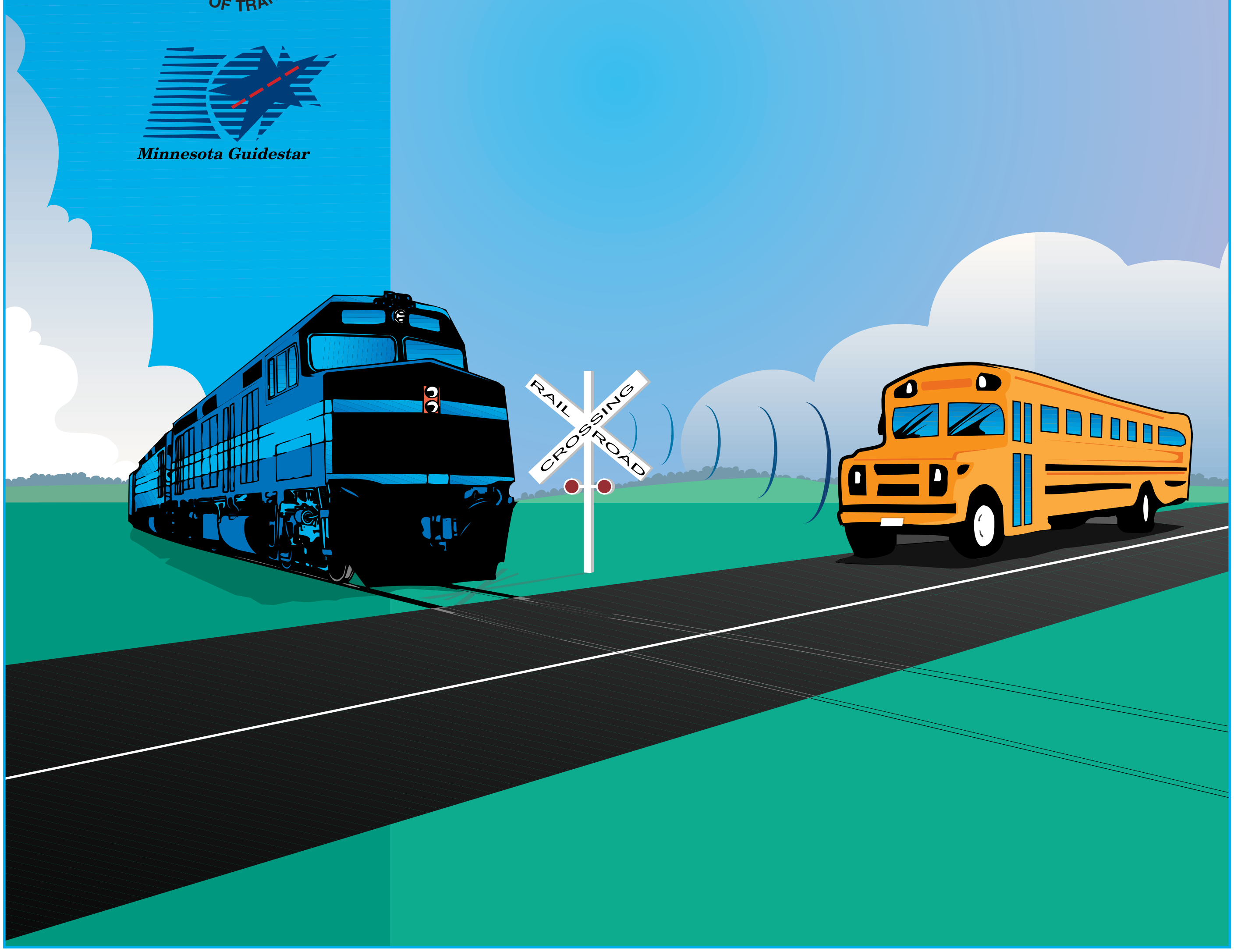
IN-VEHICLE SIGNING FOR SCHOOL BUSES AT RAILROAD-HIGHWAY GRADE CROSSINGS

EVALUATION REPORT

AUGUST 1998

MINNESOTA DEPARTMENT OF TRANSPORTATION

Minnesota Guidestar



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TC&W Railroad:
- William Drusch, President
- Brian Gardner, Signal Maintainer
- Rachel Huls, Office Manager
- Tim Jeske, Director - Mechanical and Maintenance
- Dan Rickel, General Manager - Operations

Glencoe/Silver Lake School District:
- Derald Bielke, Transportation Director
- All bus drivers

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EXECUTIVE SUMMARY

The Minnesota Department of Transportation, 3M, and Dynamic Vehicle Safety Systems have developed an in-vehicle signing system to alert drivers of potentially dangerous railroad crossing situations. In this project the in-vehicle signing system was installed in 29 school buses in Glencoe, Minnesota. The system was operational for the 1997/1998 school year. The system was initially installed at signalized railroad crossings but the test was later expanded to evaluate the technology for use at unsignalized or passive crossings. This report evaluates the impact of the system and the performance of the system's technology.

The conflict of vehicles and trains at at-grade crossings can cause serious accidents. There are a significant number of railroad-highway accidents in Minnesota each year and the fatality rate for motorists involved in accidents with trains is 30 times higher than the rate for an accident with another motor vehicle. The in-vehicle signing system is a supplemental warning system to alert drivers to these potentially dangerous situations.

The in-vehicle signing system is designed to provide timely information to drivers approaching railroad crossings. The system is activated when a receiver on the school bus traveling toward the crossing comes within range of a radio signal emitted at the crossing. The system operates by providing the school bus driver with two types of information on rail crossings: the bus's proximity to an at-grade railroad crossing (crossing alert) and whether or not a train is present at or near the crossing (train warning). Both visual and variable audio signals are given. The system also has the ability to discern the direction the bus is traveling relative to the crossing, thereby preventing nuisance warnings when the vehicle is within the vicinity of the crossings but not intending to cross the tracks.

In the evaluation of this project an attempt was made to quantify the impact of the warning system on bus driver behavior. Analysis of bus approach speed, stopping location, stopping time, and driver scanning behavior found few statistically significant differences between the study area and the baseline areas. As an alternative, the evaluation focused on interviews and surveys of bus drivers and railroad personnel.

Results from this evaluation indicate the in-vehicle signing system is effective in warning bus drivers of the location of at-grade rail crossings and train presence. These findings are based largely on a series of interviews and surveys conducted with bus drivers and railroad personnel in both the test area (Glencoe) and in the baseline locations (Norwood and Shoreview). Bus driver opinions did vary in their confidence in the system due to some component calibration issues and bus driver misunderstanding of the system operation. The crossings containing the directional feature were found to have the highest level of bus driver confidence. Survey and interview results indicate general bus driver acceptance and perception of value in the warning system. The majority of the drivers felt the in-vehicle signing system should be installed on their bus permanently.

IN-VEHICLE SIGNING FOR SCHOOL BUSES AT RAILROAD-HIGHWAY GRADE CROSSINGS

EVALUATION REPORT

I. INTRODUCTION

A. PROJECT BACKGROUND

The Minnesota Department of Transportation (MnDOT), 3M, and Dynamic Vehicle Safety Systems (DVSS) have developed an in-vehicle signing system to alert drivers of potentially dangerous railroad crossing situations. School buses were selected for this project because they offer a controlled vehicle population. Having a finite number of installations has the advantage of offering control over a test project. In addition, a finite pool of drivers provides continuity in receiving input from the system users.

The in-vehicle signing system was installed in 29 school buses in the Glencoe/Silver Lake School District in Minnesota. The City of Glencoe has a population of approximately 5,000 people and is located approximately 45 miles west of the Twin Cities metropolitan area. The Twin Cities and Western Railroad line runs roughly east/west through the City of Glencoe. Most buses must cross the railroad tracks to access the various schools located throughout town.

It is important to note that the in-vehicle signing system does not replace or interfere with the existing traffic warning devices; the warning system is purely supplemental. Elements such as flashers, gate arms, and signing were not modified for this project and school buses were still required to come to a full stop at railroad crossings and continue to follow all current laws regarding crossings.

B. SYSTEM DESCRIPTION

Five signalized crossings were outfitted with the warning equipment. The system operates by providing the school bus driver with two types of information on rail crossings: the bus's proximity to an at-grade railroad crossing (crossing alert) and whether or not a train is present at or near the crossing (train warning). Both audio and visual signals are given. The audio signal output automatically adjusts to the ambient noise level in the bus, assuring the warning is heard by the driver.

Four out of five crossings are outfitted with a directional feature that allows the system to discern the direction a bus is traveling relative to the crossing. The system will not activate unless the vehicle direction of travel will take it through the crossing. This prevents nuisance warnings when the vehicle is within the vicinity of the crossing but not intending to cross the tracks. Because of a unique geometric approach at Hennepin Avenue, however, this directional feature could not be used because it would preclude warning for vehicles turning from a side street located very close to the crossing. As a result, vehicles traveling in the vicinity of this crossing receive the warning even if they were not approaching the crossing.

The railroad crossing warning is activated when a receiver on the school bus traveling toward the crossing comes within range of a radio signal being continuously emitted by an antenna located at the at-grade crossing. Existing equipment located at the crossing is used to detect the presence of a train. The train warning is activated when a train is detected by the equipment, and this information is broadcast and received by school buses approaching the at-grade crossing.

The major components of the in-vehicle signing system are as follows:

- Existing train detection equipment
- Crossing transmitters
- Roadside antenna signs
- Vehicle antenna plates
- Vehicle receiver
- In-vehicle display

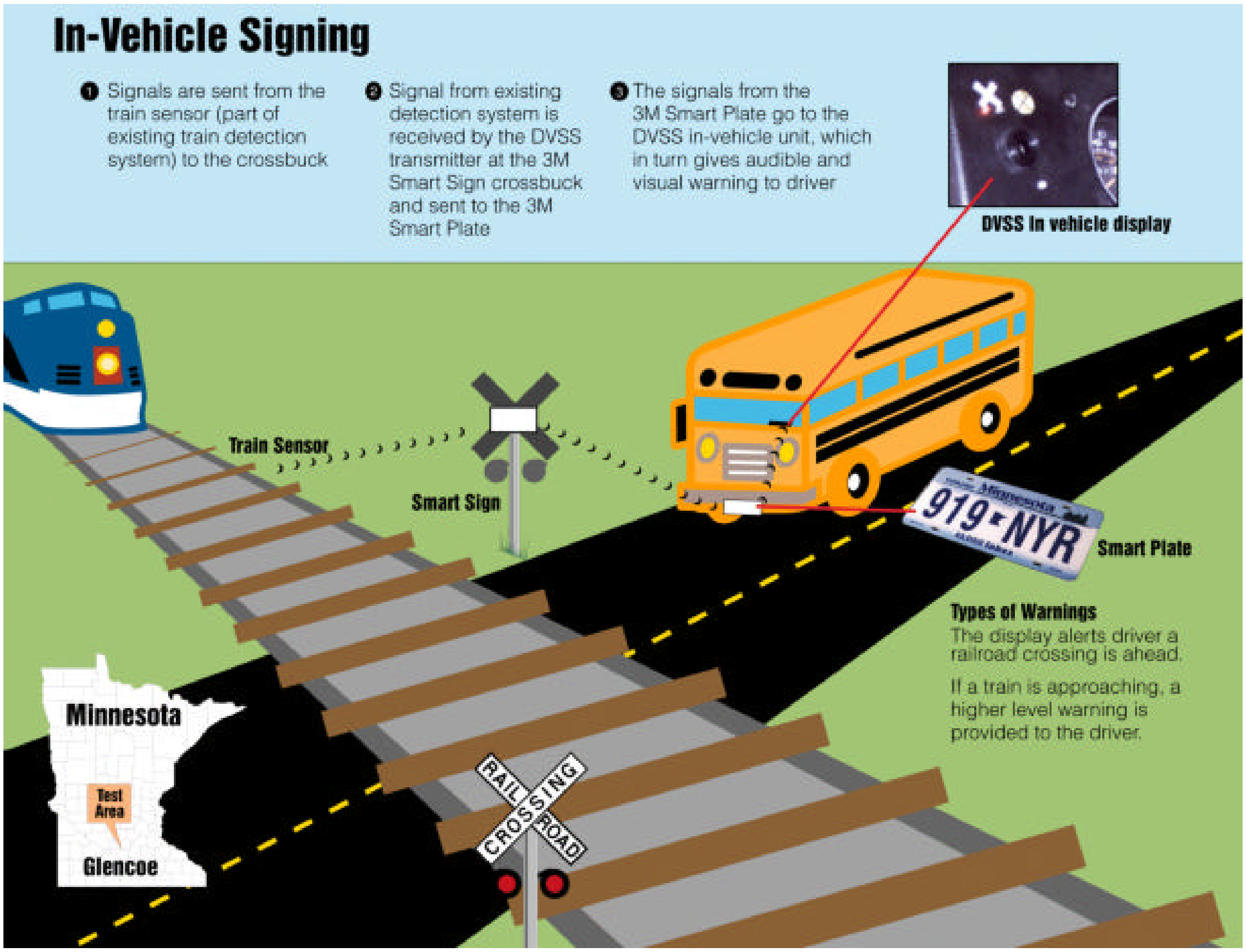
Figure 1 provides a schematic of the system in operation featuring the interaction of all of the major components. Figure 2 is a project location map indicating all of the test crossings in the City of Glencoe. The TC&W railroad line is aligned through the center of town, creating many railroad crossings. Five at-grade crossings located along bus routes were outfitted with the warning system. From west to east these crossings are as follows:

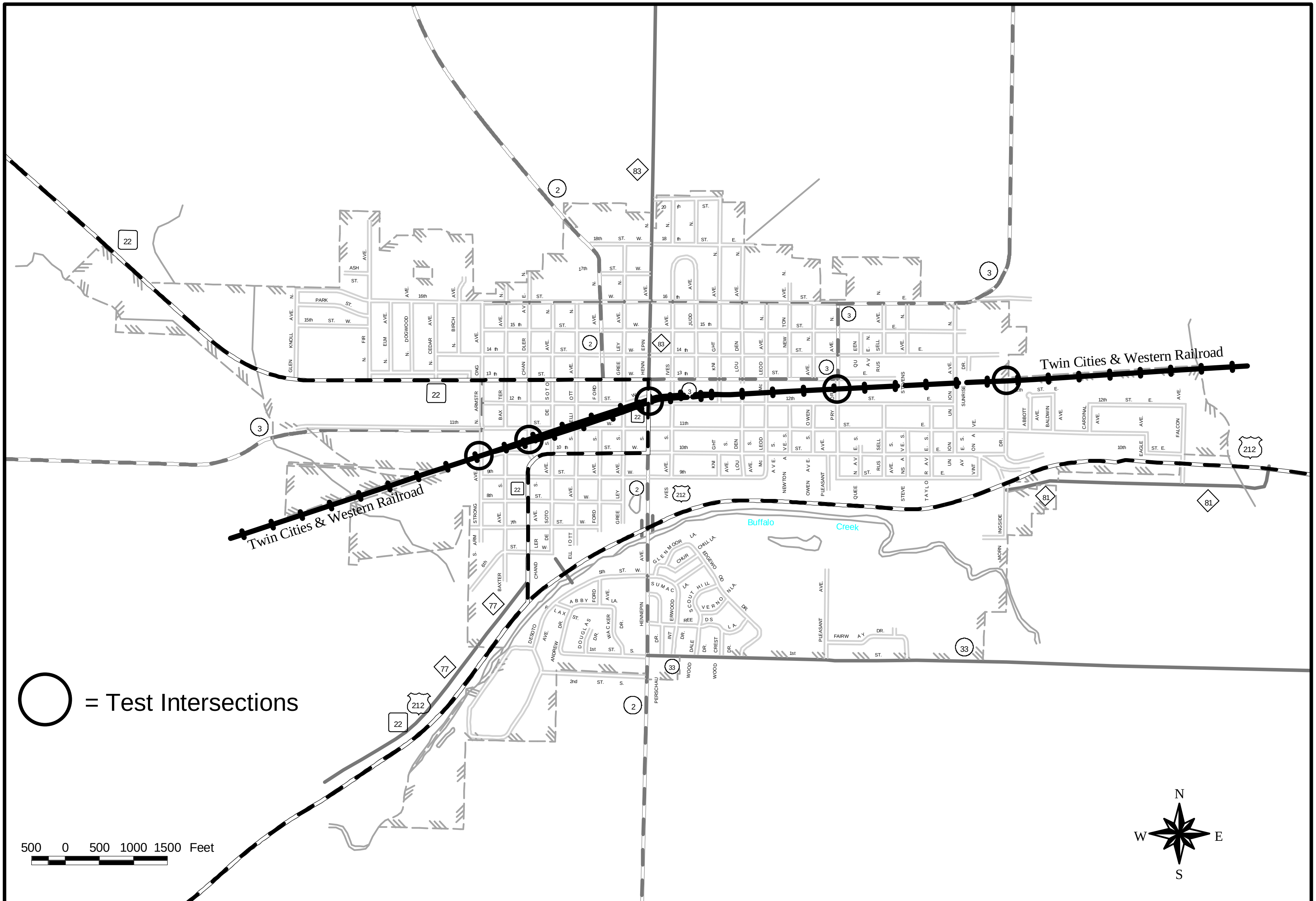
1. Armstrong Avenue
2. Chandler Avenue
3. Hennepin Avenue
4. Pryor Avenue
5. Union Avenue

C. EVALUATION OVERVIEW

There are few field deployed operational tests that address the effectiveness of in-vehicle signing systems. This evaluation provides qualitative and quantitative information on the performance of a fully deployed system. Given the low rate of accidents between school buses and trains, statistically significant data on accident reduction cannot be obtained in a one-year evaluation. Instead, the impact of the in-vehicle signing system was evaluated based primarily on changes in bus driver behavior and bus driver and train engineer perceptions of system usefulness.

Figure 1 System Schematic





SRF
CONSULTING GROUP, INC.

Project Location - City of Glencoe

In-Vehicle Signing for School Buses at Railroad - Highway Grade Crossings

Figure
2

Field data was collected to quantify the bus driver behavior at both the test location (Glencoe) and at the two control sites (Norwood and Shoreview). User perceptions were obtained from bus driver and train engineer surveys and interviews.

The scope of the in-vehicle signing project evaluation is comprised of two primary goals: to examine the impact of the system on driver behavior and to examine the performance of the technology used by the system. An individual test plan was developed for each of these goals. The data for this evaluation was collected from field observations, bus driver and train operator interviews, bus driver surveys and project maintenance and operation logs.

D. PROJECT COSTS

The in-vehicle signing project was funded by the Federal Highway Administration and the Minnesota Department of Transportation's Guidestar program. These organizations contributed \$120,000 and \$30,000 respectively. The funding was used for the system development/implementation conducted by DVSS and to fund the project evaluation conducted by SRF Consulting Group, Inc. The remaining project funding came from 3M and DVSS. These contributions played a critical role in the success of the project. Generous support from TC&W railroad and the Glencoe/Silver Lake School District was also critical to the project's success.

The In-Vehicle Signing System was evaluated as a test system under development because the system was not yet commercially marketed at the time this evaluation was conducted. Therefore, installation, maintenance, and product cost information was not available.

E. PROJECT TEAM

- Ben Osemenam, Mn/DOT Office of Advanced Transportation Systems – Project Manager
- James McCarthy, FHWA – Project Team Member
- Susan Gergen, Mn/DOT Office of Freight Railroads and Waterways – Project Team Member
- Tim Skogland, 3M – Project Team Member
- Jack Erick, DVSS – Project Team Member
- Erik Minge, SRF Consulting Group – Independent Evaluator

II. EVALUATION METHODOLOGY

The evaluation was divided into two test plans, each of which addresses a different aspect of the project evaluation. The first test plan examined the system's impact on railroad crossing safety. The second test plan explored the performance of the technology used to collect and disseminate the warning information.

A. INDIVIDUAL TEST PLAN ONE: EXAMINE THE IMPACT OF THE IN-VEHICLE SIGNING SYSTEM AT RAILROAD CROSSINGS

1. Evaluation Overview

The impact of the in-vehicle signing system was measured through bus driver behavioral changes. These changes included both quantifiable field observations of driver characteristics and qualitative feedback in the form of interviews and surveys. Baseline data was collected in order to determine bus driver behavior in areas without an in-vehicle signing system.

The following types of field data were collected by SRF Consulting Group personnel. Refer to the table below and to the sample data collection sheet in Appendix A.

Data	Collection Method
Bus Number	Manual observation
Time of Day	Manual observation
Bus Direction	Manual observation
Approach Speed	Manual measurement with radar gun
Dwell Time	Manual measurement with stop watch
Stop Distance	Manual measurement with pavement markings
Bus Empty/Non-empty	Manual observation
Scan Observation	Manual observation

A definition of some of these parameters is given below:

1. Dwell time was defined as the time it takes a bus to travel from a point 100 feet upstream of the tracks to the nearest rail of the tracks. In the initial data collection effort the duration of bus stop time was collected. However, this parameter was found to be a poor measure of driving behavior because some buses came to a near stop and then slowly accelerated after looking for a train, while other buses briefly came to a full stop and then continued. Dwell time was found to more fully capture the driving behavior as buses approached the tracks.

2. Stop distance was defined as the distance from the nearest rail of the crossing the point where the bus came to a stop. This parameter was measured by observing the bus's location in relation to paint marks placed on the road surface. Paint marks were placed at five foot intervals and data collection personnel recorded the bus's stopping location to the nearest five

feet. Since many buses did a rolling stop, the location where the bus reached its slowest speed was used.

3. Bus empty or non-empty is a measure of whether any children were on the bus (bus occupancy).

4. Driver scanning behavior is a qualitative measure of the driver's effort in checking for the presence of trains at a crossing. Three categories were used:
   - No Scan, the driver did not look both ways for a train
   - Brief Scan, the driver looked both ways for a train
   - Extensive Scan, the driver did the minimum required by law, turn on 4-way flashers, come to a full stop, and open the door and window to look both ways for a train.

2. Evaluation Objectives

The specific evaluation objectives, hypotheses, measures of effectiveness and data sources are as follows:

Evaluation Objectives	Hypotheses	MOEs	Data Sources
1-1 Identify changes in bus driver behavior caused by the system	1-1.1 The system does Not adversely impact driver Behavior	• Approach speed	Field observation
		• Dwell time	Field observation
		• Stop location	Field observation
		• Driver scanning behavior	Field observation
1-2 Identify bus driver perception of system's utility	1-2.1 The system enhances bus driver awareness of railroad crossings	• Bus driver perception of system effectiveness	Driver surveys, driver interviews, driver logs
	1-2.2 The system enhances bus driver awareness of train presence	• Bus driver perception of system effectiveness	Driver surveys, driver interviews, driver logs
	1-2.3 The bus drivers have confidence in the system	• Bus driver perception of system effectiveness	Driver surveys, driver interviews, driver logs

3. Baseline Data Collection Plan

The first step in identifying the changes in bus driver behavior caused by the system was to collect baseline data. Baseline data identified bus driver behavior in situations where an in-vehicle signing system was not deployed. Since the evaluation phase of this project did not start until after the system was installed, there was not an opportunity to obtain baseline data in Glencoe. As an alternative, baseline data was collected in Norwood and Shoreview where there is not an in-vehicle signing system.

The baseline data collection consists of both field observations of bus driver behavior and of bus driver surveys. Norwood was selected because it is on the same railroad line as Glencoe and thus has a similar amount of rail traffic. Norwood is also similar because it is a small rural school district. Shoreview was selected because there is a higher volume of rail traffic along the Burlington Northern rail line. The railroad crossing of Victoria Avenue near County Road E is located near two schools, increasing the odds of a school bus and train conflict.

The detailed baseline data collection schedule follows:

Day*	Location
Monday 3/2/98	Faxon Street - Norwood
Tuesday 3/3/98	Faxon Street - Norwood
Wednesday 3/4/98	Faxon Street - Norwood
Thursday 3/5/98	Faxon Street - Norwood
Monday 3/9/98	Faxon Street - Norwood
Monday 3/9/98	Bongards Creamery - Norwood
Tuesday 3/31/98	Victoria Street - Shoreview
Wednesday 5/6/98	Victoria Street - Shoreview
Monday 5/18/98	Victoria Street - Shoreview
Wednesday 5/20/98	Victoria Street - Shoreview
Thursday 5/21/98	Victoria Street - Shoreview

*All data collected in the p.m. period.

The following contingency plans were developed to accommodate any external influences that may affect the field data collection process:

- **Traffic congestion** could hinder bus movements near rail crossings. To address this influence each crossing was observed once and assessed for this problem. If significant, another location was selected.

- **Observation locations** could be limited at particular sites. The obvious presence of data collection personnel could influence the bus driver's behavior. If a concealed location could not be used, other locations were considered.

- **Frequency of trains** is usually low during the hours the school buses are in operation. The number of observations involving both a train and school bus was very low. TC&W was contacted to request that a train be sent on days when data collection was done.

In addition to field data collection, baseline bus driver surveys were administered in the Norwood/Young America School District. The baseline survey asked bus drivers the same questions regarding rail safety as the Glencoe bus drivers. A sample survey is provided in Appendix C on page C-1.

4. Glencoe Data Collection Plan

The ongoing data collection took place in Glencoe. The same types of data collected in the baseline locations were collected in Glencoe as well. Afternoon bus operations were observed from 2:30 to 3:30 p.m. The crossings of Pryor and Hennepin Avenues were selected for observation because the majority of the rail crossings occur at these locations. The spring data collection period consisted of roughly the same amount of data collection as the winter period, but with additional emphasis placed on interview and survey results. All bus drivers were interviewed at least once. Three series of surveys were administered.

The detailed Glencoe data collection schedule follows:

Location*	Number of days observed
Pryor Avenue	12
Hennepin Avenue	11

*All data collection will be in the p.m. period.

5. Data Analysis Plan

The data from each observation period was entered into a spreadsheet for analysis. Various statistical calculations including mean, range, standard deviation, confidence interval test, and Chi Squared tests were performed. The following were evaluated:

- Is there a correlation between bus driver behavior and the in-vehicle signing system?
- Is the difference between the baseline data and system data statistically significant?
- If there is no significant difference between the baseline and system data, then the focus needs to be on bus driver surveys and any other information available.
- What extent do extraneous influences such as individual driver differences, road geometrics, weather conditions, etc. have on the variability in the data?
- How much data needs to be collected to satisfy the test objectives?

Note that the vast majority of the data was collected when trains were not present. This infrequency of train activity made the number of bus/train conflicts very low and did not provide a statistically significant sample size. Thus it was not possible to compare bus driver behavior with and without trains present. Instead, data from Glencoe was compared to the behavior at crossings without an in-vehicle signing system.

B. INDIVIDUAL TEST PLAN TWO: EXAMINE THE PERFORMANCE OF THE TECHNOLOGY USED BY THE IN-VEHICLE SIGNING SYSTEM

1. Evaluation Overview

The performance of the in-vehicle signing system is of fundamental importance in evaluating the success of this project. The performance of the system includes assessments of system reliability and accuracy.

2. Evaluation Objectives

The specific evaluation objectives, hypotheses, measures of effectiveness and data sources are as follows:

Evaluation Objectives	Hypotheses	MOEs	Data Sources
2-1 Identify the system's reliability	2-1.1 The crossing warning system will perform reliably	• Type of crossing warning system failures	Driver surveys, driver interviews, driver logs, 3M logs
	2-1.2 The train warning system will perform reliably	• Type of train warning system failures	Driver surveys, driver interviews, driver logs, 3M logs
	2-1.3 The train detection equipment will perform reliably	• Type of train detection equipment failures	TC&W failure rates or average national rates
2-2 Identify the system's accuracy	2-2.1 The crossing warning system will activate when and only when crossings are approached	• Occurrence of false positive and false negative warning system failures	Driver surveys, driver interviews, driver logs, 3M logs
	2-2.2 The train warning system will activate when and only when a train is present	• Occurrence of false positive and false negative train warning system failures	Driver surveys, driver interviews, driver logs, 3M logs
	2-2.3 The train detection equipment will perform accurately	• Occurrence of false positive/false negative train detection failures	TC&W failure rates or average national rates

3. Data Collection Plan

Bus driver surveys and interviews were administered throughout the evaluation period. Three series of bus driver surveys and an interview of all bus drivers was conducted. Refer to Appendices B through F for the bus driver survey and interview results. In addition, surveys and other pertinent information were collected from 3M, DVSS and TC&W railroad.

The following data was assembled upon completion of the 1997/1998 school year:

- Bus driver surveys
- Bus driver interviews
- Bus driver logs
- TC&W railroad interviews
- 3M/DVSS logs

4. Data Analysis Plan

The interview and survey data collected from school bus drivers were analyzed to answer the following questions:

- Do bus drivers understand how the in-vehicle signing system works?
- Did the system work consistently at all crossing locations?
- Was the system more useful at one crossing than another?
- Do bus drivers feel more confidant in making stop-and-go decisions at the system crossings?
- Do bus drivers think the system is effective in improving crossing safety?
- Do bus drivers think the system should be installed on a permanent basis?
- Has the system changed bus driver behavior?
- Do bus drivers have any suggestions for improving the system?
- Did system start-up issues affect bus drivers' reaction to the system?

Interview data was collected from TC&W personnel including train engineers. The following were addressed:

- Did the in-vehicle signing system integrate smoothly with the railroad's in-place warning system?
- Was the system disruptive to normal rail operations?
- What school bus behaviors at rail crossings are most dangerous?
- Do railroad personnel think the system is effective in improving crossing safety?

III. STATISTICAL ANALYSIS

A. STATISTICAL APPROACH

Both the survey results and the manual field data were subjected to statistical analysis. Some data was non-parametric and required a probability distribution for analysis. In these cases a chi-squared test was used. The majority of the data lended itself to statistical test procedures using Z-tests or T-tests.

The first step in the statistical test process was to develop a set of Null Hypotheses. Inferential statistical tests were then used to test each hypothesis using the data collected in both Glencoe and the baseline locations. The purpose of the tests was to either prove or disprove the Null Hypotheses (denoted H_o). If sample evidence strongly suggested that H_o is false for a given confidence interval, then the hypothesis is rejected and the Alternative Hypotheses (denoted H_1) accepted. A confidence interval of 95% was used for all tests.

The minimum sample size, such as the number of dwell time field observations, is a function of the desired confidence interval. A greater variance in data requires a larger sample size in order to obtain a statistically significant analysis. The statistical test used to evaluate the null hypotheses depended on the sample size and the nature of the sample data. If the sample data was normally distributed then either a T-test or a Z-test was used. A T-test was used when the sample size is 30 or less. For sample sizes greater than 30, a Z-test was used.

B. NULL HYPOTHESES

The first step in the statistical process was to develop a set of test hypotheses. The following Null Hypotheses (H_o) and Alternative Hypotheses (H_1) were proposed for test Objective 1-1 (see page 7), *Identify changes in bus driver behavior caused by the system*:

H_o: There **is not** a statistically significant difference in **approach speeds** for buses in Glencoe compared to buses in baseline locations
H_1: There **is** a statistically significant difference in **approach speeds** for buses in Glencoe compared to buses in baseline locations

H_o: There **is not** a statistically significant difference in **dwell time** for buses in Glencoe compared to buses in baseline locations
H_1: There **is** a statistically significant difference in **dwell time** for buses in Glencoe compared to buses in baseline locations

H_o: There **is not** a statistically significant difference in **stopping location** for buses in Glencoe compared to buses in baseline locations
H_1: There **is** a statistically significant difference in **stopping location** for buses in Glencoe compared to buses in baseline locations

H_o: There **is not** a statistically significant difference in **driver observation behavior** for buses in Glencoe compared to buses in baseline locations

H_1: There **is** a statistically significant difference in **driver observation behavior** for buses in Glencoe compared to buses in baseline locations

H_o: In **Glencoe,** there **is not** a statistically significant difference in **driver observation behavior** for **empty** buses compared to **non-empty** buses

H_1: In **Glencoe,** there **is** a statistically significant difference in **driver observation behavior** for **empty** buses compared to **non-empty** buses

H_o: In **baseline locations,** there **is not** a statistically significant difference in **driver observation behavior** for **empty** buses compared to **non-empty** buses

H_1: In **baseline locations,** there **is** a statistically significant difference in **driver observation behavior** for **empty** buses compared to **non-empty** buses

C. T-TESTS AND Z-TESTS

After the field data was collected it was inspected to see if it was normally distributed. The following normality tests were performed:

1. Unimodal distribution
2. Median value close to mode
3. Arthimetic mean close to mode

Normally distributed data has a symmetric and bell shaped distribution. The data is centered about the mean value and is spread out to an extent determined by the standard deviation. Normally distributed data is unimodal, meaning the distribution has only one peak. The median value is defined as the central data value, the mode value is defined as the data value that occurs most frequently, and the arithmetic mean is defined as the average of the data values. These three tests will be used to determine if the data collected is normally distributed.

After verifying the data was normally distributed, T-tests and Z-tests were applied. Each of the three nominal data sets were analyzed: dwell time, stop distance and approach speed. The results were prepared to determine if a significant difference exists between the data sets. For example, in regards to dwell time, Pryor Avenue data was compared to baseline data to determine if the data sets were significantly different.

To perform the T-tests and Z-tests, the mean of each data set, standard deviation of each data set, sample size, and confidence interval are required. The following assumptions and test procedures were used to determine significant statistical difference between data sets:

- Z value: 1.96 for a 95% confidence interval
- Test: Absolute value of ($mean_1$ - $mean_2$) >=< 1.96 x Standard Deviation*
- *Where: Standard Deviation = ($s_1^2/n_1 + s_2^2/n_2$)

The hypothesis testing involved collecting a sample of data and making inferences about the population as a whole. The resulting statistical findings are subject to the chance that a type I or a type II error has occurred. These errors are defined as follows:

Type 1 error: A type I error is the chance of **rejecting** the null hypothesis (H_0) when it is **true**. The level of significance is the probability of a type I error occurring and is denoted as "α".

Type 2 error: A type II error is the chance of **not rejecting** the null hypothesis (H_0) when it is **false**. The probability of a type II error occurring and is denoted by "β".

Ideally, it is desired to minimize the chances of type I and type II errors. Standard test procedures allow the user to control the probability of a type I error occurring, but provides no direct control over the probability of a type II error occurring. For example, if the probability of a type I error occurring is chosen to be very small, such as 0.01 or 1%, the probability of a type II error occurring will increase. A compromise between the probability of a type I error and the probability of a type II error must be made. For this test a five percent probability of a type I error (five percent level of significance) was used.

D. CHI-SQUARED TESTS

Data such as the bus driver scanning behavior and bus loading (empty vs. non-empty) required non-parametric analysis tools. These data types can be subjected to bivariate categorical analysis using the chi-squared test. Bivariate categorical analysis refers to an analysis involving two types of data such as, driver scanning behavior and bus occupancy. Bivariate categorical analysis using the chi-squared test is an approximation based on a type of probability distribution called a chi-squared distribution. The following chi-squared tests were conducted. They were derived directly from the null hypotheses identified in the preceding section.

1. Significance between driver scanning behavior and test location
2. Significance between driver scanning behavior and bus occupancy in Glencoe
3. Significance between driver scanning behavior and bus occupancy in baseline locations

The first step in conducting this test was to construct contingency tables for the categories under examination. These tables are used to calculate the expected values. Next the chi-squared values were compared for each test. The chi-squared test statistic (X^2) was calculated by summing the square of the differences between the observed and expected values and dividing by the expected value. Specifically, $X^2 = \Sigma$ (observed data - expected data)^2 / expected data. When discrepancies between the observed and expected data are large, X^2 is large. When discrepancies between the observed and expected data are small, X^2 is small.

Chi-squared critical values ($X^2_{critical}$) are tabulated and can be determined from the degrees of freedom and the desired level of significance. A 5 percent level of significance was used in this analysis, corresponding to a confidence level of 95%. The null hypotheses was tested by comparing X^2 and $X^2_{critical}$. $X^2 < X^2_{critical}$ implies a significant difference exists between Glencoe and the baseline data. If this occurs the null hypothesis is accepted. $X^2 > X^2_{critical}$ implies that no significant difference exists between the Glencoe and the baseline data. If this occurs the null hypothesis is rejected and the alternative hypothesis is accepted.

IV. RESULTS

The results presented in this section have been organized to provide a brief overview of the findings followed by a more detailed presentation of results for each test objective. The first section is a summary of results, the next section includes a discussion of the test setup and the data collection approach. The subsequent sections provide additional detail including the findings for each survey, interview, and field data parameter. Finally, the appendices provide further detail on all data collected.

A. SUMMARY OF RESULTS

Individual Test Plan Number One examined the qualitative and quantitative impacts of the in-vehicle signing system. The results from this test plan are summarized by the test hypotheses and Measures of Effectiveness as identified in the table below.

Evaluation Objectives	Hypotheses	MOEs	Result
1-1 Identify changes in bus driver behavior caused by the system	1-1.1 The system does not adversely impact driver behavior	• Approach speed	No significant change
		• Dwell time	No significant change
		• Stop location	No significant change
		• Driver scanning behavior	No significant change
1-2 Identify bus driver perception of system's utility	1-2.1 The system enhances bus driver awareness of **railroad crossings**	• Bus driver perception of system effectiveness	Bus drivers perceive the system to be effective in enhancing awareness of railroad crossings
	1-2.2 The system enhances bus driver awareness of **train presence**	• Bus driver perception of system effectiveness	Bus drivers perceive the system to be effective in enhancing awareness of train presence
	1-2.3 The bus drivers have confidence in the system	• Bus driver perception of system effectiveness	Bus drivers are split in their confidence in the system

Individual Test Plan Number Two examined the performance of the technology used in the in-vehicle signing system. Elements of the system's reliability and accuracy were also examined. The results from this test plan are summarized by test hypotheses and Measures of Effectiveness as presented in the table below.

Evaluation Objectives	Hypotheses	MOEs	RESULTS
2-1 Identify the system's reliability	2-1.1 The **crossing** warning system will perform reliably	• Type of crossing warning system failures	Reliable[1]
	2-1.2 The **train** warning system will perform reliably	• Type of train warning system failures	Reliable[1]
	2-1.3 The train detection equipment will perform reliably	• Type of train detection equipment failures	Reliable
2-2 Identify the system's accuracy	2-2.1 The **crossing** warning system will activate when and only when crossings are approached	• Occurrence of false positive and false negative warning system failures[2]	False negative and false positive warning failures did occur, but unable to quantify[2]
	2-2.2 The **train** warning system will activate when and only when a train is present	• Occurrence of false positive and false negative train warning system failures[2]	False negative warning failures did occur, but unable to quantify[2]
	2-2.3 The train detection equipment will perform accurately	• Occurrence of false positive/false negative train detection failures	The train detection equipment performed accurately

Notes:

1. Some failures were noted, they can be attributed to one of the following:
   - Installation of non-production components
   - Bus driver misunderstanding of system operation
   - Other problems that diagnostic investigation could not verify
2. False negative/false positive warnings are defined as follows:
   - False negative warnings are defined as the system failing to issue a warning when in the proximity of a railroad crossing/presence of a train.
   - False positive warnings are defined as the system issuing a warning when not in the proximity of a railroad crossing/ presence of a train.

B. DETAILED RESULTS

Detailed results on each objective, hypothesis, and Measure of Effectiveness (MOE) are presented in this section.

Objective 1-1: Identify changes in bus driver behavior caused by the system

Hypothesis 1-1.1 The system does not adversely impact driver behavior

1. Approach Speed
   Approach speed was selected for analysis because it provides a measure of the degree of safety being practiced by drivers approaching crossings. The speed of buses was captured with a radar gun when they were at a distance of approximately 100 feet from the crossing. Due to limited radar gun availability, only a few data collection periods included approach speed data.

Results: A significant difference does not exist in approach speeds between the Pryor Avenue crossing in Glencoe and the Faxon Avenue crossing in Norwood. However, a significant difference does exist in approach speeds between the Hennepin Avenue crossing in Glencoe and the Faxon Avenue crossing in Norwood. The mean approach speed in Glencoe was approximately 19.0 miles per hour and the mean approach speed in Norwood was approximately 22.5 miles per hour. The data is too variable and the difference in locations is too significant to draw sound conclusions on the system's impact on driver behavior.

2. Dwell Time
   Dwell time was measured for every bus approaching a crossing. The dwell time was arbitrarily defined as the time a bus dwelled in a zone between the railroad tracks and a point 100 feet upstream.

Results: There was not a statistically significant difference in dwell time at crossings in Glencoe versus crossings in the baseline locations. However, when comparing winter to spring, a statistically significant difference did exist between Glencoe and the baseline location. The average dwell time for Glencoe and the baseline in the winter was approximately 7 seconds, and in the spring it was approximately 13 seconds. No factors were identified that could explain the difference between the two seasons. This result is most likely not related to the in-vehicle system.

3. Stop Location
   The distance from where a school bus stopped to the nearest railroad track was used as a measure of driver behavior. Paint marks were placed on the pavement at five foot intervals to aid in the stopping measurement. In many situations the buses did not come to a full stop, in these cases the stop location was assumed to be the point where the bus was traveling the slowest.

Results: There was not a statistically significant difference in stop distance at crossings in Glencoe versus crossings in the baseline location in the spring. However, a statistically significant difference did exist in stop distance between Glencoe and the baseline locations in the winter. No factors were identified that could explain the difference between the two seasons. This result is most likely not related to the in-vehicle system

4. Driver Scanning Behavior
   School bus drivers are required to come to a full stop, activate their 4-way flashers, and open their door and window to obtain an unobstructed view of the railroad tracks in both directions. School bus driver behavior was observed at all crossings in order to ascertain how well they performed the required railroad crossing scanning procedure. Three levels of observations were used: none, brief, and extensive.

Results: There was not a statistically significant difference in driver observations at crossings in Glencoe versus crossings in the baseline locations in the spring. However, a statistically significant difference did exist in driver observations between Glencoe and the baseline locations in the winter. In Glencoe, the drivers at Hennepin Avenue did an extensive scan 58 percent of the time. At Pryor Avenue, 66 percent of drivers performed an extensive scan. In Norwood 5 percent of drivers performed an extensive scan. In Shoreview 75 percent of drivers performed an extensive scan. The frequency of trains at these different test sites may have an influence on the driver's scanning behavior. Permanent and/or temporary obstructions potentially increase the extent of a driver's scanning behavior.

When examining the results obtained from the field data collected, it is important to remember that a true baseline condition was not established. Instead of collecting before and after data in Glencoe, the data from Glencoe was compared to data in Norwood and Shoreview. The crossings in Norwood and Shoreview have different train frequencies, approach geometrics, and driver populations. In addition, the presence of field data collection personnel may have introduced a bias to bus driver behavior at all test locations.

Objective 1-2: Identify bus driver's perception of system utility

The bus driver and train engineer survey and interview data was aggregated to obtain the following results. In addition, a statistical analysis was performed on the questions that lent themselves to this type of analysis. The mean and standard deviation were calculated where applicable. Refer to Appendices B through F for the detailed bus driver and train engineer interview and survey results.

Hypothesis 1-2.1 The system enhances driver awareness of railroad **crossings**

Bus drivers were interviewed and surveyed in order to obtain their perception of the system's effectiveness in enhancing their awareness of railroad crossings. This hypothesis addresses the awareness of crossings only, the presence of trains is addressed in Hypothesis 1-2.2.

Results: The system was found to enhance driver awareness of railroad crossings. It is important to note that the deployment of this project also played a role in enhancing driver awareness. It is difficult to separate the effect of the system from the effect of the publicity that accompanied the project.

Hypothesis 1-2.2 The system enhances driver awareness of **train** presence

Bus drivers were interviewed and surveyed in order to obtain their perception of the system's effectiveness in enhancing driver awareness of a train's presence. This hypothesis differs from Hypothesis 1-2.1 because it identifies the driver awareness of train presence, rather than awareness of the crossing itself.

Results: The system was found to enhance driver awareness of train presence. An interview with one of the bus drivers provided a good example of how the system can improve safety at railroad-highway grade crossings: the driver was preoccupied with maintaining order in the bus and, as she approached a rail crossing, the in-vehicle signing system warned her of an approaching train. Immediately her attention was drawn into focus on the crossing. A nearby building partially obstructed her view of the train's approach, making the warning information particularly useful.

Hypothesis 1-2.3 The bus drivers have confidence in the system

Bus drivers were interviewed and surveyed to determine their confidence in the system. Confidence includes qualitative measures such as driver perception of reliability.

Results: The bus drivers were found to have varying opinions on their confidence in the system. Some drivers felt very confident in the system, while others had varying levels of confidence. The system performance at Hennepin Avenue was a factor in shaping driver confidence. At this location the directional feature was disabled, causing the system to activate when vehicles were not approaching the crossing. This is not considered a failure, since the system was operating as intended, but this did have the effect eroding driver confidence in the system.

Objective 2-1: Identify the system's reliability

Hypothesis 2-1.1 The **crossing** warning system will perform reliably

In this hypothesis the types of crossing warning system failures are measured. This hypothesis addresses the system's reliability to indicate proximity to crossings. The presence of trains is addressed in Hypothesis 2-1.2. Bus driver interviews and surveys and 3M/DVSS interviews are the primary data sources.

Results: The system is fairly reliable; there were some crossing warning failures. Due to difficulty in quantifying the system's performance, the primary measure of reliability is driver surveys. In survey number three, for example, bus drivers were asked if the *over the past two weeks, has the system in your bus worked consistently?* A total of 8 respondents indicated the system had **always worked**. a total of 6 indicated the system **usually worked**, 1 indicated the system **sometimes worked**, and 1 indicated the system **never worked**. The results from survey four were similar, refer to Appendices D and E.

There are various causes for these failures:

- Some system failures are due to the fact that this is a test and the products being evaluated are not final production units. These test units have been susceptible to corrosion and water damage that a final product would not.
- Another problem encountered involves bus driver misunderstanding of the system operation. In some cases drivers continued to report problems with their systems when they were actually functioning as designed, particularly at the Hennepin Avenue crossing. At this location the compass function was disabled to accommodate unique crossing geometrics. Without this function vehicles received a warning signal when in the vicinity of the crossing, but not actually approaching the crossing. Drivers frequently identified this as a system failure when in fact the system was functioning as intended.
- In other cases system problems indicated by drivers could not be identified by project personnel.

A review of the types of failures indicates that nothing inherent in the technology used in this project could be identified as a cause for problems in the system's performance.

Hypothesis 2-1.2 The **train** warning system will perform reliably

In this hypothesis the types of train warning system failures are measured. This hypothesis addresses the system's reliability to indicate the presence of oncoming trains. Bus driver interviews and surveys and 3M/DVSS interviews are the primary data sources

Results: The system is fairly reliable; there were some crossing warning failures. The same failure issues described in the previous hypothesis apply to train presence warning failures as well.

Hypothesis 2-1.3 The train detection equipment will perform reliably

The measure for this hypothesis are the types of existing train detection equipment failures. TC&W interviews and national statistics are the primary data sources.

Results: Failure rates for modern train detection equipment is very low. There was no evidence to suggest failures in the existing train detection equipment.

Objective 2-2: Identify the system's accuracy

Hypothesis 2-2.1 The **crossing** warning system will activate when and only when crossings are approached

In this hypothesis the occurrence of false positive and false negative warning system failures are measured. False negative warnings are defined as the system failing to issue a warning when in the proximity of a railroad crossing. Similarly, false positive warnings are defined as the system issuing a warning when not in the proximity of a railroad crossing. This hypothesis addresses the system's accuracy in indicating the proximity to crossings. Hypothesis 2-2.2 examines train presence.

Results: False negative and false positive crossing warning failures did occur, but accurately quantifying these events was difficult because there was no way to record a failure. Instead surveys and interviews of bus drivers were used to identify the occurrence of failures.

False positive failures were particularly difficult to identify because most of these failures were related to the system at Hennepin Avenue. At this location the directional feature was disabled, causing the system to activate when vehicles were not approaching the crossing. This is not considered a failure, since the system was operating as intended, but this did have the effect eroding driver confidence in the system.

Hypothesis 2-2.2 The **train** warning system will activate when and only when crossings are approached

In this hypothesis the occurrence of false positive and false negative train warning system failures are measured. This hypothesis addresses the system's accuracy in indicating the presence of trains. Note that the occurrence of false negative failures can create a dangerous crossing situation, especially if drivers become complacent and do not rely on their own judgment at crossings.

Results: No false positive failures were identified. False negative failures, however, did occur, but quantifying this event was difficult because there was no way to record a failure. Instead surveys and interviews of bus drivers were used to identify the failures. Surveys 3 and 4 asked drivers if the system failed to warn of the presence of a train. One of 17 drivers indicated their system had failed, indicating a false negative failure, refer to Appendices D and E.

Hypothesis 2-2.3 The train detection equipment will perform accurately

In this hypothesis the occurrence of false positive and false negative failures of the existing train detection equipment are measured.

Results: While this was not thoroughly explored, the train detection equipment was observed to perform accurately. No information suggested the detection ever failed to operate correctly.

C. BUS DRIVER SURVEY FINDINGS

1. Initial Glencoe Bus Driver Survey Results (Survey Number 1)

Fifteen school bus drivers in the Glencoe study area were surveyed to obtain data on school bus operation safety issues. This survey was conducted in December 1997 shortly after the system was installed. Because the system was inplace and the drivers had received training, the survey did not capture true baseline conditions. As an alternative, a baseline survey was administered in the nearby city of Norwood (see survey number 2, Appendix C). In questions one, three, and four, bus drivers were asked to rank several statements according to importance. The average ranking was used to present the survey results. The full interview form and results are available in the Appendix B.

2. Baseline Bus Driver Survey Results (Survey Number 2)

Eleven school bus drivers in the Norwood School District were surveyed to obtain data on school bus operation safety issues. Norwood was used to provide baseline data because the drivers had minimal knowledge of the in-vehicle signing system deployed in Glencoe. In questions one, three and four bus drivers were asked to rank several statements according to importance. The average ranking was used to present the survey results. The survey form and complete results are available in Appendix C.

3. Glencoe/Baseline Bus Driver Survey Comparison (Survey numbers 1 and 2)

In this section the initial survey conducted in Glencoe is compared to the baseline survey conducted in Norwood. Identical questions were presented to each of these groups in order to identify differences in bus driver attitudes regarding rail crossing safety issues. Most of the questions produced very similar results. However, question seven introduced a significant difference between the two groups.

Results from question seven indicate the majority of the Glencoe bus drivers do not feel comfortable relying on an automatic train warning system at railroad crossings. Nine of the 15 bus drivers said they disagreed strongly with the statement “I feel comfortable relying on an automatic train warning system at railroad crossings”.

Bus drivers in Norwood, however, showed an even mixture of responses to question seven, relying on an automatic system. (Note that the term “automatic train warning system” was intentionally left undefined so that drivers would not be forced to consider the in-vehicle signing system deployed in Glencoe. Some drivers may have interpreted this to mean a track-side warning while other drivers with knowledge of the in-vehicle signing system deployed in Glencoe may have used this interpretation.) A possible explanation for the reluctance of Glencoe drivers to rely on the automatic warning system may be due an increased awareness that this project has brought to safety procedures.

Interestingly, the responses to every other question from both groups of drivers were very similar. Similarity in bus driver safety awareness programs from one school bus company to the next is one possible explanation for this phenomenon. The population and size of the urban areas in which the study took place is another possible explanation. It is also possible that safety issues concerning school buses remain constant throughout all geographical locations. Another likely reason is that Glencoe bus drivers have increased their awareness towards crossing safety as a result of this project - they have been told that an automatic train warning system serves a supplemental function and they must still rely on their own senses.

4. Ongoing Glencoe Bus Driver Survey Results (Survey Numbers 3 and 4)

Additional surveys were administered to Glencoe bus drivers in order to determine the performance of the system and document any changes in bus driver perception of the system. The survey form and complete results are available in Appendix D and E.

D. BUS DRIVER INTERVIEW FINDINGS

Twenty bus drivers in the Glencoe/Silver Lake School District were interviewed to obtain their personal observations of the in-vehicle signing system. All of the interviews were conducted by SRF Consulting Group personnel. While each individual interview is important, the interview findings show a predominant response for each question, lending themselves to a summarized response format. A summary of the interview responses is given below, the full interview form and results are available in Appendix F.

1. *What does the display do when you approach a crossing? What if a train is coming?*

- Ninety percent of the bus drivers knew the warning system's functions at railroad crossings.
- All the bus drivers were aware the warning system flashes yellow and beeps when approaching a crossing.

2a. Do you think the display is effective in improving crossing safety?

- Eleven respondents think the system is effective in improving railroad crossing safety. Three did not think the system was. Three said they "didn't really think it helped". Three were undecided.
- The majority of the drivers feel like the system is an extra tool that makes a person more observant. The drivers all agreed that the system should not be relied upon 100%.

Instead, reliance on oneself, experience, and good decision making are the most important tools.

2b. Do you feel more confident with your stop and go decisions?

- Thirteen bus drivers indicated they did not feel more confident in their stop and go decision because of the system. Three felt more confident. Two thought the system helped them. One driver felt the same with or without the system. In general, the drivers only rely on themselves.

3. Would you recommend that this display be installed in your bus permanently?

- Sixteen driver's thought the system should be permanently installed, two were not sure if it would be beneficial, and two said they did not think it should be installed. Some yes answers were followed by a justification, which can be seen in Appendix F.

One driver who was against the system being installed noted the system was another headache on a noisy bus. Another driver indicated the volume should be adjustable because every bus is different.

4. Has your behavior changed with the display installed in your bus?

- Seventeen drivers said the system has not changed their behavior. Three drivers said the system made them "more aware".
- In general, the drivers said they know their routes and know when to stop. Some drivers were irritated with the system and didn't want to change their habits because they knew the system was temporary.

5. Do you have any other suggestions, such as how to improve the display?

A common response to this question was the desire to have the system installed in more locations, especially locations where drivers were less familiar with the crossing locations.

6. Do you have any problems with the system?

The majority of the problems with the system were items that were identified and corrected during the system installation. Some drivers reported problems in rain and a few other conditions, refer to Appendix F.

E. TC&W TRAIN ENGINEER INTERVIEW FINDINGS

Two TC&W train engineers were interviewed regarding how the in-vehicle signing system incorporated with normal rail operations. The interview was conducted by SRF Consulting Group Personnel. Detailed interview results can be found in Appendix F.

1. *Did the in-vehicle signing system integrate smoothly with the railroad's inplace warning system?*
2. *Was the system disruptive to normal rail operations?*

   - According to the TC&W train engineers, the in-vehicle signing system was non-disruptively integrated with the railroad's inplace warning system.

3. *What school bus behaviors at rail crossings are the most dangerous?*

   - Violations at gated and non-gated crossings are worse in rural than in metro areas. Because of this added danger, the system would be more useful at rural locations. Train Engineers have observed many motorists going through rural or passive locations without looking. An in-vehicle signing system would cue drivers to be more careful at certain crossings.

4. *Do railroad personnel think the system is effective in improving crossing safety?*

   - The railroad personnel indicated the system has had a positive effect on bus driver behavior at rail-highway crossings. For example, when a train was idle near a crossing, the buses used to stop, look at a train, and determine it was not moving, and then go, regardless of the trackside warning signal. Now drivers wait for the signal to go out before proceeding across the tracks
   - The railroad personnel definitely think the system improves crossing safety and hope the system becomes universal (i.e. by expanding to other crossings and other vehicles such as trucks). Trucks are more of a concern than passenger cars because they cause significantly more damage in a train/vehicle collision. However, the railroad personnel added that "machines don't take the place of human eyes" and not to rely on the system 100%. Also, the system doesn't cure dangerous behavior; drivers would be just as likely to violate crossings if they had an in-vehicle signing system.

F. MANUAL FIELD DATA COLLECTION FINDINGS

Extensive dwell time, stop distance, and approach speed data were collected in Glencoe and the baseline locations. The mean, standard deviation, and other statistical parameters were calculated for each of these measures (see Table 1 - Summary of Field Data). The data was then inspected for normality. As seen in Table 1, the only subset of the field data that did not meet the normality criteria was the Faxon Avenue dwell time during the winter data collection period. This data failed because it did not appear to have a unimodal distribution. The distribution for each of these data sets is provided in Appendix H, Summarized Field Data.

Preliminary inspection of the field data reveals a significant variation within each data set. Notice that the standard deviation for each data point is quite large, blurring the distinction between parameters observed from location to location and from season to season. See pages G-1 to G-5 in Appendix G for a visual representation of the data variability. The graphs are generated by plotting the mean for each test site and then adding and subtracting one standard deviation.

Preliminary inspection of the field data also reveals a substantial variation from one data set to another. For example, the data collected in the winter varies greatly from the data collected in the spring. Figures 3 through 5 display the distribution of dwell time data in the winter and dwell time data in the spring for Pryor Avenue, Hennepin Avenue, and Victoria Street at County Road E. The winter data clearly exhibits a lower average dwell time than the spring data. No obvious explanation can account for this difference. Are bus drivers less likely to slow down in the winter because they need their momentum to surmount the vertical crest at the rail crossings? Are the drivers driving more cautiously in the spring because there are more children walking home from school? Or perhaps the presence of field data collection personnel affected the bus driver behavior differently in the winter versus spring.

While the cause of these variations is unclear, it does indicate a problem with the field data that makes drawing strong conclusions about the dwell time, stop distance, and approach speed parameters questionable. The test hypotheses seek to determine whether the in-vehicle signing system has an impact on driver behavior. This impact is difficult to determine, especially given the assumption that bus driver behavior in Glencoe is comparable to bus driver behavior in the baseline locations (Glencoe could not be used as a baseline location because the evaluation did not begin until after the Glencoe bus drivers had been trained on the system).

The dwell time, stop distance, and approach speed field data were statistically and graphically analyzed after the field data collection was complete. The hypotheses were tested with T-tests and Z-tests as described earlier. Given the unexpected differences between the winter and spring data, a test was first done to determine if there was a significant difference between the two seasons. Five out of the six tests revealed a significant difference between the two data sets (see Table 2). As a result of this test, the winter and spring data sets were examined independently of one another. In the winter, five out of ten tests revealed a significant difference and in the spring one out of four tests revealed a significant difference (see pages G-6 and G-7 in Appendix G). Further detailed statistical analysis was done with this data, but no clear conclusions about the impact of the in-vehicle signing system could be made.

Table 1 - Summary of Field Data

Winter Data

Dwell Time

Location	*Mean*	*Standard Deviation s*	Sample Size *n*	*Median*	*Mode*	*Unimodal?*	*Normal?*
Glencoe-Pryor Ave.	6.76	2.2	94	6.8	6.8	Yes	Yes
Glencoe-Hennepin Ave.	7.39	1.2	76	7.1	5.9	Yes	Yes
Baseline-Faxon Ave.	10.03	2.9	21	8.9	8.9	No	No
Baseline-Vict. St. & C.R. E	6.84	0.8	16	6.9	5.8	Yes	Yes

Stop Distance

Location	*Mean*	*Standard Deviation s*	Sample Size *n*	*Median*	*Mode*	*Unimodal?*	*Normal?*
Glencoe-Pryor Ave.	24.67	7.1	122	23.0	20.0	Yes	Yes
Glencoe-Hennepin Ave.	24.26	6.3	128	25.0	25.0	Yes	Yes
Baseline-Faxon Ave.	22.50	6.1	22	20.0	20.0	Yes	Yes
Baseline-Vict. St. & C.R. E	26.35	3.6	23	25	25.0	Yes	Yes

Approach Speed

Location	*Mean*	*Standard Deviation s*	Sample Size *n*	*Median*	*Mode*	*Unimodal?*	*Normal?*
Glencoe-Prior Ave.	19.00	4.8	8	20.0	20.0	Yes	Yes
Glencoe-Hennepin Ave.	19.30	2.5	21	19.0	19.5	Yes	Yes
Baseline-Faxon Ave.	22.40	2.3	10	20	20.0	Yes	Yes

Spring Data

Dwell Time

Location	*Mean*	*Standard Deviation s*	Sample Size *n*	*Median*	*Mode*	*Unimodal?*	*Normal?*
Glencoe-Prior Ave.	13.08	4.1	84	12.2	12.0	Yes	Yes
Glencoe-Hennepin Ave.	14.21	4.9	55	12.9	11.6	Yes	Yes
Baseline-Vict. St. & C.R. E	12.70	8.8	109	10.8	9.0	Yes	Yes

Stop Distance

Location	*Mean*	*Standard Deviation s*	Sample Size *n*	*Median*	*Mode*	*Unimodal?*	*Normal?*
Glencoe-Prior Ave.	24.67	7.1	88	20.0	20.0	Yes	Yes
Glencoe-Hennepin Ave.	26.58	6.2	101	30.0	30.0	Yes	Yes
Baseline-Vict. St. & C.R. E	23.20	3.8	125	25	25.0	Yes	Yes

Figure 3 - Pryor Avenue, Dwell Time

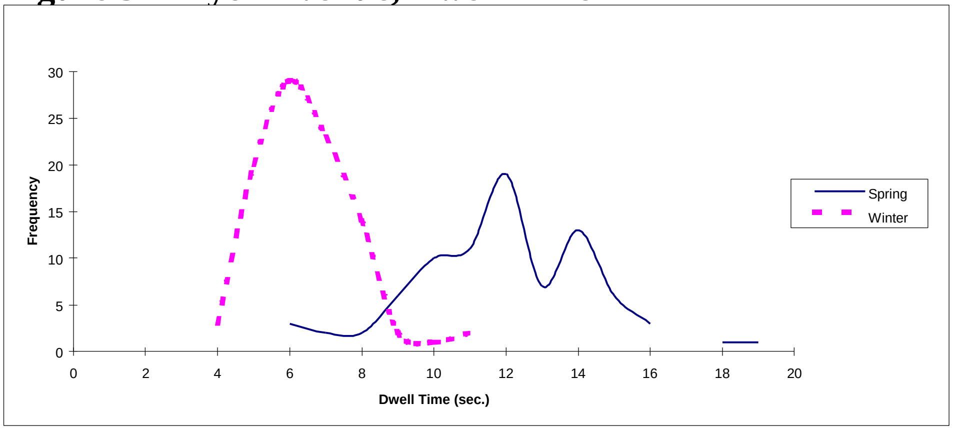


Figure 4 - Hennepin Avenue, Dwell Time

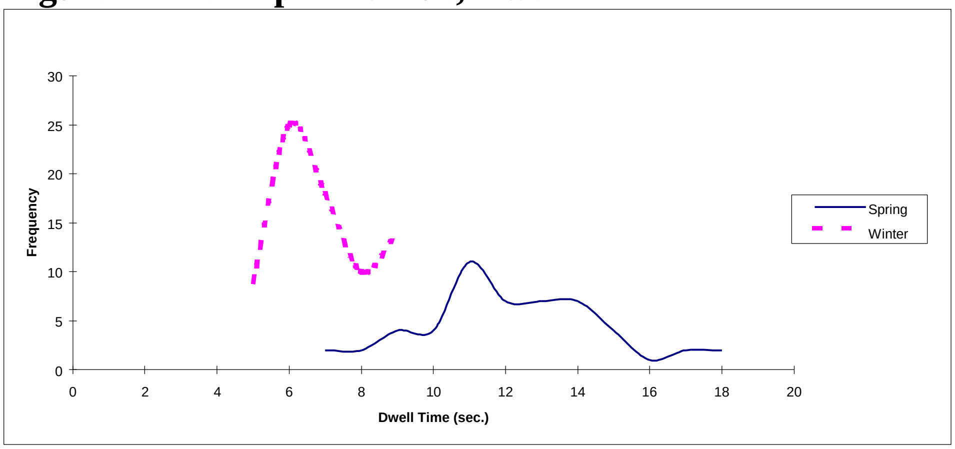


Figure 5 - Victoria St. and C.R. E, Dwell Time

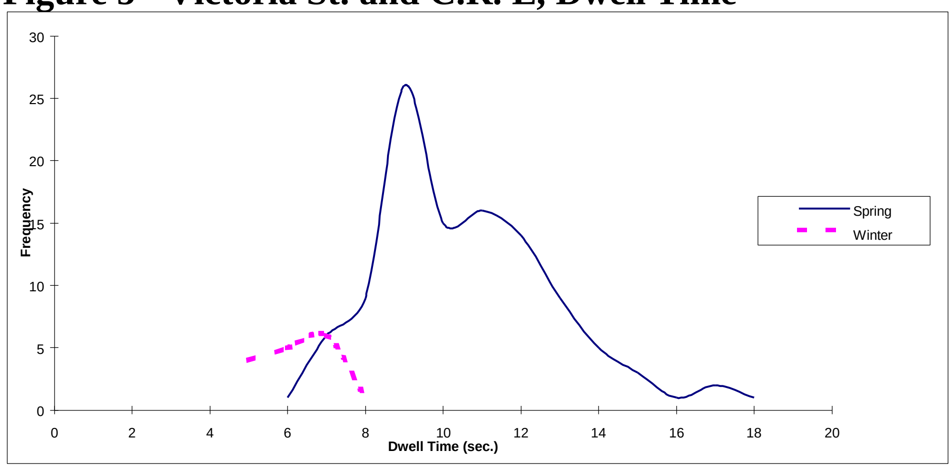


Table 2 - Test For Significant Difference Between Winter and Spring Data for Each Intersection

Winter Data

Dwell Time

Location	*Mean (sec.)*	*Std. Dev. (sec.)*	*n*
Glencoe-Pryor Ave.	6.8	2.2	94
Glencoe-Hennepin Ave.	7.4	1.2	76
Baseline-Vict. St. & C.R. E	6.8	0.8	16

Spring Data

Dwell Time

Location	*Mean (sec.)*	*Std. Dev. (sec.)*	*n*
Glencoe-Pryor Ave.	13.1	4.1	84
Glencoe-Hennepin Ave.	14.2	4.9	55
Baseline-Vict. St. & C.R. E	12.7	8.8	109

Dwell Time

Winter versus Spring Comparison	*abs (u1-u2) (sec.)*		*1.96 * SD* (sec.)*	*Different?*
Glencoe-Pryor Ave.	6.3	>	1.0	Yes
Glencoe-Hennepin Ave.	6.8	>	1.3	Yes
Baseline-Vict. St. & C.R. E	5.9	>	1.7	Yes

Winter Data

Stop Distance

Location	*Mean (ft.)*	*Std. Dev. (ft.)*	*n*
Glencoe-Pryor Ave.	24.7	7.1	122
Glencoe-Hennepin Ave.	24.3	6.3	128
Baseline-Vict. St. & C.R. E	26.4	3.6	23

Spring Data

Stop Distance

Location	*Mean (ft.)*	*Std. Dev. (ft.)*	*n*
Glencoe-Pryor Ave.	24.7	7.1	88
Glencoe-Hennepin Ave.	26.6	6.2	101
Baseline-Vict. St. & C.R. E	23.2	3.8	125

Stop Distance

Winter versus Spring Comparison	*abs (u1-u2) (ft.)*		*1.96 * SD* (ft.)*	*Different?*
Glencoe-Pryor Ave.	0.0	<	2.0	No
Glencoe-Hennepin Ave.	2.3	>	1.6	Yes
Baseline-Vict. St. & C.R. E	3.2	>	1.6	Yes

Several inherent problems exist that may explain the lack of conclusive results. First, the test site and the baseline site were in different geographical locations, making consistent data collection impossible. Second, the bus was not viewed perpendicular to the direction of travel. This made it difficult to accurately identify the bus's stopping location and approach speed. The precise identification of stop location was also made difficult because many of the buses did not come to a full stop; in these cases the observer noted the distance at which the bus was traveling the slowest. Finally, the bus drivers were able to see the observer, which likely caused them to consciously changed their driving behavior.

In addition to the T-tests and Z-tests, Chi-squared tests were used for the non-parametric bus driver scanning behavior data. A requirement of these tests is that no expected values can be less the 5. Since there were very few "no scan" observations in the data set, the expected value for this category was less than 5 for each of the tests. This data had to be combined with the "brief scan" data, refer to pages G-8 through G-11 in Appendix G. Notice the data is shown before and after the data was combined.

The Chi-squared tests revealed that there is not a significant difference in driver observation behavior between Glencoe and the baseline locations. Further examination of the data, however, revealed that there is a significant difference in driver observation behavior depending on whether the bus is empty or not. This was found in both Glencoe and Norwood. Note that in Glencoe this difference was more statistically significant. See page G-9 in Appendix G for contingency tables for the observed and expected outcomes for empty versus non-empty buses. Refer to the detailed test results in Section B for an overview of the results for each test hypothesis.

V. CONCLUSIONS

The in-vehicle signing system was installed in 29 school buses in the Glencoe/Silver Lake School District in Glencoe, Minnesota. Five signalized railroad-highway grade crossings along the Twin Cities and Western Railroad line were outfitted with the warning equipment. The system operates by providing the school bus driver with two types of information on rail crossings : the bus's proximity to an at-grade railroad crossing (crossing alert) and whether or not a train is present at or near the crossing (train alert). Both visual and variable audio signals are given to drivers approaching the crossings. The audio signal output automatically adjusts to the ambient noise level in the bus, assuring the warning is heard by the driver. The system also has the ability to discern the direction the vehicle is traveling relative to the crossing. Therefore, the warning system will not activate unless the vehicle's direction of travel will take it through the crossing. This prevents nuisance warnings when the vehicle is within the vicinity of the crossings but not intending to cross the tracks. Four out of the five crossings were outfitted with this directional feature.

In the evaluation of this project an attempt was made to quantify the impact of the warning system on driver behavior. Analysis of various measures of effectiveness found no statistically significant difference between bus driver behavior in the study area and in the control area. Instead, this study's findings are based largely on interviews and surveys of bus drivers and railroad personnel.

Results from this evaluation indicate the in-vehicle signing system is effective in warning bus drivers of the presence of at-grade rail crossings and train presence. These findings are based largely on a series of interviews and surveys conducted with bus drivers and railroad personnel in both the test area (Glencoe) and in the baseline locations (Norwood and Shoreview). The survey and interview results indicate general bus driver acceptance and perception of value in the warning system. The crossings containing the directional feature were found to have the highest level of bus driver confidence in the system. The majority of the drivers felt the in-vehicle signing system should be installed on their bus permanently.

A concern with any new technology is that it not be allowed to replace the human element in making safe driving decisions. This evaluation addressed the in-vehicle signing system's impact on driver behavior. The field data collected did not reveal a significant difference between bus driver behavior in the study and control areas. Also, interview and survey results indicated the drivers in Glencoe were, if anything, less likely to rely on an automatic warning device at railroad-highway grade crossings. Note, however, that this project was an intensive field test of in-vehicle signing technology, and, as a result, the bus drivers were very conscious of railroad crossing safety. A wider deployment would probably not provide this level of attention, which could in turn increase the chance of drivers relying on technology instead of personal judgment.

VI. NEXT STEPS

The feasibility of installing the in-vehicle signing system at passive crossings was examined. A brief field test was conducted at the Union Avenue crossing by modifying the train detection method. Instead of utilizing the existing track-side train detection equipment, the system responded to the radio signal originating from the Head of Train/End of Train (HOT/EOT) telemetry system in use by most trains. When the modified system detected the train's radio signal, the train presence in-vehicle signing was activated. Even though the track-side warning lights remained in operation, the system was tested to simulate a passive crossing situation.

To evaluate the passive crossing application, four school bus drivers in the Glencoe study area participated in a passive crossing test during the summer of 1998. During the test, each driver was interviewed to obtain their perceptions of the change in system operation that was done to accommodate passive crossings. Specifically, the drivers were asked the following questions:

1. What does the system do when you approach a crossing, what does the system do when you approach a crossing and a train is coming
2. Have you noticed any change in the operation of the system?
3. Describe the change?
4. What do you think of the change?
5. In this case the system triggered without the lights, do you feel this was effective?
6. If the system triggered after the track side lights, how would you feel?
7. Did you feel the system worked adequately today?

Interview results reveal the drivers felt the system's deployment at a passive crossing improved safety by providing earlier notice of an approaching train. The technology used to detect the train appeared to perform adequately for this application. One of the buses experienced a problem that was unrelated to the modifications being evaluated in this study. Refer to Appendix I for the complete interview results. The evaluation at passive crossings was very brief, further testing is required to fully identify the performance of the system.

APPENDIX A

SAMPLE FIELD DATA COLLECTION SHEET

Appendix A
Sample Field Data Collection Sheet

Name____
Date____
Time____
Intersection____
Distance from Track to Point of Speed Measurement__________
Length of Dwell Time Zone (if different than above) __________
Weather/Road Conditions______________________________
Rail Activity During Observation_________________________
Approximate number of cars in train ________________
Number of vehicles stopped in front of bus____________

	Bus No.	Time	Bus Dir.	Approach Speed	Dwell Time	Stop Distance	Bus Full/Empty	Scan Obs.	Comments
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									

Key to Bus Driver Scanning Observation
N No Scan
B Brief Scan
E Extensive Scan (open door and window, look both ways)

APPENDIX B

INITIAL GLENCOE BUS DRIVER SURVEY RESULTS (SURVEY NUMBER 1)

Appendix B
Initial Glencoe Bus Driver Survey Results (Survey Number 1)

Thanks for taking a few minutes to fill out this survey. This survey was prepared to gather information on safety issues regarding school bus operations. If you have any questions or comments regarding the in-vehicle warning system or bus safety in general please feel free to add them to the form. Since we are not evaluating individual bus drivers, putting your initials on the form is optional.

Driver's Initials ________________ Date ***December 12, 1997***

1. *Please rank the following school bus safety issues in the order of importance: (1: most important, 5: least important)*

a) ***2.8*** Children on the bus distracting driver
b) ***3.3*** Children walking to and from the bus
c) ***2.9*** Visibility for the driver (low tree branches, snow drifts, dirty windows, etc.)
d) ***2.7*** Railroad crossings
e) ***2.6*** Motorists ignoring school bus warning signs

2. *Have you ever been in any near misses involving a train?*

a) ***0*** Pulling onto the tracks and then backing up when a train was observed
b) ***1*** Sliding into the crossing during icy weather conditions
c) ***0*** Other____

3. *Rank the following in order of importance when approaching a railroad crossing. (1: most important, 3: least important)*

a) ***2.4*** Hearing a train approach
b) ***1.7*** Seeing the railroad crossing warning lights
c) ***1.7*** Seeing the train itself

4. *Please rank the following factors according to how they affect your ability to determine when a train is approaching a railroad crossing on your bus route. (1: most important, 7: least important)*

a) ***4.2*** View blocked by **temporary** things (snowpiles, trucks) at railroad crossings **with warning lights**.
b) ***3.5*** View blocked by **permanent** things (buildings) at railroad crossings **with warning lights**.
c) ***2.4*** View blocked by **temporary** things (snowpiles, trucks) at railroad crossings **without warning lights.**
d) ***1.8*** View blocked by **permanent** things (buildings) at railroad crossings **without warning lights.**
e) ***3.7*** Bad weather conditions
f) ***4.6*** Distracting behavior of children on bus
g) ***5.8*** Cleanliness of the bus windows

Please answer the following questions regarding railroad crossings on your bus route.

5. *I feel comfortable with how well I can actually see whether a train is coming or not.*

Agree Strongly	Agree Somewhat	Undecided	Disagree Somewhat	Disagree Strongly
8	***4***	***1***	***1***	***1***

6. *I feel comfortable with my judgment about whether a train is coming or not.*

Agree Strongly	Agree Somewhat	Undecided	Disagree Somewhat	Disagree Strongly
5	***8***	***0***	***1***	***0***

7. *I feel comfortable relying on an automatic train warning system at railroad crossings.*

Agree Strongly	Agree Somewhat	Undecided	Disagree Somewhat	Disagree Strongly
0	***3***	***2***	***1***	***9***

Please respond to the following questions about how you approach railroad crossings.

8. I approach a railroad crossing with warning lights more slowly when the lights are flashing than when they are not flashing.

Agree Strongly	Agree Somewhat	Undecided	Disagree Somewhat	Disagree Strongly
6	***6***	***0***	***3***	***0***

9. I approach a railroad crossing <u>without warning lights</u> more slowly than one <u>with lights</u> (but not flashing).

Agree Strongly	Agree Somewhat	Undecided	Disagree Somewhat	Disagree Strongly
2	***6***	***3***	***3***	***1***

10. I stop longer and look 'harder' at a railroad crossing <u>without warning lights</u> than one <u>with lights</u> (but not flashing).

Agree Strongly	Agree Somewhat	Undecided	Disagree Somewhat	Disagree Strongly
5	***2***	***1***	***5***	***2***

11. I approach a railroad crossing with warning lights faster when the lights are not flashing.

Agree Strongly	Agree Somewhat	Undecided	Disagree Somewhat	Disagree Strongly
0	***3***	***1***	***5***	***6***

12. After I have waited for a train to go by, I would like help in finding out if another train is coming.

Agree Strongly	Agree Somewhat	Undecided	Disagree Somewhat	Disagree Strongly
5	***6***	***3***	***1***	***0***

13. It would be valuable to have an automatic train warning system inside my bus to let me know when a train is approaching, even at a railroad crossing <u>with warning lights</u>.

Agree Strongly	Agree Somewhat	Undecided	Disagree Somewhat	Disagree Strongly
8	***4***	***3***	***0***	***0***

14. How far ahead of the crossing should the signal for an automatic train warning system inside my bus begin?

1/2 Block	1 Block	1 1/2 Block	2 Blocks	More than 2 blocks
3	***6***	***2***	***3***	***1***

15. It would be valuable to have an automatic train warning system inside my bus to inform me of when a train is approaching a railroad crossing <u>without warning lights</u>.

Agree Strongly	Agree Somewhat	Undecided	Disagree Somewhat	Disagree Strongly
10	***2***	***3***	***0***	***0***

16. It would be valuable to have an automatic train warning system inside my bus to inform me of when a train is approaching a railroad crossing <u>with warning lights</u>.

Agree Strongly	Agree Somewhat	Undecided	Disagree Somewhat	Disagree Strongly
9	***3***	***3***	***0***	***0***

17. How loud should an automatic train warning signal be?

Same level as existing noise level	A little louder than existing noise	A lot louder than existing noise
4	***7***	***4***

18. Comments

- ***<u>If signal consistently works properly it's a good thing - but when it doesn't I just tune it out and find it another distraction.</u>***
- ***<u>Some adjustments need to be made to get consistent warnings at the same crossing sometime it works sometimes not.</u>***

Survey #1 Statistical Analysis		
Question Number	Mean Response	Response Standard Deviation
5) I feel comfortable with how well I can actually see whether a train is coming or not. (1 = Agree Strongly…. 5 = Disagree Strongly)	1.9 (Agree Somewhat)	1.17
6) I feel comfortable with my judgment about whether a train is coming or not. (1 = Agree Strongly…. 5 = Disagree Strongly)	1.8 (Agree Somewhat)	1.34
7) I feel comfortable relying on an automatic train warning system at railroad crossings. (1 = Agree Strongly…. 5 = Disagree Strongly)	4.1 (Disagree Somewhat)	1.12
8) I approach a railroad crossing with warning lights more slowly when the lights are flashing than when they are not flashing. (1 = Agree Strongly…. 5 = Disagree Strongly)	2.0 (Agree Somewhat)	1.07
9) I approach a railroad crossing <u>without warning lights</u> more slowly than one <u>with lights</u> (but not flashing). (1 = Agree Strongly…. 5 = Disagree Strongly)	2.7 (Undecided)	0.75
10) I stop longer and look a 'harder' at a railroad crossing <u>without warning lights</u> than one <u>with lights</u> (but not flashing). (1 = Agree Strongly…. 5 = Disagree Strongly)	2.8 (Undecided)	0.73
11) I approach a railroad crossing with warning lights faster when the lights are not flashing. (1 = Agree Strongly…. 5 = Disagree Strongly)	3.9 (Disagree Somewhat)	1.03
12) After I have waited for a train to go by, I would like help in finding out if another train is coming. (1 = Agree Strongly…. 5 = Disagree Strongly)	2.0 (Agree Somewhat)	1.07
13) It would be valuable to have an automatic train warning system inside my bus to let me know when a train is approaching, even at a crossing <u>with warning lights</u>. (1 = Agree Strongly…. 5 = Disagree Strongly)	1.7 (Agree Somewhat)	1.35

Survey #1 Statistical Analysis - continued		
Question Number	Mean Response	Response Standard Deviation
14) How far ahead of the crossing should the signal for an automatic train warning system inside my bus begin . (1 = ½ block…. 5 = More than 2 blocks)	2.5 (1 block)	0.79
15) It would be valuable to have an automatic train warning system inside my bus to inform me of when a train is approaching a railroad crossing without lights. (1 = Agree Strongly…. 5 = Disagree Strongly)	1.5 (Agree Somewhat)	1.48
16) It would be valuable to have an automatic train warning system inside my bus to inform me of when a train is approaching a railroad crossing with warning lights . (1 = Agree Strongly…. 5 = Disagree Strongly)	1.6 (Agree Somewhat)	1.41
17) How loud should an automatic train warning signal be? (1 = Same level as existing noise level…3 = A lot louder than existing noise)	2.0 (A little louder than existing noise)	0.14

Appendix B - continued

Narrative Results Description (Survey Number 1)

Fifteen school bus drivers in the Glencoe study area were surveyed to obtain data on school bus operation safety issues. This survey was conducted in December 1997 shortly after the system was installed. Because the system was inplace and the drivers had received training, the survey did not capture true baseline conditions. Instead, a baseline survey was administered in the nearby city of Norwood. In questions one, three and four bus drivers were asked to rank several statements according to importance. The average ranking was calculated for the survey analysis. The survey form and results are provided at the beginning of this appendix.

The bus drivers felt motorists ignoring school bus warning signs is the most important school bus safety issue. Railroad crossings was listed as the second most important safety issue. Children on the bus distracting the driver was considered the third most important issue. The drivers felt visibility for the driver was the fourth most pressing safety issue. Finally, children walking to and from the bus was given as the least important school bus safety issue.

Out of the 15 school bus drivers, one has had a near miss involving a train. The situation involved sliding into the crossing during icy weather conditions.

Seeing the railroad crossing warning lights and seeing the train itself were listed as the most important defenses when approaching a railroad crossing. Hearing the train approach was felt by the bus drivers to be the second most important defense.

The most important factor affecting the driver's ability to determine when a train is approaching a railroad crossing is having their view blocked by permanent objects when a crossing does not have warning lights. Second most important was listed as having their view blocked by temporary objects when the crossing does not have warning lights. Having their view blocked by permanent objects with crossing warning lights was listed as the third most important factor. fourth most important is bad weather conditions. The fifth most important factor is having their view blocked by temporary objects when warning lights are present at a crossing. Distracting behavior of children on the bus and cleanliness of the bus windows were given as the sixth and seventh most important factors respectively.

Eight drivers indicated they feel very comfortable with whether or not they can see a train coming. Four feel somewhat comfortable. One driver indicated he/she is undecided as to whether or not they feel comfortable with their ability to see a train coming. One driver feels somewhat uncomfortable with their ability to see a train coming. One driver does not feel comfortable with whether or not they can see a train coming.

Five drivers trust their judgment about whether or not a train is coming Eight bus drivers somewhat trust their judgment. One bus driver disagrees somewhat with saying he/she feels comfortable with their judgment about whether or not a train is coming. None of the drivers distrust their judgment about whether or not a train is coming.

A lopsided response occurred when the drivers were asked if they felt comfortable relying on an automatic train warning system at railroad crossings. Zero drivers said they would feel comfortable relying on the system. Three would feel somewhat comfortable. Two drivers were undecided. One would feel somewhat uncomfortable. Nine would feel uncomfortable relying on an automatic train warning system at railroad crossings.

The majority of the bus drivers said they approach a railroad crossing with warning lights more slowly when the lights are flashing than when they are not flashing. six drivers said they do approach the crossing more slowly. six drivers said they approach somewhat more slowly. Three drivers disagree somewhat with saying they slow their approach speed when the lights are flashing.

A variety of responses incurred about whether or not the drivers approach a railroad crossing without warning lights more slowly than one with lights (but not flashing). Two drivers said they approach more slowly. Six drivers thought they approached somewhat more slowly. Three drivers were undecided. Three drivers disagree somewhat as to whether or not they reduce their approach speed. One driver does not approach more slowly.

Five drivers stop longer and look ‘harder’ at a railroad crossing without warning lights than one with lights (but flashing). Two drivers stop somewhat longer and look somewhat ‘harder’. Two disagree somewhat as to whether they stop longer and look ‘harder’, and two drivers do not think they stop longer and look ‘harder at a railroad crossing without warning lights than one with lights (but not flashing).

The bus drivers, in general, disagreed when asked if they approached a railroad crossing with warning lights faster when the lights are not flashing. Overall, the drivers felt they do not approach the crossing faster. No drivers indicated they approach the crossing faster. Three drivers felt they approached a railroad crossing somewhat faster when the lights are not flashing. One driver was undecided. Five drivers disagreed somewhat in saying they approach a railroad crossing faster with warning lights that are not flashing. Six drivers did not think they approached the crossing faster in this situation.

The bus drivers were asked if they would like help determining if another train is coming after they have waited for a train. Five drivers felt they would like help determining if another train was coming. Six bus drivers indicated they need somewhat more help determining if another train was coming. Three drivers were undecided. One driver disagreed somewhat with saying he/she needed more help. No drivers said they did not need additional assistance determining if another train was coming.

A very positive response was received when the drivers were asked if they felt the in-vehicle warning system would be an asset at railroad crossings, even at railroad crossings with warning lights. Eight drivers felt strongly that the system would be an asset. Four said the system would be somewhat of an asset. Three drivers were undecided as to whether or not the system would be beneficial as a permanent addition to the buses. No drivers disagreed with the system being permanently installed.

Responses for how far ahead of the crossing the signal for an automatic train warning system inside a bus should begin covered the whole range. Three drivers indicated one half of a block would be sufficient. Six drivers indicated 1 block would be best. Two bus drivers felt one and one half blocks would be ideal. Three drivers would like the system to signal a railroad crossing two blocks ahead of time. One driver indicated he/she would like the system to trigger at a distance greater than two blocks.

Ten bus drivers indicated they strongly agree the automatic train warning system inside the bus at railroad crossings without warning lights would be a valuable asset. Two agreed the system would be a somewhat valuable asset. Three drivers indicated they were undecided about the value an in-vehicle warning system provides to drivers. No drivers disagreed with the fact the system provides some value.

A similar response as above occurred when the bus drivers were asked if the automatic train warning system inside the buses were valuable at crossing with warning lights. Nine drivers strongly agreed the system would be a valuable resource to have on a school bus. Three drivers agree somewhat the system would be a valuable tool. Three drivers were undecided about the usefulness of the in-vehicle warning system. None of the bus drivers disagreed with the system being installed for this situation.

The majority of the bus drivers felt the noise level should be louder than the current level. Four drivers indicated the noise level should be kept the same. Seven would like the noise level a little louder than the existing system's volume. Four drivers indicated they would like the system to be a lot louder than the existing noise level.

Two additional comments were given, they include:

- "If the signal consistently works properly, it is a good thing. When it doesn't work I just tune it out and find it to be another distraction."
- "Some adjustments need to be made to get consistent warnings at the same crossings. Sometimes it works and sometimes not."

APPENDIX C

BASELINE BUS DRIVER SURVEY RESULTS
(SURVEY NUMBER 2)

Appendix C
Baseline Bus Driver Survey Results (Survey Number 2)

Thanks for taking a few minutes to fill out this survey. This survey was prepared to gather information on safety issues regarding school bus operations. If you have any questions or comments regarding the in-vehicle warning system or bus safety in general please feel free to add them to the form. Since we are not evaluating individual bus drivers, putting your initials on the form is optional.

1. ***Please rank the following school bus safety issues in the order of importance: (1: most important, 5: least important)***

a) ***2.6*** Children on the bus distracting driver
b) ***4.0*** Children walking to and from the bus
c) ***2.9*** Visibility for the driver (low tree branches, snow drifts, dirty windows, etc.)
d) ***3.1*** Railroad crossings
e) ***2.4*** Motorists ignoring school bus warning signs

2. ***Have you ever been in any near misses involving a train?***

a) ***1*** Pulling onto the tracks and then backing up when a train was observed
b) ***0*** Sliding into the crossing during icy weather conditions
c) ***0*** Other____________________

3. ***Rank the following in order of importance when approaching a railroad crossing. (1: most important, 3: least important)***

a) ***2.7*** Hearing a train approach
b) ***1.3*** Seeing the railroad crossing warning lights
c) ***2.0*** Seeing the train itself

4. ***Please rank the following factors according to how they affect your ability to determine when a train is approaching a railroad crossing on your bus route. (1: most important, 7: least important)***

a) ***5.0*** View blocked by **temporary** things (e.g. snowpiles, trucks) at railroad crossings **with warning lights**.
b) ***3.4*** View blocked by **permanent** things (e.g. buildings) at railroad crossings **with warning lights**.
c) ***2.1*** View blocked by **temporary** things (e.g. snowpiles, trucks) at railroad crossings **without warning lights**.
d) ***2.1*** View blocked by **permanent** things (e.g. buildings) at railroad crossings **without warning lights.**
e) ***4.0*** Bad weather conditions
f) ***5.1*** Distracting behavior of children on bus
g) ***6.3*** Cleanliness of the bus windows

Please answer the following questions regarding railroad crossings on your bus route.

5. ***I feel comfortable with how well I can actually see whether a train is coming or not.***

Agree Strongly	Agree Somewhat	Undecided	Disagree Somewhat	Disagree Strongly
4	*4*	*0*	*2*	*0*

6. ***I feel comfortable with my judgment about whether a train is coming or not.***

Agree Strongly	Agree Somewhat	Undecided	Disagree Somewhat	Disagree Strongly
7	*3*	*0*	*0*	*0*

7. ***I feel comfortable relying on an automatic train warning system at railroad crossings.***

Agree Strongly	Agree Somewhat	Undecided	Disagree Somewhat	Disagree Strongly
3	*2*	*2*	*2*	*2*

Please respond to the following questions about how you approach railroad crossings.

8. I approach a railroad crossing with warning lights more slowly when the lights are flashing than when they are not flashing.

Agree Strongly	Agree Somewhat	Undecided	Disagree Somewhat	Disagree Strongly
3	***2***	***1***	***3***	***2***

9. I approach a railroad crossing <u>without warning lights</u> more slowly than one <u>with lights</u> (but not flashing).

Agree Strongly	Agree Somewhat	Undecided	Disagree Somewhat	Disagree Strongly
4	***1***	***0***	***3***	***3***

10. I stop longer and look 'harder' at a railroad crossing <u>without warning lights</u> than one <u>with lights</u> (but not flashing).

Agree Strongly	Agree Somewhat	Undecided	Disagree Somewhat	Disagree Strongly
5	***2***	***0***	***2***	***2***

11. I approach a railroad crossing with warning lights faster when the lights are not flashing.

Agree Strongly	Agree Somewhat	Undecided	Disagree Somewhat	Disagree Strongly
1	***1***	***0***	***5***	***4***

12. After I have waited for a train to go by, I would like help in finding out if another train is coming.

Agree Strongly	Agree Somewhat	Undecided	Disagree Somewhat	Disagree Strongly
3	***3***	***2***	***1***	***2***

13. It would be valuable to have an automatic train warning system inside my bus to let me know when a train is approaching, even at a railroad crossing <u>with warning lights</u>.

Agree Strongly	Agree Somewhat	Undecided	Disagree Somewhat	Disagree Strongly
3	***2***	***4***	***1***	***0***

14. Comments

- ***<u>I don't have any trouble with railroad tracks and trains.</u>***

15. Number of railroad track crossings in the morning.
2.7

16. Number of railroad track crossings in the afternoon.
3.0

17. Number of times you have had to stop for a train in the last month.
0.2

Survey #2 Statistical Analysis		
Question Number	Mean Response	Response Standard Deviation
5) I feel comfortable with how well I can actually see whether a train is coming or not. (1 = Agree Strongly…. 5 = Disagree Strongly)	2.0 (Agree Somewhat)	1.67
6) I feel comfortable with my judgment about whether a train is coming or not. (1 = Agree Strongly…. 5 = Disagree Strongly)	1.3 (Agree Strongly)	2.72
7) I feel comfortable relying on an automatic train warning system at railroad crossings. (1 = Agree Strongly…. 5 = Disagree Strongly)	2.8 (Undecided)	1.02
8) I approach a railroad crossing with warning lights more slowly when the lights are flashing than when they are not flashing. (1 = Agree Strongly…. 5 = Disagree Strongly)	2.9 (Undecided)	1.00
9) I approach a railroad crossing <u>without warning lights</u> more slowly than one <u>with lights</u> (but not flashing). (1 = Agree Strongly…. 5 = Disagree Strongly)	3.0 (Undecided)	1.00
10) I stop longer and look a 'harder' at a railroad crossing <u>without warning lights</u> than one <u>with lights</u> (but not flashing). (1 = Agree Strongly…. 5 = Disagree Strongly)	2.5 (Agree Somewhat)	1.15
11) I approach a railroad crossing with warning lights faster when the lights are not flashing. (1 = Agree Strongly…. 5 = Disagree Strongly)	3.9 (Disagree Somewhat)	1.41
12) After I have waited for a train to go by, I would like help in finding out if another train is coming. (1 = Agree Strongly…. 5 = Disagree Strongly)	2.6 (Undecided)	1.07
13) It would be valuable to have an automatic train warning system inside my bus to let me know when a train is approaching, even at a crossing <u>with warning lights</u>. (1 = Agree Strongly…. 5 = Disagree Strongly)	2.3 (Agree Somewhat)	1.38

Appendix C - continued

Narrative Results Description (Survey Number 2)

Eleven school bus drivers in the Norwood School District were given a survey to obtain data on school bus operation safety issues. The responses summarized below are the personal opinions of each driver. In questions one, three and four bus drivers were asked to rank several statements according to importance. The average ranking was calculated for the survey analysis. The survey form and results are provided at the beginning of this Appendix.

The bus drivers felt motorists ignoring school bus warning signs is the most important school bus safety issue. Children on the bus distracting the driver was listed as the second most important safety issue. Two safety concerns were given as third most important, visibility for the driver and railroad crossings. Finally, children walking to and from the bus was given as the least important school bus safety issue.

Out of the eleven school bus drivers, one has had a near miss involving a train. The situation involved pulling onto the tracks and backing up when a train was observed.

Seeing the railroad crossing warning lights was listed as the most important defense when approaching a railroad crossing. Seeing the train itself was given as the second most important, and actually hearing the train approach was the least important.

The most important factor affecting the driver's ability to determine when a train is approaching a railroad crossing is having their view blocked by temporary or permanent objects when a crossing does not have warning lights. Having their view blocked by permanent objects with crossing warning lights was listed as the second most important factor. Third most important is bad weather conditions. The fourth most important factor is having their view blocked by temporary objects when warning lights are present at a crossing. Distracting behavior of children on the bus and cleanliness of the bus windows were given as the fifth and sixth most important factors respectively.

Four drivers indicated they feel very comfortable with whether or not they can see a train coming. Four feel somewhat comfortable and two feel somewhat uncomfortable.

Seven drivers trust their judgment about whether or not a train is coming Three bus drivers somewhat trust their judgment. None of the drivers do not trust their judgment.

A mixture of responses occurred when the drivers were asked if they felt comfortable relying on an automatic train warning system at railroad crossings. Three drivers said they would feel comfortable relying on the system. Two would feel somewhat comfortable. Two drivers were undecided. Two would feel somewhat uncomfortable. Two drivers indicated they would feel uncomfortable relying on an automatic train warning system at railroad crossings.

A variety of responses were received when the drivers were asked if they approach a railroad crossing with warning lights more slowly when the lights are flashing than when they are not flashing. Three drivers said they do approach the crossing more slowly. Two drivers said they approach somewhat more slowly. One driver was undecided if he/she did or did not approach more slowly. Three drivers disagree somewhat with saying they slow their approach speed. Two indicated they do not approach more slowly.

The responses for whether or not the drivers approach a railroad crossing without warning lights more slowly than one with lights (but not flashing) were concentrated at both ends of the spectrum. Four drivers said they approach more slowly. One driver thought he/she approached somewhat more slowly. Three drivers disagree somewhat as to whether they reduce their approach speed. Three drivers do not approach more slowly.

The majority of the drivers agreed they do stop longer and look 'harder' at a railroad crossing without warning lights than one with lights (but not flashing). Overall, five drivers do stop longer and look 'harder'. Two drivers stop somewhat longer and look somewhat 'harder'. Two disagree somewhat in saying they stop longer and look 'harder', and two drivers do not think they stop longer and look 'harder at a railroad crossing without warning lights than one with lights (but not flashing).

A lopsided response occurred when the drivers were asked if they approach a railroad crossing with warning lights faster when the lights are not flashing. In general, the drives felt they do not approach a crossing faster. One driver thought he/she did approach the crossing faster. One driver felt they approached a railroad crossing with lights somewhat faster when the lights are not flashing. Five drivers disagreed somewhat in saying they approach a railroad crossing faster with warning lights that are not flashing. Four drivers did not think they approached the crossing faster in this situation.

When bus drivers were asked if they would like help determining if another train is coming after they have waited for a train, a mixture of responses were given. Three drivers felt they would like help determining if another train was coming. Three bus drivers felt as though they need somewhat more help determining if another train was coming. Two drivers were undecided. One driver disagreed somewhat with saying they need more help. Two drivers said they did not need additional assistance determining if another train was coming.

A positive response was received when the drivers were asked if they felt the in-vehicle warning system would be an asset at railroad crossings, even at railroad crossings with warning lights. Three drivers felt strongly that the system would be an asset. Two said the system would be somewhat of an asset. Four drivers were undecided as to whether or not the system would be beneficial as a permanent addition on the buses. Only one driver disagreed somewhat with the system being installed on a permanent basis.

Finally, each bus crosses the railroad tracks an average of 3.0 times each morning and each afternoon. The survey found that 0.2 bus drivers have had to stop for a train on their route in the past month.

APPENDIX D

ONGOING GLENCOE BUS DRIVER SURVEY RESULTS (SURVEY NUMBER 3)

Appendix D

Ongoing Glencoe Bus Driver Survey Results (Survey Number 3)

Thanks for taking a few minutes to fill out this survey. This survey was prepared to gather information on safety issues regarding school bus operations at rail crossings. If you have any questions or comments regarding the in-vehicle warning system or bus safety in general please feel free to add them to the form. **Since we are not evaluating individual bus drivers, putting your initials on the form is optional.**

Driver's Initials ____________________ Date ***March 12, 1998***

1. ***How many times in the past two weeks has a train been present at a crossing you approached?***
   - *9* — ***0***
   - *5* — ***1***
   - *1* — ***2***
   - *0* — ***3 or more***

2. ***If a train was present in the last two weeks, did the system warn you of the approaching train?***
   - *6* — ***Yes***
   - *0* — ***No***

3. ***Has your driving behavior changed because of the Train Warning System?***
   - *13* — ***No, I continue to use the same procedures when approaching rail crossings***
   - *2* — ***Yes, Because of the system I approach crossings differently now (describe changes)***

   I prepare to stop sooner. The noise it gives off makes you more aware.

4. ***Over the past two weeks, has the system in your bus worked consistently?***
   - *8* — ***Always worked***
   - *6* — ***Usually worked***
   - *1* — ***Sometimes worked***
   - *1* — ***Never worked***

5. ***Identify the specific problems, if any, you have had with the system in the last two weeks.***
   - *0* — ***System failed to warn of approaching train***
   - *3* — ***System failed to warn of approach to railroad crossing***
   - *6* — ***System warned of approach to railroad crossing when bus was not near a crossing***
   - *1* — ***System operates better at some intersections than others (describe)***

6. ***Have you noticed if any of the following affected the train warning system in the last two weeks?***
   - *1* — ***Presence of other traffic***
   - *1* — ***Which crossing is being used***
   - *3* — ***Direction bus is facing***
   - *1* — ***Cold Weather***
   - *1* — ***Snow***
   - *1* — ***Other*** *Fog*

Survey #3 Statistical Analysis		
Question Number	Mean Response	Response Standard Deviation
1) How many times in the past two weeks has a train been present at a crossing you approached? (0 times …..3 or more times)	0.5	0.66
4) Over the past two weeks, has the system in your bus worked consistently? (1 = Always worked….. 4 = Never worked)	1.9 (Usually worked)	0.49

Narrative Results Description (Survey Number 3)

Sixteen school bus drivers in the Glencoe study area were given a survey to obtain data on school bus operations safety issues. The responses summarized below are the personal opinions of each driver. The objective of this survey was to determine the performance of the system and document any changes in bus driver perceptions of the system. The survey form and results are provided at the beginning of this appendix.

1. *How many times in the past two weeks has a train been present at a crossing you approached?*

    - Nine drivers have had zero trains present on their routes in the past two weeks. Five said a train had been present at a crossing during their routes. One driver encountered a train on their route twice in the past two weeks. None of the bus drivers have had three or more trains present at a crossing they approached in the past two weeks.

2. *If a train was present in the last two weeks, did the system warn you of the approaching train?*

    - A total of six drivers from question one indicated a train had been present at a crossing they approached in the past two weeks. The system warned the drivers of an approaching train during each of the encounters.

3. *Has your driving behavior changed because of the Train Warning System?*

    - The majority of the bus drivers indicated they continued to use the same procedures when approaching rail crossings even though the system warned them of an approaching train.
    - Thirteen drivers said they continued to use the same procedures when approaching rail crossings. Two drivers approached the crossing differently. One driver said they "prepare to stop sooner", another driver said "the noise it gives off makes you more aware".

4. Over the past two weeks, has the system in your bus worked consistently?

    - Eight drivers said the system always worked consistently. Six bus drivers indicated the system usually worked. One driver's response was the system sometimes worked. One driver thought the system never worked.

5. *Identify the specific problems, if any, you have had with the system in the last two weeks.*

- None of the drivers have had the system fail to warn them of an approaching train in the past two weeks. Three drivers said the system failed to warn them of an approach to a railroad crossing. Six drivers indicated the system warned them of an approach to a railroad crossing when the bus was not near a crossing. One driver felt the system operates better at some intersections than other.

6. *Have you noticed if any of the following affected the train warning system in the last two weeks?*

One driver said the presence of traffic affect the system. One driver obtained varying results from the system depending on which crossing is being used. Three of the drivers noticed the direction in which the bus is facing affects the train warning system. One driver indicated snow affected the train warning system during their route at least once in the two weeks preceding the survey. Fog affected the system during one driver's route.

APPENDIX E

ONGOING GLENCOE BUS DRIVER SURVEY RESULTS
(SURVEY NUMBER 4)

Appendix E

Ongoing Glencoe Bus Driver Survey Results (Survey Number 4)

Thanks for taking a few minutes to fill out this survey. This survey was prepared to gather information on safety issues regarding school bus operations at rail crossings. If you have any questions or comments regarding the in-vehicle warning system or bus safety in general please feel free to add them to the form. **Since we are not evaluating individual bus drivers, putting your initials on the form is optional.**

Driver's Initials ____________________ Date ***May 8, 1998***

1. ***How many times in the past two weeks has a train been present at a crossing you approached?***

- *5* ***0***
- *7* ***1***
- *2* ***2***
- *0* ***3 or more***

2. ***If a train was present in the last two weeks, did the system warn you of the approaching train?***

- *10* ***Yes***
- *1* ***No***

3. ***Has your driving behavior changed because of the Train Warning System?***

- *13* ***No, I continue to use the same procedures when approaching rail crossings***
- *1* ***Yes, Because of the system I approach crossings differently now (describe changes)***

I prepare to stop sooner. The noise it gives off makes you more aware.

4. ***Over the past two weeks, has the system in your bus worked consistently?***

- *5* ***Always worked***
- *7* ***Usually worked***
- *1* ***Sometimes worked***
- *0* ***Never worked***

5. ***Identify the specific problems, if any, you have had with the system in the last two weeks.***

- *0* ***System failed to warn of approaching train***
- *2* ***System failed to warn of approach to railroad crossing***
- *2* ***System warned of approach to railroad crossing when bus was not near a crossing***
- *2* ***System operates better at some intersections than others (describe)***

6. ***Have you noticed if any of the following affected the train warning system in the last two weeks?***

- *0* ***Presence of other traffic***
- *0* ***Which crossing is being used***
- *2* ***Direction bus is facing***
- *0* ***Cold Weather***
- *0* ***Snow***
- *0* ***Other*** *Fog*

Survey #4 Statistical Analysis		
Question Number	Mean Response	Response Standard Deviation
1) How many times in the past two weeks has a train been present at a crossing you approached? (0 times …..3 or more times)	0.8	0.54
4) Over the past two weeks, has the system in your bus worked consistently? (1 = Always worked….. 4 = Never worked)	1.6 (Usually worked)	0.63

Narrative Results Description (Survey Number 4)

Fourteen school bus drivers in the Glencoe study area were given a survey to obtain data on school bus operations safety issues. The responses summarized below are the personal opinions of each driver. The objective of this survey was to determine the performance of the system and document any changes in bus driver perceptions of the system. The survey form and results are provided at the beginning of this appendix.

1. *How many times in the past two weeks has a train been present at a crossing you approached?*

    - Five drivers have had zero trains present on their routes in the past two weeks. Seven said a train had been present at a crossing during their routes. Two driver encountered a train on their route twice in the past two weeks. None of the bus drivers have had three or more trains present at a crossing they approached in the past two weeks.

2. *If a train was present in the last two weeks, did the system warn you of the approaching train?*

    - The system warned drivers during ten of the bus/train coincidences from question one. However, during the two weeks preceding this interview, the system did not warn the driver of an approaching train once.

3. *Has your driving behavior changed because of the Train Warning System?*

    - The majority of the bus drivers indicated they continued to use the same procedures when approaching rail crossings even though the system warned them of an approaching train.
    - Thirteen drivers said they continued to use the same procedures when approaching rail crossings. One driver approached the crossing differently.

4. *Over the past two weeks, has the system in your bus worked consistently?*

    - Five drivers said the system always worked consistently. Seven bus drivers indicated the system usually worked. One driver’s response was the system sometimes worked. None of the drivers said the system never worked.

5. *Identify the specific problems, if any, you have had with the system in the last two weeks.*

    - None of the drivers have had the system fail to warn them of an approaching train in the past two weeks. Two drivers said the system failed to warn them of an approach to a railroad crossing. Two drivers indicated the system warned them of an approach to a railroad crossing when the bus was not near a crossing. Two driver felt the system operates better at some intersections than other.

6. *Have you noticed if any of the following affected the train warning system in the last two weeks?*

    - Out of the 14 drivers surveyed, only two noticed the train warning system being affected by the direction the bus was facing. No other factors were listed as affecting the train warning system in the two weeks preceding the administration of this survey.

APPENDIX F

BUS DRIVER/TRAIN OPERATOR INTERVIEW RESULTS

Appendix F

Bus Driver / Train Engineer Interview Questions

Bus Driver Interview Questions

1. What does the display do when you approach a crossing?
   What if a train is coming?

2. Do you think the display is effective in improving crossing safety?
   Do you feel more confident with your stop and go decisions?

3. Would you recommend that this display be installed i n your bus permanently?

4. Has your behavior changed with the display installed in your bus?

5. Do you have any other suggestions, such as how to improve the display?

TC&W Interview Questions

1. Did the in-vehicle warning system integrate smoothly with the railroad's inplace warning system?

2. Was the system disruptive to normal rail operations?

3. What school bus behaviors at rail crossings are most dangerous?

4. Do railroad personnel think the system is effective in improving crossing safety?

Appendix F - continued

Bus Driver Interview Questions Results

1a. What does the display do when you approach a crossing?

1) Yellow lights, beeps two blocks before.
2) No answer.
3) Yellow and beeps.
4) Yellow and beeps once.
5) Yellow and beeps twice.
6) Blue to yellow and beeping.
7) Yellow.
8) Makes me more aware, yellow and beeps.
9) Flashes and beeps.
10) Yellow and beeps.
11) Beeps and flashes yellow.
12) Yellow, not as loud.
13) No answer.
14) Beeps and flashes.
15) Beeps and yellow.
16) Yellow, beeps.
17) Yellow and beeping two blocks before.
18) Yellow and beeps two to three blocks, up to four blocks with some buses.
19) Flashing yellow, beeping.
20) No idea, doesn't pay attention.

1b. What if a train is coming?

1) Red and continuous beeping.
2) No answer.
3) Red and beeps louder.
4) Red when track side lights come on, beeps.
5) Red and continuous.
6) Red and beeps continuously.
7) Red and louder.
8) Red and beep is more annoying.
9) Red flashing and continuous beeping.
10) Red.
11) Continuous beeping and red flashing.
12) Red.
13) No answer.
14) No train has come.
15) Never had a train, but should beep and red.

16) Red, beeps.
17) Red and continuous beeping.
18) Red flashing and beeping if train flashers are on.
19) Red and beeps (doesn't remember if continuous).
20) Haven't had a train, should flash red.

2a. Do you think the display is effective in improvi ng crossing safety?

1) Not really, still want to look both ways.
2) Yes.
3) No, it's annoying, I tune it out.
4) Yes.
5) Yes, would be a wonder on crossings I'm not familiar with.
6) Yes, definitely.
7) Yes, extra tool.
8) Yes, more observant.
9) Wakes you up a little, but I depend on myself - if was in unfamiliar territory, it would be better.
10) No, not consistent.
11) Yes, immediately know what is going on - good in group situations.
12) Might be, still really cautious.
13) Yes.
14) Beeping is, but not lights - depends on time of day, not noticeable on bright days.
15) Not really, been a driver so long that I don't depend on it.
16) Yes, but I wouldn't count on it.
17) Yes, as long as a person doesn't depend on it.
18) Yes, makes you aware of tracks, lack of attention.
19) Don't know, watch for traffic, don't pay attention to it, better at rural crossings.
20) If it's looked at, but not for me.

2b. Do you feel more confident with your stop and go decisions?

1) It helps.
2) No, rely on myself.
3) No, rely on myself.
4) Yes, helps to make stop.
5) No, I feel it's an asset but I do the looking.
6) Still have to be cautious, others don't have system.
7) No, still always look both ways because it's an experimental system.
8) No, cautious before too.
9) No, same, depend on myself.
10) Same.
11) Yes.
12) No, not unless it's all over, but do here.

13) Yes.
14) No, no change.
15) No, look anyway, don't depend on it.
16) No.
17) No.
18) No, but if train had a signal it would be better, come on earlier than with the current trackside warning.
19) No change.
20) No.

3. Would you recommend that this display be installed in your bus permanently?

1) Don't know.
2) Yes.
3) No. doesn't work - mind of it's own.
4) Yes.
5) Yes, if and when they go.
6) Yes.
7) Yes.
8) Yes, every bus everywhere, really good idea.
9) No, depend on yourself, good drivers. It's another headache on a noisy bus.
10) Not if it doesn't work all the time.
11) Yes.
12) Yes, unless it's expensive.
13) Yes, once bugs are worked out.
14) Yes.
15) Yes, if it worked at strange crossings.
16) Yes, if it was in unfamiliar places.
17) Yes, it's another safety thing.
18) Yes, if all trains had it installed as a backup.
19) Yes.
20) Yes, it's beeping at weird times, i.e. southbound on Hennepin , it beeps at the four-way (she thinks, she's used to it).

4. Has your behavior changed with the display installed in your bus?

1) No.
2) No.
3) No.
4) Makes more aware, but driver knows his own route. Would be best late at night at unfamiliar crossings.
5) No, I still stop, I'm familiar.
6) No.
7) No, still double check.

8) Just more aware, I carry handicapped kids.
9) No.
10) No.
11) Makes more aware of trains, but I didn't change my behavior.
12) No.
13) No.
14) No, we know it's a test system, don't want to change because system is temporary.
15) No.
16) No, but irritated.
17) No, I drive the same.
18) No, same caution used, don't rely on system.
19) No.
20) No.

5. Do you have any other suggestions, such as how to improve the display?

1) No.
2) No, works pretty well.
3) It's okay if it works. I'd turn it off if I could.
4) No.
5) Would be great in St. Michael because there isn't good sight distance.
6) Seems pretty good the way it is.
7) Not foolproof, not consistent, goes off whenever.
8) Make it not go off on 16th.
9) Go a little further in advance.
10) Sometimes it works, sometimes it doesn't.
11) No.
12) Still have passengers.
13) Adjust loudness, allow driver to change volume, different buses are different loudness.
14) Dangerous crossing by Silver Lake because of poor sight distance. Make the distance of beeping consistent from bus to bus.
15) Would be more useful if you didn't know track was there.
16) No.
17) Not too many trains, some drivers never encounter a train.
18) Fog decreases sight of red flashers, sound is important.
19) Others have weather problems. Better to tie the system to the train itself, not the active warning.
20) At first it beeped all over town, now it's fixed. I'm so used to it I tune it out.

6. Do you have any problems with the system?

1) Works good.
2) Has worked very well, distance range varies, should be improved to be more dependable.
3) Sat and watched a parked train, system never triggered, finally just went.
4) Goes off at high school, bumps, and northbound Hennepin after tracks.
5) Works well.
6) Sometimes goes off on the bridge, sometimes westbound on 11th. Rain, fog and humidity affect it.
7) Works well.
8) Doesn't work lately - saw train but no lights at a crossing. When the train
9) came, the lights went but not the in vehicle display.
10) Didn't work in rain two weeks ago (just once southbound Pryor).
11) In rain it didn't work until you were close (last few months).
12) Problems at first, now it works better.
13) Overall the system is worthy for what it's trying to do. Sometimes my cruise control doesn't work, sometimes this system doesn't work, overall it's worthy.
14) Works fine, problems at first with long distance. Took out the fuse because it was annoying.
15) No problems.

Appendix F - continued

TC&W Interview Questions Results

1. *Did the in-vehicle warning system integrate smoothly with the railroad's inplace warning system?*

   - Appeared to.

2. *Was the system disruptive to normal rail operations?*

   - No.

3. *What school bus behaviors at rail crossings are most dangerous?*

   - See separate comments

4. *Do railroad personnel think the system is effective in improving crossing safety?*

   - Definitely, hope it becomes more universal, i.e. trucks.

Other Comments:

Train engineers blow horn harder and earlier at crossings because they're worried, especially when sight distance is limited due to trees or buildings.

Motorists will wait for short trains but not for long ones.

Two track safety issues:

- Visibility problems.
- Trains use low speed when there are two trains at once (10 mph). Vehicle was struck in Chicago when it crossed tracks after first train passed.

System doesn't cure scofflaw behavior, they would be just as likely to violate crossings if they had an in-vehicle warning system.

Frequent crossings to Seneca plant in Glencoe, two to four trains a day, much less activity in Norwood.

System is good because it helps for fog.

Good to go to passive locations because it's more dangerous there. Many motorists go through passive without looking at all. When driving to work each day I go weeks without seeing vehicles stop at stop signs for crossings (rural location - County Road 4 and Dakota Rail, four miles east of Hutchinson).

Radio in car turned up can cause driver to not hear train's approach.

Were you involved in the system installation?

- Not really, present during installation, drove locomotive

Have you observed unsafe bus behavior?

- Engineer #1 No
- Engineer #2 Yes, in Iowa a bus tried to beat a train fifteen years ago. Attitude change because now the train and buses are in there together, the system reinforces the importance of rail safety.

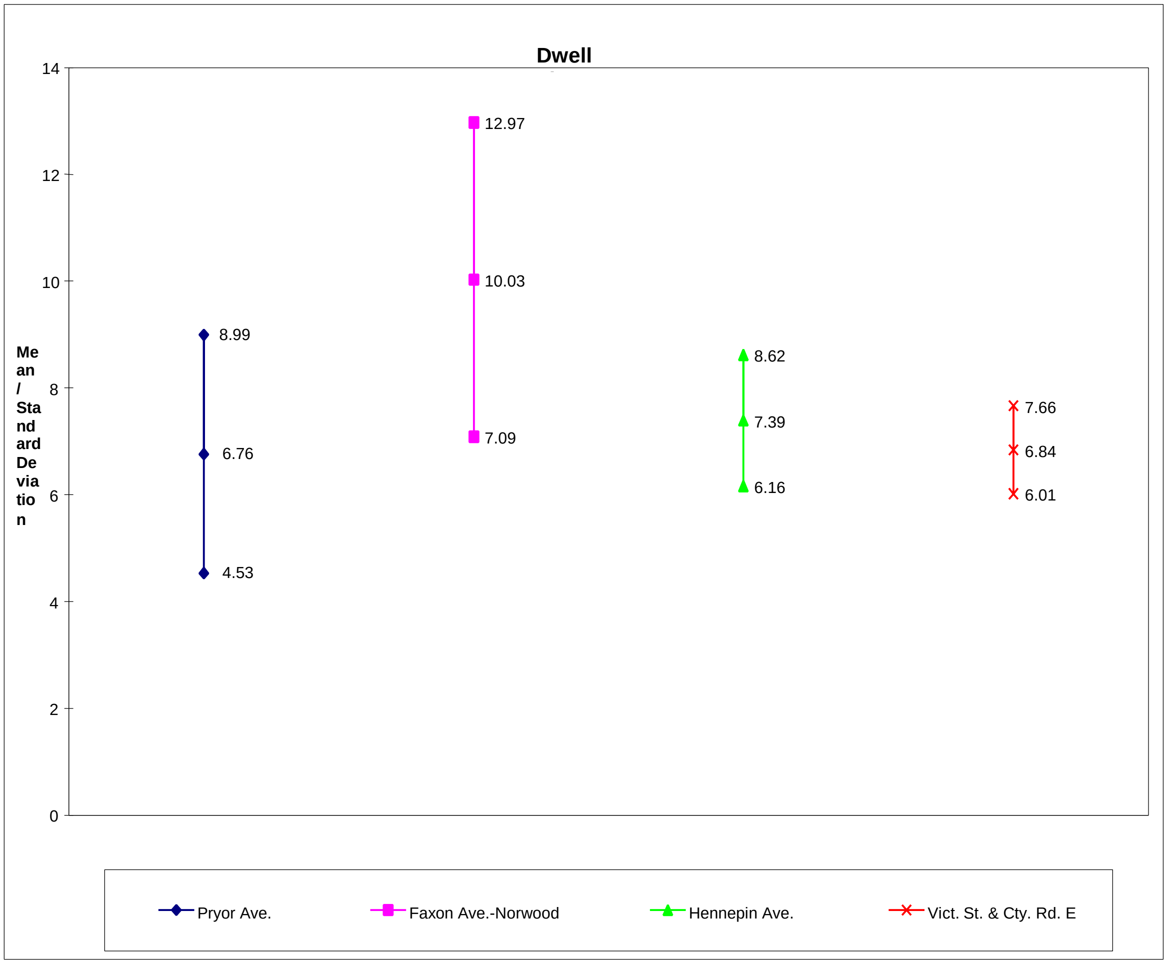
How does the warning system work?

- Engineer #1 Locomotive enters circuit, causing system to trigger.
- Engineer #2 Flashes yellow and then red if a train is present.

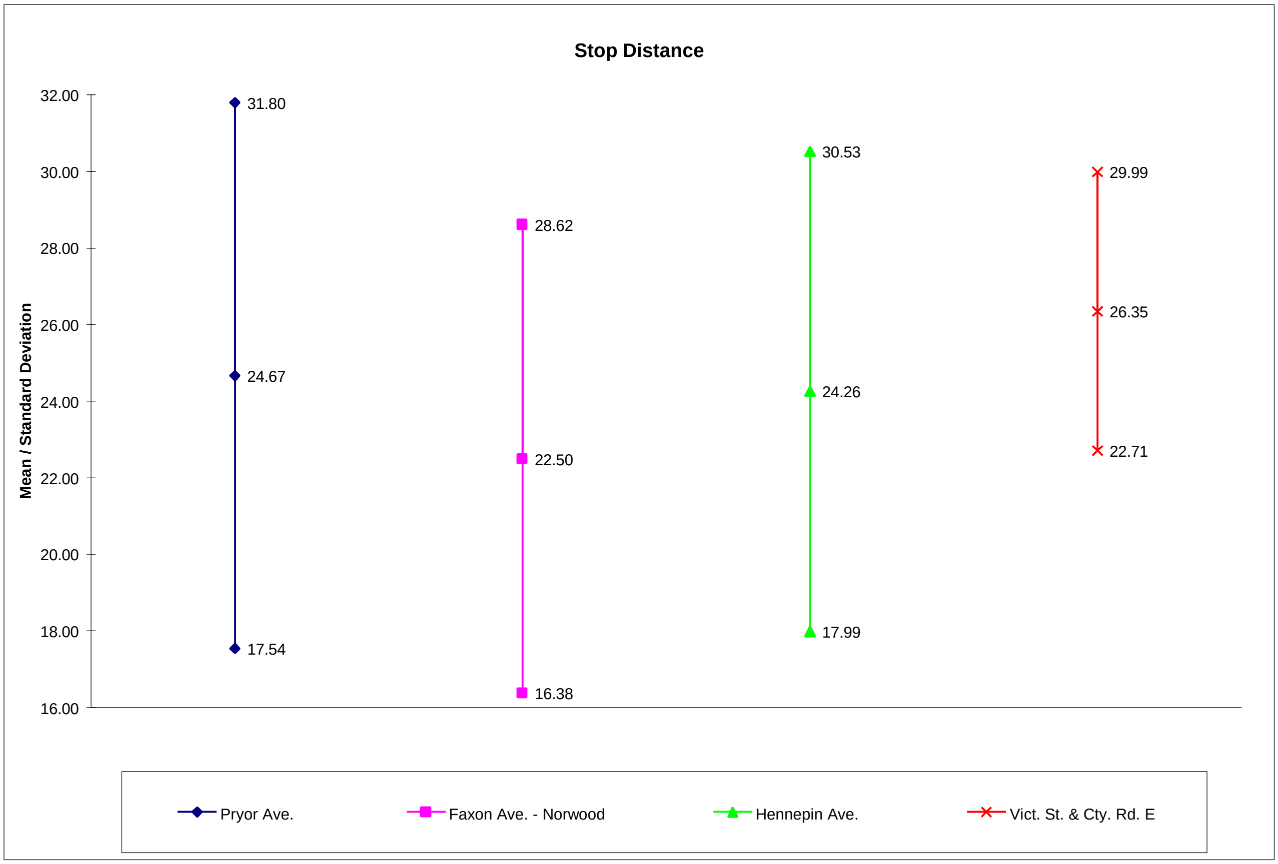
Appendix G

FIELD DATA ANALYSIS AND RESULTS

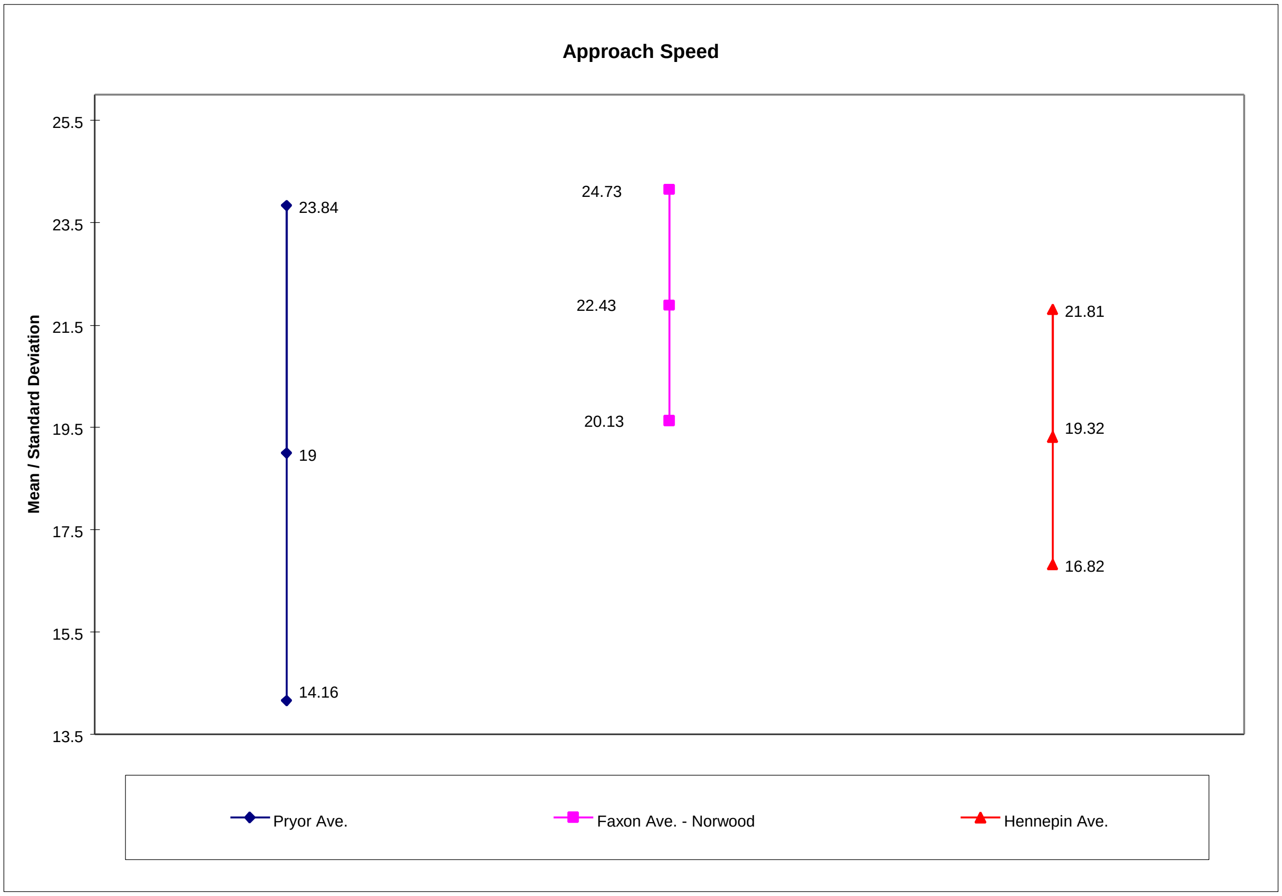
Dwell Time - Winter Observations



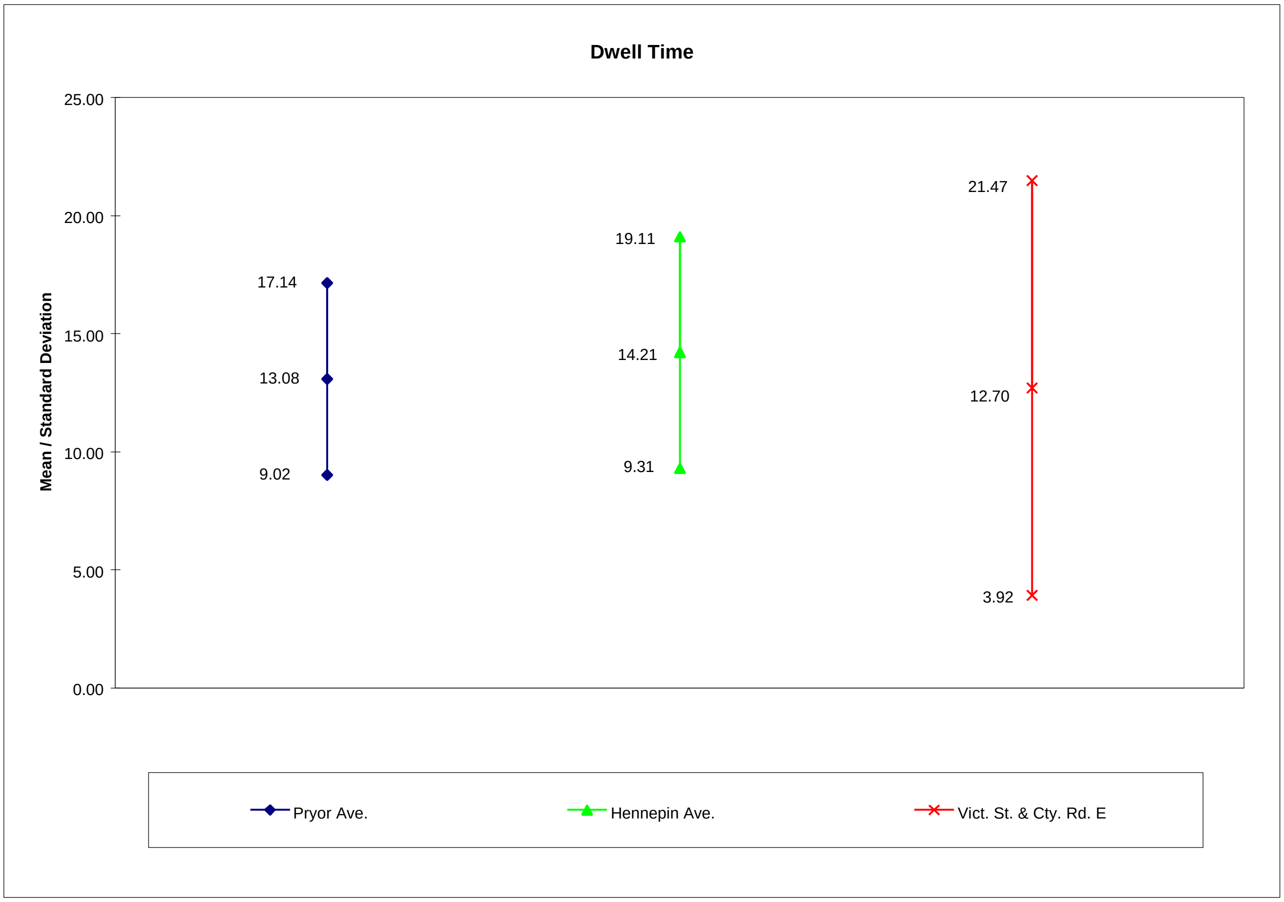
Stop Distance - Winter Observations



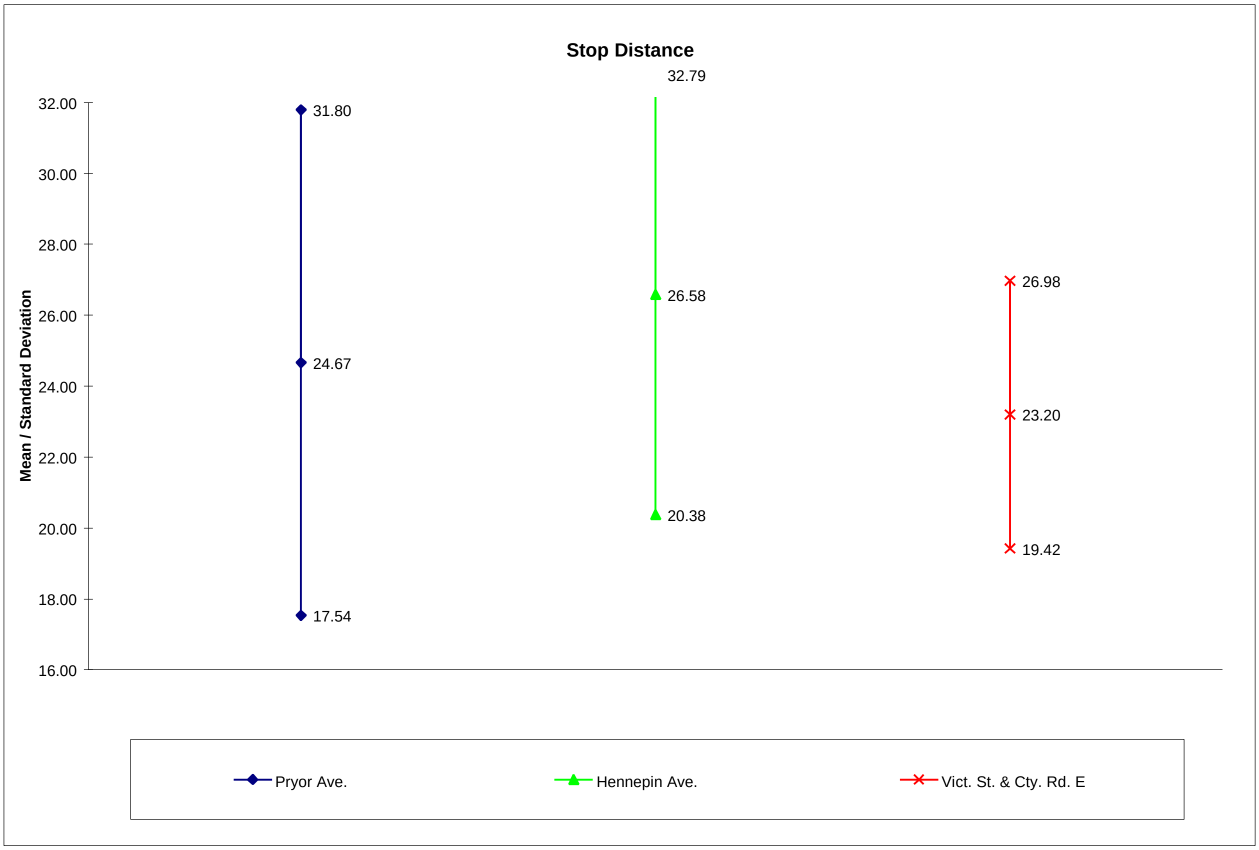
Approach Speed - Winter Observations



Dwell Time - Spring Observations



Stop Distance - Spring Observations



Test For Significant Difference Between Glencoe and Baseline Locations

Winter Data

Dwell Time

Location	*Mean (sec.)*	*Std. Dev. (sec.)*	*n*
Glencoe-Pryor Ave.	6.8	2.2	94
Glencoe-Hennepin Ave.	7.4	1.2	76
Baseline-Faxon Ave.	10.0	2.9	21
Baseline-Vict. St. & C.R. E	6.8	0.8	16

Glencoe and Baseline Comparison	*abs (u1-u2) (sec.)*		*1.96 * SD* (sec.)*	*Different?*
Pryor Ave. - Faxon Ave.	3.2	>	1.3	Yes
Pryor Ave. - Victoria St.	0.0	<	0.6	No
Hennepin Ave. - Faxon Ave.	2.6	>	1.3	Yes
Hennepin Ave. - Vict. St.	0.6	>	0.5	Yes

Stop Distance

Location	*Mean (ft.)*	*Std. Dev. (ft.)*	*n*
Glencoe-Pryor Ave.	24.7	7.1	122
Glencoe-Hennepin Ave.	24.3	6.3	128
Baseline-Faxon Ave.	22.5	6.1	22
Baseline-Vict. St. & C.R. E	26.4	3.6	23

Glencoe and Baseline Comparison	*abs (u1-u2) (ft.)*		*1.96 * SD* (ft.)*	*Different?*
Pryor Ave. - Faxon Ave.	2.2	<	2.9	No
Pryor Ave. - Victoria St.	1.7	<	2.0	No
Hennepin Ave. - Faxon Ave.	1.8	<	2.8	No
Hennepin Ave. - Vict. St.	2.1	>	1.8	Yes

Approach Speed

Location	*Mean (mph)*	*Std. Dev. (mph)*	*n*
Glencoe-Pryor Ave.	19.0	4.8	8
Glencoe-Hennepin Ave.	19.3	2.5	21
Baseline-Faxon Ave.	22.4	2.3	10

Glencoe and Baseline Comparison	*abs (u1-u2) (mph)*		*1.96 * SD* (mph)*	*Different?*
Pryor Ave. - Faxon Ave.	3.4	<	3.6	No
Hennepin Ave. - Faxon Ave.	3.1	>	1.8	Yes

Test For Significant Difference Between Glencoe and Baseline Locations

Spring Data

Dwell Time

Location	*Mean (sec.)*	*Std. Dev. (sec.)*	*n*
Glencoe-Pryor Ave.	13.1	4.1	84
Glencoe-Hennepin Ave.	14.2	4.9	55
Baseline-Vict. St. & C.R. E	12.7	8.8	109

Glencoe and Baseline Comparison	*abs (u1-u2) (sec.)*		*1.96 * SD* (sec.)*	*Different?*
Pryor Ave. - Victoria St.	0.4	<	1.9	No
Hennepin Ave. - Vict. St.	1.5	<	2.1	No

Stop Distance

Location	*Mean (ft.)*	*Std. Dev. (ft.)*	*n*
Glencoe-Pryor Ave.	24.7	7.1	88
Glencoe-Hennepin Ave.	26.6	6.2	101
Baseline-Vict. St. & C.R. E	23.2	3.8	125

Glencoe and Baseline Comparison	*abs (u1-u2) (ft.)*		*1.96 * SD* (ft.)*	*Different?*
Pryor Ave. - Victoria St.	1.5	<	1.6	No
Hennepin Ave. - Vict. St.	3.4	>	1.4	Yes

Chi Squared Analysis

Glencoe - winter vs. spring

Observed Driver Observations

	Extensive	Brief	None	*sum*	
winter	114	100	1	215	0.53
spring	117	71	3	191	0.47
sum	231	171	4	**406**	**total**
	0.57	0.42	0.01		

Expected Driver Observations

	Extensive	Brief	None	
winter	122.33	90.55	2.12	215
spring	108.67	80.45	1.88	191
	231	171	4	**406**

Degrees of Freedom = 2

X^2critical : 5.99

X^2 = 4.55

Observed Driver Observations

	Extensive	Brief	None	*sum*	
winter	114	101		215	0.53
spring	117	74		191	0.47
sum	231	175	0	**406**	**total**
	0.57	0.43	0.00		

Expected Driver Observations

	Extensive	Brief	None	
winter	122.33	92.67		215
spring	108.67	82.33		191
	231	175	0	**406**

Degrees of Freedom = 1

X^2critical : 3.84

X^2 = 2.80

X^2crit > X^2 implies no significant difference exists between winter data and spring data.

Baseline - winter vs. spring

Observed Driver Observations

	Extensive	Brief	None	*sum*	
winter	18	6	0	24	0.16
spring	87	34	5	126	0.84
sum	105	40	5	**150**	**total**
	0.70	0.27	0.03		

Expected Driver Observations

	Extensive	Brief	None	
winter	16.80	6.40	0.80	24
spring	88.20	33.60	4.20	126
	105	40	5	**150**

Degrees of Freedom = 2

X^2critical : 5.99

X^2 = 1.08

Observed Driver Observations

	Extensive	Brief	None	*sum*	
winter	18	6		24	0.16
spring	87	39		126	0.84
sum	105	45	0	**150**	**total**
	0.70	0.30	0.00		

Expected Driver Observations

	Extensive	Brief	None	
winter	16.80	7.20		24
spring	88.20	37.80		126
	105	45	0	**150**

Degrees of Freedom = 1

X^2critical : 3.84

X^2 = 0.34

X^2crit > X^2 implies no significant difference exists between winter data and spring data.

Chi Squared Analysis

Driver Observations - Glencoe vs. Baseline Locations

Observed Driver Observations: Glencoe vs. Baseline

	Extensive	Brief	None	*sum*	
Glencoe	231	171	4	406	0.70
Baseline	106	61	5	172	0.30
sum	337	232	9	**578**	**total**
	0.58	0.40	0.02		

Expected Driver Observations: Glencoe vs. Baseline

	Extensive	Brief	None	
Glencoe	236.72	162.96	6.32	406
Baseline	100.28	69.04	2.68	172
	337	232	9	**578**

Degrees of Freedom = 2

X^2critical 5.99

X^2 = 4.66

Observed Driver Observations: Glencoe vs. Baseline

	Extensive	Brief	None	*sum*	
Glencoe	231	175		406	0.70
Baseline	106	66		172	0.30
sum	337	241	0	**578**	**total**
	0.58	0.42	0.00		

Expected Driver Observations: Glencoe vs. Baseline

	Extensive	Brief	None	
Glencoe	236.72	169.28		406
Baseline	100.28	71.72		172
	337	241	0	**578**

Degrees of Freedom = 1

X^2critical 3.84

X^2 = 1.11

X^2crit > X^2 implies no significant difference exists between Glencoe and the baseline data.

Glencoe - Bus Empty vs. Bus Non-Empty

Observed Driver Observations

	Extensive	Brief	None	*sum*	
empty	96	116	3	215	0.53
full	135	55	1	191	0.47
sum	231	171	4	**406**	**total**
	0.57	0.42	0.01		

Expected Driver Observations

	Extensive	Brief	None	
empty	122.33	90.55	2.12	215
full	108.67	80.45	1.88	191
	231	171	4	**406**

Degrees of Freedom = 2

X^2critical 5.99

X^2 = 28.02

Observed Driver Observations

	Extensive	Brief	None	*sum*	
empty	96	119		215	0.53
full	135	56		191	0.47
sum	231	175	0	**406**	**total**
	0.57	0.43	0.00		

Expected Driver Observations

	Extensive	Brief	None	
empty	122.33	92.67		215
full	108.67	82.33		191
	231	175	0	**406**

Degrees of Freedom = 1

X^2critical 3.84

X^2 = 27.94

X^2crit < X^2 implies a significant difference in driver behavior between an empty bus and a non-empty bus.

Baseline - Bus Empty vs. Bus Non-Empty

Observed Driver Observations

	Extensive	Brief	None	*sum*	
empty	46	16	1	63	0.37
full	60	45	4	109	0.63
sum	106	61	5	**172**	**total**
	0.62	0.35	0.03		

Expected Driver Observations

	Extensive	Brief	None	
empty	38.83	22.34	1.83	63
full	67.17	38.66	3.17	109
	106	61	5	**172**

Degrees of Freedom = 2

X^2critical 5.99

X^2 = 5.53

Observed Driver Observations

	Extensive	Brief	None	*sum*	
empty	46	17		63	0.37
full	60	49		109	0.63
sum	106	66	0	**172**	**total**
	0.62	0.38	0.00		

Expected Driver Observations

	Extensive	Brief	None	
empty	38.83	24.17		63
full	67.17	41.83		109
	106	66	0	**172**

Degrees of Freedom = 1

X^2critical 3.84

X^2 = 5.45

X^2crit < X^2 implies a significant difference in driver behavior between an empty bus and a non-empty bus.

Chi Squared Analysis

Driver Observations - Pryor Ave. - winter vs. spring

Observed Driver Observations: Pryor Ave. - winter vs. spring

	Extensive	Brief	None	*sum*		
winter	65	34	0	99		0.52
spring	48	39	3	90		0.48
sum	113	73	3	**189**	**total**	
	0.60	0.39	0.02			

Expected Driver Observations: Pryor Ave. - winter vs. spring

	Extensive	Brief	None	
winter	59.19	38.24	1.57	99
spring	53.81	34.76	1.43	90
	113	73	3	**189**

Degrees of Freedom = 2

X^2critical 5.99

X^2 = 5.48

Observed Driver Observations: Pryor Ave. - winter vs. spring

	Extensive	Brief	None	*sum*		
winter	65	34		99		0.52
spring	48	42		90		0.48
sum	113	76	0	**189**	**total**	
	0.60	0.40	0.00			

Expected Driver Observations: Pryor Ave. - winter vs. spring

	Extensive	Brief	None	
winter	59.19	39.81		99
spring	53.81	36.19		90
	113	76	0	**189**

Degrees of Freedom = 1

X^2critical 3.84

X^2 = 2.98

X^2crit > X^2 implies no significant difference between winter and spring data for Pryor Ave.

Driver Observations - Hennepin Ave. - winter vs. spring

Observed Driver Observations

	Extensive	Brief	None	*sum*		
winter	49	66	1	116		0.53
spring	69	32	0	101		0.47
sum	118	98	1	**217**	**total**	
	0.54	0.45	0.00			

Expected Driver Observations

	Extensive	Brief	None	
winter	63.08	52.39	0.53	116
spring	54.92	45.61	0.47	101
	118	98	1	**217**

Degrees of Freedom = 2

X^2critical 5.99

X^2 = 15.22

Observed Driver Observations

	Extensive	Brief	None	*sum*		
winter	49	67		116		0.53
spring	69	32		101		0.47
sum	118	99	0	**217**	**total**	
	0.54	0.46	0.00			

Expected Driver Observations

	Extensive	Brief	None	
winter	63.08	52.92		116
spring	54.92	46.08		101
	118	99	0	**217**

Degrees of Freedom = 1

X^2critical 3.84

X^2 = 14.80

X^2crit < X^2 implies a significant difference in driver behavior between winter and spring data for Hennepin Ave.

Driver Observations - Victoria St. & Cty. Rd. E - winter vs. spring

Observed Driver Observations

	Extensive	Brief	None	*sum*		
winter	18	6	0	24		0.16
spring	87	34	5	126		0.84
sum	105	40	5	**150**	**total**	
	0.70	0.27	0.03			

Expected Driver Observations

		Extensive	Brief	None	
	winter	16.80	6.40	0.80	24
38	spring	88.20	33.60	4.20	126
49		105	40	5	**150**

Degrees of Freedom = 2

X^2critical 5.99

X^2 = 1.08

Observed Driver Observations

	Extensive	Brief	None	*sum*		
winter	18	6		24		0.16
spring	87	39		126		0.84
sum	105	45	0	**150**	**total**	
	0.70	0.30	0.00			

Expected Driver Observations

	Extensive	Brief	None	
winter	16.80	7.20		24
spring	88.20	37.80		126
	105	45	0	**150**

Degrees of Freedom = 1

X^2critical 3.84

X^2 = 0.34

X^2crit > X^2 implies no significant difference between winter and spring data for Victoria St. & Cty. Rd. E

hi Squared Analysis

ver Observations - Glencoe vs. Baseline - winter

served Driver Observations

	Extensive	Brief	None	*sum*	
lencoe	114	100	1	215	0.90
aseline	18	6	0	24	0.10
sum	132	106	1	**239**	**total**
	0.55	0.44	0.00		

Expected Driver Observations

	Extensive	Brief	None	
Glencoe	118.74	95.36	0.90	215
Baseline	13.26	10.64	0.10	24
	132	106	1	**239**

Degrees of Freedom = 2

X^2critical : 5.99

X^2 = 4.25

served Driver Observations

	Extensive	Brief	None	*sum*	
lencoe	114	101		215	0.90
aseline	18	6		24	0.10
sum	132	107	0	**239**	**total**
	0.55	0.45	0.00		

Expected Driver Observations

	Extensive	Brief	None	
Glencoe	118.74	96.26		215
Baseline	13.26	10.74		24
	132	107	0	**239**

Degrees of Freedom = 1

X^2critical : 3.84

X^2 = 4.22

X^2crit < X^2 implies a significant difference in driver behavior between the Glencoe and Baseline for the winter data.

ver Observations - Glencoe vs. Baseline - spring

served Driver Observations

	Extensive	Brief	None	*sum*	
lencoe	117	71	3	191	0.60
aseline	87	34	5	126	0.40
sum	204	105	8	**317**	**total**
	0.64	0.33	0.03		

Expected Driver Observations

	Extensive	Brief	None	
Glencoe	122.91	63.26	4.82	191
Baseline	81.09	41.74	3.18	126
	204	105	8	**317**

Degrees of Freedom = 2

X^2critical : 5.99

X^2 = 4.82

served Driver Observations

	Extensive	Brief	None	*sum*	
lencoe	117	74		191	0.60
aseline	87	39		126	0.40
sum	204	113	0	**317**	**total**
	0.64	0.36	0.00		

Expected Driver Observations

	Extensive	Brief	None	
Glencoe	122.91	68.09		191
Baseline	81.09	44.91		126
	204	113	0	**317**

Degrees of Freedom = 1

X^2critical : 3.84

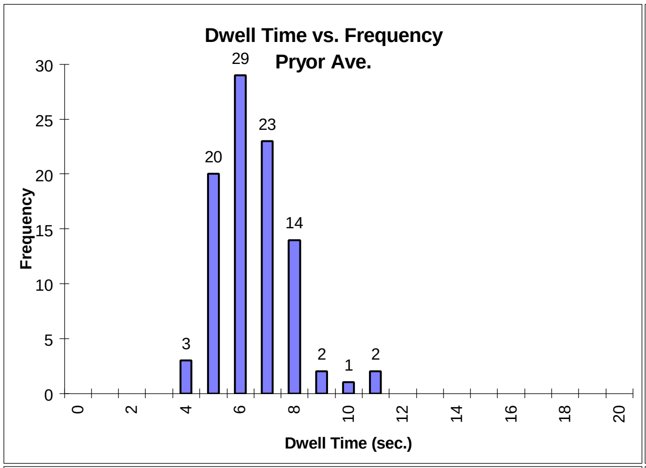
X^2 = 2.01

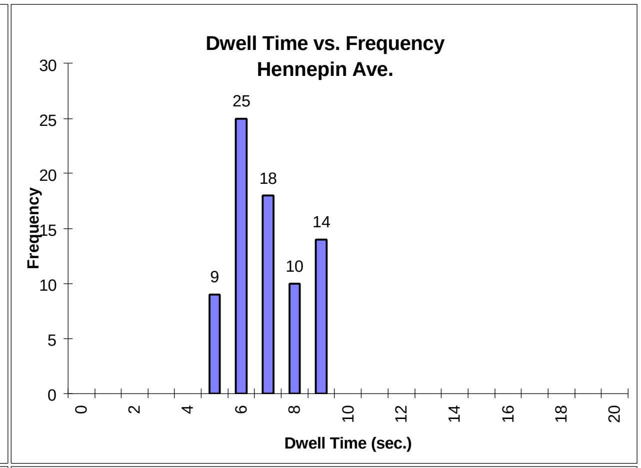
X^2crit > X^2 implies no significant difference exists between winter data and spring data.

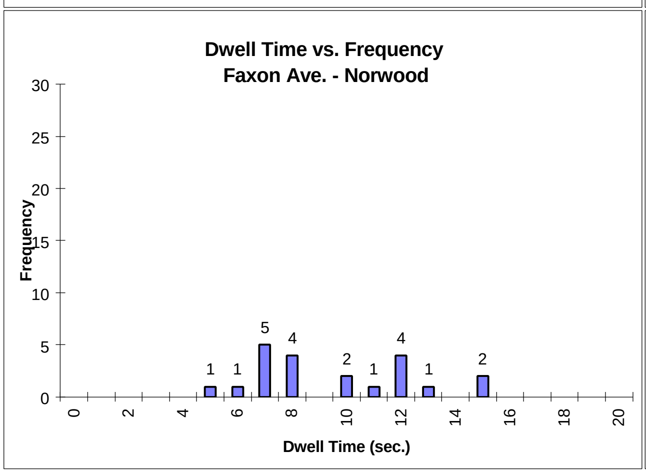
Appendix H

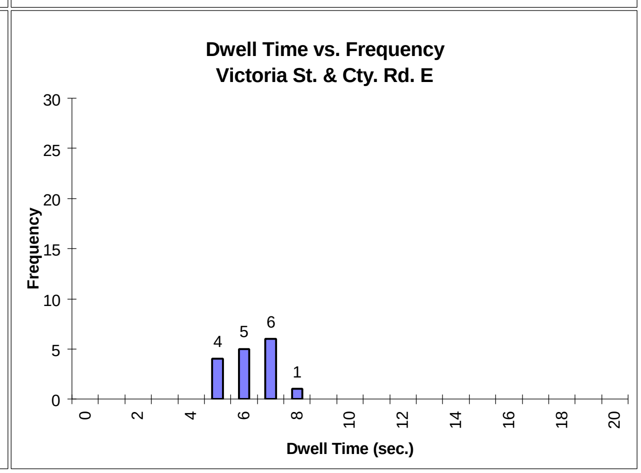
SUMMARIZED FIELD DATA

Dwell Time - Winter Observations

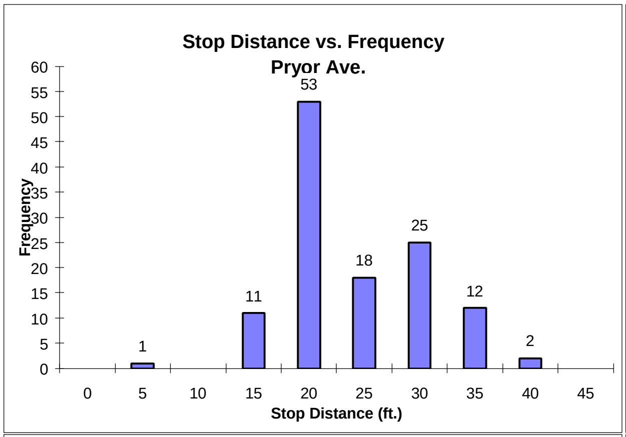


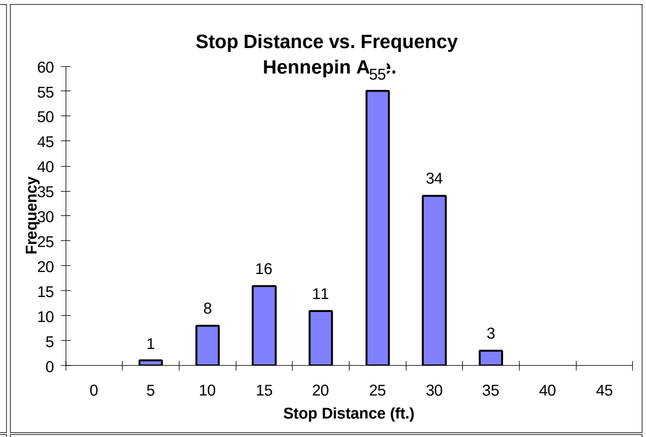


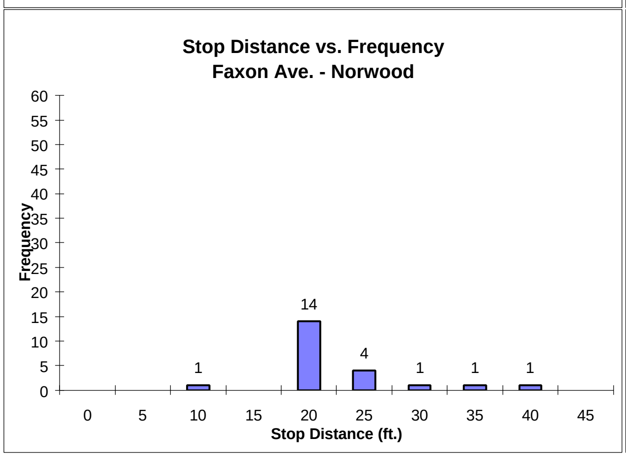


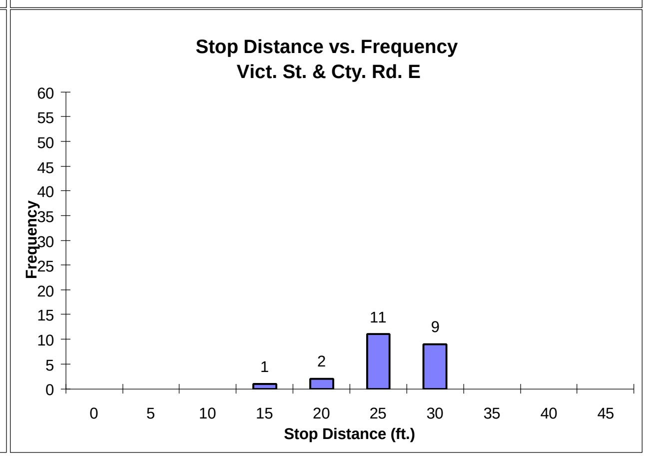


Stop Distance - Winter Observations

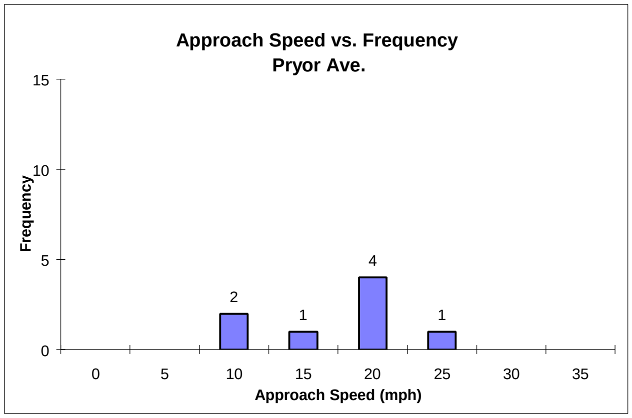


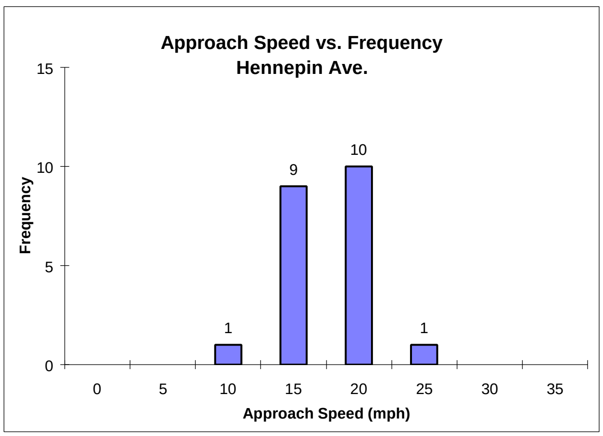


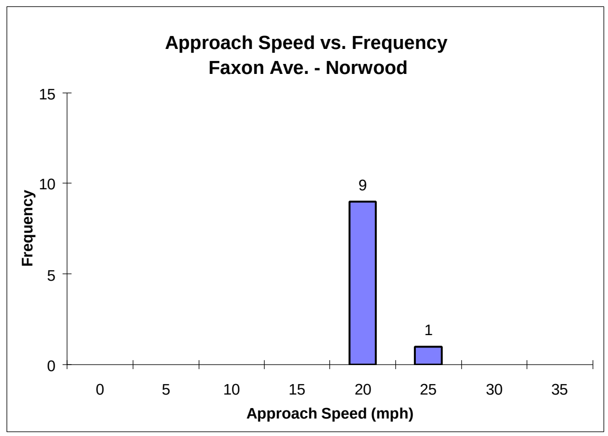




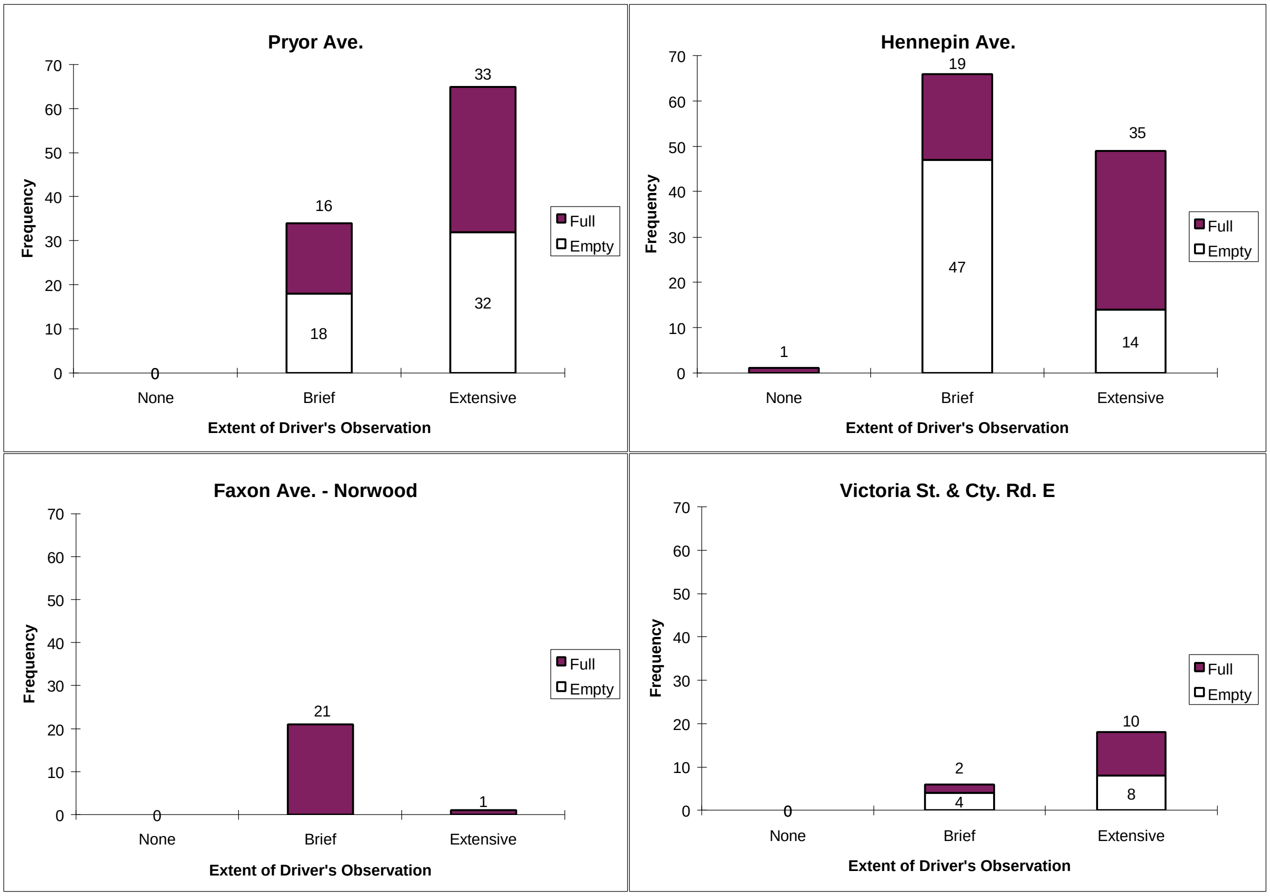
Approach Speed - Winter Observations



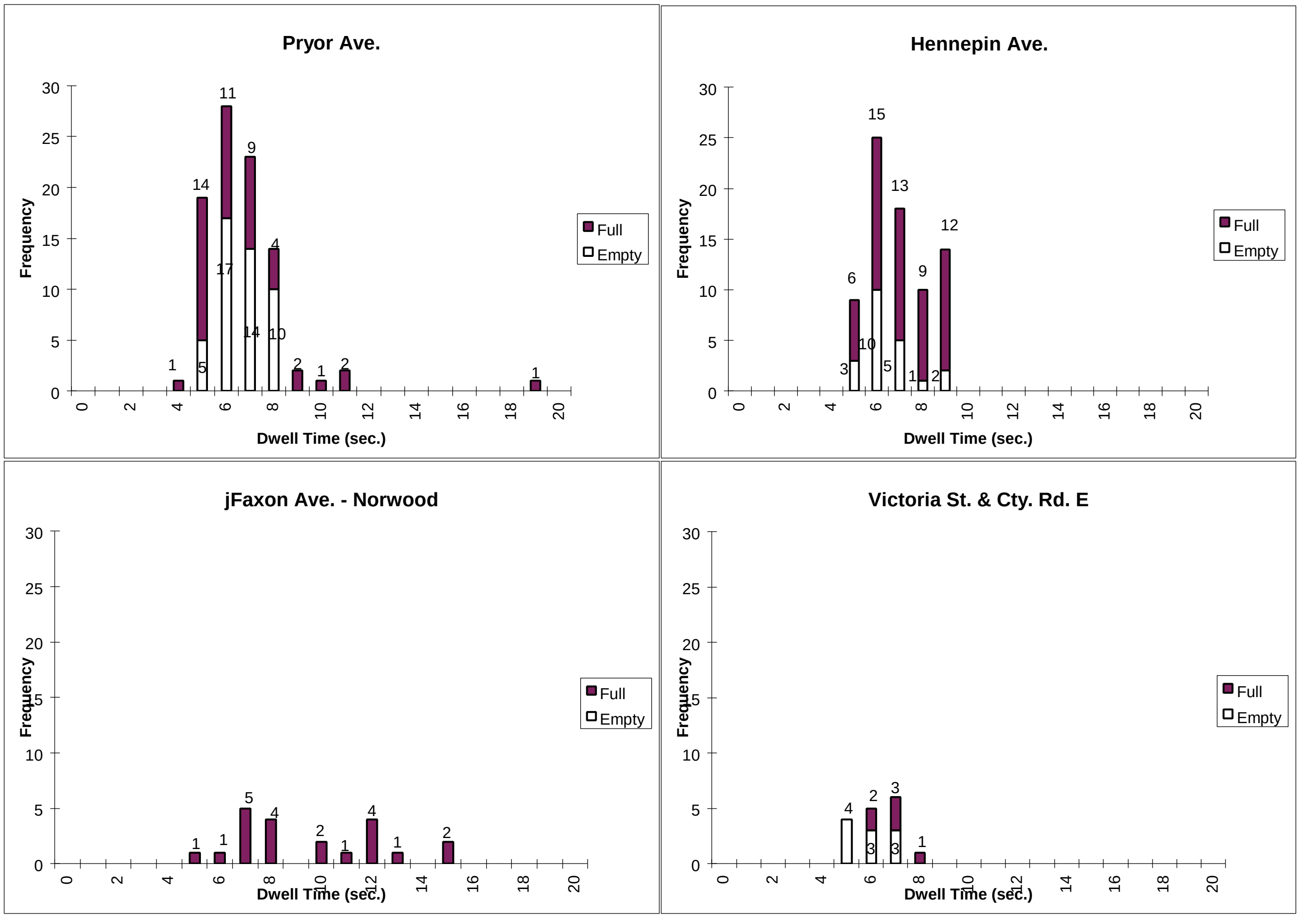




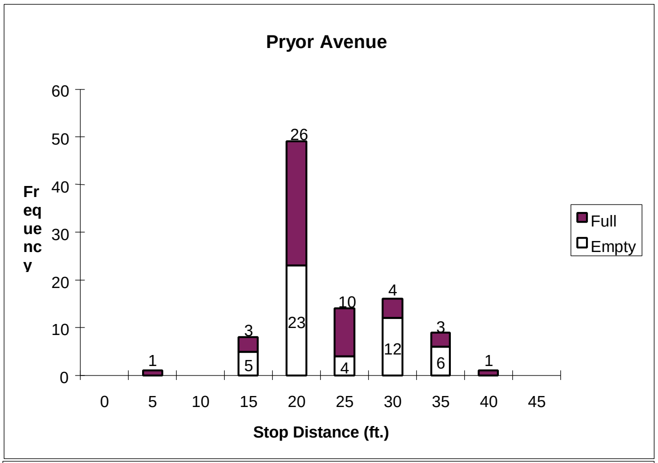
Drive Observations vs. Frequency Winter Observations

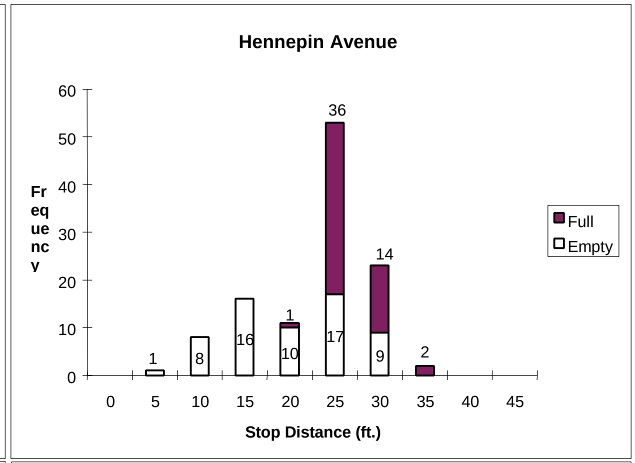


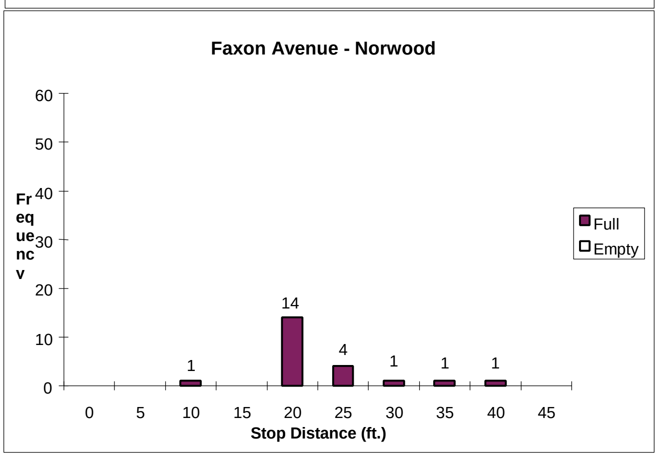
Dwell Time vs. Frequency Winter Observations

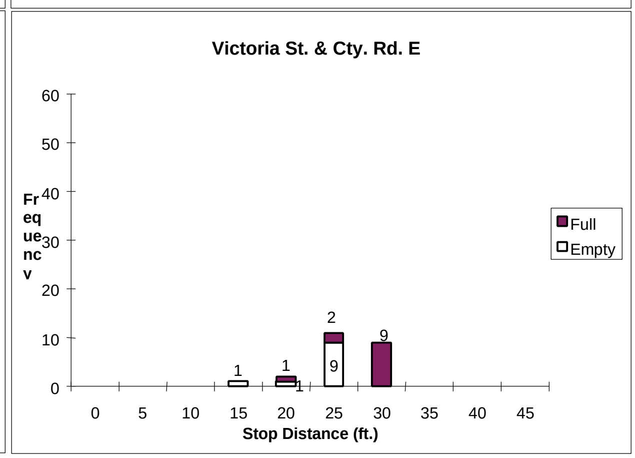


Stop Distance vs. Frequency Winter Observations

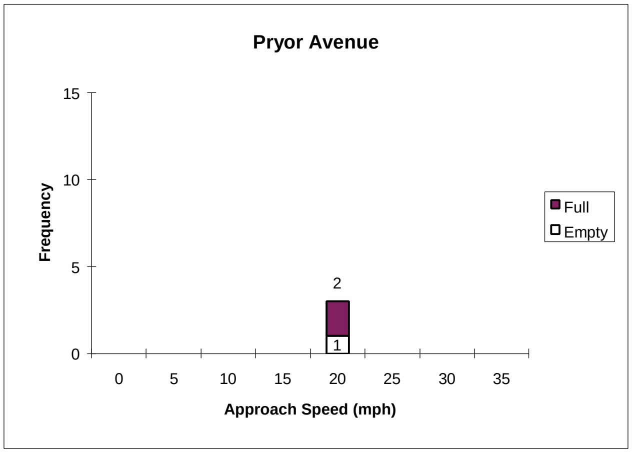


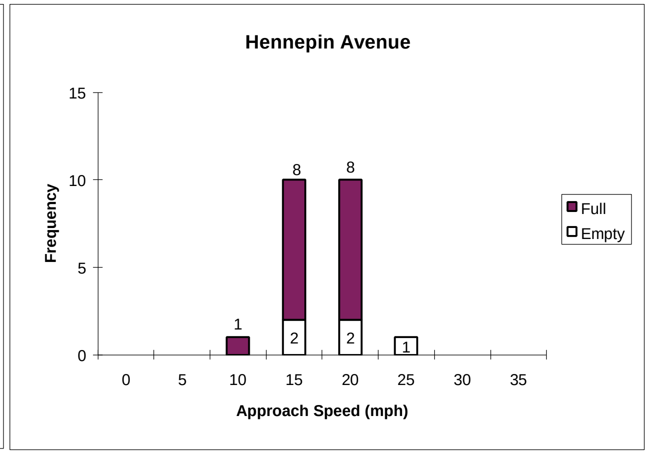


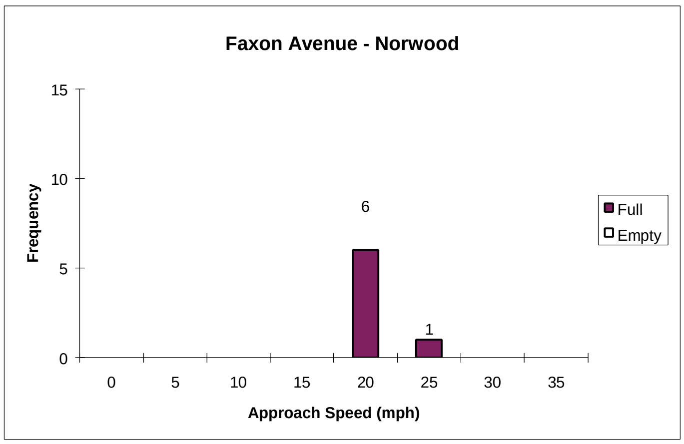




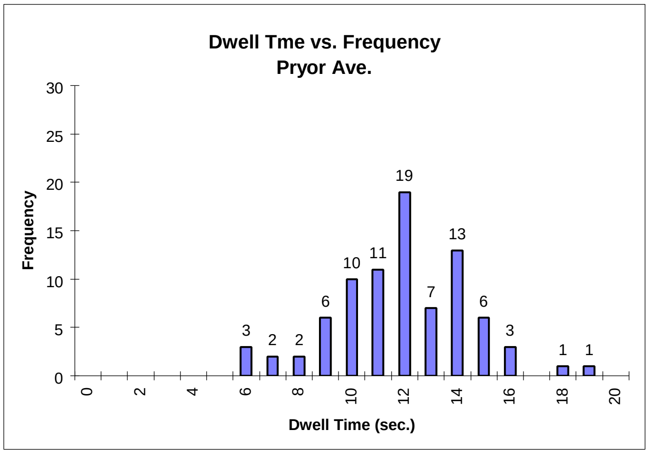
Approach Speed vs. Frequency

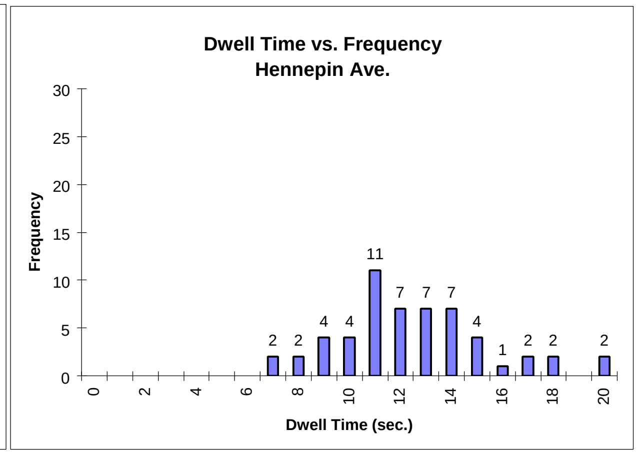


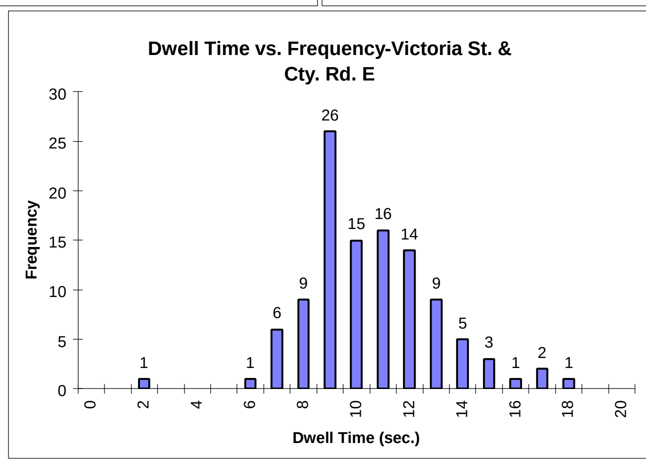




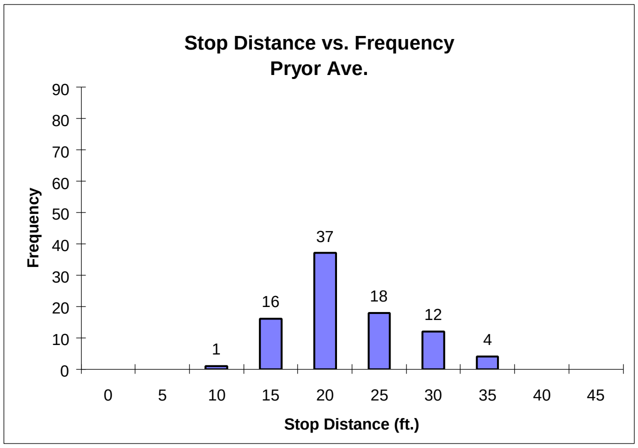
Dwell Time - Spring Observations

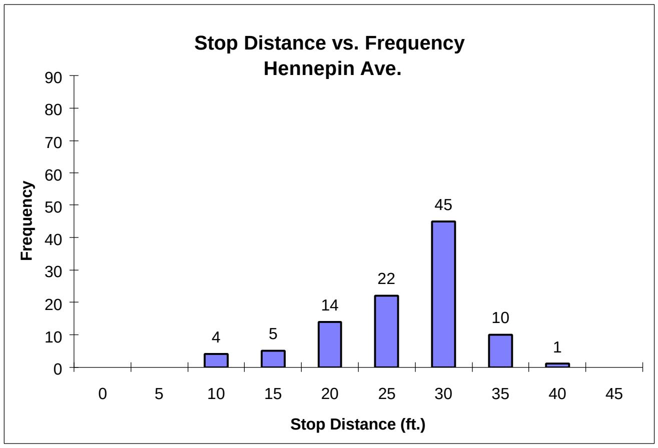


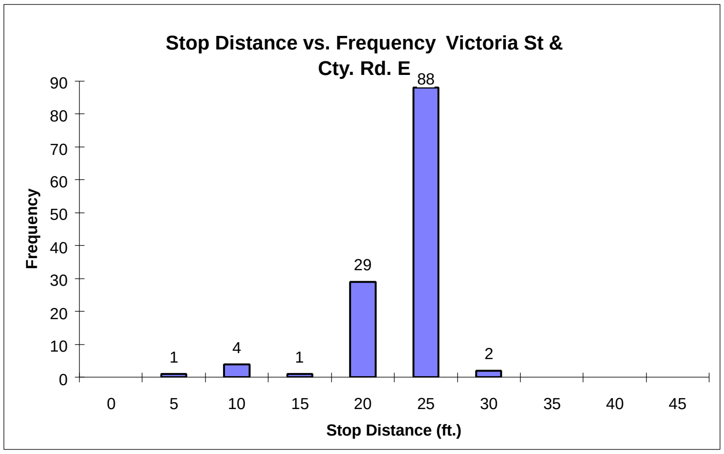




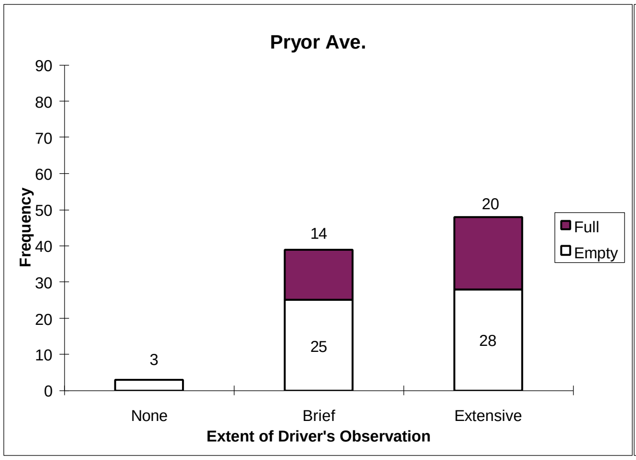
Stop Distance - Spring Observations

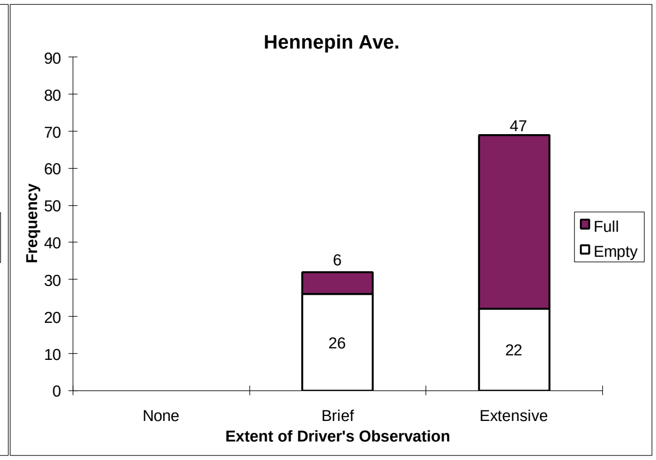


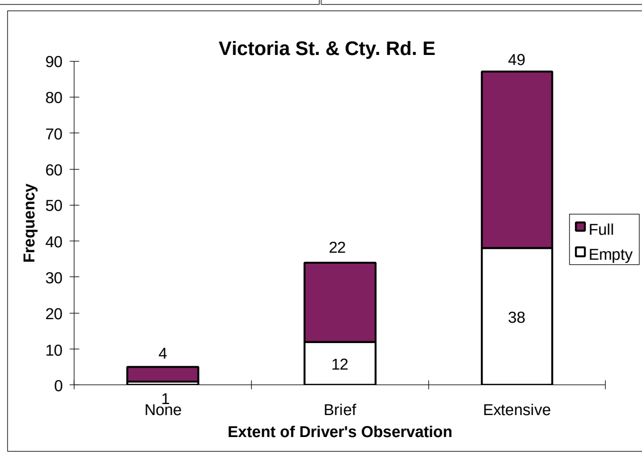




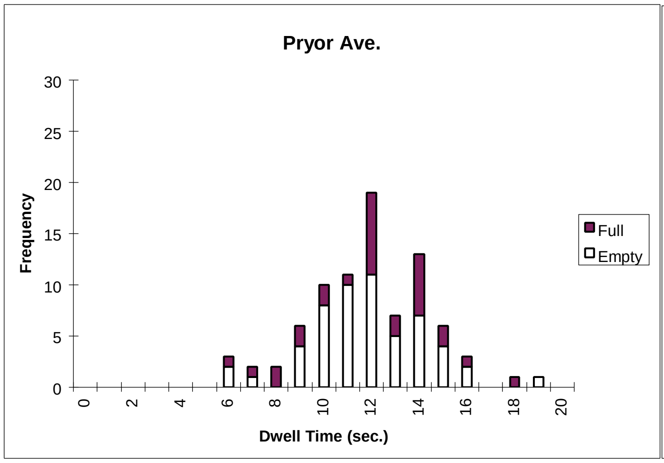
Driver Observation vs. Frequency-Spring Observations

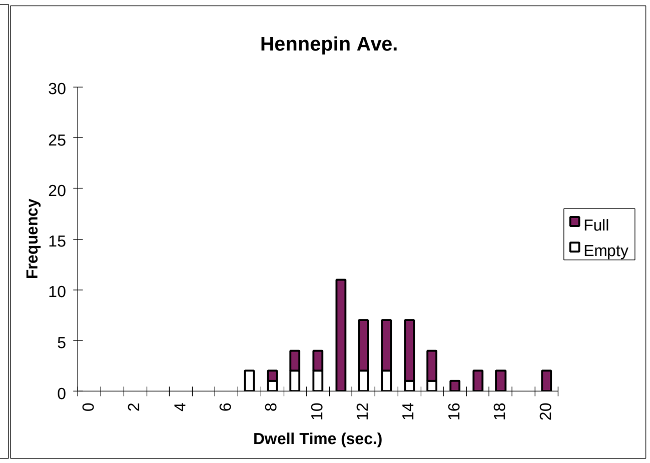


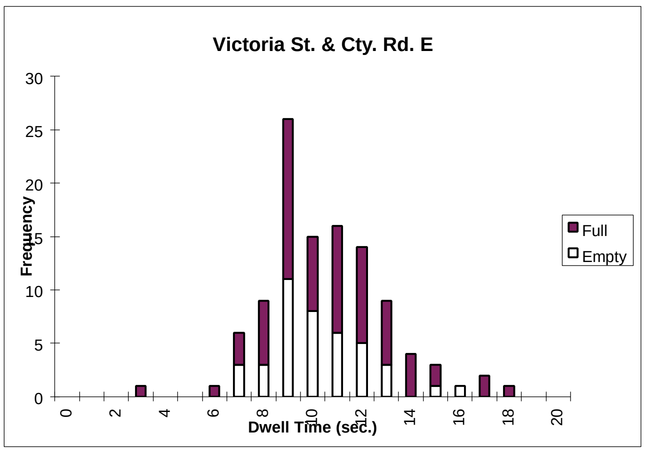




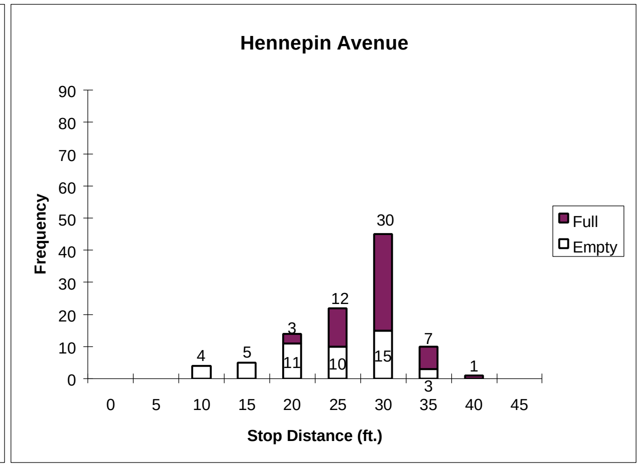
Dwell Time vs. Frequency Spring Observations







Stop Distance vs. Frequency Spring Observations



APPENDIX I

BUS DRIVER INTERVIEW RESULTS

Appendix I

Bus Driver Interview Questions
Passive Crossing Application
July 20, 1998

1. *What does the system do when you approach a crossing? - What if a train is coming?*

Driver 1	Yellow comes on – if train then: reds come on and beeping
Driver 2	One to two blocks before yellows flash – if train then: beeps and red flash
Driver 3	Yellows then reds– if train then : beeping
Driver 4	Yellows two to two and a half blocks before and three to four beeps– if train then: red and beeps with trackside crossing

2. *Have you noticed any change in the operation of the system?*

Note: One bus had a system malfunction that was not related to the modification. The interview responses from this driver were omitted from the findings.

- Yes
- Yes
- Yes

3. *Describe the change.*

- Went off before the track-side lights did (beep too).
- Didn't work.
- Worked well today, yellows came on sooner, reds came on sooner and stayed on longer than normal. Also, the trackside lights were on less time than the in-vehicle lights.
- Lights came on before track-side, a long time before in run #1.

4. *What do you think of the change?*

- More effective, however, people say don't rely on lights in the bus.

- I would like to see the in-vehicle flash before the track-side.

- Seems better - improved. My regular bus is in consistent. Also, the more warning the better. The system in this person's regular bus worked intermittently, it showed reds sometimes when no train was present.

- Change is good

5. *In this case the system triggered without the lights do you feel this was effective?*

- Yes - safe

6. *If the system triggered <u>after</u> the trackside lights, how would you feel?*

- No real difference.

- They should come on before or at the same time as the trackside warning, otherwise, it is not as safe.

- The system should come on before or at the same time as the trackside warning, not after.

7. *Did you feel the system worked adequately today?*

- Yes

- The system worked great today. The beeping quit and lights stayed on intermittently. This was O.K., but because otherwise there is a lot of beeping (in the regular bus it was a little loud).

- Would be great if this system was independent of the track-side lights because it would be a back-up if trackside system failed.