% significance level

1. Difference in Variance - Entire Approach Data Set

$N_{(Before)}$ =	38,515	$N_{(After)}$ =	40,820
Variance Before =	41.286	Variance After =	37.949
F Statistic =	1.088	Deg. of Free 1, $_1\upsilon$ =	38514
Critical Statistic =	1.00	Deg. of Free 2, $_2\upsilon$ =	40819

Hence: Reject Ho - Conclude Speed Variance Reduction is Significant

2. Difference in Variance - Daytime Approach Data Set

$N_{(Before)}$ =	25,860	$N_{(After)}$ =	27,636
Variance Before =	41.406	Variance After =	36.534
F Statistic =	1.133	Deg. of Free 1, $_1\upsilon$ =	25859
Critical Statistic =	1.00	Deg. of Free 2, $_2\upsilon$ =	27635

Hence: Reject Ho - Conclude Speed Variance Reduction is Significant

3. Difference in Variance - Nighttime Approach Data Set

$N_{(Before)}$ =	12,655	$N_{(After)}$ =	13,184
Variance Before =	39.895	Variance After =	39.618
F Statistic =	1.007	Deg. of Free 1, $_1\upsilon$ =	12654
Critical Statistic =	1.00	Deg. of Free 2, $_2\upsilon$ =	13183

Hence: Reject Ho - Conclude Speed Variance Reduction is Significant

*To determine if the speed variance decreased after DSM installation **(long term).***

Ho: Variance$_{(before)}$ - Variance$_{(after)}$ = 0 Ha: Variance$_{(before)}$ - Variance$_{(after)}$ > 0

Reject Ho if Fstatistic > Critical statistic; 95% significance level

1. Difference in Variance - Entire Approach Data Set

$N_{(Before)}$ =	40,820		$N_{(After)}$ =	7,018	
Variance Before =		37.949	Variance After =	51.620	Variance actually increased
F Statistic =		0.735	Deg. of Free 1, $_1$υ =	40819	
Critical Statistic =		1.00	Deg. of Free 2, $_2$υ =	7017	

Hence: Accept Ho - Conclude Speed Variance Reduction is not Significant

2. Difference in Variance - Daytime Approach Data Set

$N_{(Before)}$ =	27,636		$N_{(After)}$ =	2,461	
Variance Before =		36.534	Variance After =	41.650	Variance actually increased
F Statistic =		0.877	Deg. of Free 1, $_1$υ =	27635	
Critical Statistic =		1.00	Deg. of Free 2, $_2$υ =	2460	

Hence: Accept Ho - Conclude Speed Variance Reduction is not Significant

3. Difference in Variance - Nighttime Approach Data Set

$N_{(Before)}$ =	13,184		$N_{(After)}$ =	4,557	
Variance Before =		39.618	Variance After =	54.950	Variance actually increased
F Statistic =		0.721	Deg. of Free 1, $_1$υ =	13183	
Critical Statistic =		1.00	Deg. of Free 2, $_2$υ =	4556	

Hence: Accept Ho - Conclude Speed Variance Reduction is not Significant

HYPOTHESIS TEST FOR A DIFFERENCE IN PROPORTIONS - APPROACH SPEED DATA COMPLIANCE WITH SPEED LIMIT - 55 MPH

*To determine if the proportion of drivers complying with the speed limit of 55 mph increased after DSM Installation **(short term).***

Ho: Proportion$_{(before)}$ - Proportion$_{(after)}$ = 0 **Ha: Proportion$_{(before)}$ - Proportion$_{(after)}$ < 0**

Reject Ho if Z statistic test < Critical statistic; 95% significance level

1. Difference in Proportions - Entire Approach Data Set

$N_{(Before)}$ =	38,515	$N_{(After)}$ =	40,820
Proportion Before =	0.559	Proportion After =	0.782
Z test Statistic =	-66.87	p(pooled) =	0.674
Critical Statistic =	-1.645	q(pooled) =	0.326

Hence: Reject Ho - Conclude 55 mph Advisory Speed Compliance is increased

2. Difference in Proportions - Daytime Approach Data Set

$N_{(Before)}$ =	25,860	$N_{(After)}$ =	27,636
Proportion Before =	0.527	Proportion After =	0.763
Z test Statistic =	-57.11	p(pooled) =	0.649
Critical Statistic =	-1.645	q(pooled) =	0.351

Hence: Reject Ho - Conclude 55 mph Advisory Speed Compliance is increased

3. Difference in Proportions - Nighttime Approach Data Set

$N_{(Before)}$ =	12,655	$N_{(After)}$ =	13,184
Proportion Before =	0.627	Proportion After =	0.823
Z test Statistic =	-35.47	p(pooled) =	0.727
Critical Statistic =	-1.645	q(pooled) =	0.273

Hence: Reject Ho - Conclude 55 mph Advisory Speed Compliance is increased

*To determine if the proportion of drivers complying with the speed limit of 55 mph increased after DSM Installation **(long term).***

Ho: Proportion$_{(before)}$ - Proportion$_{(after)}$ = 0 **Ha: Proportion$_{(before)}$ - Proportion$_{(after)}$ < 0**

Reject Ho if Z statistic test < Critical statistic; 95% significance level

1. Difference in Proportions - Entire Approach Data Set

$N_{(Before)}$ =	40,820		$N_{(After)}$ =	7,018	
Proportion Before =		0.782	Proportion After =		0.850
Z test Statistic =		-12.97	p(pooled) =		0.792
Critical Statistic =		-1.645	q(pooled) =		0.208

Hence: Reject Ho - Conclude 55 mph Advisory Speed Compliance is increased

2. Difference in Proportions - Daytime Approach Data Set

$N_{(Before)}$ =	27,636		$N_{(After)}$ =	2,461	
Proportion Before =		0.763	Proportion After =		0.800
Z test Statistic =		-4.26	p(pooled) =		0.766
Critical Statistic =		-1.645	q(pooled) =		0.234

Hence: Reject Ho - Conclude 55 mph Advisory Speed Compliance is increased

3. Difference in Proportions - Nighttime Approach Data Set

$N_{(Before)}$ =	13,184		$N_{(After)}$ =	4,557	
Proportion Before =		0.823	Proportion After =		0.877
Z test Statistic =		-8.48	p(pooled) =		0.837
Critical Statistic =		-1.645	q(pooled) =		0.163

Hence: Reject Ho - Conclude 55 mph Advisory Speed Compliance is increased

HYPOTHESIS TEST FOR A DIFFERENCE IN PROPORTIONS - APPROACH SPEED DATA COMPLIANCE WITH SPEED LIMIT + 5 MPH

To determine if the proportion of drivers complying with the speed limit of 55 mph + 5 mph increased after DSM installation ***(short term).***

Ho: Proportion$_{(before)}$ - Proportion$_{(after)}$ = 0 **Ha: Proportion$_{(before)}$ - Proportion$_{(after)}$ < 0**

Reject Ho if Z test statistic < Critical statistic; 95% significance level

1. Difference in Proportions - Entire Approach Data Set

$N_{(Before)}$ =	38,515	$N_{(After)}$ =	40,820
Proportion Before =	0.837	Proportion After =	0.944
Z test Statistic =	-48.61	p(pooled) =	0.892
Critical Statistic =	-1.645	q(pooled) =	0.108

Hence: Reject Ho - Conclude 55 + 5 mph Speed Compliance is increased

2. Difference in Proportions - Daytime Approach Data Set

$N_{(Before)}$ =	25,860	$N_{(After)}$ =	27,636
Proportion Before =	0.819	Proportion After =	0.939
Z test Statistic =	-42.91	p(pooled) =	0.881
Critical Statistic =	-1.645	q(pooled) =	0.119

Hence: Reject Ho - Conclude 55 + 5 mph Speed Compliance is increased

3. Difference in Proportions - Nighttime Approach Data Set

$N_{(Before)}$ =	12,655	$N_{(After)}$ =	13,184
Proportion Before =	0.876	Proportion After =	0.956
Z test Statistic =	-23.27	p(pooled) =	0.917
Critical Statistic =	-1.645	q(pooled) =	0.083

Hence: Reject Ho - Conclude 55 + 5 mph Speed Compliance is increased

*To determine if the proportion of drivers complying with the speed limit of 55 mph + 5 mph increased after DSM installation **(long term).***

Ho: Proportion$_{(before)}$ - Proportion$_{(after)}$ = 0 **Ha: Proportion$_{(before)}$ - Proportion$_{(after)}$ < 0**

Reject Ho if Z test statistic < Critical statistic; 95% significance level

1. Difference in Proportions - Entire Approach Data Set

$N_{(Before)}$ =	40,820	$N_{(After)}$ =	7,018
Proportion Before =	0.944	Proportion After =	0.964
Z test Statistic =	-6.72	p(pooled) =	0.947
Critical Statistic =	-1.645	q(pooled) =	0.053

Hence: Reject Ho - Conclude 55 + 5 mph Speed Compliance is increased

2. Difference in Proportions - Daytime Approach Data Set

$N_{(Before)}$ =	27,636	$N_{(After)}$ =	2,461
Proportion Before =	0.939	Proportion After =	0.949
Z test Statistic =	-1.98	p(pooled) =	0.940
Critical Statistic =	-1.645	q(pooled) =	0.060

Hence: Reject Ho - Conclude 55 + 5 mph Speed Compliance is increased

3. Difference in Proportions - Nighttime Approach Data Set

$N_{(Before)}$ =	13,184	$N_{(After)}$ =	4,557
Proportion Before =	0.956	Proportion After =	0.972
Z test Statistic =	-4.75	p(pooled) =	0.960
Critical Statistic =	-1.645	q(pooled) =	0.040

Hence: Reject Ho - Conclude 55 + 5 mph Speed Compliance is increased

HYPOTHESIS TEST FOR A DIFFERENCE IN PROPORTIONS - APPROACH SPEED DATA COMPLIANCE WITH SPEED LIMIT + 10 MPH

To determine if the proportion of drivers complying with the speed limit of 55 mph + 10 mph increased after DSM installation in the short term.

Ho: Proportion$_{(before)}$ - Proportion$_{(after)}$ = 0 **Ha: Proportion$_{(before)}$ - Proportion$_{(after)}$ < 0**

Reject Ho if Z test statistic < Critical statistic; 95% significance level

1. Difference in Proportions - Entire Approach Data Set

$N_{(Before)}$ =	38,515	$N_{(After)}$ =	40,820
Proportion Before =	0.958	Proportion After =	0.988
Z test Statistic =	-26.53	p(pooled) =	0.974
Critical Statistic =	-1.645	q(pooled) =	0.026

Hence: Reject Ho - Conclude 55 + 10 mph Speed Compliance is increased

2. Difference in Proportions - Daytime Approach Data Set

$N_{(Before)}$ =	25,860	$N_{(After)}$ =	27,636
Proportion Before =	0.952	Proportion After =	0.987
Z test Statistic =	-23.81	p(pooled) =	0.970
Critical Statistic =	-1.645	q(pooled) =	0.030

Hence: Reject Ho - Conclude 55 + 10 mph Speed Compliance is increased

3. Difference in Proportions - Nighttime Approach Data Set

$N_{(Before)}$ =	12,655	$N_{(After)}$ =	13,184
Proportion Before =	0.970	Proportion After =	0.991
Z test Statistic =	-11.93	p(pooled) =	0.980
Critical Statistic =	-1.645	q(pooled) =	0.020

Hence: Reject Ho - Conclude 55 + 10 mph Speed Compliance is increased

To determine if the proportion of drivers complying with the speed limit of 55 mph + 10 mph increased after DSM installation in the long term.

Ho: Proportion$_{(before)}$ - Proportion$_{(after)}$ = 0 **Ha: Proportion$_{(before)}$ - Proportion$_{(after)}$ < 0**

Reject Ho if Z test statistic < Critical statistic; 95% significance level

1. Difference in Proportions - Entire Approach Data Set

$N_{(Before)}$	=40,820	$N_{(After)}$ =	7,018
Proportion Before =	0.988	Proportion After =	0.989
Z test Statistic =	-0.48	p(pooled) =	0.988
Critical Statistic =	-1.645	q(pooled) =	0.012

Hence: Accept Ho - Conclude 55 + 10 mph Speed Compliance is not increased

2. Difference in Proportions - Daytime Approach Data Set

$N_{(Before)}$ =	27,636	$N_{(After)}$ =	2,461
Proportion Before =	0.987	Proportion After =	0.995
Z test Statistic =	-3.42	p(pooled) =	0.988
Critical Statistic =	-1.645	q(pooled) =	0.012

Hence: Reject Ho - Conclude 55 + 10 mph Speed Compliance is increased

3. Difference in Proportions - Nighttime Approach Data Set

$N_{(Before)}$ =	13,184	$N_{(After)}$ =	4,557
Proportion Before =	0.991	Proportion After =	0.993
Z test Statistic =	-1.54	p(pooled) =	0.991
Critical Statistic =	-1.645	q(pooled) =	0.009

Hence: Accept Ho - Conclude 55 + 10 mph Speed Compliance is not increased