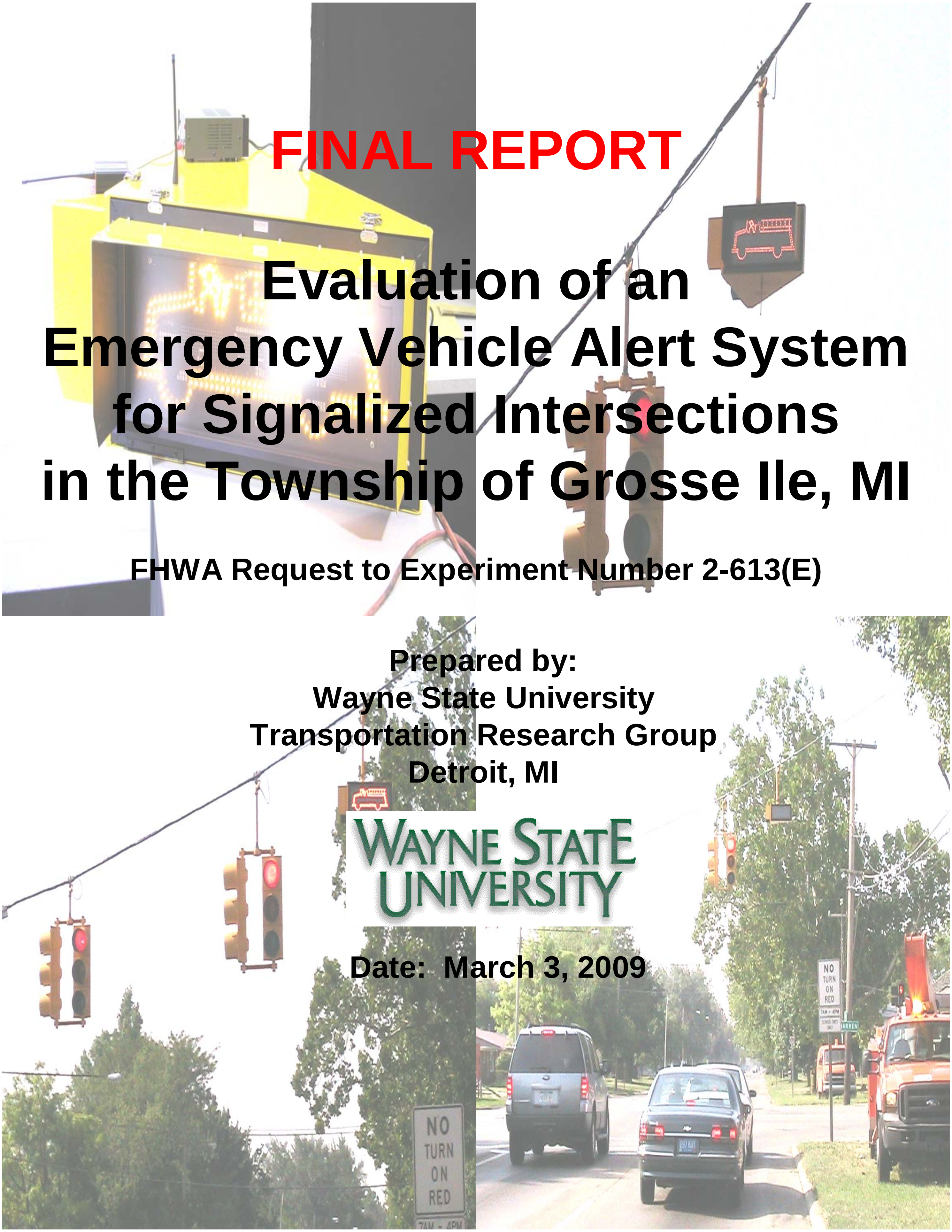

FINAL REPORT

Evaluation of an Emergency Vehicle Alert System for Signalized Intersections in the Township of Grosse Ile, MI

FHWA Request to Experiment Number 2-613(E)

Prepared by:
Wayne State University
Transportation Research Group
Detroit, MI

Date: March 3, 2009

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1. INTRODUCTION

Emergency vehicles (i.e., police cars, fire trucks, and ambulances) en route to incidents are encountered by the driving population on a daily basis. A recent questionnaire survey conducted in the City of Dearborn Heights, Michigan revealed that over 98 percent of respondents had encountered an emergency vehicle in service on a public roadway [*1*]. The response time of these emergency vehicles in attending to incidents is often critical to saving lives and property and the delay experienced en route to an incident can be a significant problem. In addition to delayed incident response, emergency vehicle crashes are also a serious public safety concern as evidenced by the 136 emergency-vehicle involved fatalities which occurred nationwide from 2004 to 2007 [*2*]. Emergency vehicle crashes have been particularly problematic in the State of Michigan, which has experienced over 3,000 crashes involving emergency vehicles en route to an incident during this same four-year time period [*3*].

A common cause of delay and emergency vehicle crashes, particularly at urban intersections, is the failure of non-emergency vehicle drivers to yield the right-of-way to an approaching emergency vehicle [*4,5,6*]. Often, this failure is due to drivers not being able to recognize the approaching emergency vehicle in time to react appropriately or failing to recognize the vehicle altogether. To minimize the crash risks associated with these behaviors, emergency vehicle operators are trained to slow down or stop to reduce the potential for traffic crashes and near misses at urban intersections. In addition to driver training, rotating or oscillating emergency lights and sirens on the emergency vehicles function as a warning to motorists and pedestrians, urging them to move aside to provide for safe passage of the emergency vehicles. However, in spite of these precautions, recognition remains a problem. In the aforementioned survey, 82.9% of respondents indicated they had noticed an emergency vehicle, but were unable to react appropriately in the time available on at least one occasion [*1*]. Such data establish the importance of providing sufficient advance warning of approaching emergency vehicles.

To aid in providing such advance warning, the emergency vehicle alert system (EVAS) shown in Figure 1 was developed by E-Light, LLC of Livonia, Michigan. This system consists of an illuminated sign that is mounted adjacent to a traffic signal and utilizes high output amber LED lights to alert motorists of an approaching emergency vehicle.

Figure 1. Emergency Vehicle Alert System (EVAS)

The system requires emergency vehicles to be equipped with a transmitter that can be activated on demand via a Department of Defense general control frequency that employs an encrypted data stream. When an emergency vehicle begins approaching an intersection, the transmitter is activated and a signal is relayed to a receiver located on the light assembly. The transmitted signal can be detected from a distance of up to 2,000 feet. Until the signal is detected, the sign remains unlit with a dark face. When the transmitter is activated, the sign displays an image of a fire truck (MUTCD symbol W11-8), providing a visual warning to motorists regarding the oncoming emergency vehicle. The display flashes once per second, as per MUTCD specifications, until the emergency vehicle has cleared the intersection. The receiver monitors signal strength and the device automatically shuts off after a preset time interval when a drop in signal strength has occurred. A schematic diagram illustrating the operation of the system is shown in Figure 2.

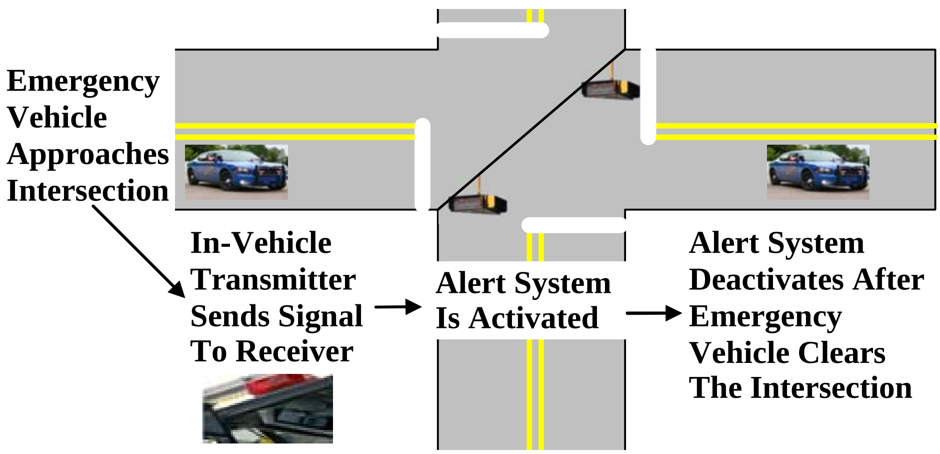


Figure 2. Operation of Emergency Vehicle Alert System (EVAS)

Due to the experimental nature of the EVAS, an evaluation was conducted to assess its impacts on traffic operations and safety. This research was part of an experiment being conducted with the permission of the Federal Highway Administration (FHWA) as per Request to Experiment Number 2-613(E) – Emergency Vehicle Alert System for Signalized Intersections. A copy of the FHWA approval letter for this experiment is included in Appendix I.

The Township of Grosse Ile, Michigan, shown on the map in Figure 3, agreed to participate in the experimental use of this newly developed traffic control device in an effort to minimize the risks faced by their emergency vehicle drivers en route to incidents. This experiment was the second test of the alert system, which was first evaluated at three intersections in the City of Dearborn Heights, Michigan during the summer of 2007 [*1*].

The Wayne State University Transportation Research Group (WSU-TRG) conducted this evaluation of the effectiveness of the alert system, the objective of which was to determine its impact on traffic safety and operations at the study intersections through field behavioral studies conducted before and after installation of the warning signs.

This report summarizes the tasks completed to satisfy this objective. The remainder of the report documents the project methodology, the data collection process, the selection of appropriate statistical techniques and subsequent statistical analysis, and the results and conclusions of the study.

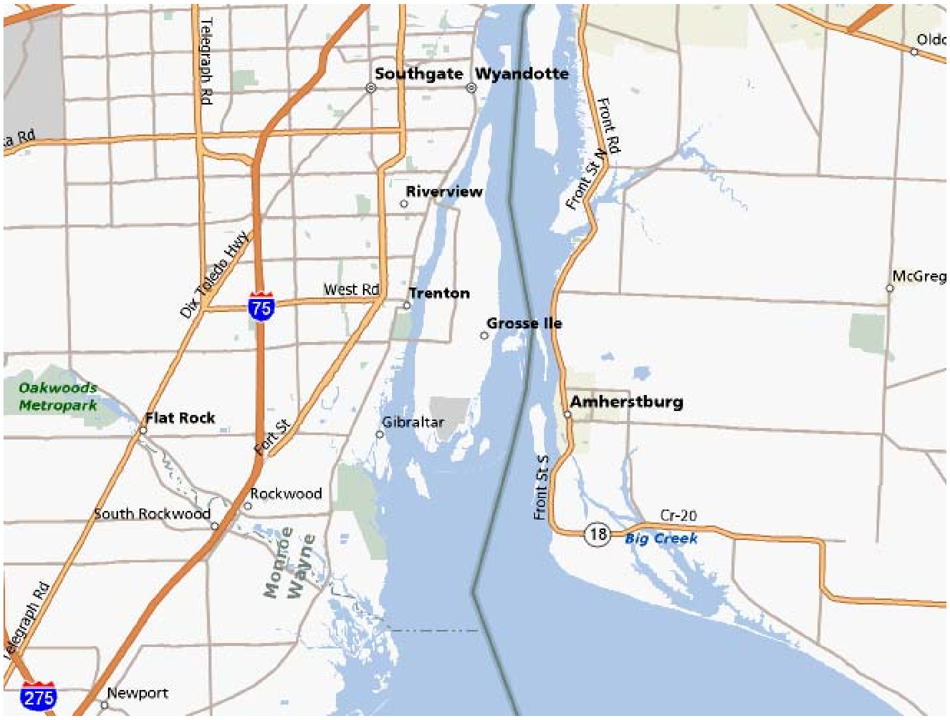


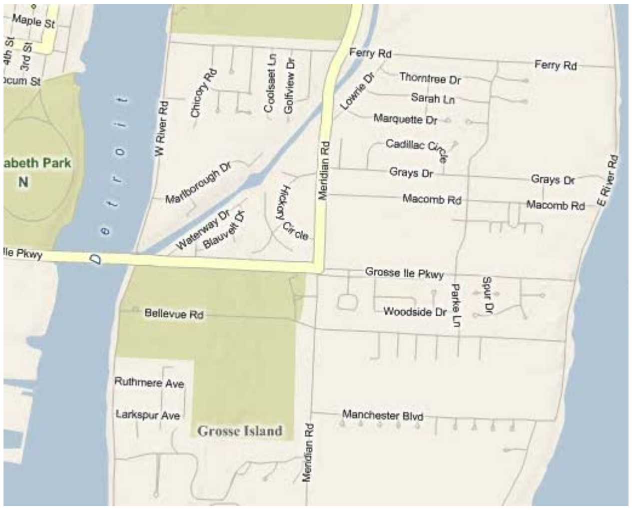
Figure 3. Project Location Map [*7*]

2. STUDY INTERSECTIONS

Two intersections were selected in the Township of Grosse Ile, Michigan for testing of the alert system. The study sites were selected in consultation with the Grosse Ile Fire Department and included the intersections of Meridian Road and Grosse Ile Parkway and Meridian Road and Macomb Road. An overview map of Grosse Ile and aerial photographs of the two study intersections are shown in Figure 4.

On its eastbound approach, Grosse Ile Parkway has one through lane and one left turn lane while its westbound approach includes separate right-turn, through, and left-turn lanes. Meridian Road has two through lanes in each direction (northbound and southbound) at its intersection with Grosse Ile Parkway. The traffic signal at this intersection operates on a fixed cycle with permitted left turns and the surrounding land use is exclusively residential.

At its intersection with Macomb Road, Meridian Road includes two southbound through lanes, one northbound through lane, and one northbound right-turn lane. Westbound Macomb Road, which terminates at Meridian, includes an exclusive left-turn lane and an exclusive right-turn lane. This traffic signal also operates on a fixed cycle and the surrounding land use is primarily commercial, with a gas station located on the northeast corner of the intersection, a strip mall located on the southeast corner, and wooded areas located along the west edge of Meridian.



Township of Grosse Ile


Grosse Ile Parkway @ Meridian Road


Macomb Road @ Meridian Road

Figure 4. Study Intersections [*8*]

3. EXPERIMENTAL DESIGN

In order to evaluate the effectiveness of the EVAS, a before-and-after evaluation methodology was utilized as illustrated in Figure 5. The "Before" period consisted of the time period prior to the installation of the alert system at the test sites. The "After" period was defined as the period beginning two months after the installation and implementation of the EVAS. The reason for the two-month period between the EVAS installation and the collection of the "After" period data was to allow for a public information and educational campaign to alert the traveling public of the newly installed devices and their intended function.

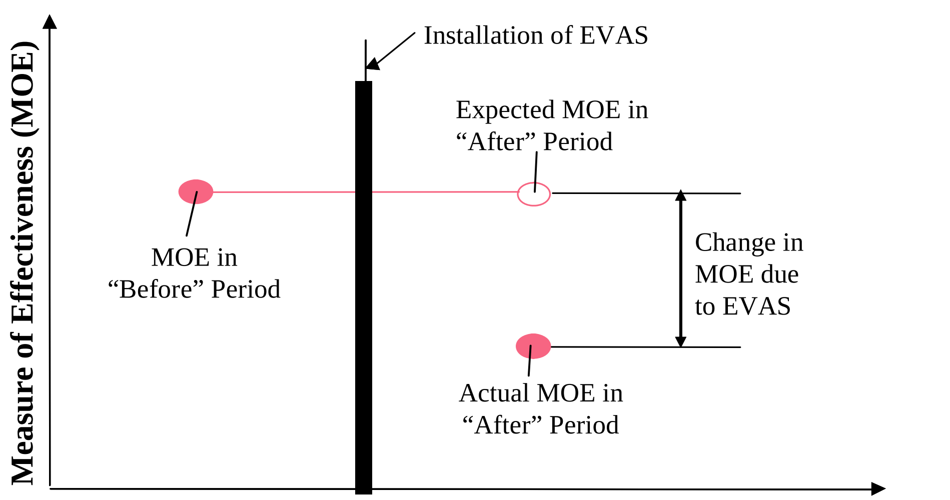


Figure 5. Before-and-After Evaluation Plan [*9*]

Prior to conducting these behavioral field studies, site surveys were conducted at each of the intersections to determine the site characteristics and identify any potential issues which may have affected the project, including any sight distance issues and the adjacent land use characteristics. Condition diagrams were prepared for each intersection and are shown in Appendix II.

Pre-installation field behavioral data was collected at each intersection between August 22nd and August 27th of 2008. The EVAS light assemblies were installed at each of the study locations during September of 2008. Following installation, a two-month period passed prior to collection of the after period data to allow for drivers to become accustomed to the EVAS. At the conclusion of this learning period, post-installation data collection was performed between November 10th and November 14th of 2008.

The field behavioral studies followed the experimental testing procedure developed during the first phase of testing conducted in the City of Dearborn Heights, Michigan [*1*]. The Grosse Ile Police and Fire Departments aided in the data collection, which was conducted over two six-hour periods at each location during both the "Before" and "After" periods. The data collection schedule for each location is illustrated in Table 1.

Table 1. EVAS Data Collection Schedule

Study Period	Intersection	Date
Before	Grosse Ile Parkway & Meridian Road	August 22, 2008
	Macomb Road & Meridian Road	August 25, 2008
	Grosse Ile Parkway & Meridian Road	August 26, 2008
	Macomb Road & Meridian Road	August 27, 2008
After	Grosse Ile Parkway & Meridian Road	November 10, 2008
	Macomb Road & Meridian Road	November 11, 2008
	Grosse Ile Parkway & Meridian Road	November 12, 2008
	Macomb Road & Meridian Road	November 14, 2008

On each day of data collection, simulated emergency vehicle runs were conducted every 30 minutes on alternating approaches, resulting in a minimum of twelve runs per location. On the days during which studies were conducted, there were also several unscheduled (i.e., actual) emergency vehicle runs that were recorded and included in the analysis dataset.

The most critical situation in terms of safety is when an emergency vehicle is approaching an intersection when the cross-street traffic has a green light. Consequently, test runs were scheduled such that the emergency vehicle arrived at the intersection shortly after its approach had received a red signal indication.

At the intersection of Grosse Ile Parkway and Meridian Road, police, fire, and rescue vehicles alternated runs on each of the four approaches so that each vehicle was utilized at least once per approach. At the intersection of Macomb Road and Meridian Road, a similar plan was utilized, but emergency vehicles alternated between the three approaches. Emergency personnel were instructed to conduct the simulated runs in an identical manner prior to and after installation of the EVAS.

The WSU-TRG field data collection team consisted of four members, who simultaneously recorded motorist and pedestrian behavior on all four intersection approaches using video cameras located 150 feet upstream of the stop bar. The video recordings were used to document safety and operational characteristics at each intersection during the emergency vehicle runs before and after installation of the alert system. The video data was used in the subsequent statistical analysis to assess the impacts of the system on various MOEs.

4. STATISTICAL ANALYSIS

The installation of the alert system was expected to improve the safety characteristics of the test intersections. Principally, the system is designed to increase safety at intersections by warning drivers of an approaching emergency vehicle. The most direct measure of effectiveness for such a safety device is the number of traffic crashes experienced at each treated location. However, due to the random and infrequent nature of crashes involving emergency vehicles, the number of crashes does not provide an ideal measure of effectiveness for such a study.

For this reason, traffic conflicts and "violations" were evaluated as a surrogate measure of safety. Traffic conflicts are interactions between two or more vehicles or road users when one or more vehicles or road users take evasive action, such as braking or weaving, to avoid a collision [*10,11*]. However, traffic conflicts were also found to occur relatively infrequently, so further surrogate measures were also collected, principally the frequency and proportion of "violations". For the purpose of this study, any motorists who crossed the stop bar when the approaching emergency vehicle was within 150 feet of the intersection were considered violators. As violations occur on a considerably more frequent basis than crashes or traffic conflicts, this technique shortens the time period required to make an informed decision in regard to the effectiveness of experimental devices.

There are a number of additional surrogate measures that were evaluated, including the proportion of yielding vehicles, the time difference between emergency vehicle arrival and the time at which vehicles yield or violate the EVAS, and the time required for traffic to restart after an emergency vehicle has departed the intersection. Changes in each of these variables can be ascertained by examining the mean, variance, and distribution of each MOE.

It is customary to use statistical analysis in the effectiveness evaluation process. Such analyses ensure that the observed differences between the "Before" and "After" periods are in fact due to the alert system and not due to chance. To determine whether the observed changes were statistically significant, statistical tests were conducted to compare each selected MOE before and after the installation of the EVAS at the test locations. The null hypotheses for each test stated no difference between the selected MOEs before and after the installation of the EVAS.

Each test statistic was calculated and compared to a critical value based upon a 95-percent confidence level. If the calculated test statistic was greater than the associated critical value, the null hypothesis could be rejected, meaning that the difference in that particular MOE was due to the implementation of the alert system. In addition to the calculated test statistics, the corresponding p-value is reported for each statistic. The p-value represents the probability that a test statistic as large as the calculated value is obtained based on random chance. A p-value of 0.05 or less is equivalent to a test statistic that is significant at a 95 percent confidence level.

The statistical tests performed to test the effectiveness of the system, including the following:

- Z-Test of Proportions – to examine differences between MOEs expressed as proportions
- Kolmogorov-Smirnov Test – to determine if continuous data were normally distributed
- Welch's t-Test – to examine differences between means of normally distributed MOEs
- Mann-Whitney U Test – to examine differences between means of non-normal MOEs

Testing Differences in Sample Proportions

To compare those MOEs that were expressed in terms of percentages, the Z-test of proportions [*12*] was utilized. The Z-test allows for a determination of whether a proportion measured during the "Before" period (sample 1) is significantly different from the same proportion measured during the "After" period. Stated mathematically:

$$Z = \frac{\hat{P}_1 - \hat{P}_2}{\sqrt{\hat{P}\left(1-\hat{P}\right)\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}},$$

where:

$n_1 =$ Number of observations (e.g., vehicles) in sample 1

$n_2 =$ Number of observations in sample 2

$X_1 =$ Number of observations in sample 1 meeting a given condition (e.g., yielding vehicle)

$X_2 =$ Number of observations in sample 2 meeting a given condition

$\hat{P}_1 = \frac{X_1}{n_1}$

$\hat{P}_2 = \frac{X_2}{n_2}$

$\hat{P} = \frac{X_1 + X_2}{n_1 + n_2}$

This Z-statistic is compared to a critical value from the standard normal table. For the Z-test, a two-tailed critical value was used as no a priori knowledge was available as to the effects of the alert system, resulting in a critical Z-statistic equal to 1.96. For any values larger than 1.96, it can be claimed that the test result is statistically significant at a 95 percent confidence level.

One-Sample Kolmogorov-Smirnov Test

The One-Sample Kolmogorov–Smirnov Test is used to examine the goodness-of-fit of known reference distribution to a sample probability distribution [*13*]. For this study, the One-Sample Kolmogorov-Smirnov Test was used to determine whether each of the selected MOEs which were expressed as continuous values (rather than proportions) could be approximated by a normal distribution. For those variables which are approximately normally distributed, t-Tests are appropriate for comparing the mean values between the "Before" and "After" periods. For those variables which are not normally distributed, the Mann-Whitney Test is appropriate. Table 2 presents the results of the One-Sample Kolmogorov-Smirnov Tests and indicates which of the two tests was selected for use in the subsequent comparison of the before-and-after data for the particular MOE.

Table 2. Selection of Appropriate Statistical Tests

Measure of Effectiveness (MOE)	One-Sample K-S Test Statistic	P-Value	Appropriate Test Statistic
Violations Per Run	3.894	<0.001	Mann-Whitney
Crossing Violations	4.843	<0.001	Mann-Whitney
Right Turn Violations	5.368	<0.001	Mann-Whitney
Left Turn Violations	4.679	<0.001	Mann-Whitney
Time between First Yield and Emergency Vehicle Arrival (sec)	1.073	0.200	Welch's t
Time between Last Violation and Emergency Vehicle Arrival (sec)	0.968	0.306	Welch's t
Clearance Time for Emergency Vehicle (sec)	0.982	0.290	Welch's t
Time Until Traffic Restarts (sec)	1.858	0.002	Mann-Whitney

Welch's t-Test

For those MOEs which are normally distributed, their mean values were compared using Welch's t-Test. Welch's t was appropriate rather than Student's t due to the fact that the variances for all of the selected MOEs were significantly different between the "Before" and "After" periods. The formula for Welch's t-Test is presented here:

$$t = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\left(\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}\right)}},$$

where:

$n_1 =$ Number of observations (e.g., emergency vehicle runs) in sample 1 (e.g., "Before" period)

$n_2 =$ Number of observations in sample 2 (e.g., "After" period)

$x_{1i} =$ Value of MOE (e.g., emergency vehicle clearance time) for observation i in sample 1

$x_{2i} =$ Value of MOE for observation i in sample 2

$\overline{X}_1 = \frac{\sum_{i=1}^{n} x_{1i}}{n} =$ Mean value of MOE in sample 1

$\overline{X}_2 = \frac{\sum_{i=1}^{n} x_{2i}}{n} =$ Mean value of MOE in sample 2

$S_1^2 = \frac{\sum_{i=1}^{n_1} \left(x_{1i} - \overline{X}_1\right)^2}{n_1 - 1} =$ variance of MOE in sample 1

$S_2^2 = \frac{\sum_{i=1}^{n_1} \left(x_{2i} - \overline{X}_2\right)^2}{n_2 - 1} =$ variance of MOE in sample 2

The calculated t-statistic is compared to a critical t-table with degrees of freedom given by the Welch-Satterthwaite equation [*14*]. A t-statistic larger than the critical value is indicative of a statistically significant difference in the selected MOE between the "Before" and "After" periods.

Mann-Whitney Test

The Mann-Whitney test is appropriate if data corresponding to an MOE are not normally distributed [*15*]. The test is comparable to a standard t-Test conducted on data which are ranked after combining two samples. To calculate the Mann-Whitney test statistic, the data from the two samples (in this case, the "Before" and "After" periods) are combined into a single ranked series. The ranks of the observations from one sample are summed and then the Mann-Whitney Statistic, U, is computed as follows:

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

where:

R_1 = sum of the ranks in sample 1

n_1 = number of observations in sample 1

The U statistic approximately follows a standard normal distribution. This statistic is calculated as follows:

$$Z = \frac{U - m_U}{\sigma_U},$$

where:

$$m_U = \frac{n_1 n_2}{2}$$

$$\sigma_U = \sqrt{\frac{n_1 n_2 (n_1 + n_2 + 1)}{12}}$$

The calculated Z-statistic is compared to the two-tailed critical value of 1.96 from the standard normal table. A value greater than 1.96 indicates a statistically significant difference between the "Before" and "After" periods at a 95 percent confidence level.

5. RESULTS

Table 3 presents the summary statistics for each of the measures of effectiveness analyzed as a part of this study. These statistics represent the aggregate data from the studies conducted at both intersections. The data were obtained by examining each of the videos recorded as a part of the eight field studies.

The effect of the warning signs on each of the selected MOEs was examined using appropriate statistical techniques as described previously. Tables 4 through Table 11 present the results of the statistical tests which examined each MOE. These results include the sample size (number of observations) related to each MOE for both the "Before" and "After" period, the calculated test statistic, the p-value associated with this statistic, and finally, whether the test result is statistically significant at a 95 percent confidence level.

Table 3. Data Summary Table

Measure of Effectiveness (MOE)	Analysis Period	
	Before	After
Number of Emergency Vehicle Runs	56	41
Percentage of Vehicles Yielding	74.1%	94.9%
in Right Lane	91.3%	98.2%
in Center Lane	75.0%	90.9%
in Left Turn Lane	35.1%	90.9%
Early	71.4%	84.0%
Late	7.9%	0.0%
Violations	43	5
Crossing Violations	19	1
Right Turn Violations	2	1
Left Turn Violations	22	3
Traffic Conflicts	6	0
Time between First Yield and Emergency Vehicle Arrival (sec)	6.54	9.44
Time between Last Violation and Emergency Vehicle Arrival (sec)	5.64	9.37
Clearance Time for Emergency Vehicle (sec)	4.73	3.68
Time Until Traffic Restarts (sec)	3.06	6.32

Percentage of Vehicles Yielding

In an optimal situation, all vehicles arriving at an intersection while an emergency vehicle is approaching will yield the right-of-way by pulling over to the side of the right side of the road and allowing the emergency vehicle to pass. As the percentage of vehicles yielding to the emergency vehicle increases, the safety potential of the intersection increases, as well. Results of the Z-Test for the percentage of vehicles yielding are presented in Table 4. The percentage of compliant motorists (or yielding vehicles) was increased from 74.1% to 94.9% after the EVAS was installed.

Table 4. Z-Test for Percentage of Vehicles Yielding

Analysis Period	Before	After
Number of Vehicles Observed	189	99
Percentage of Vehicles Yielding	74.1%	94.9%
Z-Statistic	4.31	
p-value	<0.001	
Significant Difference?	Yes	

This increase in the percentage of yielding vehicles was found to be consistent for both the through/right-turn movements and the left-turn movements at the study intersections as shown in Table 5.

Table 5. Z-Test for Percentage of Vehicles Yielding by Lane

Lane(s)	Through Lanes		Left Turn Lane	
Analysis Period	**Before**	**After**	**Before**	**After**
Number of Vehicles Observed	152	77	37	22
Percentage of Vehicles Yielding	83.5%	96.1%	35.1%	90.9%
Z-Statistic	2.74		4.17	
p-value	0.003		<0.001	
Significant Difference?	Yes		Yes	

Vehicles were classified as yielding even if they yielded immediately after crossing the intersection. However, in an optimal situation, vehicles would yield prior to crossing the intersection. By examining the proportion of vehicles which yielded after crossing the intersection, or "yielded late", before and after the EVAS was installed, further insight is provided as to the effectiveness of the devices. Results of the Z-Test for the percentage of vehicles yielding late are presented in Table 6. During the "before" period, 7.9% of vehicles yielded after crossing the intersection. During the "after" period, no vehicles were found to yield late. Consequently, the EVAS was shown to effectively increase the proportion of yielding motorists and decrease the proportion of motorists who yielded after crossing the intersection.

Table 6. Z-Test for Percentage of Vehicles Yielding Late

Analysis Period	Before	After
Number of Vehicles Yielding	140	94
Percentage of Vehicles Yielding Late	7.9%	0.0%
Z-Statistic	2.47	
p-value	0.014	
Significant Difference?	Yes	

Violations and Traffic Conflicts

If a vehicle does not yield the right-of-way to an oncoming emergency vehicle, this action is considered a "violation". If this violation results in either the violating driver or the emergency vehicle driver being forced to take evasive action to avoid an impending collision, the event is called a "traffic conflict". As the number of violations and traffic conflicts increases, the safety potential of the intersection decreases since the potential of a crash occurrence is increased. As only six traffic conflicts were observed during the evaluation period, all of which occurred prior to EVAS installation, there is not a sufficient sample size to detect a statistically significant difference. However, results of the test for the number of violations are presented in Table 7. The results show a dramatic reduction in the number of violations, which fell from an average of 0.768 per run during the period prior to EVAS installation to only 0.122 per run after installation. These findings were statistically significant for through and left-turning vehicles. While the result was not significant at 95% confidence for right-turning vehicles, this result is likely an effect of the limited sample size as no vehicles were found to commit right turn violations in the after period.

Table 7. Mann-Whitney U Test for Number of Violations per Run

Type of Violation	All Violations		Crossing Violations		Right Turn Violations		Left Turn Violations	
Analysis Period	**Before**	**After**	**Before**	**After**	**Before**	**After**	**Before**	**After**
Violations per Run	0.768	0.122	0.340	0.024	0.036	0.024	0.393	0.073
Mann-Whitney Statistic	4.136		3.428		2.789		0.496	
p-value	<0.001		0.001		0.620		0.007	
Significant Difference?	Yes		Yes		No		Yes	

Time between First Yield and Emergency Vehicle Arrival

The safest situation from the standpoint of the emergency vehicle driver is the case where all vehicles are yielding the right-of-way at the intersection. The sooner drivers make the decision to yield, the greater is the safety potential of the intersection. Consequently, a comparison was made between the time the first vehicle yielded prior to the emergency vehicle reaching the intersection “before” and “after” the installation of the EVAS. The results, presented in Table 8, show that vehicles began yielding much earlier after the installation of the EVAS. Prior to its installation, the first vehicle to yield would typically do so approximately 6.54 seconds prior to the emergency vehicle arrival. Following installation, vehicles began yielding up to 9.44 seconds prior to emergency vehicle arrival. Consequently, the EVAS is providing emergency vehicle drivers with an additional safety buffer.

Table 8. t-Test for Time between First Yield and Emergency Vehicle Arrival

Analysis Period	**Before**	**After**
Mean Value of MOE (sec)	6.54	9.44
t-Statistic	2.87	
p-value	0.005	
Significant Difference?	Yes	

Time between Last Violation and Emergency Vehicle Arrival

The most hazardous situation from the point of view of the emergency vehicle driver is the case where its right-of-way is violated and there is high potential for a traffic crash. In the event where no crashes are experienced, the potential of a crash occurring can be measured and compared. As the time increases between the latest violating vehicle and the arrival of the emergency vehicle, the potential for a crash occurrence is decreased. The average time between the last violation and the emergency vehicle arrival is compared “before” and “after” the implementation of the EVAS. Prior to EVAS installation, the last violation occurred an average of 5.64 seconds prior to emergency vehicle arrival as shown in Table 9. Such a small time period does not provide much time for either driver to react to a potentially hazardous situation. Following the installation of the EVAS, this time increased to 9.37 seconds. Even though violations still occurred, they tended to occur much earlier and this may be an indication of drivers who noticed the emergency vehicle, but ascertained that they had sufficient time available to cross safely. Though this difference is not statistically significant, this is partially due to the a limited sample size as very few violations occurred during the “After” period at the study intersections.

Table 9. t-Test for Time between Last Violation and Emergency Vehicle Arrival

Analysis Period	Before	After
Mean Value of MOE (sec)	5.64	9.37
t-Statistic	1.55	
p-value	0.219	
Significant Difference?	No	

Clearance Time for Emergency Vehicle

The faster an emergency vehicle is able to pass through (or clear) an intersection from stop bar to stop bar, the earlier the vehicle will be able to arrive at its destination. The difference in these clearance times was evaluated before and after installation of the EVAS as illustrated in Table 10. After the EVAS was installed, drivers were able to pass from stop bar to stop bar 1.05 seconds faster than in the absence of the EVAS. This result is due to the increased compliance and, although drivers were instructed to drive in a similar manner during both analysis periods, some of this may be due to increased confidence on behalf of the emergency vehicle drivers.

Table 10. t-Test for Clearance Time for Emergency Vehicle

Analysis Period	Before	After
Mean Value of MOE (sec)	4.73	3.68
t-Statistic	3.02	
p-value	0.003	
Significant Difference?	Yes	

Time Until Traffic Restarts

From both an operational and safety standpoint, it is important to know how soon after an emergency vehicle passes through an intersection that traffic will start to move again. This is of particular concern if a second emergency vehicle is approaching an intersection shortly after the first vehicle. Consequently, the time elapsed between the emergency vehicle's passage through the intersection and the moment that traffic starts moving again was examined both before and after the EVAS was installed.

During the first phase of testing in the City of Dearborn Heights, Michigan, traffic was found to begin moving approximately 5.3 seconds after the emergency vehicle had cleared the intersection during both the "Before" and "After" periods. During the initial phase of testing, the EVAS was programmed to terminate its signal (or "gap out") approximately 15 seconds after the emergency vehicle had cleared the intersection. Based on these results, the manufacturer reduced this time to 4 seconds prior to implementing the system at the locations in Grosse Ile.

Upon this change being instituted, a t-Test was conducted on data from the Grosse Ile intersections to determine if this revised timing scheme had any effect on intersection operations. Results of the changes in this "start-up time" are shown in Table 11. Prior to system installation, traffic began moving again approximately 3.06 seconds after the emergency vehicle had cleared the intersection. After installation, the average time that elapsed until traffic restarted was approximately 6.32 seconds. It appears that drivers delayed their departure until they were certain that another emergency vehicle was not approaching. Based upon this evidence, it appears that 4 seconds may provide a reasonable duration for the system to gap out while still maintaining the attention of road users.

Table 11. t-Test for Time Until Traffic Restarts

Analysis Period	Before	After
Time between First Yield and Emergency Vehicle Arrival (sec)	3.06	6.32
Mann-Whitney Statistic	3.837	
p-value	<0.001	
Significant Difference?	Yes	

6. SUMMARY AND CONCLUSIONS

The objective of this study was to determine the effectiveness of an Emergency Vehicle Alert System (EVAS) at improving traffic safety and operations at signalized intersections during emergency vehicle runs. A field experiment was conducted at two intersections in the Township of Grosse Ile, Michigan to assist in the determination of system effectiveness. Driver behavior was recorded at each location before and after the installation of the alert system. The changes in the selected measures of effectiveness (MOEs) between the periods before and after installation of the system were tested using statistical analysis techniques in order to ascertain whether the changes observed were attributable to the utilization of the EVAS. A summary of the findings is as follows:

- The number of violations was reduced from an average of 0.768 per run during the period before EVAS installation to only 0.122 per run during the period after installation.
- Driver compliance with the EVAS experienced a substantial increase from 74.1% in the "Before" period to 94.9% in the "After" period. This increase in compliance was consistent across each of the travel lanes.
- Drivers were also found to yield sooner and, if they violated the emergency vehicle's right-of-way, they tended to do so sooner in the presence of the alert system. These findings indicate that drivers are becoming aware of the approaching emergency vehicle sooner and are able to make a quicker and more well-informed decision when reaching the intersection as to whether it is safe to proceed prior to the arrival of the emergency vehicle.
- The amount of time necessary for emergency vehicles to clear the intersection was found to decrease by 1.05 seconds after EVAS installation, which may be partially explained by increased confidence on the part of the emergency vehicle driver.
- After the alert system was installed, drivers tended to resume moving approximately 6.32 seconds after clearance, a significant increase over the 3.06-second start-up time prior to installation.

The alert system was found to consistently improve each safety-related MOE and these results were consistent with the first wave of testing conducted in Dearborn Heights as shown in Table 12. During each of the first two phases of testing, the percentage of yielding vehicles increased by over 20 percent after installation of the warning signs. Similarly, the rate of violations per emergency vehicle run was decreased by over 84 percent during each evaluation phase.

The one MOE which was not consistent between the two evaluation phases was the time which elapsed between when the emergency vehicle cleared the intersection and the time when traffic started moving again. This result was due in part a change in the programming of the gap-out time (time which elapses between when the emergency vehicle clears the intersection and the alert system ceases operation), which was reduced from 15 seconds to 4 seconds prior to installation at the two Grosse Ile intersections. It appears the new gap-out time is set appropriately, holding drivers attention to the possibility of another approaching emergency vehicle without causing drivers to ignore the system due to impatience.

Table 12. Results of Phase I and Phase II Studies

Measure of Effectiveness (MOE)	Phase I: Dearborn Heights		Phase II: Grosse Ile	
	Before	After	Before	After
Number of Emergency Vehicle Runs	41	38	56	41
Percentage of Vehicles Yielding	76.6%	97.4%	74.1%	94.9%
in Right Lane	78.9%	98.6%	91.3%	98.2%
in Center Lane	59.3%	93.2%	75.0%	90.9%
in Left Turn Lane	80.0%	100.0%	35.1%	90.9%
Early	36.6%	77.1%	71.4%	84.0%
Late	14.8%	6.7%	7.9%	0.0%
Violations	56	6	43	5
Crossing Violations	49	6	19	1
Right Turn Violations	3	0	2	1
Left Turn Violations	4	0	22	3
Traffic Conflicts	3	0	6	0
Time between First Yield and Emergency Vehicle Arrival (sec)	5.91	19.34	6.54	9.44
Time between Last Violation and Emergency Vehicle Arrival (sec)	3.33	6.00	5.64	9.37
Clearance Time for Emergency Vehicle (sec)	5.27	4.21	4.73	3.68
Time Until Traffic Restarts (sec)	5.26	5.29	3.06	6.32

Overall, the Emergency Vehicle Alert System (EVAS) was found to be effective at improving the safety of both the traveling public and the emergency vehicle drivers at the two test intersections in the City of Grosse Ile, Michigan. The EVAS led to greater driver compliance and fewer violations. Furthermore, even when violations did occur, they generally happened much earlier, mitigating the hazard posed to both drivers. The results of this evaluation show the alert system to improve motorist awareness of approaching emergency vehicles and, consequently, to reduce the risk faced by emergency vehicle and non-emergency vehicle drivers at intersections during incident response.

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APPENDIX I:
EXPERIMENTATION APPROVAL LETTER

U.S. Department
of Transportation
**Federal Highway
Administration**

1200 New Jersey Avenue, SE
Washington, DC 20590

May 13, 2008

In Reply Refer To: HOTO-1

Mr. J. Phil McGuire
Assistant Engineer of Traffic Operations
Wayne County Department of Public Services
Division of Roads
29900 Goddard Road
Detroit, MI 48242

Dear Mr. McGuire:

The purpose of this letter is to clarify our February 28 approval of an expansion of scope for approved experiment 2-613(E) - Emergency Vehicle Alert System (EVAS) for Signalized Intersections. A request for clarification was made on behalf of Wayne County by Mr. Duncan Murdock, Fire Chief for the Township of Grosse Ile.

The approval for the expansion of scope applies to the experiment being conducted by Wayne County as follows:

> In the city of Dearborn Heights, the approved experimentation was expanded from the original three intersections to include an additional thirty-two intersections.
>
> In the Township of Grosse Ile, the approved experimentation was expanded to include two additional intersections selected from candidate intersections as identified in the proposed work plan submitted February 4.

The request to expand the scope of this official experimentation research project has been assigned the same official Request to Experiment number of "2-613(E) - Emergency Vehicle Alert System for Signalized Intersections; please refer to this number and title in future correspondence. Please be advised that all future correspondence should be submitted directly by Wayne County as the agency having jurisdiction over the experimentation sites.

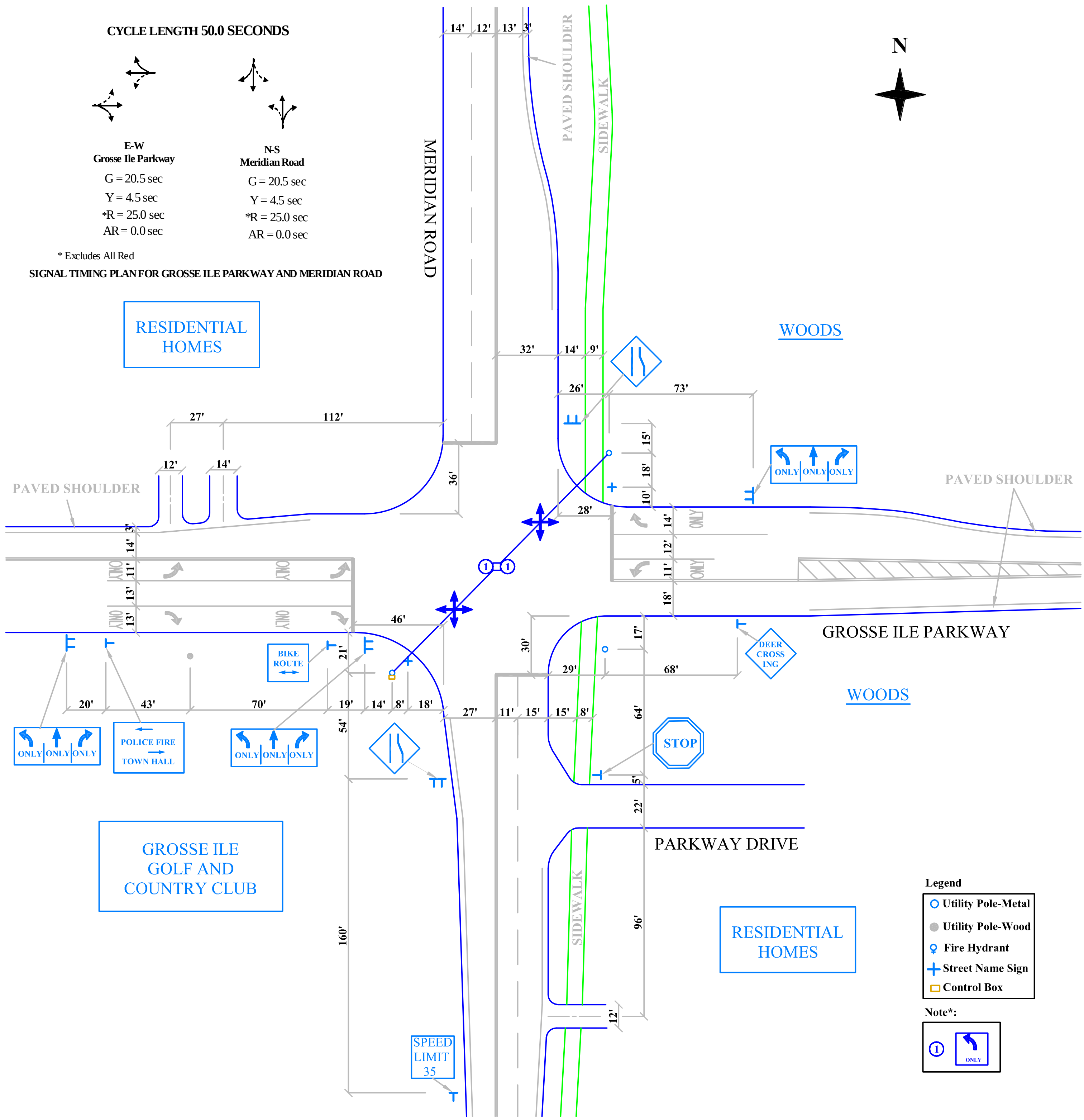
We look forward to receiving notifications of implementation dates and to your semiannual progress reports and Final Report. If we can be of further assistance on this matter, please contact Mr. Fred Ranck at 708-283-3545.

Sincerely yours,

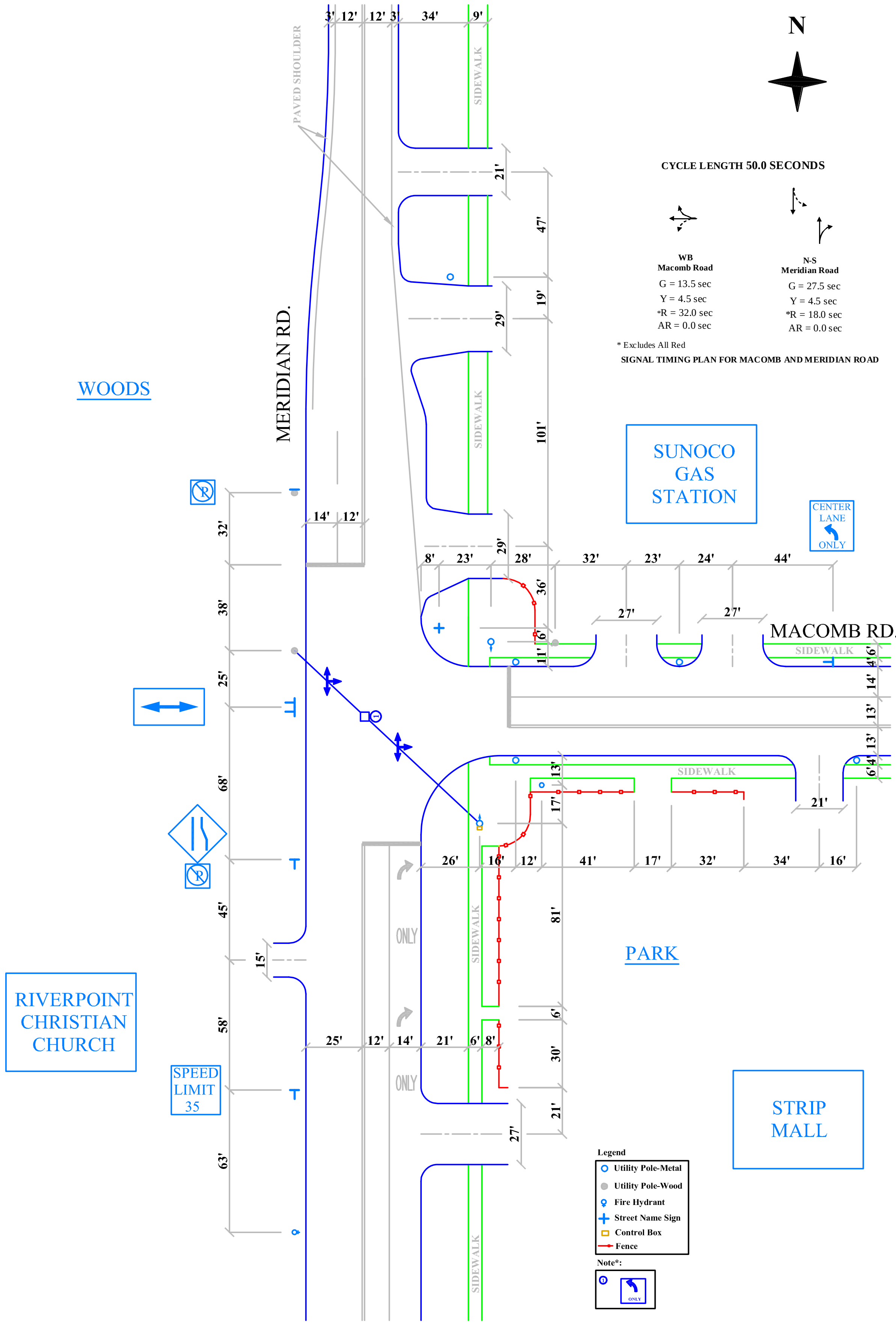
Robert Arnold
Director, Office of Transportation
Operations

cc: Mr. Michael Gust

APPENDIX II:
CONDITION DIAGRAMS



Existing Condition Diagram of Meridian Road and Grosse Ile Parkway Intersection
Grosse Ile, MI
(Not to Scale)



Existing Condition Diagram of Meridian Road and Macomb Road Intersection
Grosse Ile, MI
(Not to Scale)