IDAHO STORM WARNING SYSTEM OPERATIONAL TEST

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ACRONYMS, TERMS, AND DEFINITIONS

Handar-Belfort	Sensor marketed by Handar Corporation, manufactured by Belfort Instrument Co.
ITD	Idaho Transportation Department
ITS	Intelligent Transportation System
LIDAR	Sensor marketed by Santa Fe Technologies. LIDAR acronym for Light Detection and Ranging.
NIATT	National Institute for Advanced Transportation Technology
POE	Port-of-Entry
SSI-Belfort	Sensor marketed by Surface Systems, Inc. (SSI), manufactured by Belfort Instrument Co.
SSI-WIVIS	Sensor marketed by Surface Systems, Inc. (SSI). WIVIS acronym for Weather Identifier and Visibility Sensor. Manufactured by Scientific Technology, Inc.
UPS	Uninterruptible Power Source
USDOT	United States Department of Transportation
VMS	Variable Message Signs. Signs installed along a roadway that can be programmed to provide variable information to motorists.

EXECUTIVE SUMMARY

Introduction and Background

The Storm Warning Project was initiated in 1993 as a result of a large number of serious traffic crashes that occurred during periods of low visibility on I-84 in southeastern Idaho between 1988 and 1993. The purpose of the project was to determine if visibility sensors and the resultant information supplied to drivers on roadway message signs would reduce vehicle speeds to safe levels as warranted by weather conditions.

System Description

Sensors measuring traffic, visibility, roadway, and weather data were installed at the test site, and automatic traffic counters recorded the lane number, time, speed, and length of each vehicle passing the sensor site. To confirm visibility readings provided by the sensors, a video camera was installed at the test site and aimed at a series of target signs placed along the interstate at various known distances. During the course of the project, four variable message signs (VMSs) were installed along the test section of roadway, to provide information to travelers regarding low visibility and other road condition information in the test area. Data generated by the sensor systems were transmitted to a master computer, which recorded readings every five minutes. This information provided a baseline of driver behavior, to help determine if the signs were causing drivers to change their behavior.

Project Objectives

The project was conducted in two phases. The objectives of Phase I were to: determine if the visibility sensors provide accurate visibility measurements, determine which sensor is most reliable and most cost effective, and establish baseline driver behavior for vehicles in the test area.

The objectives of Phase II were to: assess whether the VMSs would reduce vehicle speed during periods of low visibility, determine if the sensor systems could provide usable data for

ITD personnel managing the variable message signs, and assess the relationship between vehicle speed and weather factors such as low visibility, high winds, or poor road conditions.

Results and Conclusions

This research finds that information provided to drivers during periods of poor weather encouraged them to reduce their speeds more than if the information were not provided. These and other relevant conclusions are summarized below.

- The three sensors provided reasonable estimates of the visibility present at the study site. The three sensors agreed on visibility classification (either above or below 0.23 miles) 83 percent of the time. Two of the three sensors (Handar-Belfort and SSI-Belfort) agreed 97 percent of the time. The Handar-Belfort and SSI-Belfort sensors provided the best estimates of visibility.
- After some initial problems with power supplies and communications, the system operated reliably. The cost of operating and maintaining the sensors and the supporting systems was minimal.
- Even without the information from the variable message signs, drivers reduced their speeds in poor weather conditions.
- During periods of low visibility, when all other conditions were ideal, the sign did not have an apparent effect on driver speeds. The availability of data during those conditions, however, was limited. It may be that with a larger amount of data the effects of the sign would be evident.
- When the sign was operational during periods of high winds and other extreme weather and road conditions, drivers in both directions reduced their speeds. Substantially greater speed reductions were observed in the I-84 southbound direction, where drivers benefited from the information on the sign.
- When this project began, very few road weather information stations such as these existed throughout the state. There are currently 24 sites in operation and a comprehensive site plan in place to install many others. At least in part,

the Idaho Storm Warning Project helped to illustrate how this type of data could be used to maintain the state and interstate highways more efficiently during winter weather conditions. This is a significant benefit of conducting projects such as the Storm Warning Project.

1.0 INTRODUCTION AND BACKGROUND

The purpose of the Idaho Storm Warning System Operational Test (Storm Warning Project) was to evaluate the feasibility of using advanced weather and visibility sensing equipment to provide early warning to Idaho Transportation Department (ITD) personnel and motorists regarding dangerous driving conditions due to low visibility caused by blowing or heavy snow, or blowing dust. The project was initiated in 1993, in response to 18 major traffic crashes that occurred between 1988 and 1993 on a rural section of interstate highway in southeast Idaho (Figure 1). These crashes involved a total of 91 vehicles, and resulted in 9 fatalities and 46 injuries. Poor visibility was identified as a major factor contributing to these crashe4s.

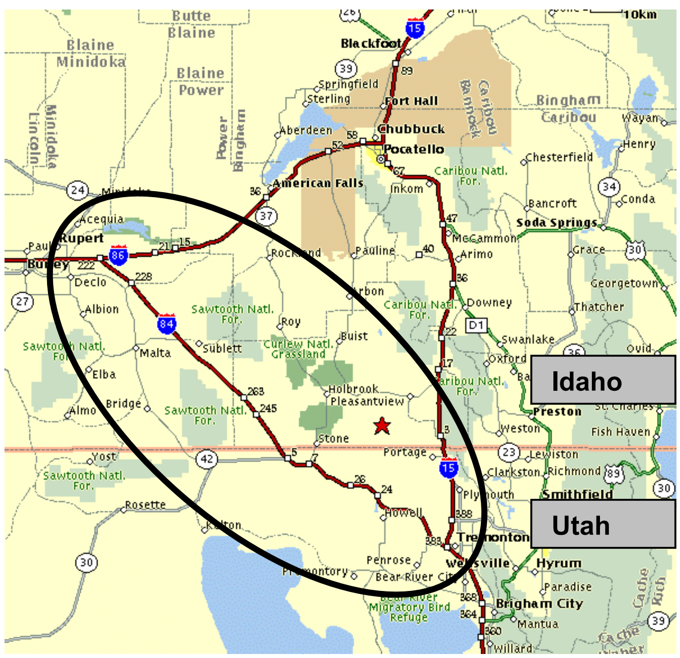

Figure 1. Storm Warning Project study area

The project is part of the U.S. Department of Transportation's (USDOT) Intelligent Transportation System (ITS) field operational test program, which is designed to test new transportation technology applications. One of the major requirements of the operational test program is that an independent evaluation of each project be conducted, in order to provide objective documentation of the effectiveness of the technology for the given application. This report, in concert with previously published progress reports contained in the Appendices, provides that documentation for the Storm Warning Project.

1.1 Overview of this Report

The report is organized to provide information in a sequence that corresponds to the chronology of the project. Section 1 introduces the project, and provides an overview of its history, a description of the systems tested, test objectives, and evaluation approach. Section 2 reports on the performance and reliability of the sensors. It documents Phase I of the project, which involved evaluating the sensors' ability to determine low visibility conditions. Section 3 discusses the response of drivers to the driving conditions and to the information provided by variable message signs. It documents Phase II of the project, which studied the degree to which driver behavior could be modified through presentation of roadway condition information via variable message signs. Section 4 presents the results and conclusions of this operational test.

The Appendix includes detailed background on the project, in the form of the following previously published reports submitted by the evaluation team:

- *APPENDIX A: Idaho Storm Warning System ITS Operational Test Phase I Interim Report, January 1997*
- *APPENDIX B: Idaho Storm Warning System ITS Operational Test Progress Report for Winter 1996/1997 - Evaluation of Weather and Traffic Conditions, December 1997*
- *APPENDIX C: Idaho Storm Warning System ITS Operational Test Progress Report for Winter 1997/1998 – Evaluation of Weather and Traffic Conditions, November 1998*

1.2 Project History

The Storm Warning Project was initiated in 1993 through a cooperative arrangement between the USDOT and the ITD. The engineering firm CH2M-HILL was retained as project manager. The independent evaluation team included Michael Kyte of the University of Idaho and Patrick Shannon of Boise State University. In addition, the suppliers of the visibility sensing equipment, discussed later in this report, were included as partners in this test.[1]

The original plan called for a two-year project covering the two phases previously mentioned. With full concurrence and support of the sponsoring agencies, the project was extended twice, to operate for an additional five years. The extensions were justified by the fact that additional data were needed to meet the project objectives. Unlike some operational tests, in which experiments can be conducted under controlled conditions, data collection for the Storm Warning Project was dependent on uncontrollable weather patterns at the test site. To satisfy the project objectives, low visibility events were required. Although the test site area was well known for such low visibility conditions, it has taken seven years to accumulate a sufficient number of such event periods to perform a meaningful evaluation.

Initially, three suppliers of sensor systems participated in the study: Surface Systems, Inc. (SSI), Handar Corporation, and Santa Fe Technologies.

SSI provided two visibility sensors. One is called WIVIS, (Weather Identifier and Visibility Sensor), and is manufactured by Scientific Technology, Inc. This sensor is referred to as SSI-WIVIS in the report. The second sensor that SSI provided was manufactured by Belfort Instrument Co., and is referred to as SSI-Belfort in the report.

[1] It should be noted that CH2M HILL, Surface Systems Incorporated, Handar Corporation, Santa Fe Technologies, and ITD made significant unreimbursed manpower and financial contributions toward the success of this operational test.

The Handar Corporation provided one sensor, which was also manufactured by Belfort. This sensor is referred to as the Handar-Belfort sensor in the report. Both of the SSI sensors and the Handar sensor were installed in the fall of 1993.

The LIDAR (Light Detection and Ranging) system, provided by Santa Fe Technologies, was installed in the fall of 1995. The LIDAR system was not operational during any of the low visibility event periods that occurred during Phase I of the study. As a result, Santa Fe Technology withdrew their LIDAR sensor from the study in 1997. No data from the LIDAR system has been used in this final evaluation.

The test plan originally called for the installation of variable message signs (VMSs) along the test sections of roadway, which would provide information to travelers regarding low visibility in the test area. The number and location of these signs was to be determined once the test had begun. By the time the test began, however, two VMSs had already been installed by ITD. In 1997 two additional signs were installed for use during Phase II. Additional visibility sensors were added at Sweetzer Summit to assist ITD personnel in responding to adverse weather conditions at that site, but the data collected by these sensors were not used in the analysis.

Two other historical notes are important. On April 11, 1996, the speed limit in the project area was increased from 65 to 75 mph for cars and trucks. In 1998, truck speeds were reduced to 65 mph. This change did not affect the data collected during Phase II, when the speed limit was 75 mph throughout the evaluation period.

1.3 System Description

1.3.1 Sensors

Sensors measuring traffic, visibility, roadway, and weather data were installed along the I-84 corridor near the Cotterell port-of-entry (POE) in southeastern Idaho (Figure 2). In addition, automatic traffic counters recorded the lane number, time, speed, and length of each vehicle passing the sensor site. This information provided a baseline of driver behavior, which could then be compared to the test data to determine whether or not the signs were indeed causing drivers to change their behavior.

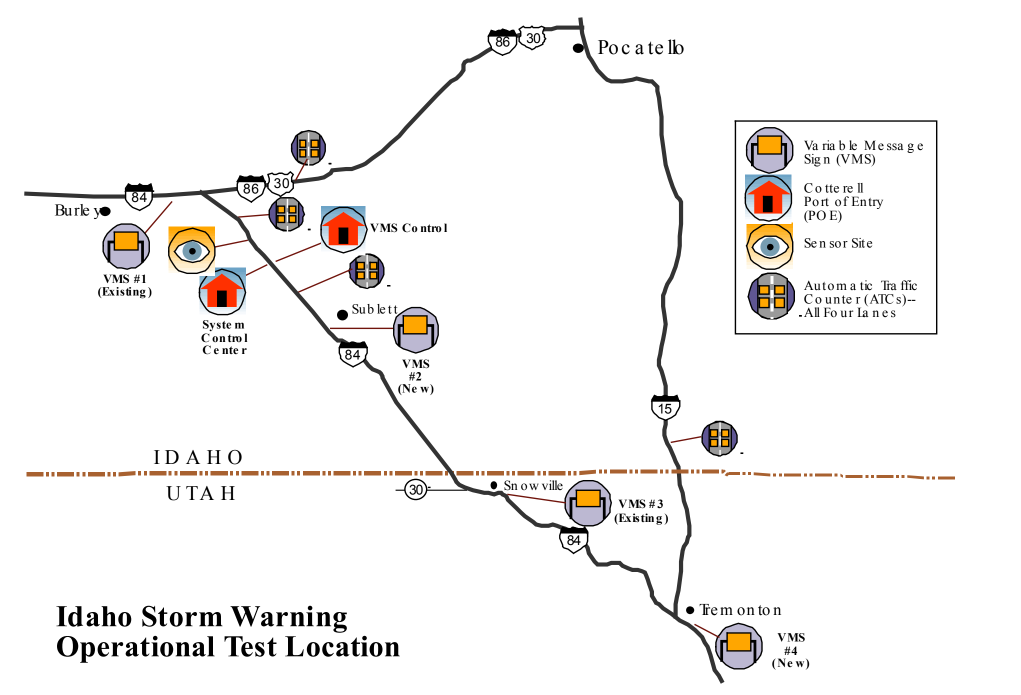

Figure 2. Storm Warning Project Test Area Layout

The SSI and the Handar systems used in the project had been in use at airports or remote mountainous regions, but at the time the test began, few had been used in rural transportation applications like the test area. Both systems measure visibility with point detection systems based on a forward scatter detection technology. In addition, the systems provided instrumentation to measure wind speed and direction, precipitation amount, air temperature, relative humidity, roadway surface condition (SSI only), and the type and rate of precipitation (SSI only). The weather and visibility sensors were located within a few hundred feet of the automatic traffic counters on I-84, so that all data represented conditions at the same location. Data generated by these systems were transmitted to a master computer located at the Cotterell POE, which recorded readings every five minutes. Traffic flow rates and speed were summarized for each five-minute period by lane and vehicle type (either passenger car or truck).

1.3.2 Video Camera

In addition to the sensor systems, a closed circuit television camera was installed at the test site. This camera was aimed at a series of five target signs that were equipped with flashing lights to enhance their visibility. The target signs were placed along the interstate at various known distances (250, 500, 850, 1200 and 1500 feet), to aid in the assessment of visibility. The time-stamped image from this camera was available in the POE building for possible use by staff during the test. The videotape was saved for later analysis.

1.3.3 Variable Message Signs

Four variable message signs (VMSs) that provided information to motorists using this section of I-84 were installed (Figure 2). Two of these, one located near Sublett and the second located just west of the I-84 and I-86 junction, have the most direct impact on motorists in the project area. The other two signs were located further south, one near the Idaho-Utah boarder and the other in Utah near the I-84 and I-15 junction at Tremonton. These southernmost signs were primarily used to assist maintenance crews in closing the interstate during periods of severe weather conditions. The VMSs were controlled by ITD maintenance staff, who maintained a log indicating the dates and times that the VMSs were employed and the messages that were used.

The data collected by the sensor systems were transmitted to the master computer at the Cotterell POE, located a short distance south of the Yale interchange. The master computer provided a warning to ITD maintenance personnel when a low visibility event was detected and provided a means to access data via a modem. The primary function of the master computer during the operational test, however, was to store the data for later analysis.

1.4 Storm Warning Test Objectives

1.4.1 Phase I

The first phase of the project evaluated the performance of the sensors. The objectives of Phase I were:

- To determine whether the visibility sensors being tested provide accurate visibility measurements in a rural setting.
- To determine which sensor system is most reliable, and most cost effective, under the rural conditions of the test environment.
- To establish baseline driver behavior for vehicles in the test area.

This analysis is documented in detail in the interim[2] and progress[3] [4]reports, all of which can be found in the Appendix to this report.

1.4.2 Phase II

Phase II of the project examined the effectiveness of the VMSs as a tool for reducing vehicle speeds during periods of low visibility. Specifically, the Phase II objectives were:

- To assess whether the use of VMSs will have the desired effect of reducing both the mean and standard deviation of vehicle speed during periods of low visibility.
- To determine how effective the sensor systems could be at providing usable data for ITD personnel managing the variable message signs in periods of low visibility, high winds, or poor road conditions.
- To assess the relationship between vehicle speed and weather factors such as low visibility, high winds, or poor road conditions.

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[2] Idaho Storm Warning System ITS Operational Test Phase I Interim Report, January 1997.
[3] Idaho Storm Warning System ITS Operational Test Progress Report for Winter 1996/1997 – Evaluation of Weather and Traffic Conditions, December 1997.
[4] Idaho Storm Warning System ITS Operational Test Progress Report for Winter 1997/1998 – Evaluation of Weather and Traffic Conditions, November 1998.

1.5 Evaluation Approach

1.5.1 Phase I

The approach used to evaluate the data began with the identification of "event" periods. These were time periods during the test when the sensors were operational and weather conditions were believed to be poor with a likelihood of low visibility. Information indicating these weather conditions included sensor data, reports from POE personnel, videotapes from the test site, vehicle speed data, and general weather information. In addition, good weather periods were identified in order to establish baseline conditions.

The next step was to compare the data to determine, to the extent possible, the accuracy of the sensors' assessment of visibility by answering questions such as:

- Did the sensors agree with one another?
- Did the video images confirm decreases in visibility indicated by the sensors?
- Did the sensor readings correlate with changes in vehicle speeds?

1.5.2 Phase II

Phase II involved collection of similar data, with the addition of road closure information and VMS logs. These additional data tracked the messages displayed on the VMSs in the test site area, including times that messages were changed, content of messages, as well as times that physical closures were required to ensure safety. The focus of the data analysis in Phase II was to assess the effect of VMS messages on changes in vehicle speed. Since drivers tended to slow during adverse weather conditions, the challenge here was to determine to what degree the VMSs contributed to changes in vehicle speed.

2.0 PHASE I - PERFORMANCE OF THE SENSORS

2.1 Methodology

The purpose of Phase I was to determine if the sensors could provide visibility readings accurate enough that ITD personnel could rely on them for providing early warning to motorists of low visibility conditions. One issue in determining whether a visibility sensor is providing accurate results is the ability to compare sensor readings to the "true visibility." In an operational test like this, it is not possible to artificially create controlled conditions with known visibility levels. Visibility changes occurred at the test site due to fog, dust, snow or other factors in uncontrolled conditions and at unknown levels. Therefore, it was necessary to use three different methodologies to evaluate the sensors. The three approaches were:

- **Video Confirmation** - The objective in using the videotapes was to simulate what a driver would see when the visibility sensors indicated low visibility. The sensor visibility readings would be compared to the perceived visibility distances, as determined from the video, for the specific time periods. Evidence for a sensor's accuracy would exist if the distance to the farthest visible target closely matched the visibility reading from the sensor.
- **Direct Sensor Comparison** - The visibility readings from the different sensors would be compared over specific periods of time. If the sensors' visibility readings matched closely (or coincided in identifying the occurrence of low visibility events), this would support the hypothesis that the sensors were working properly.
- **Visibility Readings vs Vehicle Speed** - Changes in visibility readings would be compared to changes in vehicle speeds at corresponding times. It is expected that motorists would drive slower under conditions of reduced visibility, especially when severe visibility restrictions occur. Correctly functioning sensors would provide visibility readings that were highly correlated with vehicle speed over time.

2.2 Selection of Normal Days and Event Days

Sixteen days from the winter of 1995-1996 were selected for analysis (Table 1). Three days represented normal conditions—clear visibility, good road conditions, no precipitation. Thirteen days represented conditions with visibility of 0.50 miles or less (as indicated by one or more of the three sensors and verified by ITD personnel at the Cotterel POE).

Table 1. Dates selected for Phase I sensor performance analysis

Normal Days	Event Days
December 21, 1995	December 29, 1995 (Light snow)
January 6, 1996	January 12, 1996 (Dense fog)
February 8, 1996	January 17, 1996 (Snow, I-84 closed 6:06 am)
	January 18-20, 1996 (Light snow)
	January 21, 1996 (Light to moderate snow)
	January 22, 1996 (Dense fog)
	January 24, 1996 (Light to moderate snow)
	January 29, 1996 (Light to moderate snow)
	January 30, 1996 (No precipitation)
	February 4, 1996 (Light snow)
	February 24, 1996 (Light snow)
	March 23, 1996 (Light snow)
	March 28, 1996 (Light snow)

2.3 Video Confirmation

The time-lapse video camera proved to be a useful tool for confirming significant changes in visibility levels, but was not effective in determining precise visibility distances. In addition, power failures caused the video camera to be inoperable during several time periods when the sensors indicated that a visibility event had occurred. Furthermore, assessing the visibility during darkness was difficult. Vehicle headlights caused blooming in the video image, making it difficult for observers to distinguish between the target signs and the vehicle headlights.

The evaluation team reviewed videotape for five of the event days and estimated visibility based on their judgment of the furthest observable target sign. Time series plots were prepared to compare sensor and video visibility readings. For example, Figure 3 shows the SSI-Belfort visibility data and video visibility data for the hours between 7:00 and 9:00 am on January 24, 1996, a day with blowing snow conditions. In this example, the SSI-Belfort sensor consistently reported the visibility to be higher than was determined by the video. The correlation between the sensor and video visibility was -0.209, indicating that there were differences in visibility measurements as well as an inconsistency in the magnitude of the differences across the time period.

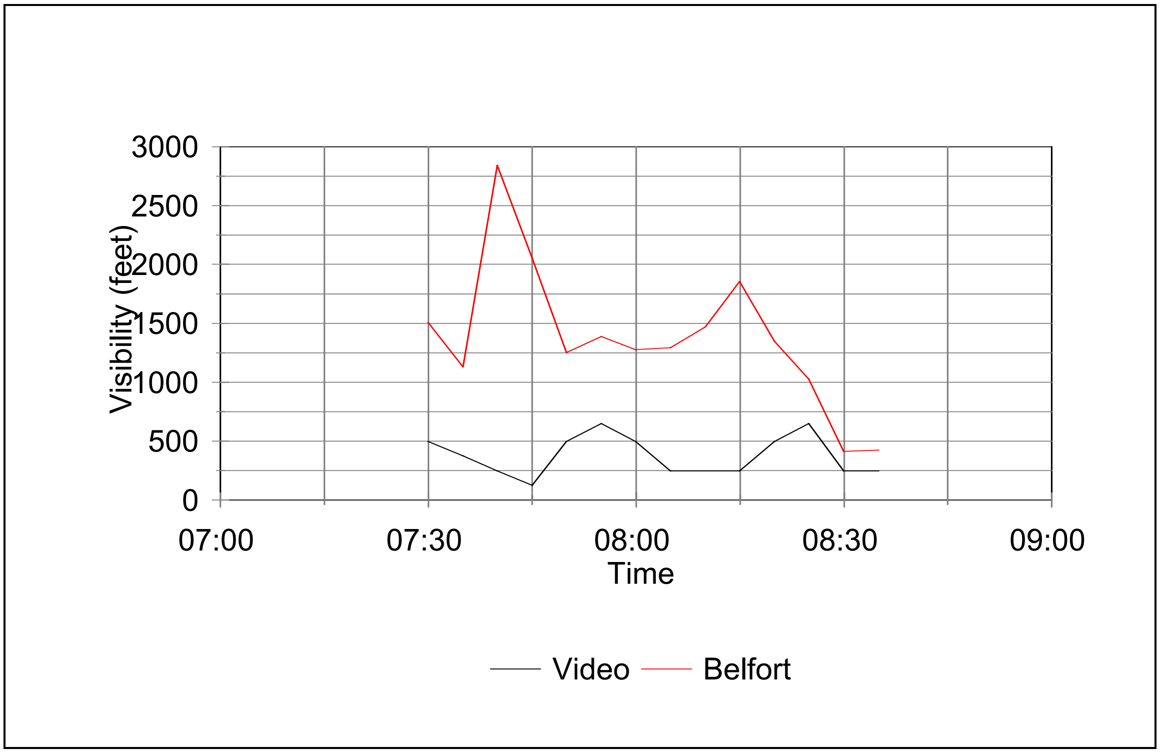

Figure 3. Sensor Analysis: Video Comparison January 24, 1996

Figure 4 shows a similar pattern on January 29, 1996, over a twelve-hour period from 6:00 am to 6:00 pm. The SSI-WIVIS sensor consistently shows much higher visibility than portrayed by the video analysis and, again, the magnitude of the difference varies. The correlation between SSI-WIVIS and video visibility readings is only -0.0092.

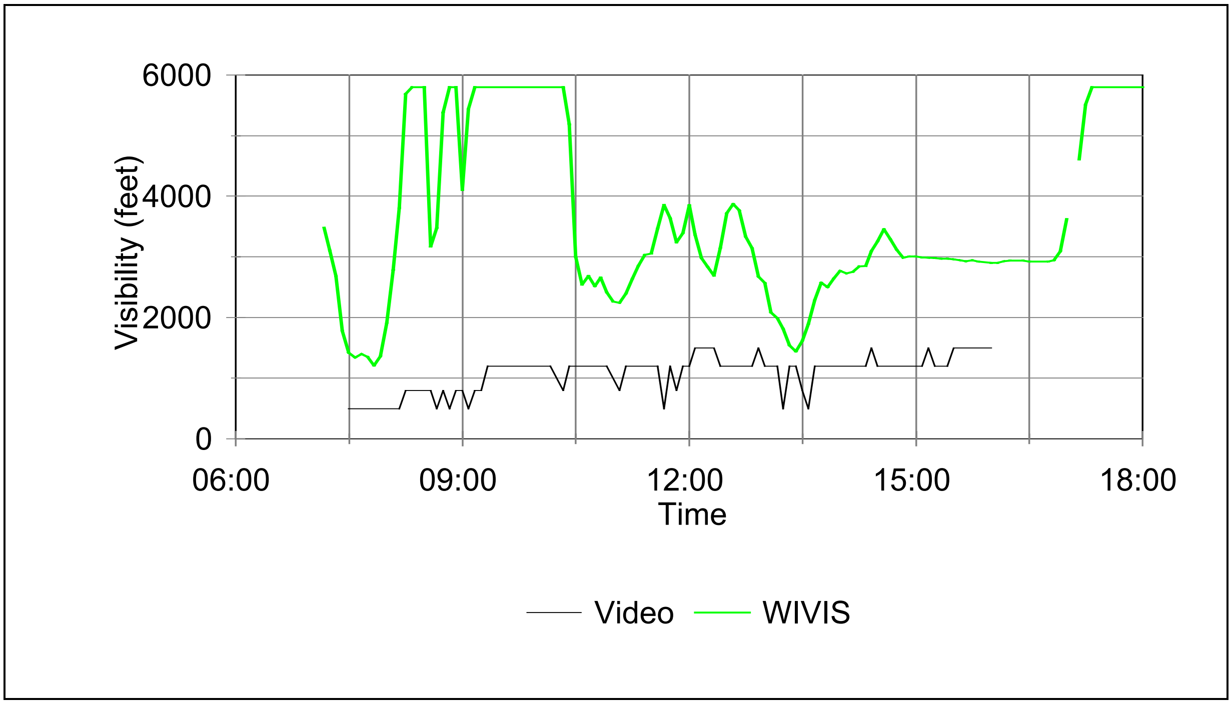

Figure 4. Sensor Analysis: January 29, 1996

Table 2 summarizes the videotape analysis. On January 24 and 29, there was poor correlation between the video and the visibility sensors. On January 30, both the video and the visibility sensors showed clear visibility. On February 4 and 24, both the video and the visibility sensors showed low visibility. Based on these results, the video analysis is inconclusive and cannot be used to substantiate whether the visibility sensors provide accurate estimates of visibility.

Table 2. Sensor Analysis - Video Summary

Date	Weather Conditions	Sensor Information	Video Information	Correlation
January 24, 1996	Blowing Snow	SSI-Belfort Sensor – mean visibility = 1,600 feet	Video – mean visibility = 460 feet	-0.209
January 29, 1996 7:00AM-9:00am	Blowing Snow	SSI-WIVIS – mean visibility = 3,950 feet	Video – mean visibility = 840 feet	-0.0092
January 29, 1996 10:00AM – 5:00pm	Blowing Snow	SSI-WIVIS – mean visibility = 2,450 feet	Video – mean visibility = 990 feet	
January 30, 1996	Clear	Handar-Belfort and SSI-Belfort indicate clear – SSI-WIVIS shows .30 to .70 miles	Video shows clear visibility	---
February 4, 1996	Snowing	All three sensors show low visibility	Video shows 1 sign at 250 feet	---
February 24, 1996	Blowing Snow	All three sensors show periods of low visibility	Video shows 2-3 signs	---

2.4 Direct Sensor Comparison

A second method for determining whether the sensors provide accurate visibility readings is to directly compare visibility data from the Handar-Belfort, SSI-Belfort, and SSI-WIVIS sensors. This analysis will attempt to answer three questions:

- Do the three sensors provide the same visibility readings before and during visibility events?
- Are the visibility readings from the three sensors correlated over time?

- Do the three sensors simultaneously identify the occurrence of low visibility (less than 0.23 miles) events?

The analysis focused on five of the thirteen event days.

2.4.1 December 29, 1995

On December 29, 1995, the test site was experiencing light snowfall. Figure 5 shows a time series plot for a one-hour period between 10:00 pm and 11:00 pm. All three sensors show visibilities below 1.0 mile. The SSI-Belfort and Handar-Belfort sensors track closely, with readings varying between 0.70 and 0.92 miles. The SSI-WIVIS sensor readings were generally less than 0.40 miles.

The correlation between visibility sensor readings is shown in Table 3. The correlation for visibility estimates was highest between SSI-Belfort and SSI-WIVIS, at 0.780. Handar-Belfort was also highly correlated with SSI-WIVIS, at 0.756, but Handar-Belfort and SSI-Belfort were less closely related, with a correlation coefficient of 0.365. This figure shows one of the characteristics of the correlation coefficient. Clearly, SSI-Belfort and Handor-Belfort produce very similar estimates of visibility, but their estimates do not always track (move up or down) closely together.

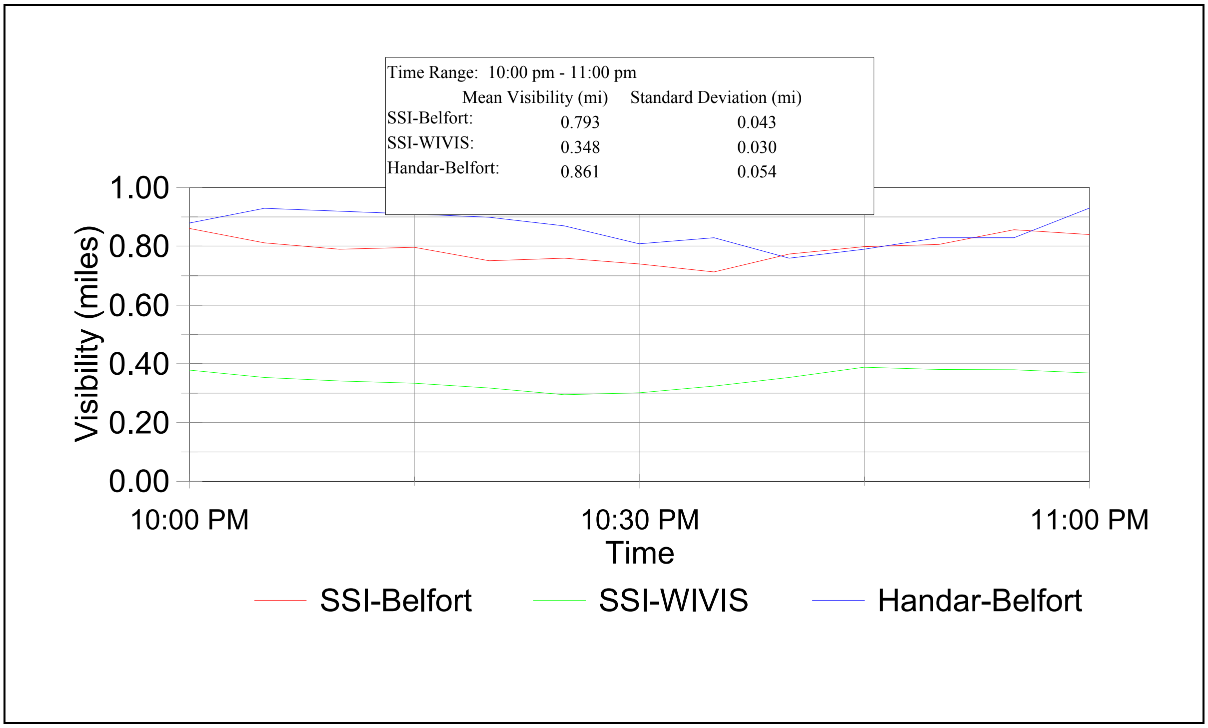

Figure 5. Sensor Analysis: Visibility Comparisons December 29, 1995

Table 3. Correlation between visibility sensor readings – December 29, 1995

Comparison	**Correlation Coefficient**
SSI-Belfort – Handar-Belfort	0.365
SSI-Belfort – SSI-WIVIS	0.780
Handar-Belfort – SSI-WIVIS	0.756

2.4.2 January 12, 1996

On January 12, 1996, the test site experienced dense fog. As shown in Figure 6, all three sensors showed a significant drop in visibility just after 1:00 am. This condition continued until just before 10:00 am. While not providing identical visibility readings, the three sensors tracked closely.

Figure 7 shows an expanded view of the 1:30 to 9:00 am time period. During this period, the SSI-WIVIS sensor showed visibilities that were consistently higher than Handar-Belfort and SSI-Belfort, a result reversed from that shown in Figure 5. For these data, the three sensors were highly correlated, as show in Table 4. Thus, even though the actual visibility readings were different for the three sensors, they tended to track together over time.

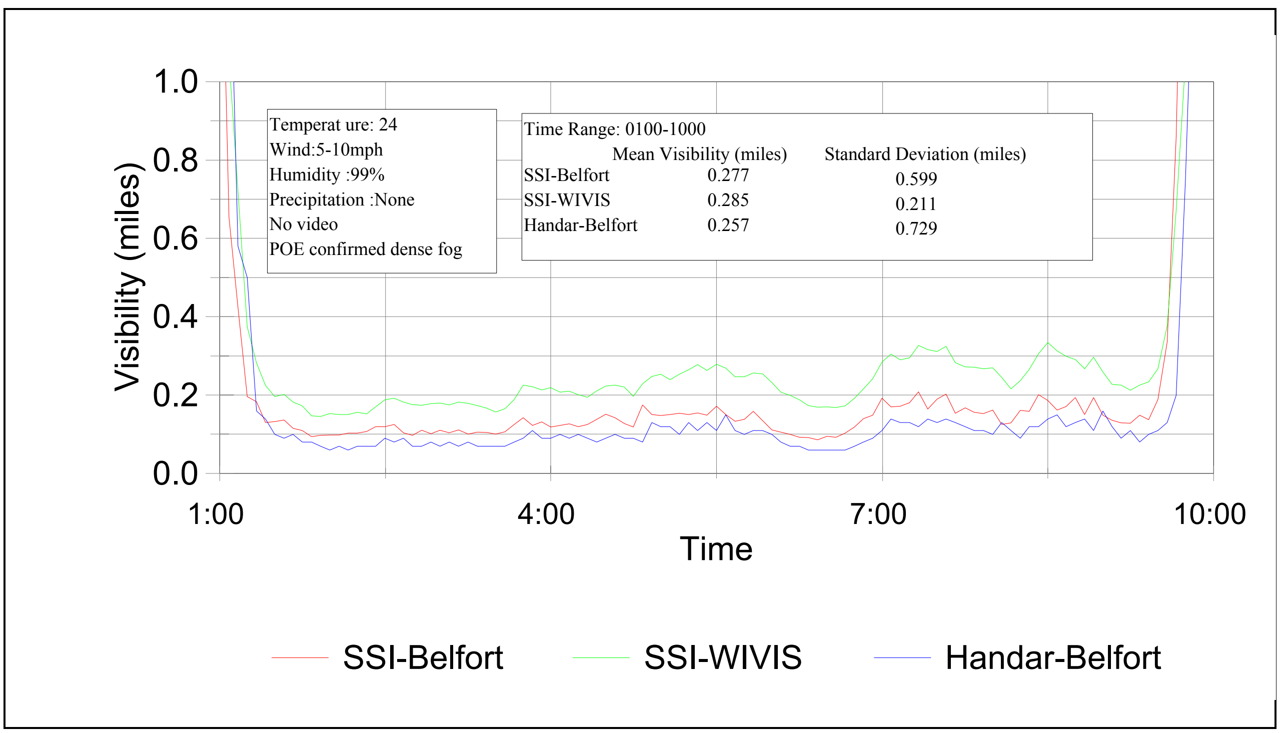

Figure 6. Sensor Analysis: Visibility Comparisons January 12, 1996

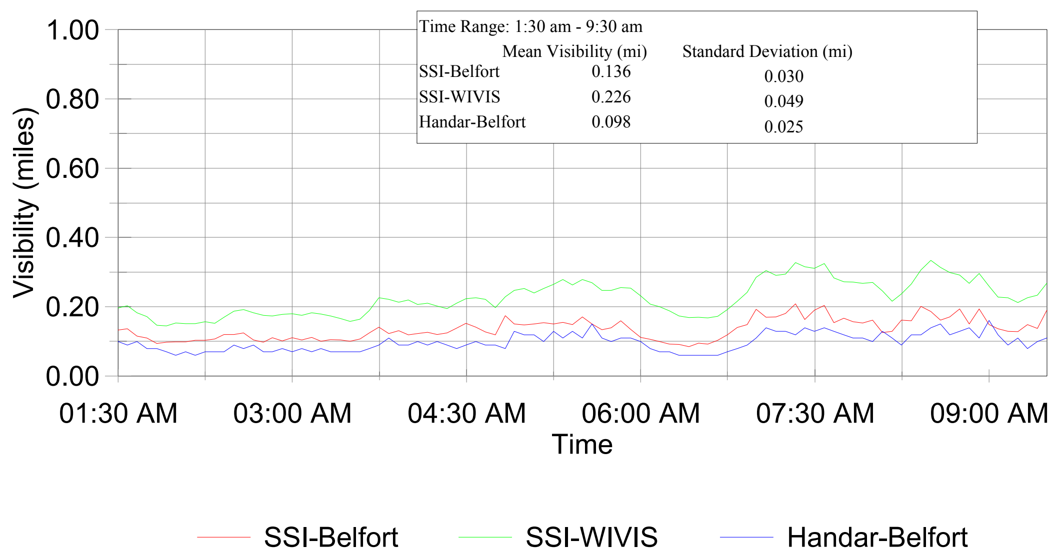

Figure 7. Sensor Analysis: Visibility Comparisons January 12, 1996

Table 4. Correlation between visibility sensor readings - January 12, 1996

Comparison	**Correlation Coefficient**
SSI-Belfort – Handar-Belfort	0.944
SSI-Belfort – SSI-WIVIS	0.919
Handar-Belfort – SSI-WIVIS	0.913

2.4.3 February 24, 2000

On February 24, 2000, between the hours of midnight and 7:30 pm, the test site experienced high winds and blowing snow. Figure 8 shows the visibility readings for the three sensors. Figure 9 shows the same data for the hours between 12:00 noon and 6:00 pm, when the most severe visibility event was occurring. The SSI-Belfort sensor tended to have higher visibility readings and the SSI-WIVIS had lower readings. Table 5 shows that the correlation between Handar-Belfort and SSI-Belfort visibilities was quite high at 0.867, indicating that even though those sensors showed different visibility readings, they did tend to track fairly well. This is not the case for the SSI-WIVIS sensor on this day. The correlations between SSI-WIVIS and the two other sensors were 0.305 and 0.288, indicating poor tracking between these two sensors.

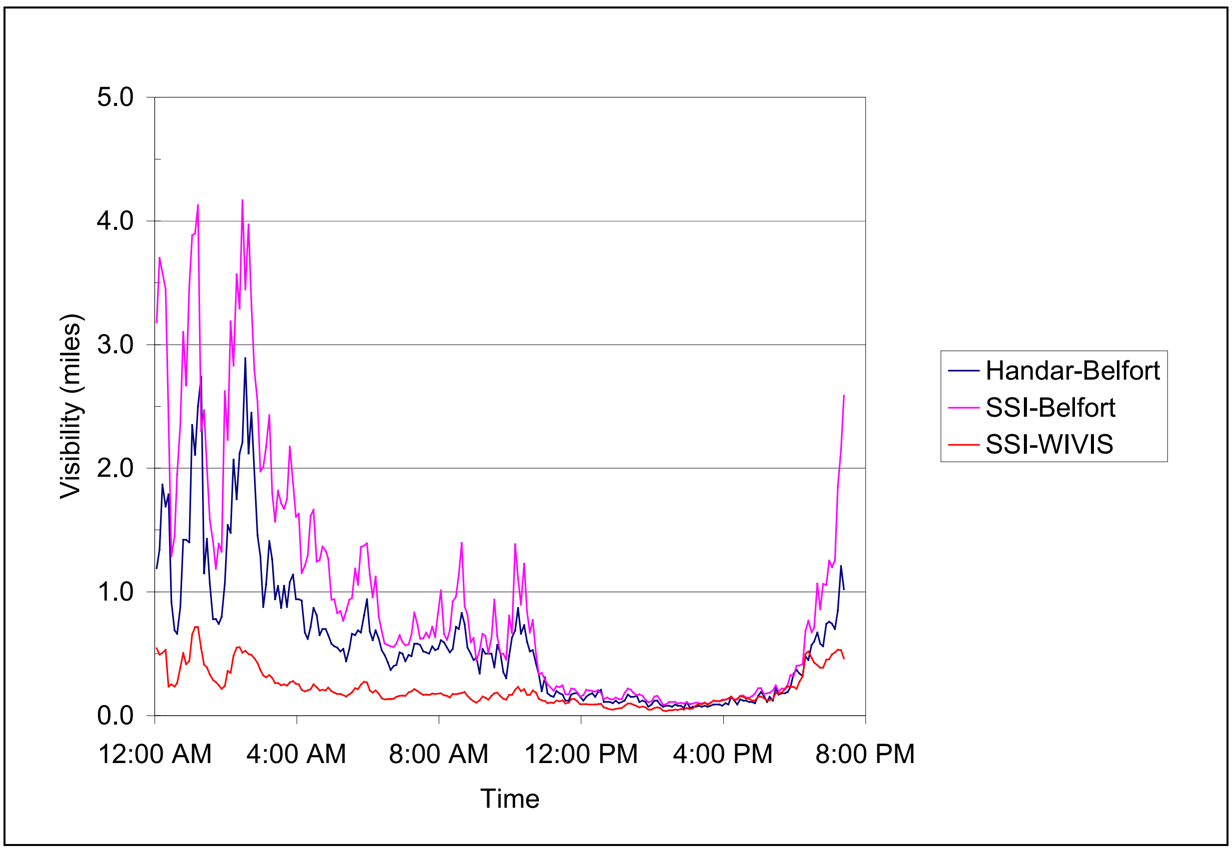

Figure 8. Sensor Analysis: Visibility Comparisons February 24, 2000

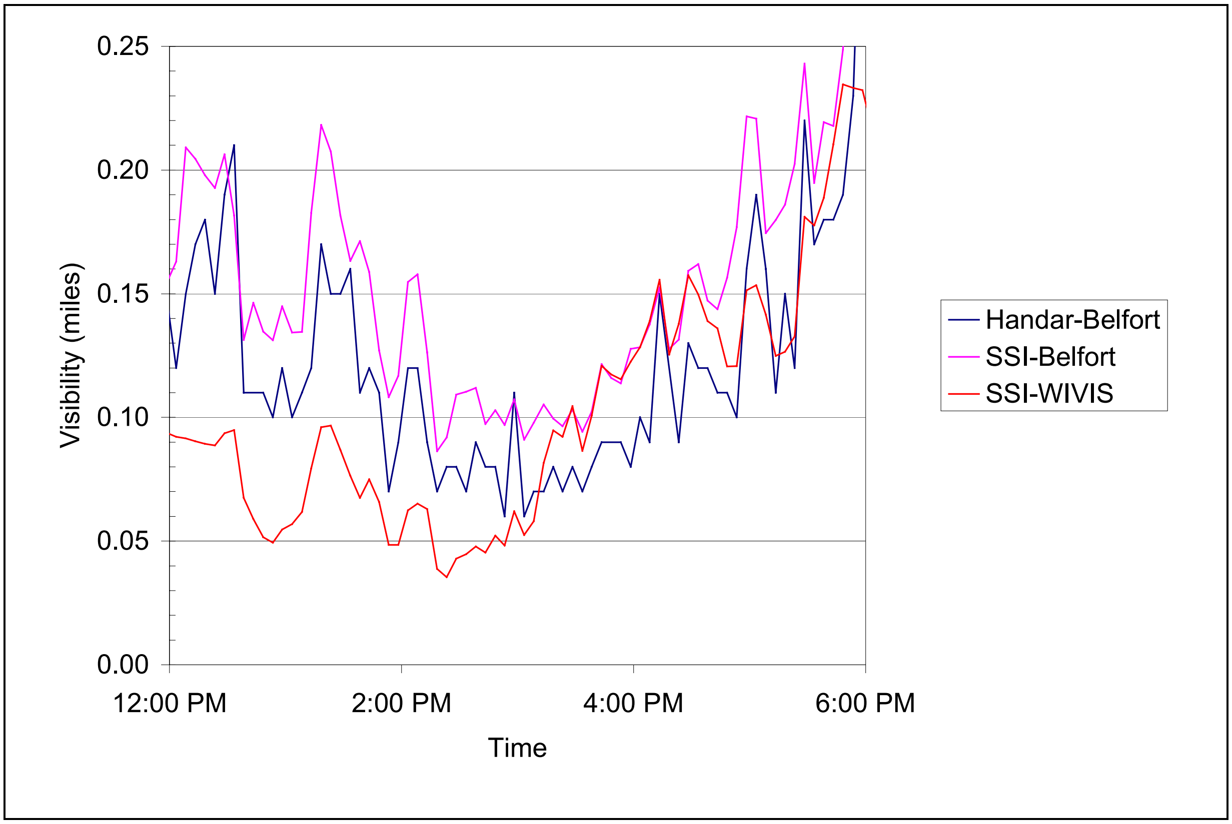

Figure 9. Sensor Analysis: Visibility Comparisons February 24, 2000

Table 5. Correlation between visibility sensor readings – February 24, 2000

Comparison	Correlation Coefficient
SSI-Belfort – Handar-Belfort	.867
SSI-Belfort – SSI-WIVIS	.305
Handar-Belfort – SSI-WIVIS	.288

2.4.4 Identification of Low Visibility Events

An analysis was conducted to determine whether the sensors concurrently identified visibility events—periods in which visibility dropped below 0.23 miles. This particular analysis was not performed in Phase I but is included here using data collected during Phase II (1998-2000).

Table 6 shows the frequency distribution for three ranges of visibility for each sensor: less than 0.10 miles, between 0.10 and 0.23 miles, and greater than 0.23 miles.

Table 6. Sensor Analysis - Visibility Comparisons Event Detection. 1997 - 2000 Event Days

Sensor	<0.10 miles	0.10 to 0.23 miles	> 0.23 miles	Total
Handar-Belfort	233 (4.9%)	585 (12.2%)	3,959 (82.9%)	4,777
SSI-Belfort	100 (1.7%)	578 (10.1%)	5,071 (88.2%)	5,749
SSI-WIVIS	549 (10.8%)	765 (15.1%)	3,762 (74.1%)	5,076

The data in Table 6 represent the number and relative frequency of five-minute intervals during which the reported visibility level was in a particular category. If the three sensors matched perfectly in their identification of a visibility event (less than 0.23 miles) or a severe visibility event (less than 0.10 miles), then the relative frequency counts in Table 6 would be the same for all three sensors in all visibility categories. This is not the case. The SSI-WIVIS sensor had the greatest propensity to report visibilities of less than 0.10 miles (10.8%) compared to Handar-Belfort (4.9 %) and SSI-Belfort (1.7%). As shown in Table 6, SSI-WIVIS also reported relatively more measurements in the 0.10 to 0.23 mile range than the other two sensors.[5]

[5] It should be noted that in nearly 70 percent of the time periods during which visibility events were detected by one or more of the sensors, the reason given was rain or snow. Fog accounted for the others.

The next question to be examined is how frequently do the visibility readings for the three sensors (or any combination of two sensors) match? There were 4,066 five-minute intervals in the data analyzed during which all three sensors simultaneously reported a visibility measurement. The three sensors agreed 82.9 percent of the time, in determining whether or not a visibility event had occurred (visibility less than 0.23 miles).

Handar-Belfort and SSI-Belfort use essentially the same visibility sensor technology, so one might expect them to provide similar visibility readings. Table 6 shows that the SSI-WIVIS sensor tends to report lower visibilities than Handar-Belfort and SSI-Belfort. There were 4,739 five-minute periods in which Handar-Belfort and SSI-Belfort simultaneously reported a valid visibility measurement.

In 14.3 percent of occurrences, both sensors identified low visibility events. In 82.5 percent of the cases, the Handar-Belfort and SSI-Belfort sensors agreed that there was no event. In 96.8 percent of the cases, the Handar-Belfort and SSI-Belfort sensors agreed on whether or not a visibility event had occurred.

Several conclusions can be reached from this direct comparison of sensor readings:

- In most cases, the magnitude of the differences in visibility readings is fairly small.
- The SSI-WIVIS sensor visibility reading is generally higher than the Handar-Belfort and SSI-Belfort sensors, when visibility is reduced due to fog. The SSI-WIVIS sensor reading is generally lower than the other two during snow events.
- Nearly 83 percent of the time, all three sensors agreed on whether the visibility was below 0.23 miles or above 0.23 miles.

- Nearly 97 percent of the time, the Handar-Belfort and SSI-Belfort sensors agreed on whether the visibility was below or above 0.23 miles.
- Overall, the sensors had a tendency to track well (high correlations), although there were exceptions.

2.5 Sensor Visibility and Vehicle Speed

The final step in assessing the performance of the visibility sensors was to examine the relationship between reported visibility and actual vehicle speeds. If, as expected, drivers reduce their speeds during poor visibility, one would expect a close relationship between visibility sensor readings and vehicle speeds.

2.5.1 January 6, 1996

On January 6, 1996, average passenger car speed at the test site was 70 mph (the speed limit at that time was 65 mph). Truck speeds were nearly 65 mph. Speeds were nearly the same during daylight and darkness (Figure 10).

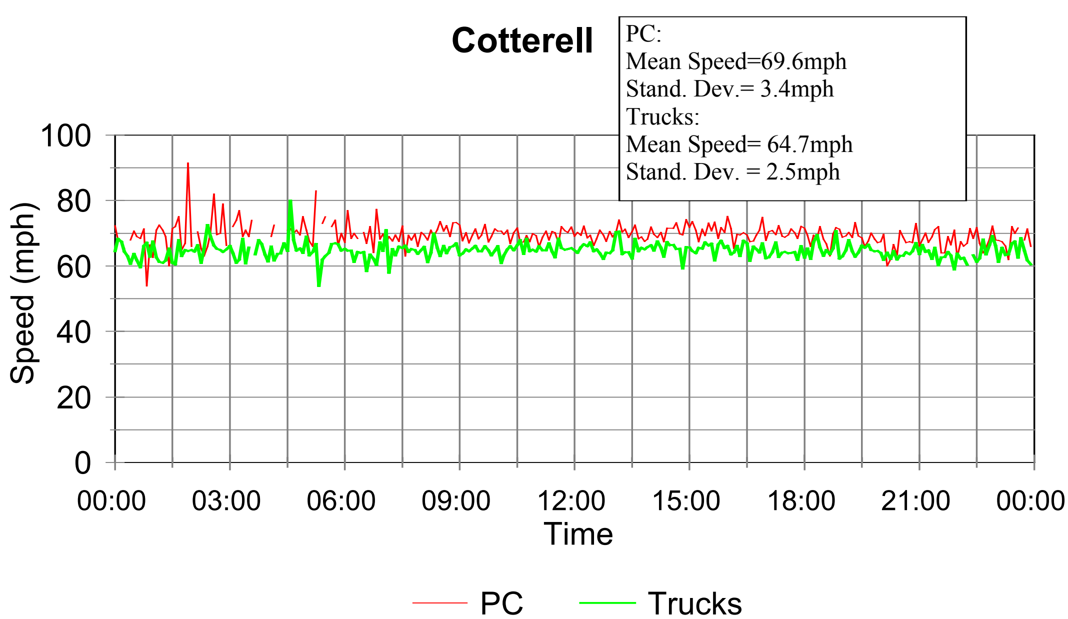

Figure 10. Vehicle Speed Analysis - Baseline Day January 6, 1996

2.5.2 December 29, 1995

Figure 11 shows a typical result when speed is analyzed in conjunction with visibility measures on a day when one or more of the sensors indicated reduced visibility. On December 29, 1995, visibility as reported by the SSI-WIVIS sensor was high (at the SSI-WIVIS maximum of 1.1 miles) throughout most of the day. During the time that visibility was high, the mean speed for trucks and passenger cars combined was approximately 66 mph. However, at approximately 6:00 pm (1800 hours), the SSI-WIVIS sensor data indicates a drop in visibility that lasted until about 11:30 pm.

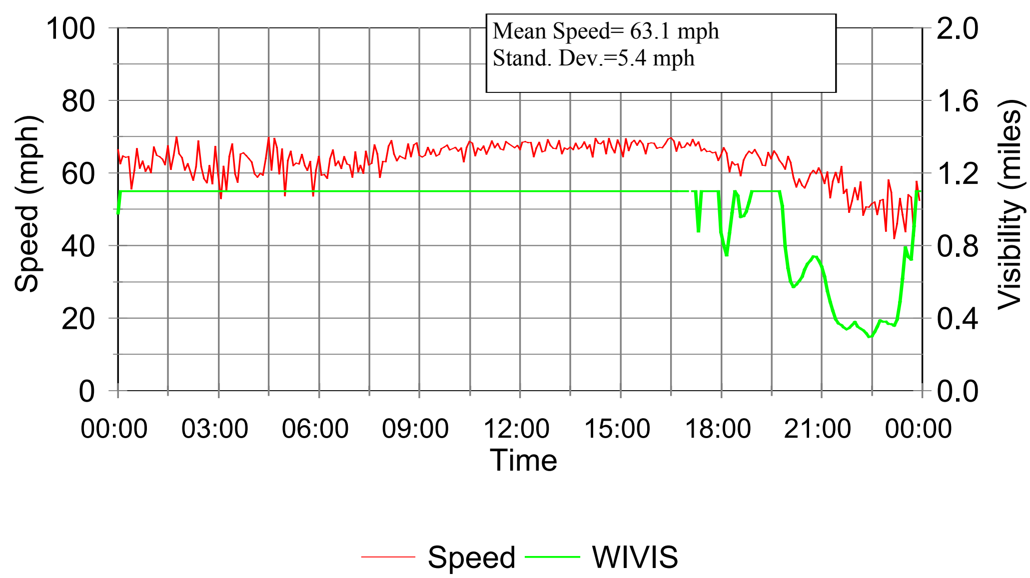

Figure 11. Average Speed (Passenger cars and trucks combined) and Visibility (SSI-WIVIS) December 29, 1995

Figure 12 shows the same day, focusing on the hours from 1800 to midnight. During this time, visibility is reported to be as low as 0.25 miles (though not below the event threshold of 0.23 miles) and mean speed of passenger cars and trucks is reduced to 57.6 mph. These reduced vehicle speeds are expected during a period of low visibility and provides evidence that the sensor is functioning properly.

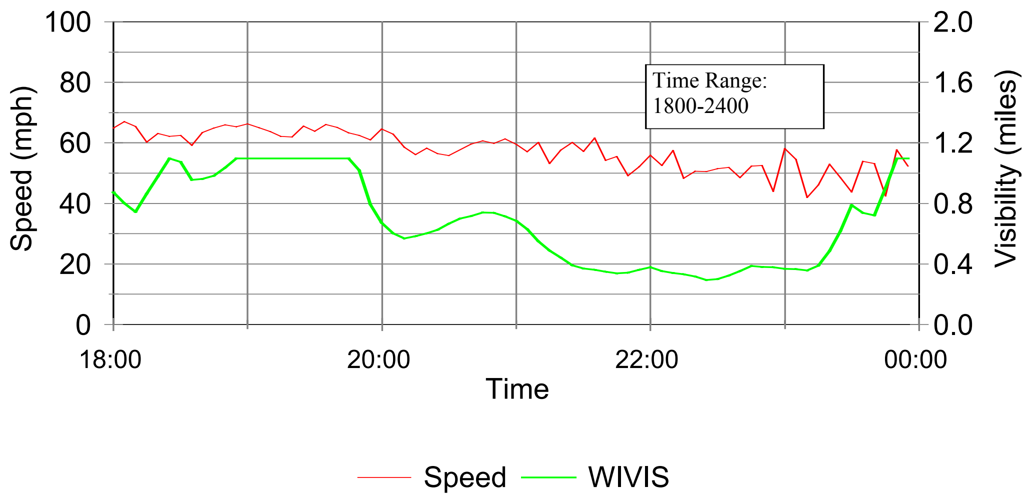

Figure 12. Low Visibility Period December 29, 1995

2.5.3 December 26-27, 1999

Figure 13 illustrates another example, on December 26 and 27, 1999. Between midnight and about 9:00 pm, the Handar-Belfort sensor showed visibility in excess of one mile, while passenger car and trucks speeds were approximately 75 mph. At about 9:00 pm, visibility dropped suddenly to well under 0.25 miles and at some points as low as 0.06 miles. Visibility remained low until about 5:00 am the next morning. Correspondingly, mean passenger car and truck speeds dropped to 65 mph. During some five-minute intervals the mean speed was in the low 50 mph range. Figure 14 shows the speed and visibility data during the low visibility period in more detail. Again, these results support the premise that the visibility sensors are correctly identifying periods of reduced visibility.

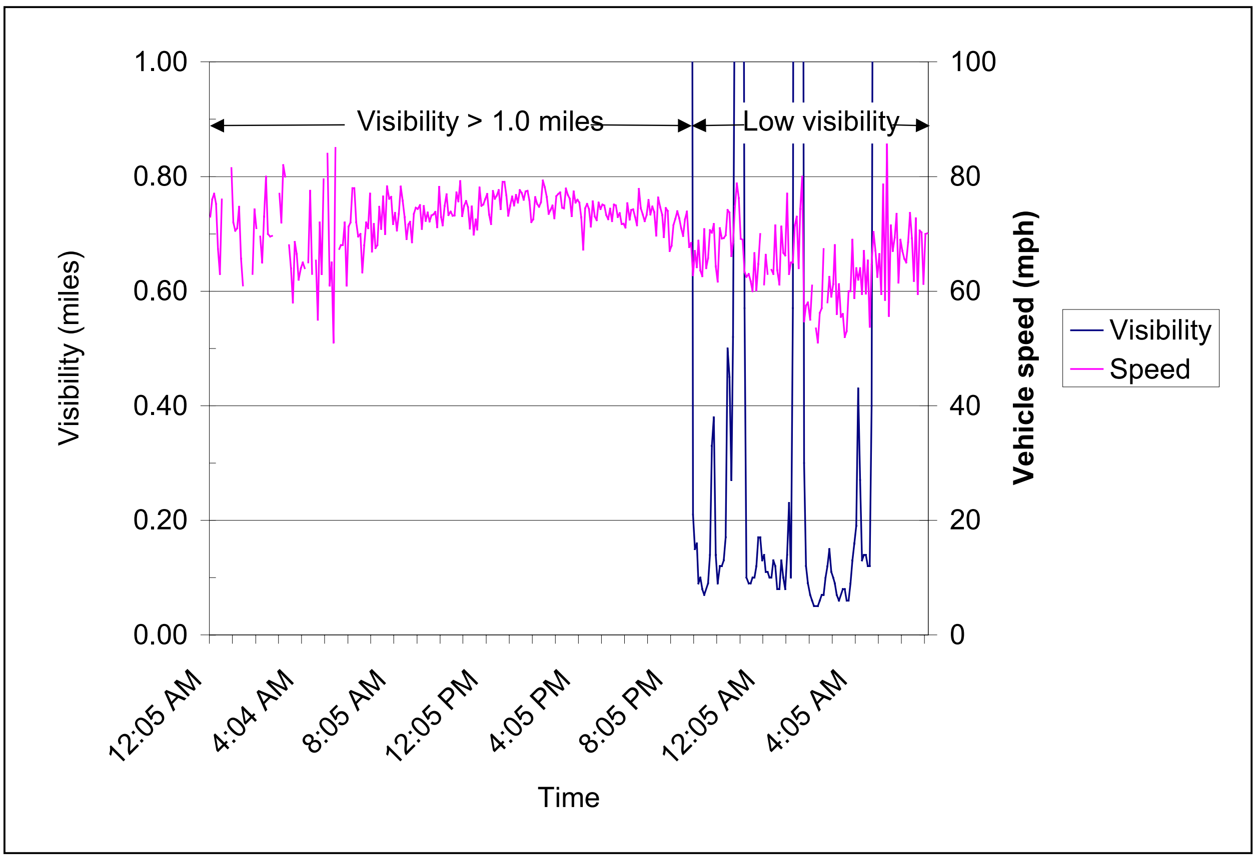

Figure 13. Average Speed (passenger cars and trucks combined) and Handar-Belfort Visibility December 26 & 27, 1999

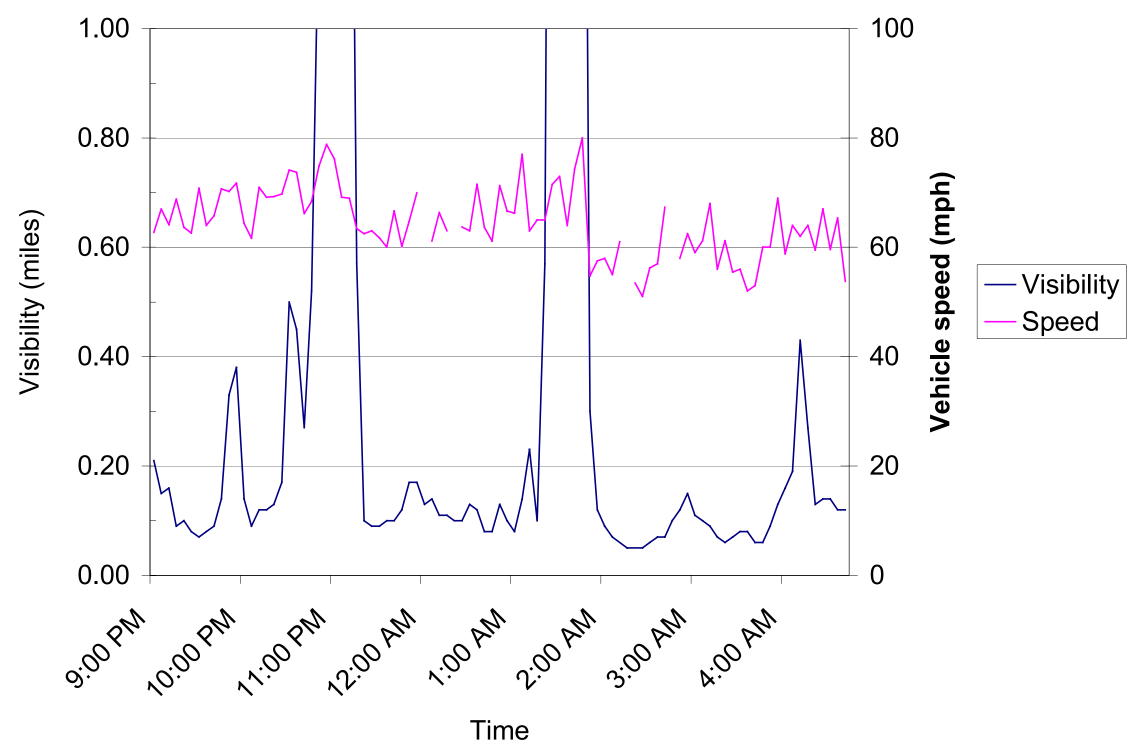

Figure 14. Low Visibility Period December 26 & 27, 1999

2.5.4 Fall 1998 – Spring 2000

Between the fall of 1998 and the spring of 2000, a total of 19 low visibility event days occurred. During this time period, the mean speed for all vehicles during good weather and high visibility was approximately 68 mph. Figure 15 shows the average vehicle speeds at three different levels of visibility, as determined by the Handar-Belfort sensor. During this time, roads were dry, there was no precipitation, and wind speeds were low. There is little difference in mean speed between the two higher visibility categories. When the visibility is below 0.10 miles, speeds drop significantly, to 58.4 mph. The finding that speeds drop when sensor visibility readings drop suggests that the sensors are capable of correctly identifying changes in visibility.

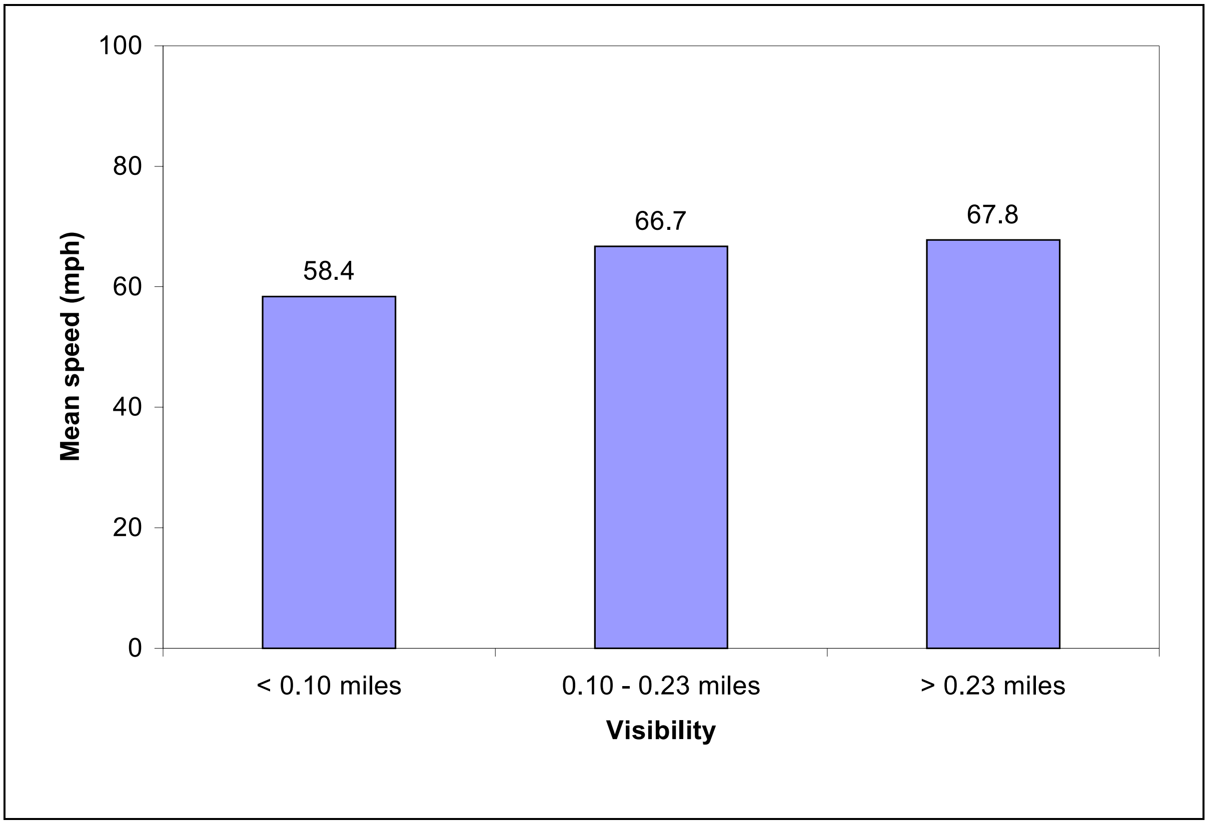

Figure 15. Mean Vehicle Speed by Visibility Level

2.6 Sensor Performance Conclusions

Based on the analyses in the preceeding section of this report, the following can be concluded:

- The Handar-Belfort and SSI-Belfort sensors provide reasonable estimates of the true visibility. The two sensors track consistently and visibility measurements and vehicle speeds appear to be correlated.
- The SSI-WIVIS sensor is probably not as accurate as the Handar-Belfort or the SSI-Belfort sensors in measuring visibility. Its readings tend to be higher than Handar-Belfort or SSI-Belfort when the visibility condition is due to fog, and lower when the visibility condition is due to snow.
- The Handar-Belfort and SSI-Belfort sensors consistently identify measurements that are below 0.23 miles or above 0.23 miles, and are thus considered effective in identifying low visibility events.

2.7 System Reliability Analysis and Conclusions

Reliability of the systems depended not only on the data collection components, including the sensors themselves and the video camera system, but it also depended upon the communications system, the AC power supply, and the integration of the system data into the master computer. The Handar and SSI sensor systems operated well, with few and minor component failures. The LIDAR sensor was not operational during the test period and therefore was not evaluated. The video camera system, which included a camera, VCR, TV monitor and data transmission system, had one major failure due to a power surge.

A primary requirement for reliable communications was the ability to transmit sensor data every five minutes from the test site to the master data collection computer, located approximately 1.5 miles away. The existing phone lines in this rural area were poor and not reliable for consistent data transmission. After one year of attempting to use the existing phone lines for data transmission, a dedicated twisted pair telephone cable was installed from the sensor site to the Cotterell POE. This line replaced the leased phone lines provided by the local phone company. After the installation of this cable, most of the data communication problems were solved.

The AC power supply in this rural area was also unreliable. Frequent power outages, shortages and surges damaged most of the electronic equipment. These AC power-related problems account for the loss of a computer motherboard, a hard drive, the power supply for the VCR, an AC adapter to the video transmission receiving unit, and multiple communication modems. Three uninterruptable power supplies (UPS) were installed at the site in an attempt to address these problems. After the installation of the UPSs, power-related problems still occurred, but to a lesser degree.

In general, the variable message signs operated satisfactorily during the test period. However, during the last two years of operation, problems began to arise with two of the older signs. These signs, installed in 1992, began to fail due to communications equipment issues and incompatibility between the DOS-based software that controlled the signs and the software on the newer computer systems. ITD is considering replacing these signs with newer models that will integrate more effectively with the other two signs.

By far the greatest challenge was integrating information from the three sensor systems into the master data collection computer. All weather and visibility data collected by the sensors were stored on the computer associated with each sensor. The master computer collected new data from the three systems every five minutes. The hardware and software originally installed to accomplish these operations were inadequate, causing frequent failures and incomplete data transmissions. The system was completely revised and a new system was installed in 1997, virtually eliminating the problems.

Once the communications, power, and integration problems were solved (after two years of operation), the sensor systems provided data on a consistent and reliable basis. A yearly visit to the site by a technician, to provide routine preventative maintenance and calibration, was included as part of the test for each system. Costs associated with this site visit were minimal and, overall, the efforts related to operations and maintenance of the sensors and other systems were insignificant.

It should be noted that, during these first two years of equipment and communication technical challenges, the test site did not experience any significant weather events. The system "growing pains" did not result in the loss of any important data.

3.0 PHASE II - DRIVER RESPONSE TO VARIABLE MESSAGE SIGNS

3.1 Methodology

The purpose of Phase II was to examine the effectiveness of the VMSs as a tool for reducing vehicle speeds during periods of low visibility. The methodology for assessing the effectiveness of the VMSs involved three steps:

- Develop a vehicle speed profile for “ideal” conditions—high visibility, dry roads, no precipitation, and no wind. This profile would serve as the baseline to which speeds under “non-ideal” conditions would be compared.
- Analyze vehicle speeds under various weather conditions in an attempt to isolate factors that resulted in vehicle speed changes.
- Analyze vehicle speeds under various weather conditions during periods in which the VMS sign was both on and off, to determine whether the use of the sign encouraged drivers to further reduce their speeds.

In order to implement these three steps, weather data were collected covering 5,790 five-minute intervals over nineteen days during the period 1997-2000 (Table 7). Visibility conditions were less than 0.23 miles for at least some of the five-minute intervals in each of these nineteen event days. Vehicle speeds by lane (lanes 1, 2, 3 and 4) and vehicle type (passenger car and truck) were recorded every five minutes. The status of the sign—on or off—was also recorded, along with the message displayed.

Table 7. VMS Analysis Event Dates

Beginning Date			Ending Date		Primary Weather Issue
November 28, 1997	11:00 PM	---	November 29, 1997	2:00 PM	Fog
December 8, 1997	8:59 PM	---	December 9, 1997	12:54 PM	Snow
December 25, 1997	12:02 AM	---	December 25, 1997	6:54 AM	Fog
December 30, 1997	5:03 PM	---	December 31, 1997	11:48 AM	Fog
January 31, 1998	7:43 AM	---	December 31, 1998	10:53 AM	Fog
February 15, 1998	12:02 AM	---	February 15, 1998	11:22 PM	Snow
February 24, 1998	8:17 PM	---	February 25, 1998	5:57 AM	Snow
February 9, 1999	10:00 AM	---	February 10, 1999	8:55 AM	Snow
April 1, 1999	7:00 AM	---	April 1, 1999	7:55 PM	Snow
April 8, 1999	7:30 PM	---	April 9, 1999	3:55 PM	Snow
November 17, 1999	11:08 AM	---	November 18, 1999	1:48 PM	Wind
December 2, 1999	11:45 AM	---	December 3, 1999	5:00 PM	Snow
December 26, 1999	12:05 AM	---	December 27, 1999	7:10 AM	Fog
December 28, 1999	12:05AM	---	December 30, 1999	5:00 PM	Fog
January 4, 2000	12:05 AM	---	January 5, 2000	4:55 PM	Wind
January 8, 2000	12:05 AM	---	January 9, 2000	5:00 PM	Wind
January 18, 2000	12:05 AM	---	January 19, 2000	5:00 PM	Snow
January 26, 2000	12:05 AM	---	January 26, 2000	11:00 PM	Snow
February 24, 2000	12:03 AM	---	February 25, 2000	4:58 PM	Snow

3.2 Vehicle Speed Baseline

In order to determine whether the VMSs have an effect on driver behavior and resulting vehicle speeds, it was necessary to establish a baseline profile for vehicle speeds when the driving conditions were considered ideal. Traffic data were gathered for each lane. Lanes 1 and 2 are the southbound lanes and lanes 3 and 4 are the northbound lanes.

Driving conditions are considered ideal when visibility exceeds 0.23 miles, wind speed is less than 10 mph, roads are dry and there is no precipitation. Figure 16 shows the combined mean speeds for passenger cars and trucks under these conditions. These mean values are computed from all five-minute intervals during the nineteen event periods (Table 7 above). The average speed for passenger cars under ideal weather conditions was 72.7 mph, while trucks traveled at a slower average speed of 61.2 mph. Passenger cars and trucks traveling south in lanes 1 and 2 averaged 69.1 mph, compared to 66.1 mph for vehicles traveling north in lanes 3 and 4.

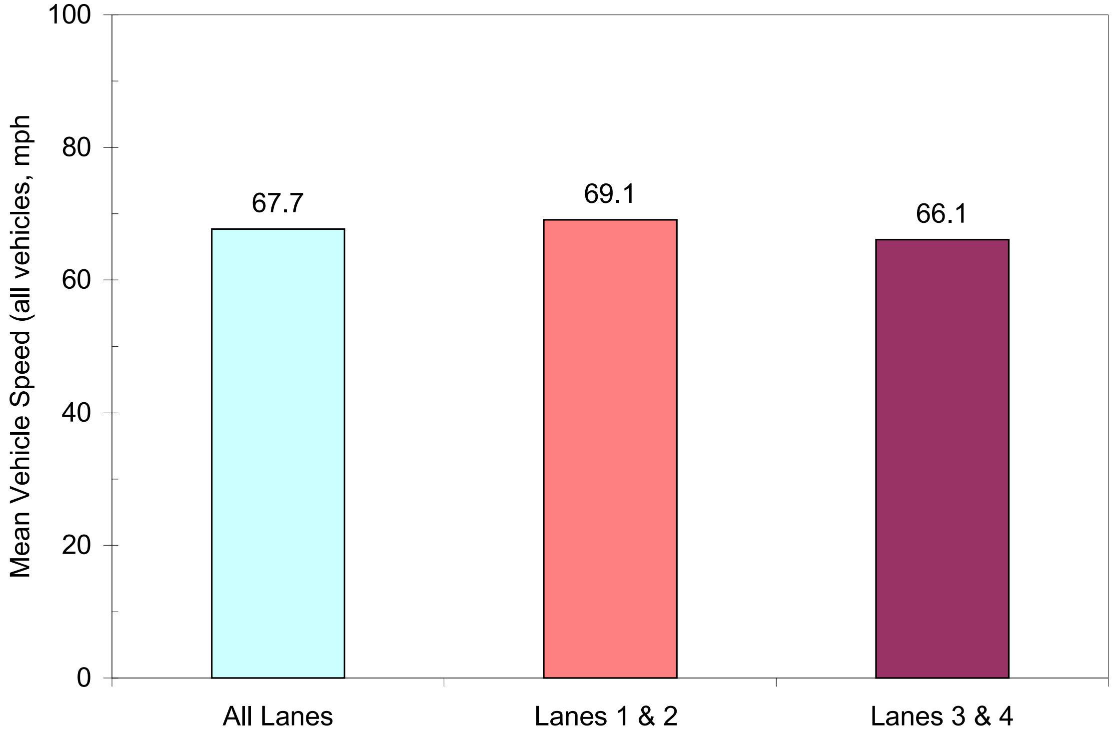

Figure 16. Ideal Day Profile – All Vehicles

Figure 17 shows the distribution of mean speeds during each five-minute period under ideal driving conditions for all vehicles traveling in both directions. There is considerable variation in speed, and the distribution is skewed to the left of the median.

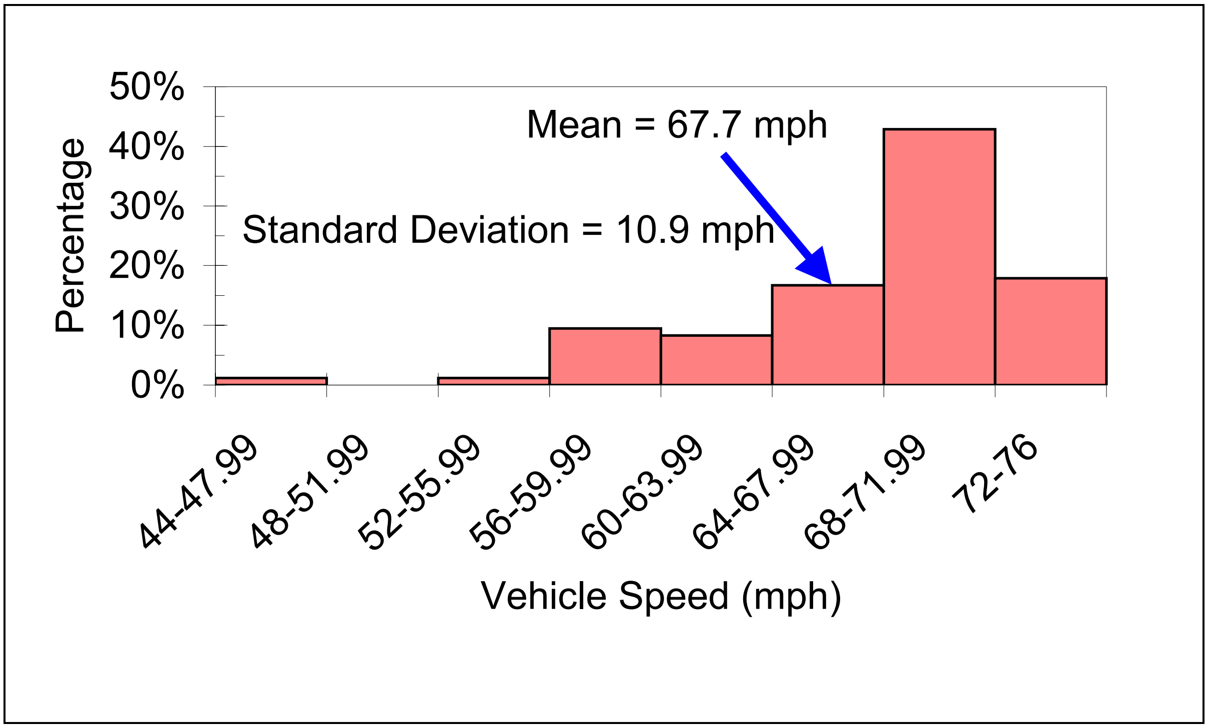

Figure 17. Speed Distribution All Vehicles – Both Directions – Ideal Conditions

Vehicles in lanes 1 and 2 traveled at slightly higher speeds but with less variability than vehicles in lanes 3 and 4. Figures 18 and 19 show the speed distribution under ideal conditions for all vehicles in lanes 1 and 2 and lanes 3 and 4, respectively. Table 8 summarizes the baseline speed information for passenger cars and trucks combined.

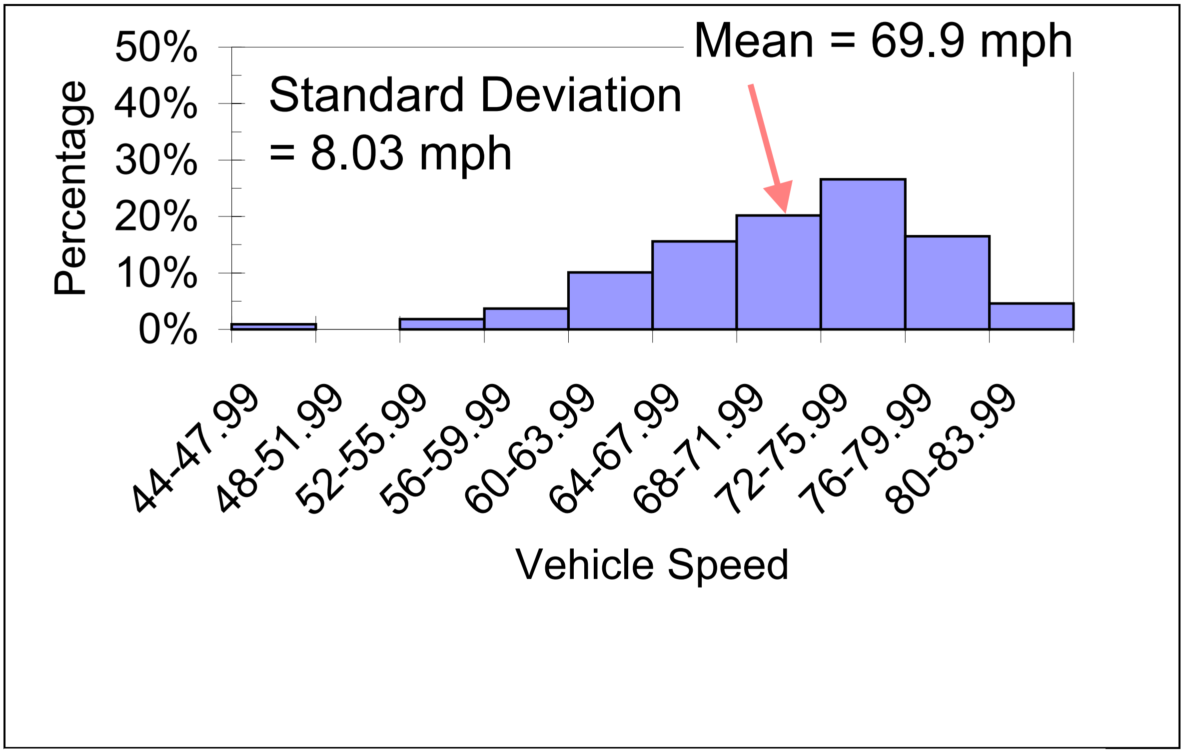

Figure 18. Lanes 1 & 2 Speed Distribution All Vehicles – Ideal Conditions

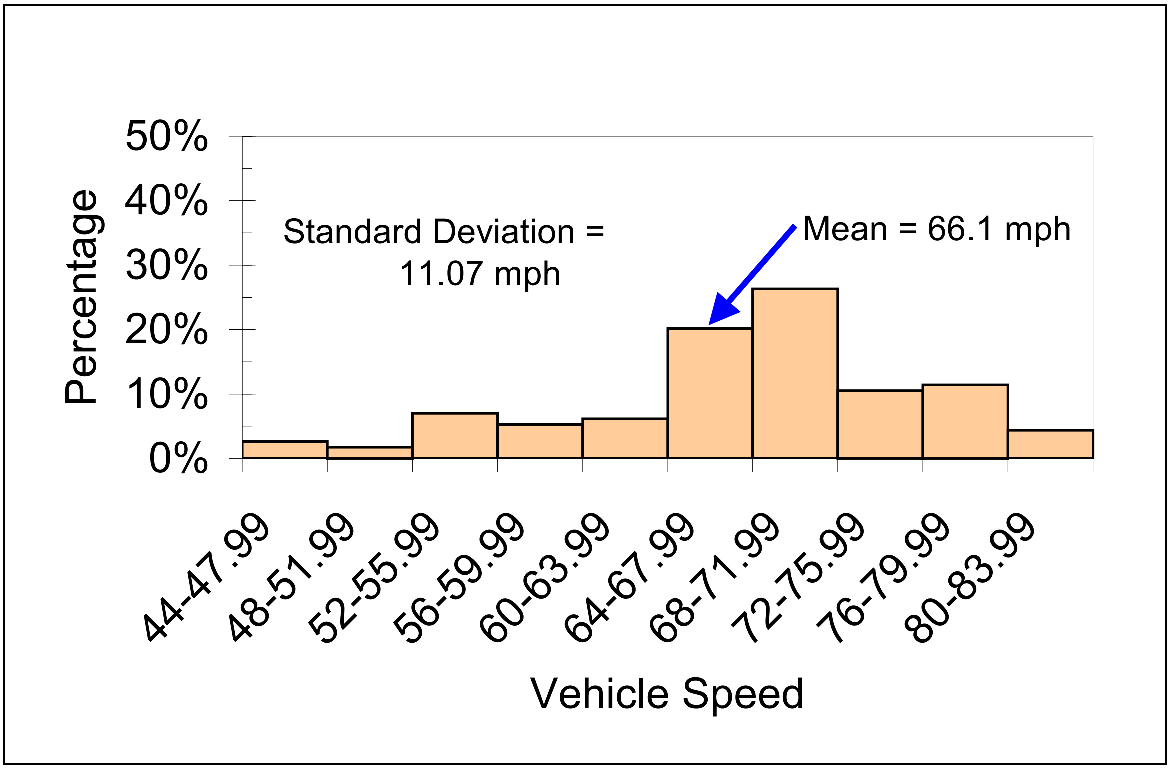

Figure 19. Lanes 3 & 4 Speed Distribution All Vehicles – Ideal Conditions

Table 8. Baseline Speed Summary All Vehicles – Ideal Conditions

Speed (mph)					
	Mean	**Median**	**Minimum**	**Maximum**	**Standard Deviation**
All Lanes	67.7	69.3	47	76	10.9
Lanes 1 & 2	69.1	71.6	46	81	8.03
Lanes 3 & 4	66.1	69.1	38	82	11.07
Note: The values for All Lanes represent the average speeds for all vehicles traveling all four lanes during the same five minutes.					

3.3 Vehicle Speeds During Non-Ideal Conditions

This section presents an analysis of vehicle speeds under various non-ideal weather conditions and examines, among other things, the changes that occur in average speed due to poor weather conditions. All results presented here are based on data collected when the VMSs were not in use during the 19 event days of 1997-2000, shown previously in Table 7. In other words, during these 19 event days, drivers were making decisions based on their own perceptions of weather conditions without any additional information from signs or other sources.

3.3.1 Low Visibility

Data gathered during Phase I of this operational test showed that drivers tended to reduce their speeds when visibility decreased to very low levels. Data gathered during Phase II confirmed this finding.

For example, consider the event period beginning at 12:05 am on December 26, 1999 and ending on December 27, 1999 at 7:10 am. As shown in Figure 20, at approximately 9:00 pm on December 26, visibility dropped suddenly due to heavy fog at the test site. Prior to this time, vehicles had been traveling at average speeds exceeding 70 mph. When the visibility dropped, average speeds dropped to 60 mph and below. When visibility increased, at about 4:30 am on December 27, average vehicle speeds increased to 70 mph and above. Overall, for this event period, when visibility was greater than 0.10 mile, average vehicle speed (passenger cars and trucks combined) was 68.1 mph, but when visibility was less than 0.10 mile, average speed dropped to 58.2 mph.

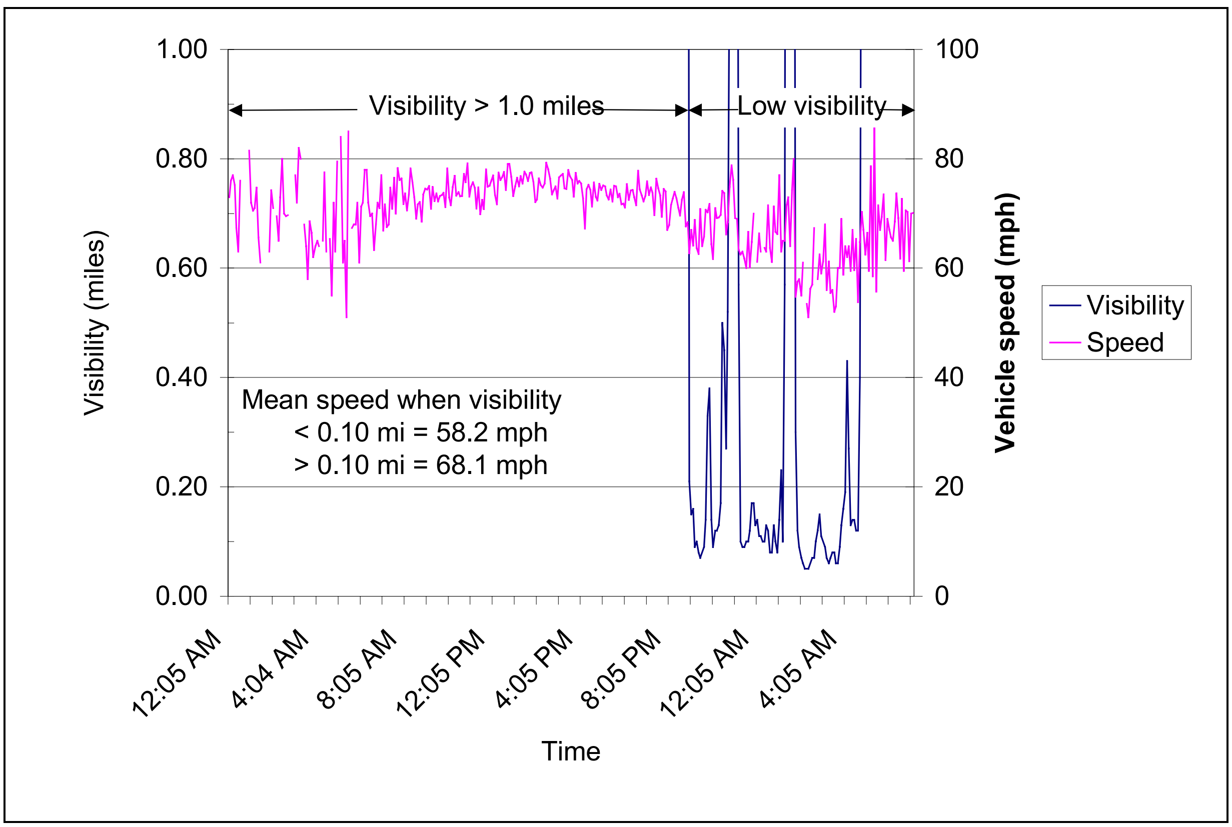

Figure 20. December 26 & 27, 1999 Fog Event Period

These results parallel driver reactions during all other event periods. When all other weather conditions are ideal—dry pavement, no precipitation, and low wind speed—drivers tend to reduce their speed when visibility is significantly reduced. Figure 21 shows that when visibility is below 0.10 miles, vehicle speeds average eight to ten mph less than when the visibility distance is greater than 0.10 miles.

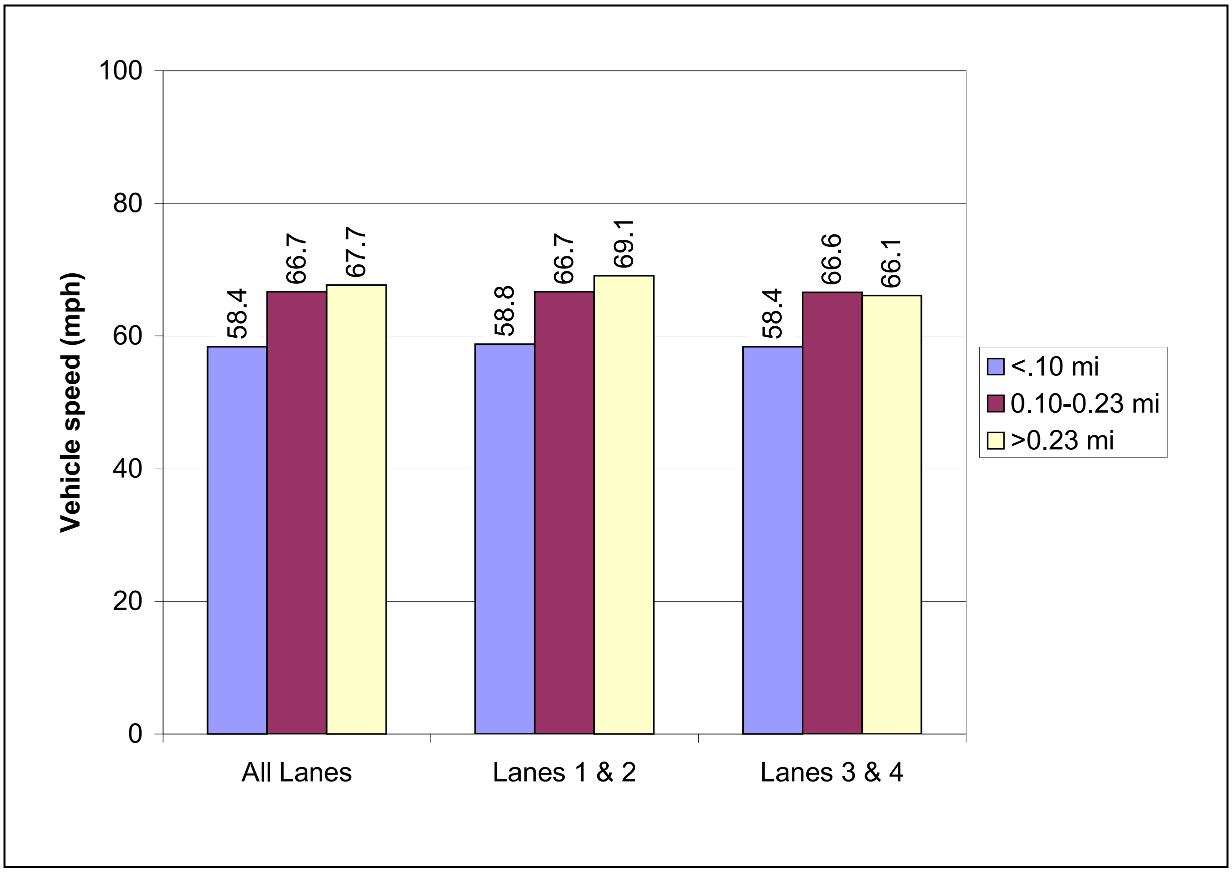

Figure 21. Mean Speed by Visibility Levels

3.3.2 High Winds

Drivers also tend to reduce their speeds during other weather-related conditions such as high winds. Consider the event period from 12:05 am to 11:00 pm on January 4, 2000, shown in Figure 22. Until approximately 4:00 pm, wind speeds were moderate, below 20 mph, and vehicle speeds averaged 65.6 mph. However, between 4:00 and 11:00 pm wind speeds increased to 30 mph and higher, during which time mean vehicle speed dropped substantially to 52.5 mph.

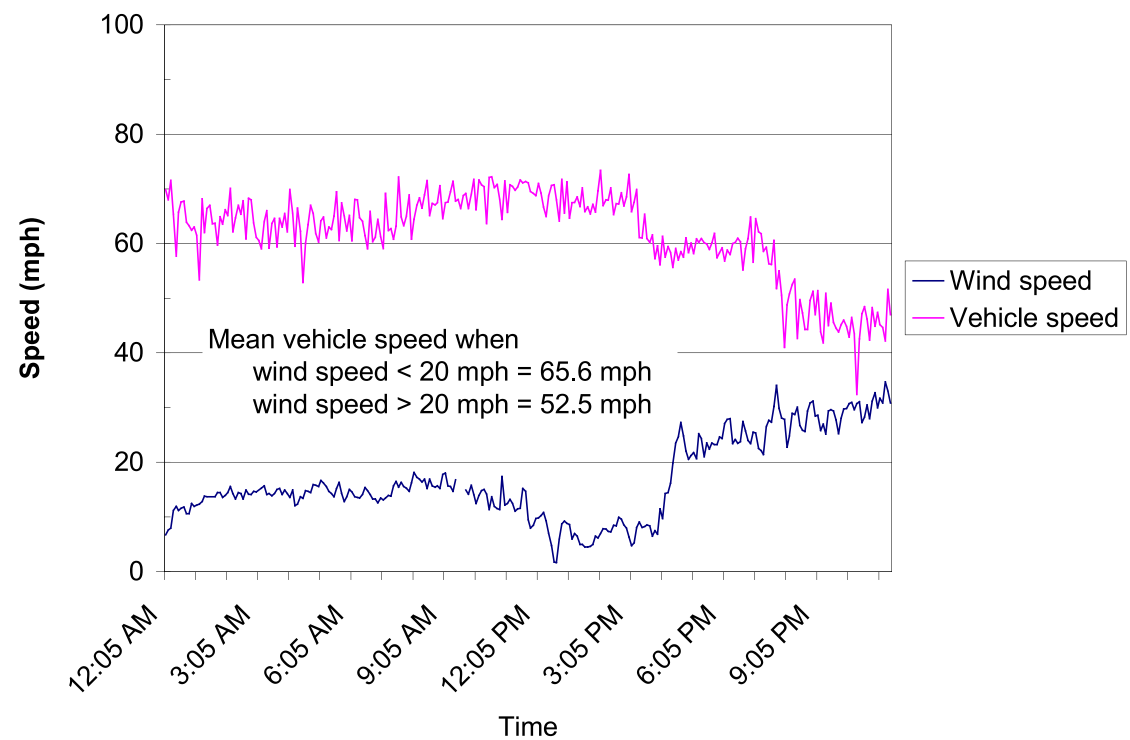

Figure 22. High Wind Event Period January 4, 2000

Figure 23 shows that during periods of high wind, drivers reduce their speed. Note that the mean speeds reflect only the impact of wind. All other weather conditions are ideal—high visibility, dry roads, and no precipitation.

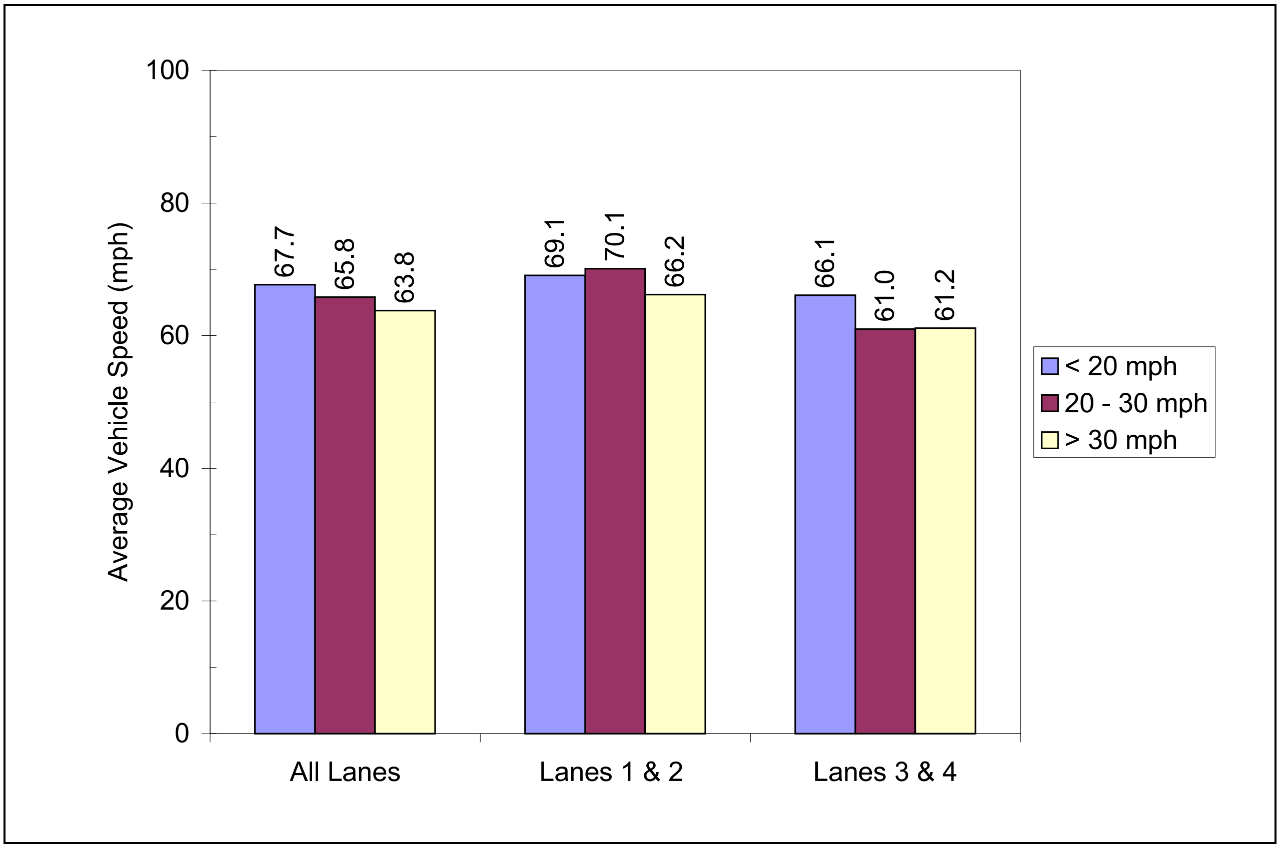

Figure 23. Mean Vehicle Speed by Wind Speed Levels

3.3.3 Heavy Precipitation and Wet Roads

When heavy precipitation is occurring and the road is wet, vehicle speeds drop substantially (Figure 24). In fact, these data indicate that the combination of wet roads and heavy precipitation results in greater speed reductions than is the case with low visibility or high wind conditions only.

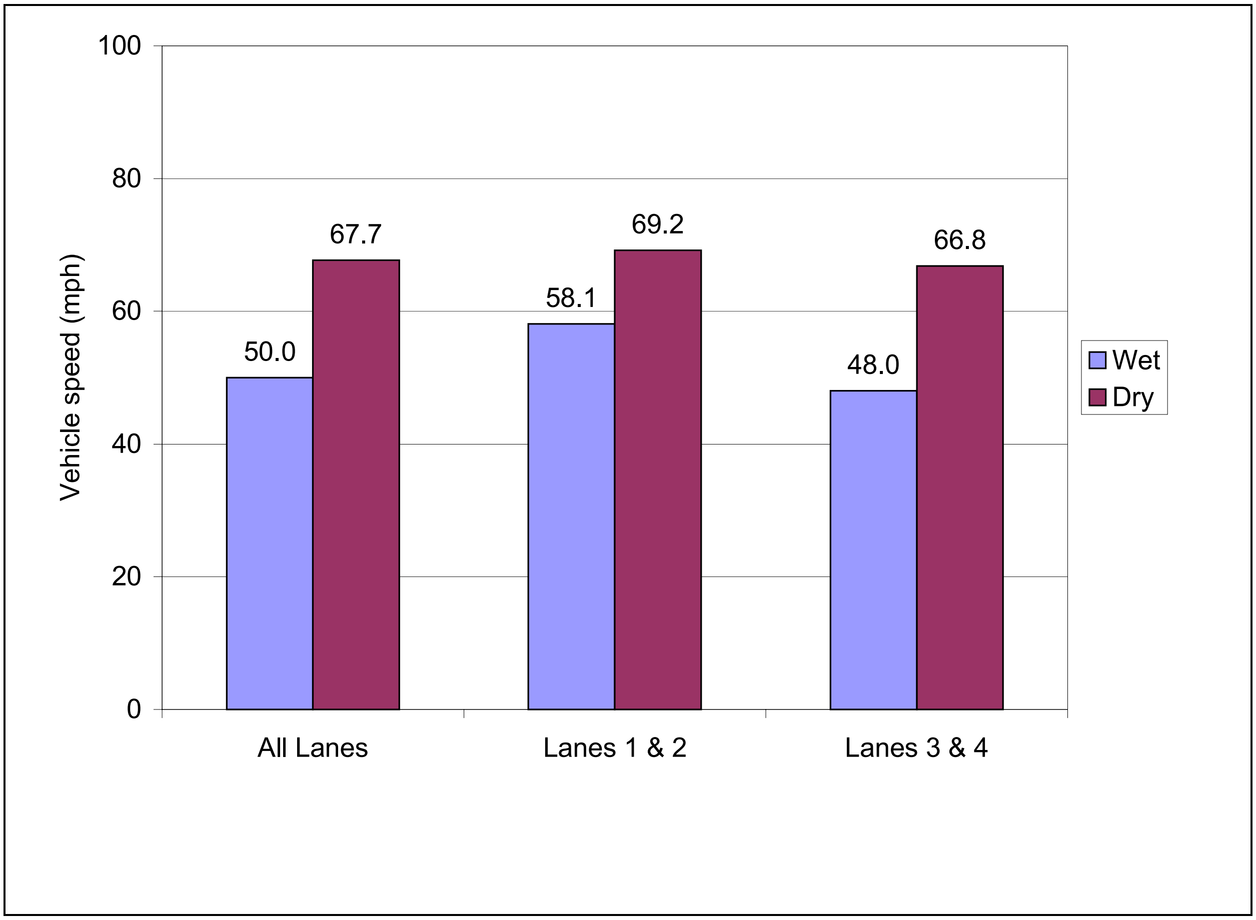

Figure 24. Mean Vehicle Speed with Heavy Precipitation and Wet Roads

3.3.4 Severe Weather Conditions

Figure 25 shows the mean speed reductions that occur under the most severe weather conditions. Mean speed is reduced to approximately 40 mph when wind speeds exceed 30 mph, visibility is less than 0.23 miles, heavy snowfall is occurring, and the road surface is snow covered.

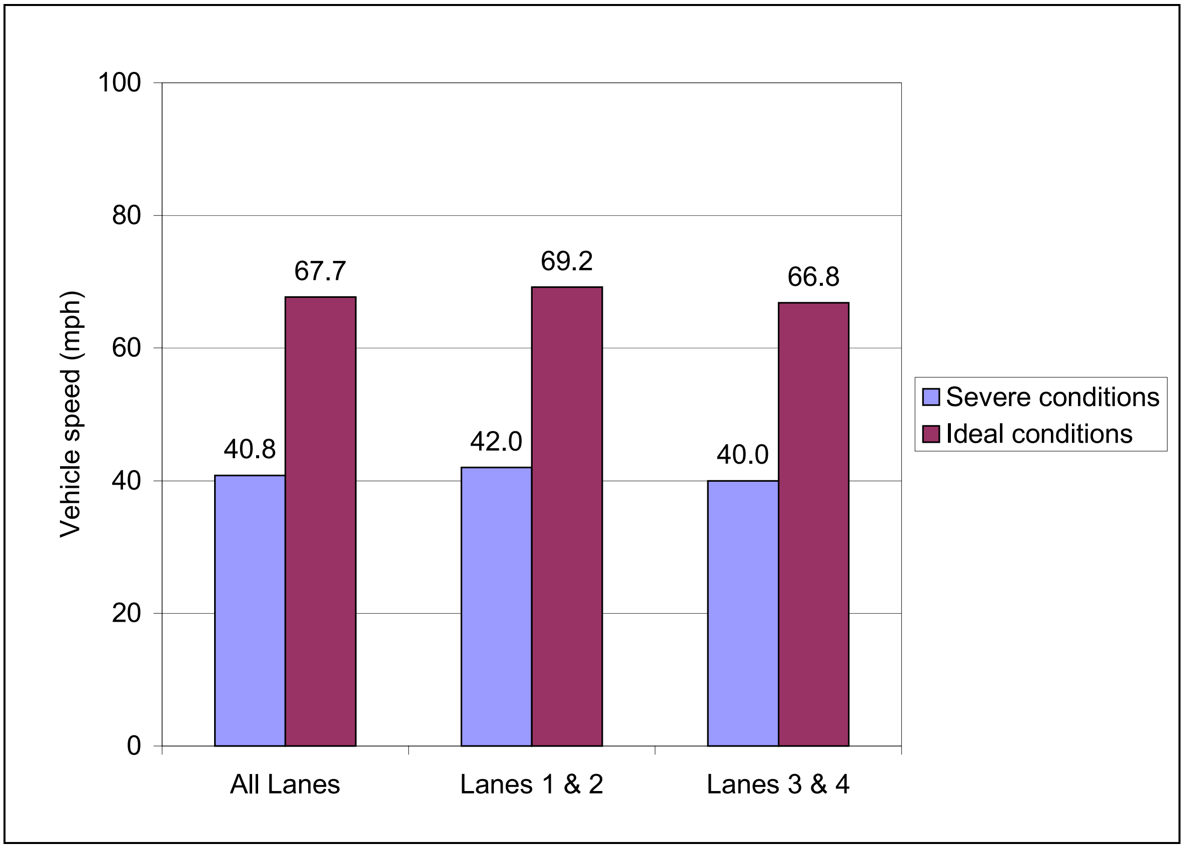

Figure 25. Mean Speed – Most Severe Weather Conditions

3.4 Impact of Variable Message Signs

While it has been determined that drivers reduce their speeds during poor weather conditions on their own, it is important to determine whether VMS messages can result in even further speed reductions. Four VMSs are located along the I-84 corridor (Refer to Figure 1). Two of these are located in Utah and are not thought to affect traffic speeds at the test site, which is approximately 40 miles north of the nearer of these two signs. However, these signs will impact traffic volumes when they indicate that the I-84 corridor is closed. A third VMS is located south of Sublet, facing the northbound lanes. It is believed that any potential impact that messages on this sign might have on driver behavior will be diluted by the time vehicle speeds are measured, approximately 12 miles north of the sign location. However, the fourth sign, located facing the southbound lanes (Lanes 1 and 2) at the I-84/I-86 interchange, is only five miles from the test site. The proximity of this sign to the sensor site indicates that speed reductions encouraged by the sign might be measurable.

Traffic in southbound lanes 1 and 2 is facing the fourth sign and is potentially influenced by the messages when the sign is on. Traffic moving north in lanes 3 and 4 will not see the sign and will not be influenced by its message. Thus, when the fourth VMS is operational, most, if not all differences in speed between the northbound lanes and the southbound lanes can be attributed to the message on this sign.

The VMSs are operated manually by ITD personnel, who use their own judgment regarding when to use the signs and what message to display. They are signaled, however, by the visibility sensor system at the test site when visibility is below 0.23 miles. They can also access the other weather data recorded by the sensor systems for help in making their determination regarding the use of the signs.

Of the 5,790 five-minute intervals included in the nineteen event periods between 1997 and 2000, the fourth sign was operating for 2,072 intervals, or almost 36 percent of the time. However, since ITD personnel controlled the use of the sign, there were instances in which the sensors indicated low visibility but the signs were not used. In other instances, the sensors indicated that the visibility situation had improved, but the signs remained on. In some, if not all, of these instances, the reason may have been based on the variable weather patterns in the area. For example, while the weather may have cleared at the sensor site, low visibility conditions were still occurring in the area along the northern section of the I-84 corridor, warranting continued use of the sign. Therefore, it should be recognized that the VMS analysis is not based on highly controlled experimental conditions and the results of the analysis detailed in this section of the report cannot be considered conclusive.

The key issue addressed in this section of the report is whether driver behavior is appropriately influenced through the use of the VMS during poor weather conditions. Of specific interest is whether the mean and standard deviation of vehicle speeds in lanes 1 and 2 are lower than in lanes 3 and 4 under poor driving conditions during intervals when the VMS is operational.

Figure 26 shows mean speeds for both directions for all weather conditions combined. The data show little or no effect of the VMS on driver speeds when all weather conditions are considered together. However, subsequent sections of this report show that the VMS does have an effect on driver speeds during certain visibility and weather conditions.

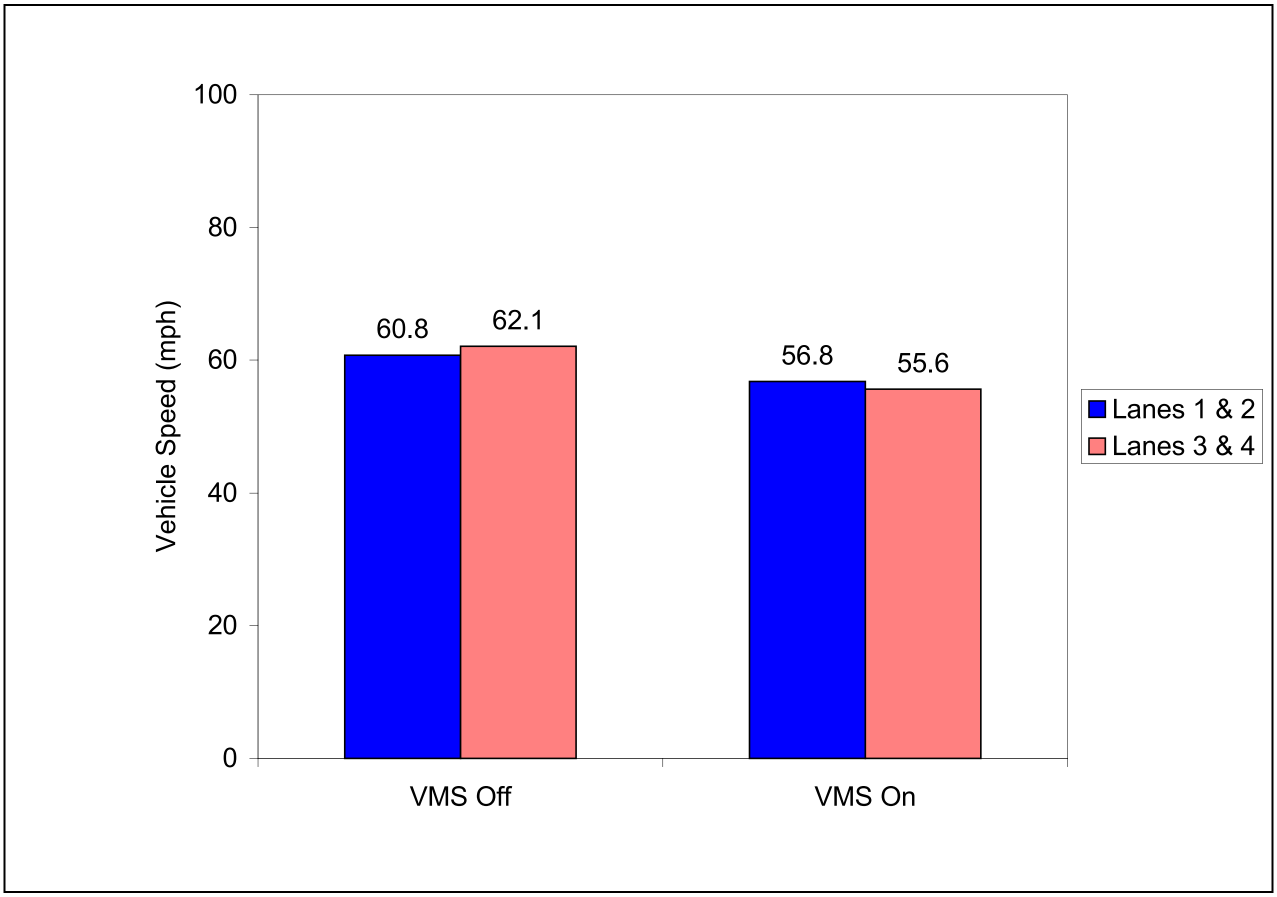

Figure 26. VMS Analysis – All Weather Conditions Combined

3.4.1 Visibility

During the 19 event periods, there were no situations in which the VMS was operational, visibility at the test site was less than 0.23 miles, and all other conditions were ideal. As a result, it was not possible to isolate any effect of the VMS when visibility was the only weather issue. Figure 27 illustrates periods when visibility was less than 0.23 miles and all road conditions (wet, snow, and chemically wet) are included. It compares mean speeds for traffic in lanes 1 and 2 and lanes 3 and 4 during periods of low visibility, when the variable message signs were on and when they were off. As expected, the mean speeds were approximately the same for traffic moving in each direction when the signs were off and when the signs were on. However, when the signs were on, mean speeds in both directions were lower than when the signs were off. Since lanes 3 and 4 should be unaffected by the signs, there is insufficient data to determine that the speed reduction in lanes 1 and 2 is a result of the sign being turned on.

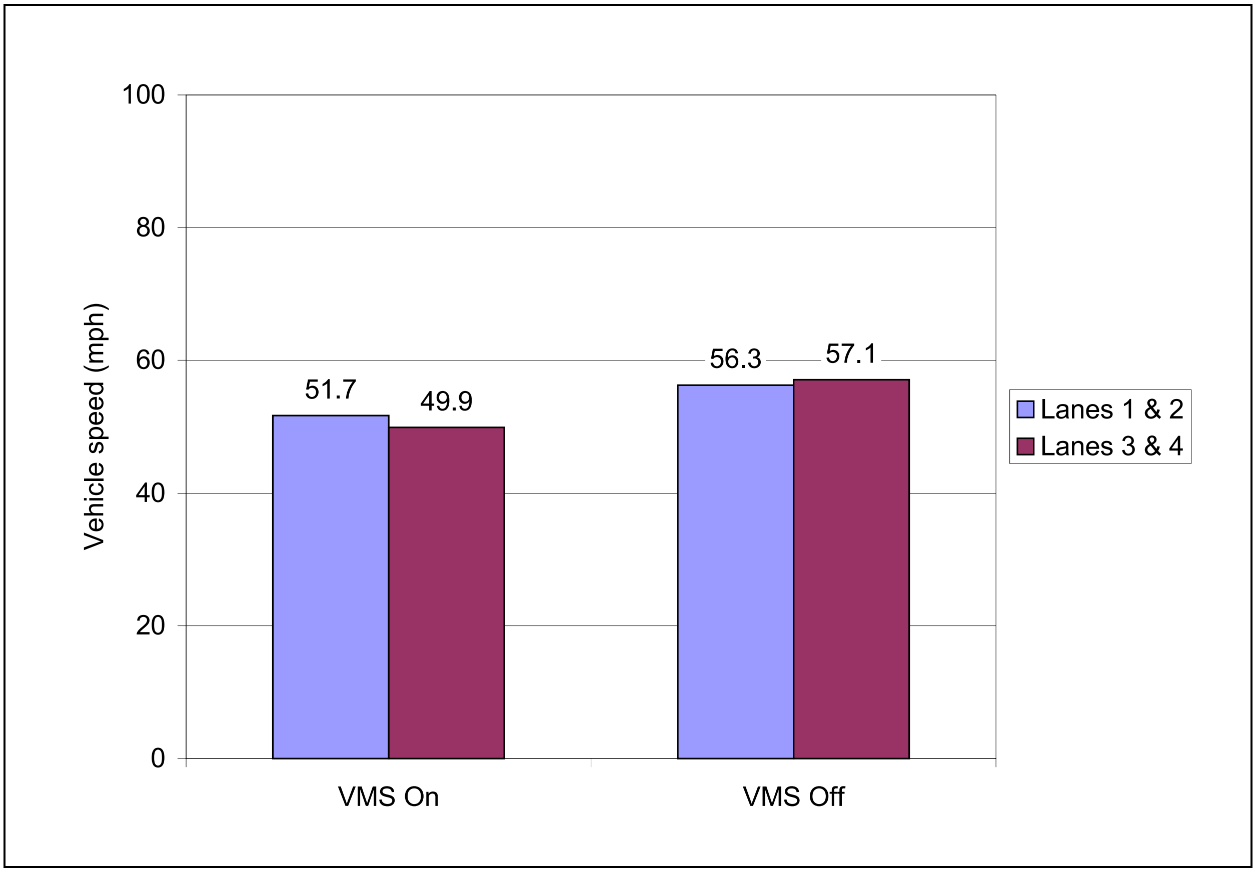

Figure 27. VMS Analysis – Low Visibility – All Road Conditions

3.4.2 High Winds

The signs were used more extensively during windy conditions. Figure 28 shows the mean speeds when wind exceeded 30 mph, and data on all other visibility, precipitation, and road conditions are included. When wind speeds are high and the sign is off, drivers reduce their speeds to an average of 54.8 mph in lanes 1 and 2 and 50.8 mph in lanes 3 and 4.

When the sign is on during high winds, drivers reduce their speeds even more. The greater speed reduction occurs in lanes 1 and 2, where drivers benefit from the information on windy conditions provided by the sign.

In lanes 1 and 2, mean speed dropped 12.5 mph when the VMS was on. The drop in mean speed in lanes 3 and 4 was 3.7 mph. In addition, the standard deviation of vehicle speed in lanes 1 and 2 dropped from 6.9 mph to 5.9 mph, but was virtually unchanged in lanes 3 and 4. This shows that the signs reduce speed variability, sometimes an important factor in vehicular crashes.

When considering both heavy winds (greater than 30 mph) and moderate to heavy precipitation simultaneously, Figure 29 shows that mean speeds in lanes l and 2 dropped from 47.0 mph when the signs were off to 41.2 when the signs were on.

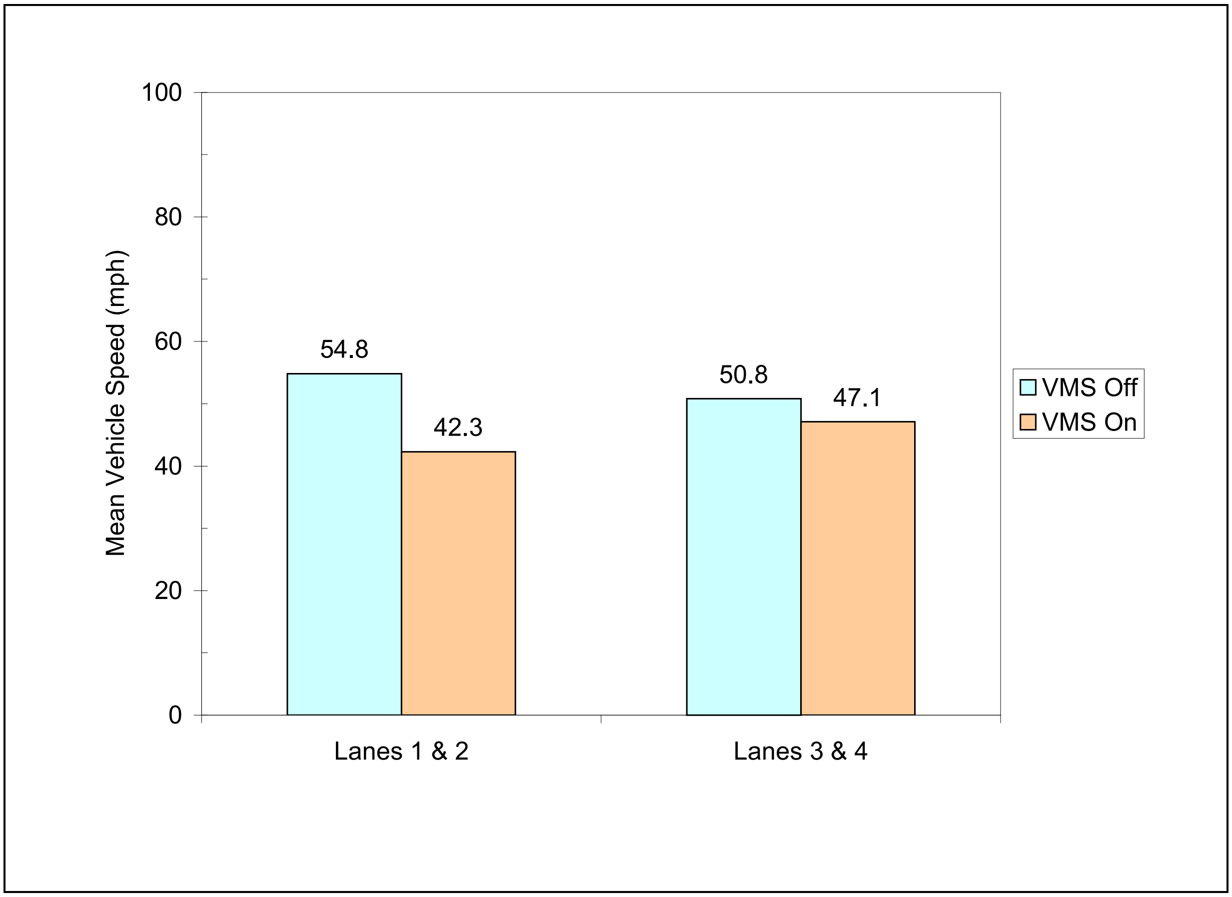

Figure 28. VMS Analysis – Wind >30mph All Road and Visibility Conditions

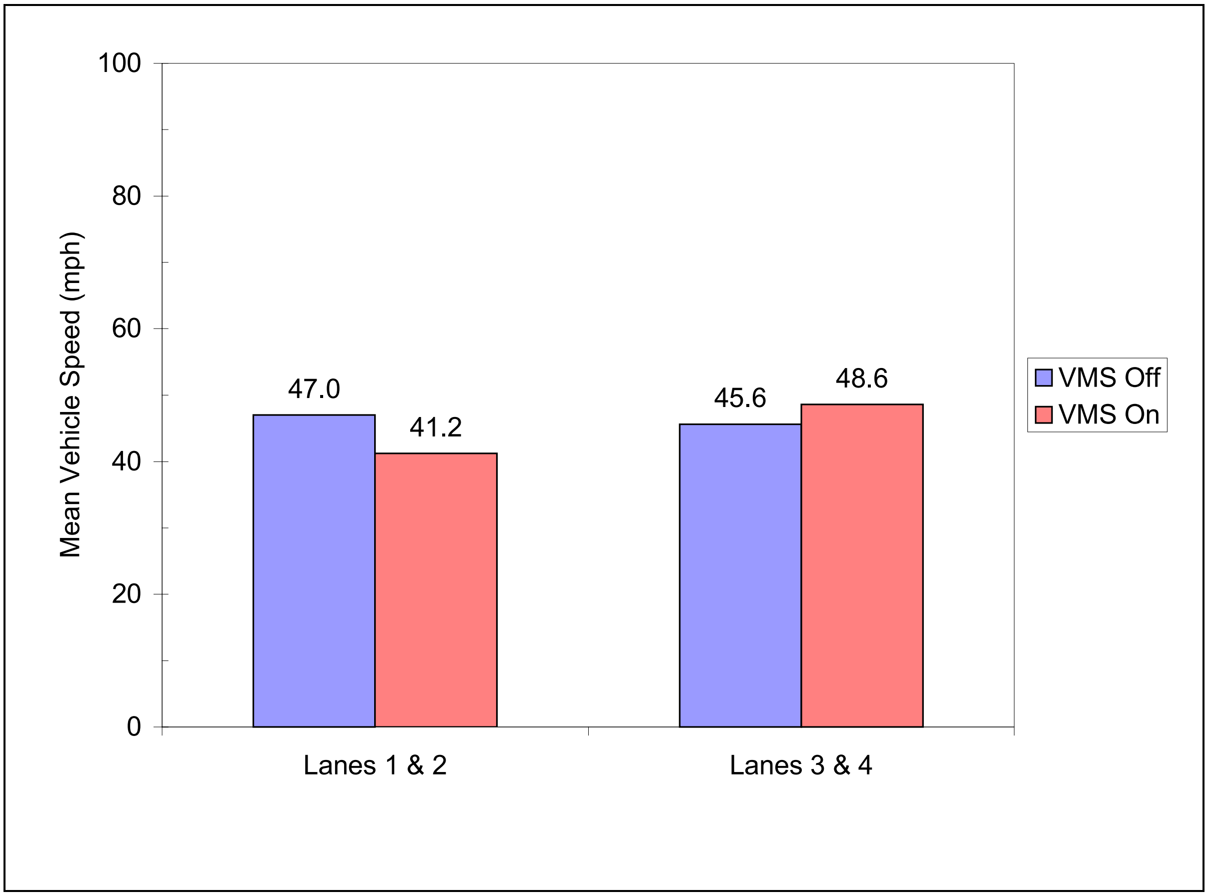

Figure 29. VMS Analysis – High Winds >30mph and Moderate to Heavy Precipitation – All Road Conditions

3.4.3 Snow

Figure 30 shows the mean speed data for conditions of high winds on snow-covered roads. Again, the use of the VMS appears to have an impact. Mean speed in lanes 1 and 2 under these conditions was 54.7 mph when the signs were not being used. The mean speed, based on a sample of 1,037 vehicles, dropped to 35.4 mph when the sign was operational. This is nearly 9 mph less than the mean speed on lanes 3 and 4, where drivers would be unaffected by the VMS sign. No measurable difference occurred in the standard deviations of the speeds in this case.

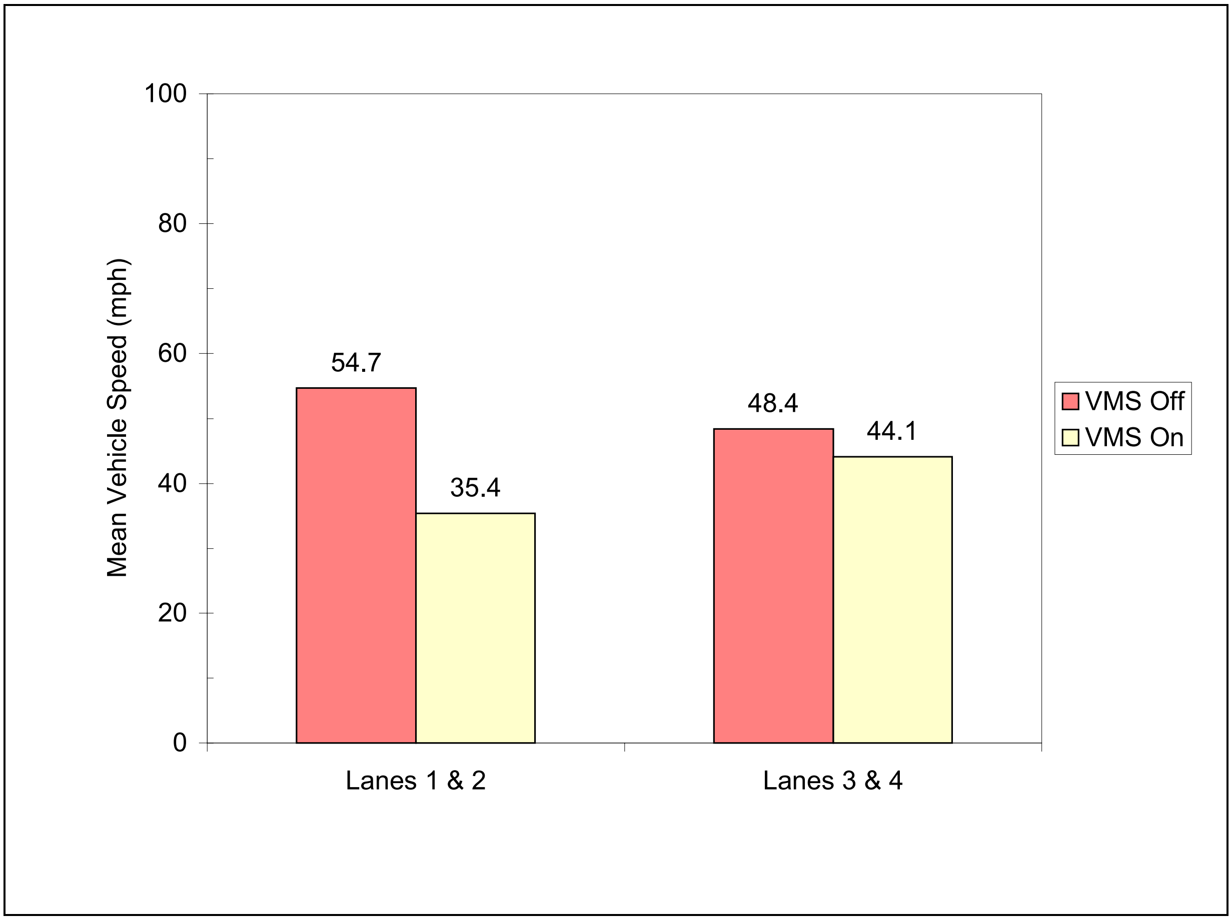

Figure 30. VMS Analysis – High Winds – Snow-Covered Roads

3.5 Key Findings - Driver Response to VMS

An extensive analysis of the event data collected during the 1997-2000 years yielded several key findings. These are:

- Under ideal driving conditions, the average vehicle speed at the test site was 72.7 mph for passenger cars, 61.2 mph for trucks, and 67.2 mph for passenger cars and trucks combined.
- When driving conditions deteriorated due to poor visibility, high winds, wet or snow covered roads, or heavy precipitation, drivers slowed their speeds without any input from variable message signs. For example, when the sign was off during periods of high wind, speed reductions of 12-16 mph below ideal conditions were measured.
- During periods of poor visibility only, there is insufficient data to determine whether messages from variable message signs caused drivers to further reduce speeds.
- Drivers do tend to make further speed reductions when VMSs are operational under conditions of heavy winds, under conditions of heavy winds and moderate to heavy precipitation, and during heavy winds when roads are snow covered. Driver speeds were nearly 20 mph lower when the signs were on than when the signs were off during these weather conditions.

4.0 RESULTS AND CONCLUSIONS

This research finds that information provided to drivers during periods of poor weather encouraged them to reduce their speeds more than if the information were not provided. These and other relevant conclusions are summarized below.

- The three sensors provided reasonable estimates of the visibility present at the study site. The three sensors agreed on visibility classification (either above or below 0.23 miles) 83 percent of the time. Two of the sensors (Handar and Belfort) agreed 97 percent of the time. The Handar and Belfort sensors provided the best estimates of visibility.
- After some initial problems with power supplies and communications, the system operated reliably. The cost of operating and maintaining the sensors and the supporting systems was minimal.
- Even without the information from the variable message signs, drivers reduced their speeds in poor weather conditions, when visibility was low, wind speeds were high, precipitation was heavy, and roadways were wet.
- During periods of low visibility, when all other conditions were ideal, the sign did not have an apparent effect on driver speeds. The availability of data during those conditions, however, was limited. It may be that with a larger amount of data the effects of the sign would be evident.
- When the sign was operational, during periods of high winds and other extreme weather conditions, drivers in both directions reduced their speeds. Substantially greater speed reductions were observed in the southbound direction, where drivers benefited from the information on the sign.
- Another important observation is the Idaho Transportation Department's increased awareness regarding the usefulness of road weather information system data. When this project began, very few of these stations existed throughout the state. There are currently 24 sites in operation and a comprehensive site plan in place to install many others. At least in part, the

Idaho Storm Warning ITS Operational Test Project helped to illustrate how this type of data could be used to maintain the state and interstate highways more efficiently during winter weather conditions. This is a significant benefit of conducting projects such as the Storm Warning Project.