MICHIGAN OHIO UNIVERSITY TRANSPORTATION CENTER

Alternate energy and system mobility to stimulate economic development.

Report No: MIOH UTC TS22p1-2 2010-Final

SAFETY EVALUATION OF SCATS CONTROL SYSTEM

FINAL REPORT

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FINAL REPORT

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Abstract

Since 1992, traffic signals in Oakland County and a portion of Macomb and Wayne Counties of Michigan have been converted to the Sydney Coordinated Adaptive Traffic System (SCATS). County traffic engineers have been adjusting various SCATS parameters to improve its effectiveness in terms of delay, traffic flow, queue length, and crash and injury occurrences.

In 2008, a study was conducted to evaluate the performance of the SCATS system on M-59, between Pontiac Lake East to Pontiac Lake West in Waterford Township, Michigan, in terms of delay, flow, queue length, fuel consumption and emission. As a part of this study various performance parameters of SCATS system were compared with the Pre-timed signal system. Performance of the SCATS system was found to be superior for several of the performance measures during each Peak period. When compared to Pre-timed signal, installation and maintenance cost of SCATS system is almost two times greater. Therefore, there is a need to determine the added related benefits of SCATS system. In this context, determination of crash benefit of SCATS can play a significant role. If we can combine congestion and crash related benefits, then it is most likely combined benefits will overweigh the cost.

Crash data from 1999 to 2008 of two corridors, one controlled by the SCATS and other by the Pre-timed signal system were examined to determine the effectiveness of SCATS system. In order to evaluate the effectiveness of SCATS signal system, intersections as well as segment crash data before and after the installation of SCATS signals were compared. In addition, a series of statistical tests were performed to compare safety performance of SCATS and pre-timed signal systems. It was observed that there was shift in severity types A and B to C, which is noteworthy. However, statistical tests were not able to identify any difference of significance at 95 percent confidence level. Finally, cost related information for both SCATS as well as Pre-timed was also computed and compared.

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1. Introduction

Increasing travel demand and lack of sufficient highway capacity is a serious problem in most major metropolitan areas in the United States. Large metropolitan cities have been experiencing increased traffic congestion problems over the past several years. The total delay that drivers experience has increased from 0.7 billion hours in 1982 to 3.7 billion hours in 2003. [1] Combining the 3.7 billion hours of delay and 2.3 billion gallons of fuel consumed, due to congestion, leads to a total congestion cost of $63 billion dollars for drivers in 85 of the largest metropolitan areas of the nation. [1]

In spite of the implementation of many demand management measures, the congestion in most urban areas is still increasing. In many areas congestion is no longer limited to two peak hours in a day; instead, it is extended to two to three hours in the morning, afternoon and evening. Thus, the congestion experienced on urban and suburban freeways and arterial streets results in delays to the motorist, excess fuel consumption and a high level of pollutant emission not only during the peak hours in a day, but also for several hours throughout the day.

As many urban areas across the nation, Oakland County, one of the largest county in the State of Michigan has been experiencing congestion for the past two decades. During the 1990's, Oakland County experienced a surge of population growth and economic development. Associated growth in traffic required in excess of a billion dollar in road improvement needs. At the current level of funding, it will take 70 years to meet the capacity needs of Oakland County roadways [2]. Looking for innovative and cost effective ways to improve road user mobility and safety, the Road Commission for Oakland County (RCOC) began investigating innovative traffic control strategies associated with Intelligent Transportation Systems (ITS). Subsequently, the County Board of Commissioners approved $2 million for the development of an advanced traffic management system in the South East Oakland County. This commitment by Oakland County toward congestion mitigation, prompted the United States Congress to financially support this effort as a Federal demonstration project with $10 million in funding. The innovative traffic control system created in Oakland County with the Federal and County funds is called "FAST-TRAC", an acronym which stands for Faster and Safer Travel through Traffic Routing & Advanced Controls.

As a part of a field demonstration project traffic signals at 28 intersections in the city of Troy within Oakland County were converted from pre-time coordinated traffic signal control to SCATS (Sydney Coordinated Adaptive Traffic System) control in 1992. SCATS is a computer controlled traffic signal system developed in Australia and used widely in the Pacific Rim. SCATS uses anticipatory and adaptive techniques to increase the efficiency of road network by minimizing the overall number of vehicular stops and delay experienced by motorists. The primary purpose of the SCATS system is to maximize the throughput of a roadway by controlling queue formation.

Since 1992, traffic signals in Oakland County and a portion of Macomb and Wayne Counties have been converted to the SCATS signal system. County traffic engineers have been adjusting various SCATS parameters to improve its effectiveness in terms of delay, traffic flow, queue length, and crash and injury occurrences.

In 2007, a study was conducted to evaluate the performance of the SCATS system on M-59, between Pontiac Lake East to Pontiac Lake West in Waterford Township, Michigan, in terms of delay, flow, queue length, fuel consumption and Emission [8]. As a part of this study various performance parameters of SCATS system were compared with the Pre-timed signal system. Some of the findings of this study are displayed in Figures 1, and 2.

Performance of the SCATS system was found to be superior for several of the performance measures during each Peak period as shown in Figures 1 and 2. However, this study did not examine the crash effectiveness of SCATS system. In fact, no in-depth study has been done to quantify the crash effectiveness of SCATS system. When compared to Pre-timed signal, installation and maintenance cost of SCATS system is almost two times greater. Therefore, there is a need to determine the added related benefits of SCATS system if any. In this context, determination of crash benefit of SCATS can play a significant role. If we can combine congestion and crash related benefits, then it is most likely combined benefits will overweigh the cost. Also, a 2008 Cambridge Systematic study determined that the cost of crashes is almost two to seven times more than the cost of congestion depending on the size of cities as shown in Figures 3 and 4 [9]. However, there have not been any comprehensive studies conducted that evaluated the safety performance of SCATS control system. To determine the safety effectiveness of SCATS system a study was conducted. The purpose of this study was two folds:

- Examine the crash experience of a corridor before and after the installation of SCATS system.
- Compare the safety performance of SCATS controlled corridor with a similar Pre-timed controlled corridor.

This report documents the findings of this study.

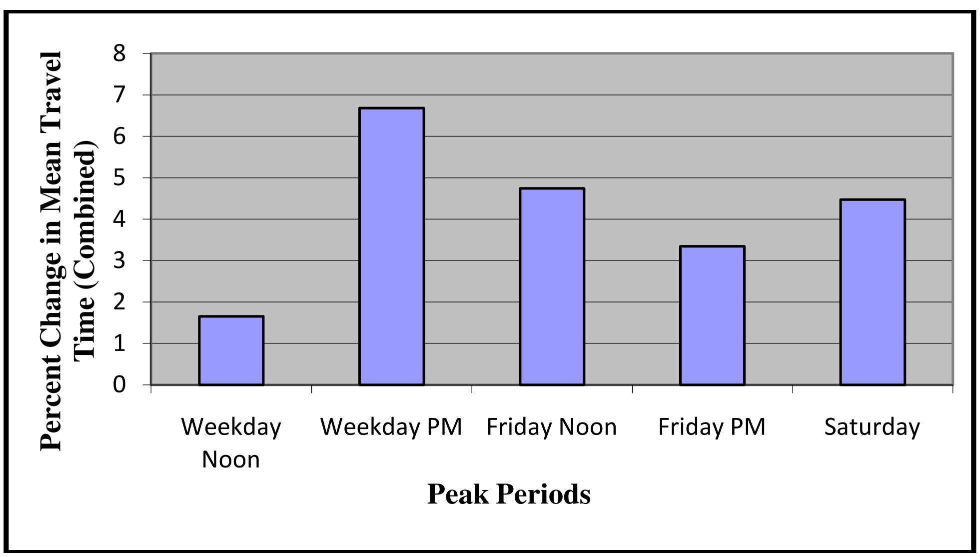
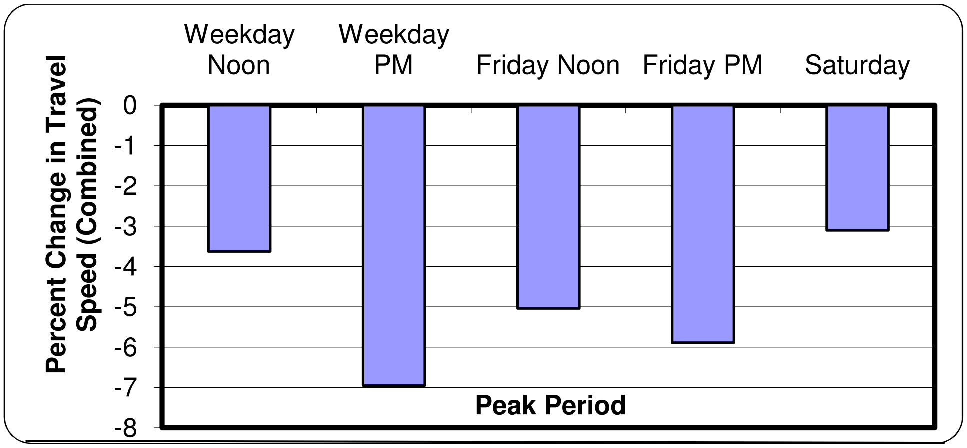


Figure 1. Difference in Travel Time between SCATS and Pre-Timed System



Note: Percent Change in Performance= ((Pre-timed-SCATS)/SCATS)*100

Figure 2. Difference in Mean Speed between SCATS and Pre-Timed System

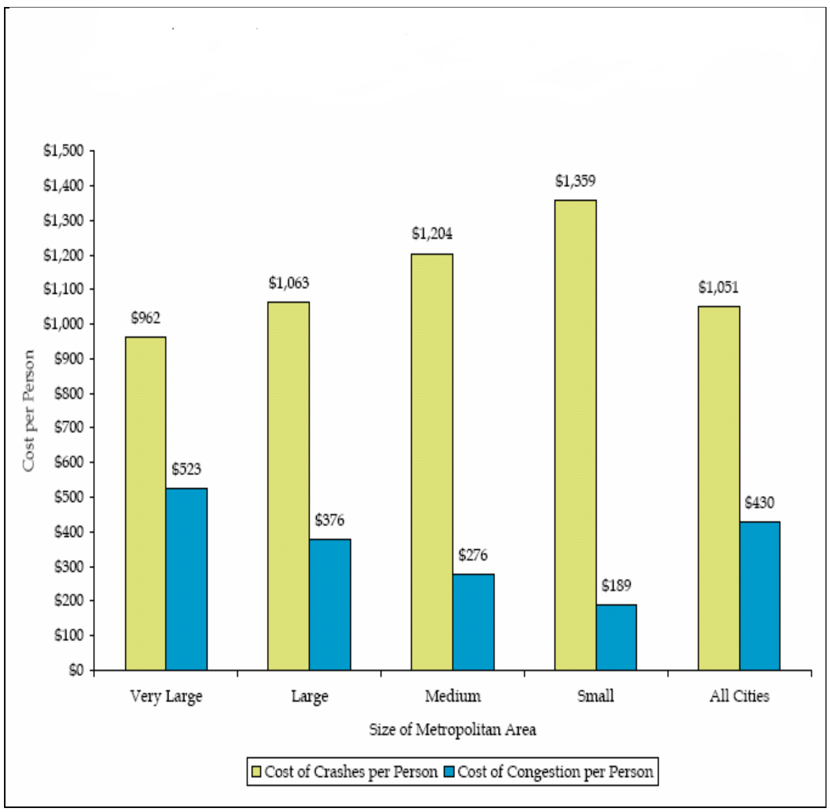


Figure 3. Cost of Crash and Congestion per Person by Size of Metropolitan Area [9]

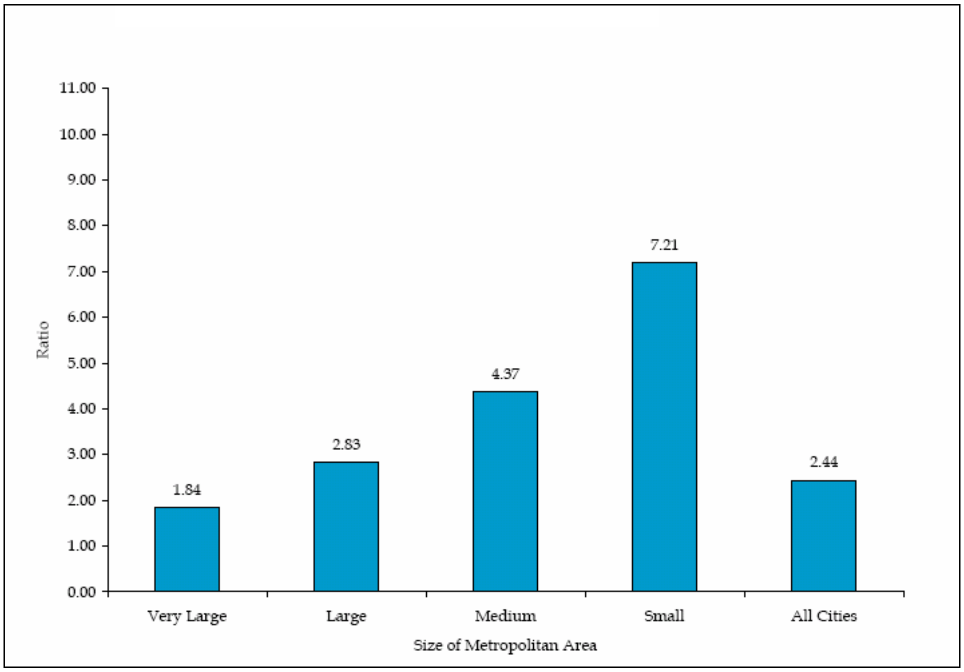


Figure 4. Ratio of Crash cost over Congestion by Size of Metropolitan Area [9]

2. Study Area

A 6.186 mile segment (mile points 12.354-18.54) along M-59 from Pontiac Lake East to Voorheis Road and an 8.03 mile segment (mile points 0.579-8.609) of Dixie Highway from Telegraph to Englewood Road, in Oakland County, Michigan were selected as a SCATS controlled and a Pre-timed controlled corridor respectively for data collection and analysis purpose. M-59 was converted to SCATS signal system in 2002. Bird's eye views of two segments are presented in Figures 5 and 6. Various attributes of these two corridors are presented in Table 1.

Table 1. Various Attributes of SCATS and Pre-timed Controlled Corridors

Attributes	SCATS Corridor	Pre-timed Corridor
Length	6.186 miles	8.03 miles
Number of Lanes	5	5
Center lane	Yes	Yes
Land use	Mostly Retail	Mostly Retail
Number of Signals	9	14
Year of conversion	2002	Not applicable
Average ADT	28,380-42,378	23,996-38, 974

Figure 5. M-59 Corridor (SCATS Controlled Segment)

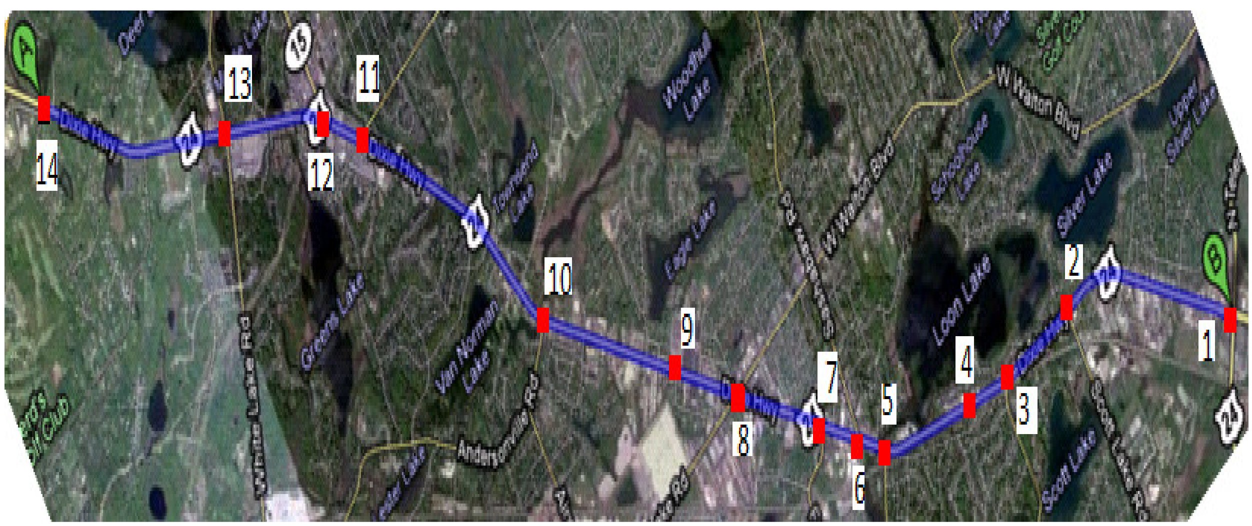


Figure 6. Dixie Corridor (Pre-timed Controlled Segment)

3. Data Collection

Crash data and traffic volume data of each corridor along with all signalized intersections within the corridor from 1999 to 2008 were collected. South East Michigan Council of Government (SEMCOG), as well as the Michigan Department of Transportation (MDOT), data sites were used to data as a part of this effort. Data were sorted by year and severity type. According to SEMCOG, various types of Crash severity are defined as follows:

Fatal: Any injury that results in death.

Injury-A (Incapacitating Injury, permanent injury): Any injury other than a fatal injury that prevents the injured person from driving, walking or normally continuing activities the person was capable of performing before the injury occurred.

Injury-B (Non-incapacitating Injury, temporary Injury): Any injury not incapacitating but evident to observers at the scene of crash in which injury occurred.

Injury-C (Possible injury, slight bruises and cuts): Any injury other than F, A or B.

Property Damage Only (PDO): Any crash that results in no fatality or injures but damage of property at least $400.00

The SCATS controlled corridor consists of nine segments of various lengths totaling 6.186 miles. Whereas the Pre-timed controlled corridor has fourteen segments of various lengths totaling 8.03 miles. Please note that Fatal accident was observed rarely, therefore, most instances it was not included as a part of analysis.

4. Data Analysis

4.1. SCATS Controlled Corridor

A 6.186 mile segment of M-59 was selected as a SCATS controlled corridor for the purpose of this study. This segment of M-59 is a five lane east-west arterial in Oakland County, Michigan and consists of nine smaller segments of varied length. Crash data and traffic volume data of each segment was collected from years 1999-2001 and 2003-2008. This corridor was converted to SCATS control system in 2002.

4.2. SCATS Segment Analysis

Crash data including severity from 1999 to 2008 (excluding the year 2002, year of switch) were presented in Table 2. For the purpose of this study, years between 1999-2001 were considered as before period and years between 2003-2008 were considered as after period. A review of mean data before and after the installation of SCATS signal indicated the followings:

- Total crash per mile per year was reduced by 16.8 percent after the installation of SCATS system.
- SCATS was able to reduce crash severity type A, B and C per year per mile by 31.032, 42.50 and 10.19 percent respectively.
- Property Damage Only crash type per year per mile went down by 16.48 percent.

Table 2. Crash Data M-59 from 1999-2008 (Segment length: 6.186 Mile)

Crash type	1999	2000	2001	Mean (99-01)	2003	2004	2005	2006	2007	2008	Mean (03-08)	Difference
Total crash	610	572	572	584.67	530	531	541	455	443	416	486	16.88%
(per mile)	98.61	92.47	92.47	94.51	85.68	85.84	87.46	73.55	71.61	67.25	78.56	
A-level	10	10	9	9.67	3	10	5	12	1	9	6.67	31.03%
(per mile)	1.62	1.62	1.45	1.56	0.48	1.62	0.81	1.94	0.16	1.45	1.08	
B-level	32	38	30	33.33	26	23	22	16	16	12	19.17	42.50%
(per mile)	5.17	6.14	4.85	5.39	4.2	3.72	3.56	2.59	2.59	1.94	3.1	
C-level	106	120	93	106.33	113	102	103	86	81	88	95.5	10.19%
(per mile)	17.14	19.4	15.03	17.19	18.27	16.49	16.65	13.9	13.09	14.23	15.44	
ABC	148	168	132	149.33	142	135	130	114	98	109	121.33	18.75%
(per mile)	23.92	27.16	21.34	24.14	22.96	21.82	21.02	18.43	15.84	17.62	19.61	
PDO	462	403	440	435	387	396	410	338	344	305	363.33	16.48%
(per mile)	74.68	65.15	71.13	70.32	62.56	64.02	66.28	54.64	55.61	49.3	58.73	
Total Injured	211	255	191	219	198	191	175	156	136	136	165.33	24.51%
(per mile)	34.11	41.22	30.88	35.4	32.01	30.88	28.29	25.22	21.99	21.99	26.73	

4.2.1. Crash Severity Analysis

Figure 7, represents crash severity in percent during before and after periods. For both time periods crash severity type C was the predominant type. Crash types B and A were reduced by close to one percent after the installation of SCATS system. Other types remained identical. Table 3 presents the proportion of each severity type during the before and after period.
While examining the distribution of severity types A, B and C during the before and after periods, it is noted that a shift from higher severity crashes to lower severity crashes was realized, which is very significant. A previous study also observed a similar trend [6].

Table 3. Distribution of Severity in Percent for Before and After Periods

Severity Type	Segment	
	Before (1999-2001)	After (2003-2008)
F	0.17%	0.27%
A	1.65%	1.37%
B	5.7%	3.94%
C	18.19%	19.65%
PDO	74.40%	74.78%

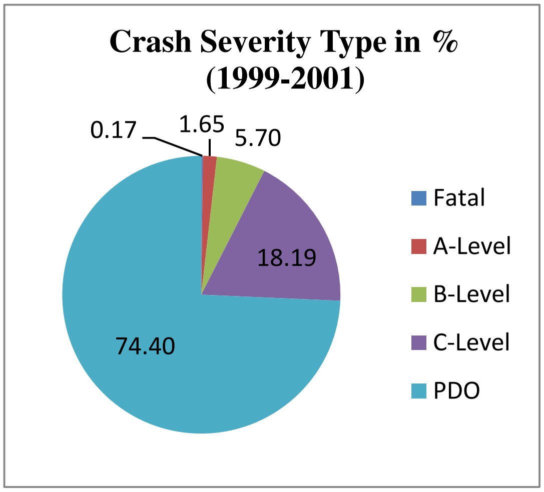
4.2.2. Computation of Before and After Crash Rate Considering Traffic Exposure

Traffic volume data were used to compute crash rate per 100 million vehicles miles for each of the ten segments as well as for complete segment. Total, as well as severity type crash rate before and after the insatllation of SCATS system are presented in Table 4 and Figure 8. Crash rate of injury type B is reduced by 34 percent, followed by a 22 percent reduction in injury type A. Reduction in types B and A crash rate resulted a slight rate increase in case of type C. However, mean total crash rate was reduced by only 5.6 percent. It is to be noted that nation wide mean crash rate has been on the decline for more than 10 years.

4.3. SCATS Intersection Analysis

There are nine signalized intersections within the 6.18 mile segment of M-59. They are:

- Pontiac Lake East
- Williams Lake road
- Oakland Blvd.
- Airport Road
- Crescent Lake Road
- Pontiac Lake West
- Cass Lake Road
- Elizabeth Lake Road
- Voorheis Road



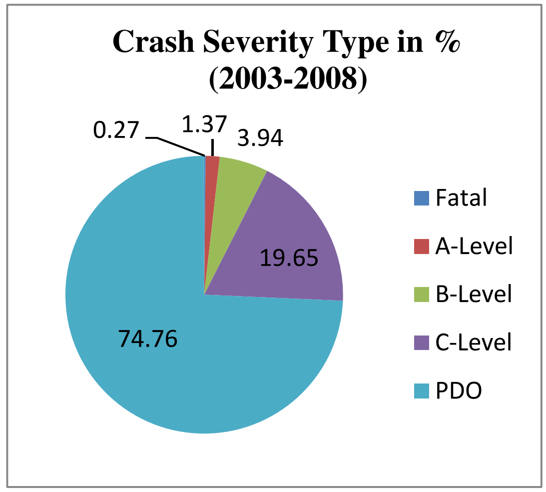


Figure 7. Various types of Severity in Percent within M-59 Corridor : Before and after the installation of SCATS system

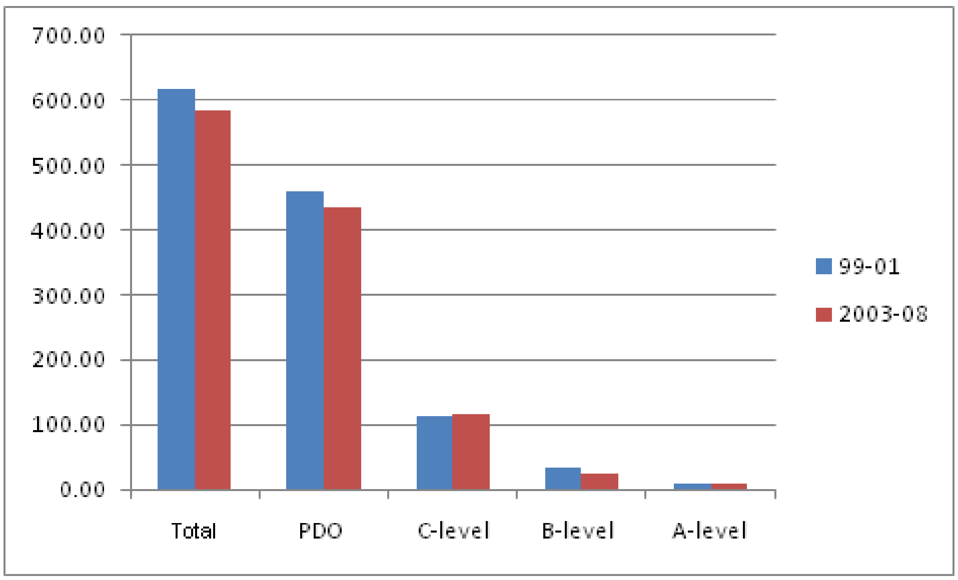


Figure 8. Graphical representation of Before-After Crash Rate

Table 4. Crash Rate by Each Segments of M-59 Corridor

Segment Number	Segment Length in Miles	Mean Crash rate/ 100 Million Vehicles Miles									
		Total Crash		Severity Type A		Severity Type B		Severity Type C		PDO	
		Before	After	Before	After	Before	After	Before	After	Before	After
1	0.351	913.97	663.87	39.4	11.85	63.03	23.71	126.07	126.45	685.48	501.85
2	0.281	1653.43	1179.7	19.68	4.94	88.58	29.62	255.89	236.93	1279.44	908.22
3	0.098	343.27	634.68	19.07	25.91	38.14	25.91	57.21	155.43	228.85	427.44
4	0.457	552.09	533.3	12.27	11.11	36.81	30.55	94.06	97.22	404.86	388.86
5	1.007	339.64	451.27	1.86	7.56	22.27	22.69	76.09	86.98	239.41	334.04
6	1.006	804.4	812.28	6.65	11.89	39.89	29.73	172.85	164.12	582.81	602.97
7	0.754	739.15	648.99	11.83	11.11	32.52	26.97	141.92	111.07	552.89	498.24
8	1.27	468.68	394.72	7.02	4.71	28.09	16.02	78.99	83.84	354.58	288.27
9	0.248	1159.59	849.07	17.98	4.82	62.92	33.77	161.8	188.15	925.87	622.33
10	0.714	408.25	386.05	13.06	1.73	26.13	10.39	68.59	70.98	303.73	302.96
Mean Rate		617.4	582.8	10.2	8	35.2	23	112.3	114.5	459.4	435.7
Difference (percent)		**-34.6(-5.61%)**		**-2.2(-21.69%)**		**-12.2(-34.71%)**		**+2.5(1.98%)**		**-23.7(-5.15%)**	

Total crash within 250ft of all intersections controlled by SCATS system along with severity type during 1999-2001 and 2003-2008 are presented in Table 5. A review of Table 5 reveals the following.

- Total crash per intersection per year is reduced by more than 24 percent after the installation of the SCATS system.
- Severity type B per intersection is reduced by 53 percent between these two study periods, followed by severity A and C respectively.

4.3.1. Share of Crash Severity

Pie charts in Figure 9, represents the percent distribution of crash severity in all intersections combined during the before and after periods. Similar to the segment analysis Property Damage Only (PDO) is the predominant type followed by severity type C. Table 6, represents percent share among severity A, B and C before and after the installation of the SCATS system. There is a drastic shift of severity type B during the after period, from 4.62 percent to 2.82 percent. A similar trend was also observed in the case of segment analysis as presented before.

4.3.2. Computation of Before and After Crash Rate for Intersections considering Traffic Exposure

Before and after crash data for each intersection controlled by the SCATS system within the 6.186 mile corridor of M-59 were used to compute the crash rate in Millions of vehicles. Crash rate by total as well as severity type before and after the installation of the SCATS system are presented in Table 7. A review of Table 7 indicates the following:

- Total crash rate per millions of vehicles is reduced by 14.98 percent after the installation of the SCATS signals.
- Crash rate of severity type B showed the highest reduction of 47.78 percent, followed by a reduction of 39.98% of severity type A.

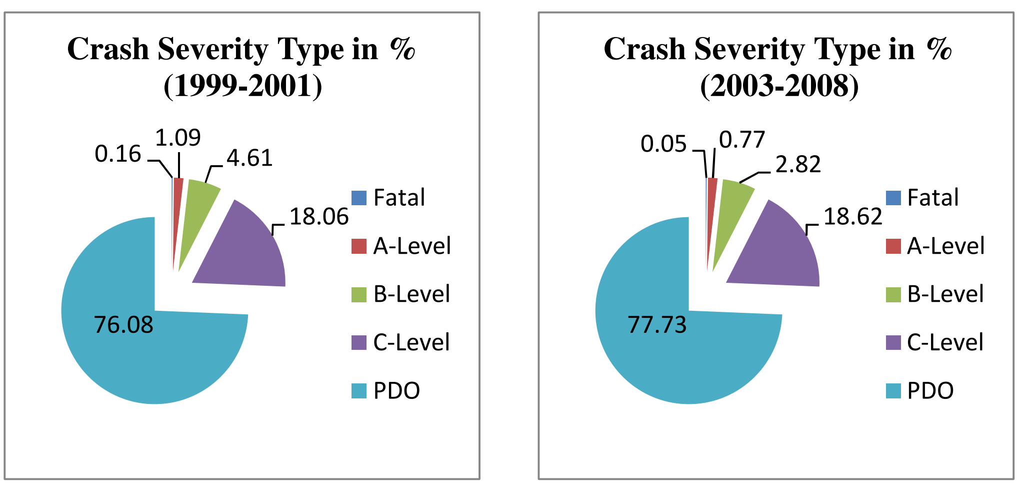


Figure 9. Various types of Severity of all Intersections in Percent within M-59 Corridor Before and after the installation of SCATS system

Table 5. Crash Data of All intersection within SCATS Corridor from 1999-2008 (without 2002)

Crash type	1999	2000	2001	Mean (99-01)	2003	2004	2005	2006	2007	2008	mean (03-08)	Difference
Total crash (per intersection)	418.00 (46.44)	467.00 (51.89)	394.00 (43.78)	426.33 (47.37)	386.00 (42.89)	318.00 (35.33)	358.00 (39.78)	292.00 (32.44)	288.00 (32.00)	307.00 (34.11)	324.83 (36.09)	-23.81%
A-level (per intersection)	4.00 (0.44)	5.00 (0.56)	5.00 (0.56)	4.67 (0.52)	3.00 (0.33)	1.00 (0.11)	3.00 (0.33)	5.00 (0.56)	0.00 (0.00)	3.00 (0.33)	2.50 (0.28)	-46.43%
B-level (per intersection)	15.00 (1.67)	30.00 (3.33)	14.00 (1.56)	19.67 (2.19)	12.00 (1.33)	7.00 (0.78)	11.00 (1.22)	8.00 (0.89)	7.00 (0.78)	10.00 (1.11)	9.17 (1.02)	-53.39%
C-level (per intersection)	66.00 (7.33)	104.00 (11.56)	61.00 (6.78)	77.00 (8.56)	75.00 (8.33)	65.00 (7.22)	59.00 (6.56)	52.00 (5.78)	59.00 (6.56)	53.00 (5.89)	60.50 (6.72)	-21.43%
ABC (per intersection)	85.00 (9.44)	139.00 (15.44)	80.00 (8.89)	101.33 (11.26)	90.00 (10.00)	73.00 (8.11)	73.00 (8.11)	65.00 (7.22)	66.00 (7.33)	66.00 (7.33)	72.17 (8.02)	-28.78%
PDO (per intersection)	333.00 (37.00)	327.00 (36.33)	313.00 (34.78)	324.33 (36.04)	296.00 (32.89)	245.00 (27.22)	285.00 (31.67)	227.00 (25.22)	221.00 (24.56)	241.00 (26.78)	252.50 (28.06)	-22.15%
Total Injured (per intersection)	121.00 (13.44)	190.00 (21.11)	111.00 (12.33)	140.67 (15.63)	128.00 (14.22)	103.00 (11.44)	97.00 (10.78)	85.00 (9.44)	84.00 (9.33)	83.00 (9.22)	96.67 (10.74)	-31.28%

Table 6. Severity Distribution in Percent for SCATS Controlled Intersections during Before and After periods

Severity Type	Before	After
F	0.16%	0.05%
A	1.09%	0.77%
B	4.61%	2.82%
C	18.06%	18.62%
PDO	76.08%	77.73%

5. Analysis of Pre-timed Controlled Segments

5.1. Pre-timed Controlled Corridor

An 8.03 mile-stretch of Dixie Highway in Oakland County, Michigan was considered in this study as the Pre-timed controlled corridor. This corridor consists of 14 Pre-timed signalized intersections. Crash data including severity for this corridor from 1999 to 2008 (excluding year 2002) are presented in Table 8. For the purpose of this study the period between 1999-2001 was designated as before period and years between 2003-2008 was considered as after period. A review of mean data during the before and after periods indicates the followings:

- Total crash per mile per year was reduced by 28.84 percent between 1999-2001 and 2003-2008.
- Between these two periods crash severity type A, B and C per year per mile were reduced by 48.8, 51.13 and 36.36 percent respectively.
- Property damage only crash type per year per mile was decreased by 24.58 percent.
- Following the national trend the crash rate of this corridor also decreased.

5.1.1. Crash Severity Distribution

Table 8 represents various types of crash severity during period 1999-2001 and 2003-2008. For both time periods, crash severity type C was the predominant type among the three severity type. However, PDO captured the highest share of crashes at 78 percent.

Table 7. Intersection Crash data M-59

Intersection	Mean Crash rate/ Million Vehicles									
	Total Crash		Severity A		Severity B		Severity C		PDO	
	Before	After	Before	After	Before	After	Before	After	Before	After
Pontiac lake rd	1.63	1.36	0.08	0.01	0.11	0.03	0.28	0.28	1.13	1.04
Williams lake rd	5.01	3.50	0.06	0.04	0.28	0.13	0.89	0.67	3.79	2.66
Oakland Blvd N	1.91	1.69	0.06	0.01	0.13	0.13	0.36	0.28	1.35	1.27
Airport rd	4.17	5.10	0.02	0.01	0.09	0.08	0.77	0.84	3.29	4.16
Crescent Lake Rd	3.77	3.34	0.00	0.01	0.11	0.07	0.69	0.55	2.97	2.70
Pontiac lake rd.	3.86	3.33	0.00	0.02	0.27	0.10	0.69	0.75	2.90	2.45
Cass Lake Rd	3.61	2.21	0.05	0.00	0.13	0.07	0.56	0.46	2.88	1.69
Elizabeth Lake Rd	2.88	2.76	0.07	0.06	0.16	0.08	0.45	0.53	2.21	2.09
Voorheis Rd	1.89	1.13	0.000	0.01	0.07	0.01	0.51	0.20	1.31	0.90
Mean Rate	3.19	2.71	0.04	0.02	0.15	0.08	0.58	0.51	2.42	2.11
Difference(percent)	0.48(-14.98%)		0.02(-39.98%)		0.07(-47.78%)		0.07(-11.97%)		0.31(-13%)	

Table 8. Segment Crash Data Dixie Highway

Type/year	1999	2000	2001	Mean (99-01)	2003	2004	2005	2006	2007	2008	Mean (03-08)	Difference
Total Crash (per mile)	593.00 (73.85)	516.00 (64.26)	442.00 (55.04)	517.00 (64.38)	415.00 (51.68)	452.00 (56.29)	373.00 (46.45)	299.00 (37.24)	328.00 (40.85)	340.00 (42.34)	367.83 (45.81)	-28.85%
A-level (per mile)	9.00 (1.12)	13.00 (1.62)	8.00 (1.00)	10.00 (1.25)	2.00 (0.25)	7.00 (0.87)	8.00 (1.00)	9.00 (1.12)	2.00 (0.25)	3.00 (0.37)	5.17 (0.64)	-48.33%
B-level (per mile)	35.00 (4.36)	33.00 (4.11)	28.00 (3.49)	32.00 (3.99)	18.00 (2.24)	22.00 (2.74)	16.00 (1.99)	13.00 (1.62)	15.00 (1.87)	10.00 (1.25)	15.67 (1.95)	-51.04%
C-level (per mile)	112.00 (13.95)	103.00 (12.83)	72.00 (8.97)	95.67 (11.91)	73.00 (9.09)	79.00 (9.84)	59.00 (7.35)	47.00 (5.85)	58.00 (7.22)	49.00 (6.10)	60.83 (7.58)	-36.41%
ABC (per mile)	156.00 (19.43)	149.00 (18.56)	108.00 (13.45)	137.67 (17.14)	93.00 (11.58)	108.00 (13.45)	83.00 (10.34)	69.00 (8.39)	75.00 (9.34)	62.00 (7.72)	81.67 (10.17)	-40.68%
PDO (per mile)	436.00 (54.30)	366.00 (45.58)	333.00 (41.47)	378.33 (47.11)	319.00 (39.73)	343.00 (42.71)	290.00 (36.11)	229.00 (28.52)	253.00 (31.51)	278.00 (34.62)	285.33 (35.53)	-24.58%
Total Injured (per mile)	232.00 (28.89)	226.00 (28.14)	167.00 (20.80)	208.33 (25.94)	145.00 (18.06)	140.00 (17.43)	125.00 (15.57)	102.00 (12.70)	113.00 (14.07)	85.00 (10.59)	118.33 (14.74)	-43.20%

Table 9. Distribution of Severity in Percent for Before and After Periods for Segment and Intersection

Severity Type	Pre-timed Segment		Pre-timed Intersections	
	Before	After	Before	After
F	0.19%	0.23	0.10%	0.20%
A	1.93%	1.40%	1.91%	0.81%
B	6.19%	4.26%	5.15%	3.63%
C	18.50%	16.54%	17.84%	16.62%
PDO	73.18%	77.57%	75.00%	78.73%

5.1.2. Computation of Crash Rate Considering Traffic Exposure

Traffic volume and segment length were used to compute the crash rate per 100 million vehicle miles for Dixie Highway segments during 1999-2001 and 2003-2008. Crash rates are presented in Table 10 and Figure 10. For the Pre-timed controlled corridor, it was observed that:

- Total Crash per mile was reduced by 24.94 percent between 1999-2001 and 2003-2008.
- Crash rate of severity type B was reduced by 48.35 percent, followed by types A (45.49%) and C (32.9%).

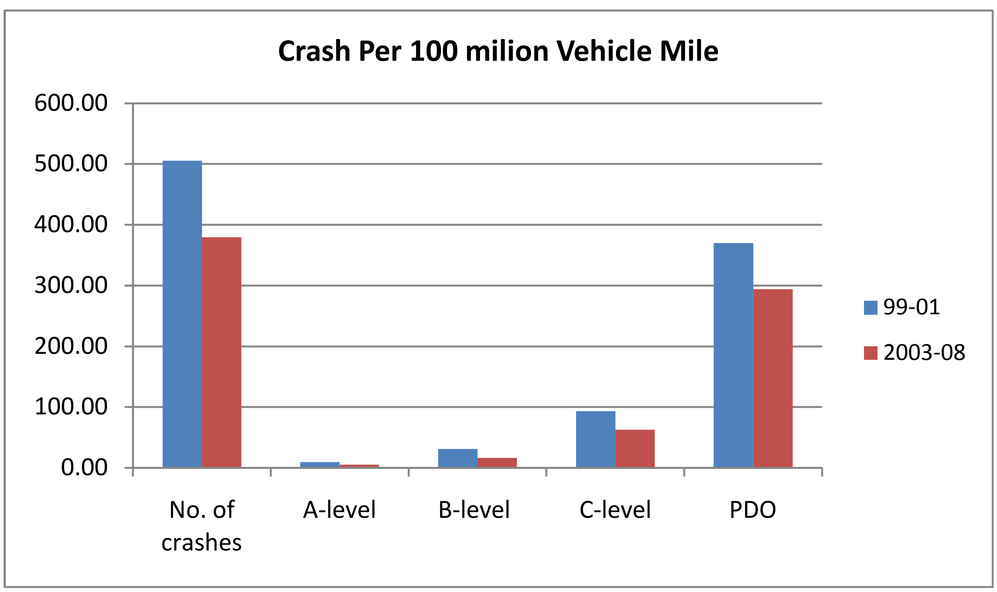


Figure 10. Crash per 100 million Vehicle Mile for Dixie Highway during 1999-2001 and 2003-2008

Table 10. Crash rate within each segments of Dixie Highway

Segment Number	Segment Length	Mean Crash rate/ 100 Million Vehicles Miles									
		Total Crash		Severity A		Severity B		Severity C		PDO	
		Before	After	Before	After	Before	After	Before	After	Before	After
1	0.49	1056.82	681.75	9.56	11.65	114.77	20.39	224.75	160.24	707.73	489.46
2	0.626	288.22	282.78	0.00	4.56	18.72	13.68	37.43	36.49	232.07	228.05
3	0.455	365.64	291.79	5.15	9.41	30.90	15.69	77.25	53.34	252.34	213.35
4	0.833	143.46	125.11	8.44	0.00	8.44	0.00	36.57	23.99	90.01	101.11
5	0.16	1158.43	1098.87	47.61	8.02	111.08	32.08	269.77	216.57	729.97	842.20
6	0.239	371.82	327.55	0.00	5.37	10.62	16.11	95.61	48.33	180.60	257.74
7	0.559	699.48	358.14	9.08	4.59	45.42	22.96	131.72	66.58	513.25	264.02
8	1.25	540.30	389.11	2.03	6.16	26.41	19.51	93.44	55.44	416.40	308.00
9	1.275	554.68	389.47	16.23	7.54	32.47	15.08	97.41	64.07	405.86	300.27
10	0.237	2096.11	1493.73	72.78	6.76	58.23	47.31	262.01	202.77	1703.09	1236.89
11	0.654	859.82	499.67	31.65	2.45	26.37	22.04	184.62	78.38	617.17	394.34
12	1.252	234.58	260.26	2.58	4.84	15.47	14.53	30.93	37.53	183.02	200.95
Mean crash rate		505.4	379.41	9.78	5.33	31.28	16.16	93.53	62.75	369.87	294.31
Difference (Percent)		125.99(-24.94%)		3.4(-45.49%)		15.1(-48.35%)		30.8(-32.91%)		75.76(-20.43%)	

5.2. Intersection Analysis

Dixie highway corridor has the following 14 pre-timed controlled intersections:

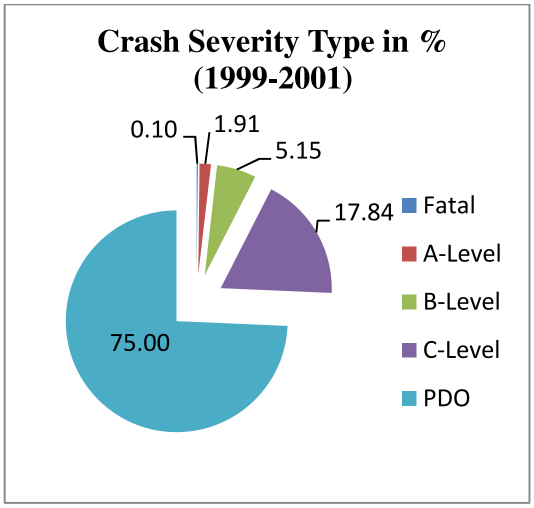
- Telegraph Road South
- Silver Lake Road
- Scott Lake Road
- Watkins Lake Road
- Hatchery Road
- Sashabaw Road
- Frembes Road
- Williams Lake Road
- Hatfield Dr.
- Andersonville Road
- Maybee Road
- Ortonville Road
- White Lake Road
- Englewood Road

Crash data of all 14 Pre-timed controlled intersections for the periods 1999-2001 and 2003-2008 were collected and then converted into crashes per intersection. Crash per intersection data are presented in Table 11. It was observed that:

- Total crashes per Pre-time signal were reduced by 29.10 percent between 1999-2001 and 2003-2008.
- Severity type A per intersection was reduced by 70 percent followed by types B and C.

5.2.1. Share of Crash Severity

Table 9 (presented before) and Figure 11 include the percent distribution of crash severity in all intersections combined during before and after periods. Similar to Pre-timed segment analysis Property Damage Only (PDO) is the predominant type followed by severity type C**.**



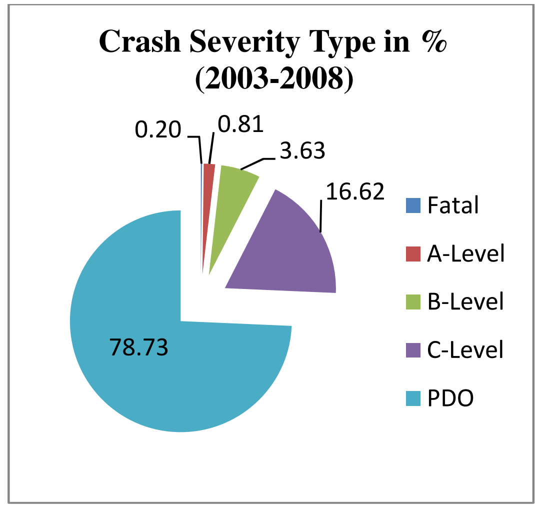


Figure 11. Distribution of Crash Severity of all Intersections in Percent between periods 1999-2001 and 2003-2008 (Dixie Highway)

5.2.2. Computation of Before and After Crash Rate for Intersections considering Traffic Exposure

Before and after crash data of each intersection controlled by the Pre-timed system within the 8.03 mile corridor of Dixie Highway were used to compute the crash rate in million of vehicles. Crash rate by total as well as severity type between 1999-2001 (before) and 2003-2008 (after) are presented in Table 12. A review of Table 12 indicates the following:

- Total crash rate per millions of vehicles is reduced by 25.77 percent between the two tested time periods.
- Crash rate of severity type A showed highest reduction of 71.05 percent, followed by a reduction of 38.08 percent for severity type C.

Table 11. Crash Data of All Intersections within Pre-Timed controlled Corridor from 1999-2008 (without 2002)

Type/year	1999	2000	2001	mean (99-01)	2003	2004	2005	2006	2007	2008	mean (03-08)	Difference
Total crash (per intersection)	369.00 (26.36)	372.00 (26.57)	307.00 (21.93)	349.33 (24.95)	276.00 (19.71)	296.00 (21.14)	242.00 (17.29)	219.00 (15.64)	211.00 (15.07)	242.00 (17.29)	247.67 (17.69)	-29.10%
A-level (per intersection)	7.00 (0.50)	7.00 (0.50)	6.00 (0.43)	6.67 (0.48)	0.00 (0.00)	3.00 (0.21)	4.00 (0.29)	4.00 (0.29)	0.00 (0.00)	1.00 (0.07)	2.00 (0.14)	-70.00%
B-level (per intersection)	19.00 (1.36)	19.00 (1.36)	16.00 (1.14)	18.00 (1.29)	13.00 (0.93)	13.00 (0.93)	10.00 (0.71)	8.00 (0.57)	6.00 (0.43)	4.00 (0.29)	9.00 (0.64)	-50.00%
C-level (per intersection)	61.00 (4.36)	76.00 (5.43)	50.00 (3.57)	62.33 (4.45)	41.00 (2.93)	55.00 (3.93)	36.00 (2.57)	38.00 (2.71)	41.00 (2.93)	36.00 (2.57)	41.17 (2.94)	-33.96%
ABC (per intersection)	87.00 (6.21)	102.00 (7.29)	72.00 (5.14)	87.00 (6.21)	54.00 (3.86)	71.00 (5.07)	50.00 (3.57)	50.00 (3.57)	47.00 (3.36)	41.00 (2.93)	52.17 (3.73)	-40.04%
PDO (per intersection)	282.00 (20.14)	269.00 (19.21)	235.00 (16.79)	262.00 (18.71)	221.00 (15.79)	225.00 (16.07)	192.00 (13.71)	168.00 (12.00)	164.00 (11.71)	200.00 (14.29)	195.00 (13.93)	-25.57%
Total Injured (per intersection)	133.00 (9.50)	145.00 (10.36)	100.00 (7.14)	126.00 (9.00)	75.00 (5.36)	89.00 (6.36)	76.00 (5.43)	73.00 (5.21)	69.00 (4.93)	52.00 (3.71)	72.33 (5.17)	-42.59%

Table 12. Intersection Crash Data Dixie Highway

Intersection	Mean Crash rate/ Million Vehicles									
	Total Crash		Severity A		Severity B		Severity C		PDO	
	Before	After	Before	After	Before	After	Before	After	Before	After
Telegraph Rd S	2.014	2.127	0.07	0.014	0.187	0.228	0.328	0.356	1.429	1.684
Silver Lake Rd	2.319	1.341	0	0	0.141	0.171	0.445	0.271	1.733	1.042
Scott Lake Rd	1.335	1.428	0	0.043	0.07	0.086	0.141	0.214	1.125	1.156
Watkins Lake Rd	0.843	0.657	0	0.014	0.07	0.086	0.234	0.128	0.538	0.499
Hatchery Rd	0.984	1.053	0.07	0.012	0.07	0.077	0.257	0.206	0.586	0.822
Sashabaw Rd	1.472	1.155	0.076	0.012	0.126	0.128	0.33	0.27	0.939	0.847
Frembes Rd	1.345	0.783	0.025	0.012	0.076	0.077	0.254	0.154	0.99	0.564
Williams Lake Rd	3.046	1.925	0	0.012	0.152	0.154	0.66	0.27	2.234	1.54
Hatfield Dr	0.735	0.449	0	0.012	0.025	0.025	0.101	0.044	0.609	0.372
Andersonville Rd	1.726	1.053	0.025	0	0.025	0.025	0.381	0.218	1.295	0.795
Maybee Rd	2.894	2.258	0.025	0	0.126	0.128	0.33	0.372	2.412	1.823
Ortonville Rd	2.843	2.387	0.05	0	0.076	0.077	0.431	0.27	2.285	2.054
White Lake Rd	4.13	2.607	0.161	0.015	0.097	0.091	0.807	0.47	3.065	1.955
Englewood Dr	1.484	0.955	0.032	0.015	0.129	0.121	0.129	0.106	1.162	0.712
Mean Rate	1.94	1.441	0.038	0.011	0.097	0.089	0.344	0.213	1.355	1.133
Difference (Percent)	0.50(-25.77%)		0.027(-71.05%)		0.008(-8.24%)		0.131(-38.08%)		0.222(-17.87%)	

6. Comparative Safety Performance Analysis

When compared, the safety performance of the SCATS and the Pre-timed corridors between 1999-2001 and 2003-2008, the higher reduction in total crash per intersection and severity combined per intersection were observed in case of the SCATS system. The performance of the Pre-timed system was superior in other categories as displayed in Table 13. However, during 2003-2008, the SCATS controlled segment and intersections experienced lower percent of severity type A and B crashes (Table 14 and Figure 12) when compared to the Pre-timed segment and intersections, which is noteworthy.

Table 13. Percent of Severity for SCATS and Pre-Timed Corridors and Intersections between 2003-2008

Severity Type	Segment		Intersections	
	M-59	Dixie Highway	M-59	Dixie Highway
A	5.5%	6.3%	3.46%	3.83%
B	15.8%	19.2%	12.7%	17.25%
C	78.7%	74.5%	83.8%	78.9%

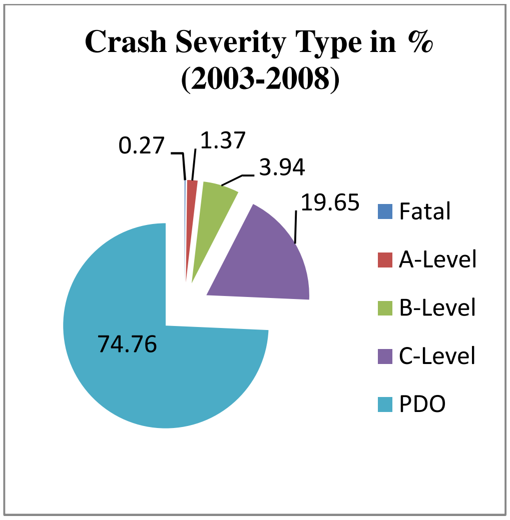
7. Statistical Analysis

The statistical significance of the effectiveness of the SCATS signals was examined by comparing

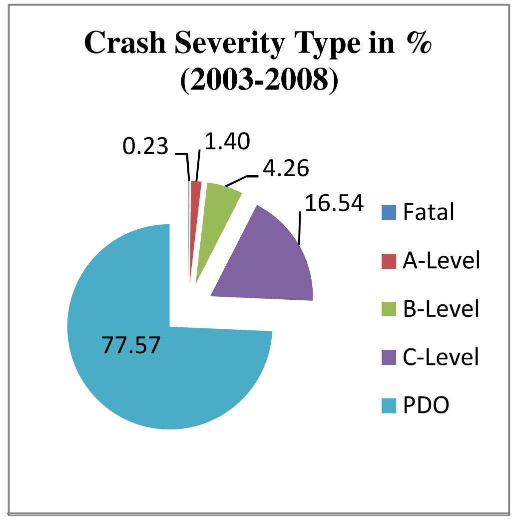
- Crash data of 1999-2001(before period) and 2003-2008(after period) on M-59 and
- Crash data of Dixie Highway (Pre-timed corridor) and M-59 (SCATS corridor) during 2003-2008.

The purpose of this analysis was to determine whether the changes observed in the measure of effectiveness were attributable to the signal system or chance. The student t-test was used to determine whether the difference in mean crash rate between before and after periods and also between the Pre-timed corridor and the SCATS corridor were significant or not. The following is the equation used to calculate the t-statistic and degrees of freedom (k') for unequal sample sizes.

$$t_{calculated} = \frac{x_b - x_a}{\sqrt{\frac{\sigma_b^2}{n_b} + \frac{\sigma_a^2}{n_a}}}$$



M-59 (SCATS)



Dixie (Pre-timed)

Figure 12. Distribution of Crash Severity of all Intersections in Percent Controlled by SCATS (M-59 Highway) and Pre-timed System (Dixie Highway) during 2003-2008

Table 14. Reduction in Crash Rate between 1999-2001 and 2003-2008 for M-59 (SCATS) And Dixie Highway (Pre-timed)

Attributes	SCATS(Percent)	Pre-timed (Percent)
Reduction in crash/mile/year	15.95 (-16.87%)	18.58(-28.95%)
Reduction in Severity (A+B+C) /mile/year	4.53(-18.75%)	6.97(-40.68%)
Reduction in crash/100 million vehicle mile	34.64(-5.61%)	126.1(-24.94%)
Reduction in Severity(A+B+C)/100 million vehicle mile	12.2(-7.73%)	50.4(-37.44%)
Reduction in crash/intersection	11.28(-23.8%)	7.26(-29.10)
Reduction in Severity (A+B+C)/Intersection	3.24(-28.78%)	2.48(-40.04%)
Reduction in crash/million Vehicle	0.477(-14.97%)	0.499(-25.7%)
Reduction in Severity (A+B+C)/Million Vehicle reduction	0.153(-20.0%)	0.166(-34.65%)

Where:
x_b= sample mean of test sites (Before Data)
x_a= sample mean of control sites (After Data)
n_b= number of test sites
n_a= number of control sites
σ_b= standard deviation of test sites
σ_b= standard deviation of control sites

If the calculated t-value is greater than the critical t-value, the difference in means is statistically significant. For the student's t-test, a two-tailed test was used which utilizes a null hypothesis that states there is no difference between the two means or treatments. The alternative hypothesis would state that one of the means is higher or lower than the other, or that one treatment is better or worse than the other treatment. The two-tailed test was used for this research, as the differences between the effectiveness of the tested systems were not known. Specifically, it could not be stated prior to this analysis that the use of the SCATS system was better or worse than the corridor that did not use the SCATS system. Statisticians in traffic engineering have consistently used an alpha equal to 0.05 or a level of confidence of 95 percent for evaluations of various treatments. Alpha is simply equal to 95 percent subtracted from 100 percent.

Based upon the statistical analysis (presented in Table 15), null hypotheses were accepted for all comparison between before and after periods of SCATS installation except severity type B due to p-values greater than 0.05. While comparing the SCATS and Pre-timed systems, other than total crash rate for intersection, null hypotheses were accepted. The acceptance of the null hypothesis for the majority of statistical tests indicates that there is no statistical difference between before and after periods of SCATS signal installation. For comparison between the systems, it means there was statistical difference between the two signal systems for any type of crash rate during the period analyzed. A significant result indicating differences between the periods or systems would be represented by a p-value less than 0.05, representing a level of confidence of 95 percent.

8. Economic Analysis

Cost, life, and salvage related information of both SCATS and Pre-timed signal systems were collected from the Road Commission for Oakland County (RCOC). While computing present worth cost and equivalent annual cost, a discount rate of four percent was considered. Present worth cost, equivalent annual cost and corridor cost per year per mile are presented in Table 16. The SCATS system cost $6,798 more in comparison to the Pre-timed system. The per mile cost of the SCATS corridor is $9,376 higher.

Table 15. Results of Statistical Analysis

Type	Parameters	M-59			
		Segment		Intersection	
		Before	After	Before	After
Total	Std. Mean	738	655	3.19	2.71
	Std. Deviation	429	244	1.18	1.26
	P-Value	0.597		0.419	
	Test Result	Before = After		Before = After	
A	Std. Mean	14.9	9.59	0.0361	0.021
	Std. Deviation	10.4	6.79	0.032	0.0185
	P-Value	0.195		0.245	
	Test Result	Before = After		Before = After	
B	Std. Mean	43.8	24.94	0.15	0.078
	Std. Deviation	21	7.13	0.0734	0.0385
	P-Value	0.021		0.021	
	Test Result	Before ≠ After		Before ≠ After	
C	Std. Mean	123.3	132.1	0.576	0.505
	Std. Deviation	61.7	53.2	0.199	0.224
	P-Value	0.738		0.489	
	Test Result	Before = After		Before = After	
		Segment (03-08)		Intersection(03-08)	
		M-59	Dixie	M-59	Dixie
Total	Std. Mean	655	517	2.71	1.421
	Std. Deviation	244	398	1.26	0.647
	P-Value	0.328		0.017	
	Test Result	M-59 = Dixie		M-59 ≠ Dixie	
A	Std. Mean	9.56	5.95	0.021	0.0118
	Std. Deviation	6.79	3.09	0.0185	0.011
	P-Value	0.146		0.204	
	Test Result	M-59 = Dixie		M-59 = Dixie	
B	Std. Mean	24.94	19.9	0.0768	0.0518
	Std. Deviation	7.13	11.4	0.0385	0.0382
	P-Value	0.227		0.146	
	Test Result	M-59 = Dixie		M-59 = Dixie	
C	Std. Mean	132.1	87	0.505	0.236
	Std. Deviation	53.2	66.9	0.224	0.102
	P-Value	0.094		0.007	
	Test Result	M-59 = Dixie		M-59 ≠ Dixie	

Table 16. Cost Information of SCATS and Pre-Timed System

Attributes	SCATS System	Pre-Timed	Difference in Cost
Initial Cost	$120, 000	$100,000	$20, 000
Maintenance cost/year	$9,000	$4,000	$5,000
Life	15 years	15 years	15 years
Salvage	0	0	0
Discount Rate	4%	4%	4%
Present Worth of Cost	$220, 062	$144,472	$75, 590
Cost/Year	$19, 788	$12, 990	$6,798
Corridor cost/mile/year[1]	$28, 789	$19, 412	$9,376

[1]= (Cost/year)*number of signal within corridor/Length of corridor in miles

Note: Length of SCATS and Pre-Timed corridors are 6.186 and 8.03 miles respectively.

8.1. Cost of Crash by Signal System Computation

The expected cost of crash by signal system per year during 2003-2008 was computed by combining percent reduction data and cost of crashes by type. Cost of crashes by type was obtained from the National Highway and Traffic Safety Administration report [7]. The mean expected cost of crash by corridor and intersections controlled by SCATS and Pre-timed signal are included in Table 17. A lower cost of crash on SCATS corridor as well as intersection was observed. Please note that the expected costs were computed by summing the percent per severity type times the cost of severity types as cited in reference [7].

9. Conclusions

In this study the safety effectiveness of the SCATS controlled signal was evaluated by performing a before and after analysis and also by comparing a SCATS controlled corridor with a Pre-timed controlled corridor. This effort compared a section of M-59 (SCATS corridor) with a section Dixie Highway (Pre-timed corridor) to assess the effectiveness of the SCATS control system on the reduction of crashes. Total crashes, as well as severity types A, B, C and PDO data were examined to quantify related benefits. The crash rate in million vehicles and 100 million vehicle miles were computed. The statistical significance of the effectiveness of the two types of signal systems were tested to determine whether the observed difference in performances were attributable to the signal system or chance. Several hypotheses were presented and tested for significance at a 95 percent level of confidence or alpha equal to 0.05.

The findings of this study can be summarized as follows:

- In case of the SCATS signal system, there was shift in severity from types A and B to C.
- Even though, the installation of SCATS system cost more, by transforming from more severe crashes to less severe crashes, it would result in savings to the travelling public.
- In most cases, statistical analysis did not prove the superiority of SCATS system at the 95 percent confidence level, when before and after data were compared. Similar results were also observed when compared between SCATS and Pre-timed signal's crash experience.

Table 17. Expected Unit Cost of Crash For SCATS And Pre-Timed Corridors And Intersections Between 2003-2008

Severity Type	Cost in year 2000 dollars	Percent of Crash by Segment on		Percent of Crash by Intersections on	
		M-59 SCATS	Dixie Hwy Pre-timed	M-59 SCATS	Dixie Hwy Pre-timed
F	$977,208	0.27%	0.23%	0.05%	0.20%
A	$1,096,161	1.37%	1.4%	0.77%	0.81%
B	1$186,097	3.94%	4.26%	2.82%	3.63%
C	$10,562	19.65%	16.54%	18.62%	16.62%
PDO	$2,532	74.76%	77.57%	77.73%	78.73%
Expected Unit Cost of [1] Crash by Control System		$28,956	$29,232	$18,111	$21,337

[1] computed by combining percent of crash by severity type and related cost

10. References

1. Texas Transportation Institute, The 2002 Urban Mobility Report, June 2002.
2. Dutta, U., "Safety Potential of Smart Control System", Proceedings of the Fifth International Conference on Application of Advanced Technologies in Transportation, ASCE, 1998.
3. FHWA/UTC workshop on Urban/ Suburban Mobility and Congestion Mitigation Research, June 6-7, 2006.
4. Taylor, W., et al., "Evaluation of SCATS corridors", Project Report 1998.
5. Oppenlander, J.C., "Sample Size Determination for Travel Time and Delay Studies", Traffic Engineering Journal, September 1976.
6. Quiroga, C.A. and Bullock, D., "Determination of Sample Sizes for Travel Time Studies", ITE Journal, August 1998.
7. Dutta, U., "Life Cycle Costing in the Transit Industry," Transportation Research Record No. 1011, 1984 (with Cook, A.R., Maze, T.H., and Glandon, M.)
8. Dutta, U. "Evaluation of SCATS System", Final Report submitted to MIOH UTC, April, 2009.
9. Cambridge Systematics " Crashes vs. Congestion: What is the Cost to Society", A Report prepared for AAA by Cambridge Systematics, March 2008.
10. Dutta, U., "Traffic Signal Installation and Accident Experience", Journal of Institute of Transportation Engineers, Vol. 60, No. 9, Sept. 1990 (with T.K. Datta).

11. List of Acronyms

FAST-TRAC	Faster and Safer Travel through Traffic Routing & Advanced Controls
ITS	Intelligent Transportation Systems
MDOT	Michigan Department of Transportation
PDO	Property Damage Only
RCOC	Road Commission for Oakland County
SCATS	Sydney Coordinated Adaptive Traffic System
SEMCOG	South East Michigan Council of Government