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Fog Sensor / ITS Integration

FINAL REPORT

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DISCLAIMER STATEMENT

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16. Abstract

The objective of this study is to deploy an integrated weather/traffic detection system that can be used to gather information about adverse weather conditions such as fog, ice, rain, and snow and traffic conditions and then evaluate the deployed system. The system was successfully deployed and evaluated. The results of the evaluation based on the data provided to the research team are presented in the report. Functional requirements of the weather / traffic information system were developed. The system was then deployed at the site selected by NJDOT. Two separate workshops were conducted to train NJDOT personnel and to demonstrate system's full availability. The availability of the system and the accuracy of the data were both evaluated and found satisfactory. Using the data that was made available to the research team, independent evaluation was also conducted to determine accuracy of the system in terms of the data it collects. The system data was determined to be accurate as a result of this evaluation effort. There were several important lessons learned in this project in terms of challenges faced during the installation of the system at a relatively remote location. These lessons were in terms of issues especially related to the power, communication, and long-term costs of maintaining and using the system. The most important lessons learned was the possibility of additional delays due to these issues when deploying Intelligent Transportation Systems and the need for considering fast changes in the technology. These lessons learned are described in detail in the Executive Summary as well as in the Conclusions section of the report.

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EXECUTIVE SUMMARY

New Jersey Department of Transportation's (NJDOT) long-term plan is to develop and implement tools to provide accurate and dependable weather information to all travelers in New Jersey. A short-term goal is to test the feasibility of a fog detection system and, if the conclusions are positive, to expand onto other roads where there are similar weather concerns. This new approach to weather and traffic information dissemination is being tested because of the deficiencies of the current system, which mainly relies on unchangeable, year-round signs or pre-canned highway advisory radio (HAR) messages.

According to NJDOT, the Wanaque Bridge on Route 287, the site at which the system is going to be installed is considered to be a fog prone area in which several fog related accidents have recently occurred. It is suggested that the frequency and total number of accidents can be reduced with an effective use of weather / traffic warning system. The proposed system will detect the existence of hazardous weather conditions then notify traffic management personnel at NJDOT (Operations North) so that the appropriate actions can be taken. The system will also detect accidents in real-time using the information obtained from traffic sensors and incident management crews. The occurrence of incidents will be verified by using a close circuit television (CCTV) camera installed on the bridge.

Functional requirements of the weather / traffic information system were developed. The system was then deployed at the site selected by NJDOT namely, the Wanaque Bridge on Route 287. Two separate workshops were conducted to train NJDOT personnel and to demonstrate system's full availability. The availability of the system and the accuracy of the data were both evaluated and found satisfactory. Data acquired from the system's sensors are archived in the server located at the NJDOT headquarters in Trenton. Using the data that was made available to the research team, independent evaluation was also conducted to determine accuracy of the system in terms of the data it collects. The system data were determined to be accurate as a

result of this evaluation effort. Tests to evaluate the impact of the system on the number of fog related accidents could not be conducted because of an internal decision by the agency not to use the system data for generating advisory information using the real-time data and then disseminating real-time warnings to motorists. There were several important lessons learned in this project in terms of challenges faced during the installation of the system at a relatively remote location. These lessons were in terms of issues especially related to the power, communication, and long-term costs of maintaining and using the system. These lessons learned can be summarized as follows:

1. Power source on the bridge took considerable time to become functional and the same was true for the phone line. This experience shows that deployment of any ITS equipment can be delayed due to the delay in obtaining power and communication lines and this fact has to be taken into account when deployment schedules are developed.
2. Cost concerns about long distance phone calls created the need for an alternative communication solution such as, the possible use of Lantronix technology or Cellular Digital Packaged Data (CDPD) modem. Final communication solution that was adopted was CDPD modem mainly due to its low monthly cost, its ability of unlimited data transfer, and its availability at the project site. It is thus important to understand the long-term communication costs of any ITS technology beyond the initial costs for acquisition, deployment, and training. However, it is also important to be able to adapt to the changes in technology during the course of the project. The decision for using CDPD modem and service instead of regular telephone saved the project considerable amount of money. More importantly, it made it possible for the DOT to have a continuous communication link to the sensors.
3. The server at NJDOT headquarters that would run SCANWEB server had to be upgraded and installed at Trenton based on the understanding that the Remote Processing Unit (RPU) at Wanaque bridge is going to be connected to this server. Moreover, through the use of a WEB Browser, the people at Operations North were able to log on to this server at Trenton. The advances in software and communication technology made it possible to have the central server at the NJDOT

headquarters and still allow the remote users who are on the NJDOT backbone to use the system from their computers. This enabled the project team to reduce costs by obviating the need for having a separate server at Operations North. However, prospective users who are not on the NJDOT backbone i.e. who are outside the NJDOT firewall will not able to access the system. This of course limited wider use of the system data for research and other purposes.

4. The availability of Variable Message Signs, the details of real-time communication between the system and the involved personnel, the availability and the cost of an operator in-the-loop for 24 hours to ensure the real-time updating of warning messages, and the long-term maintenance of the deployed system were some of the major issues that emerged after the deployment of this system. Due to these issues, real-time advisory aspect of the original system was not implemented.

INTRODUCTION

Determining weather conditions, forecasted and current, is critical for most travelers. Real time conditions can affect the users traveling plans and it can be used to determine what precautions are necessary when the trip is already underway. NJDOT has determined areas that are often affected by adverse weather conditions. One of these areas resides on the Wanaque Bridge, Route 287, in New Jersey (see Figure 1).

According to NJDOT, the main concern at this location is reduced visibility due to the fog. Several fog-related accidents have been reported at this location. This research evaluated an integrated weather system as a viable solution to prevent further incidents by detecting environmental conditions and to provide motorists with real-time warnings about visibility.

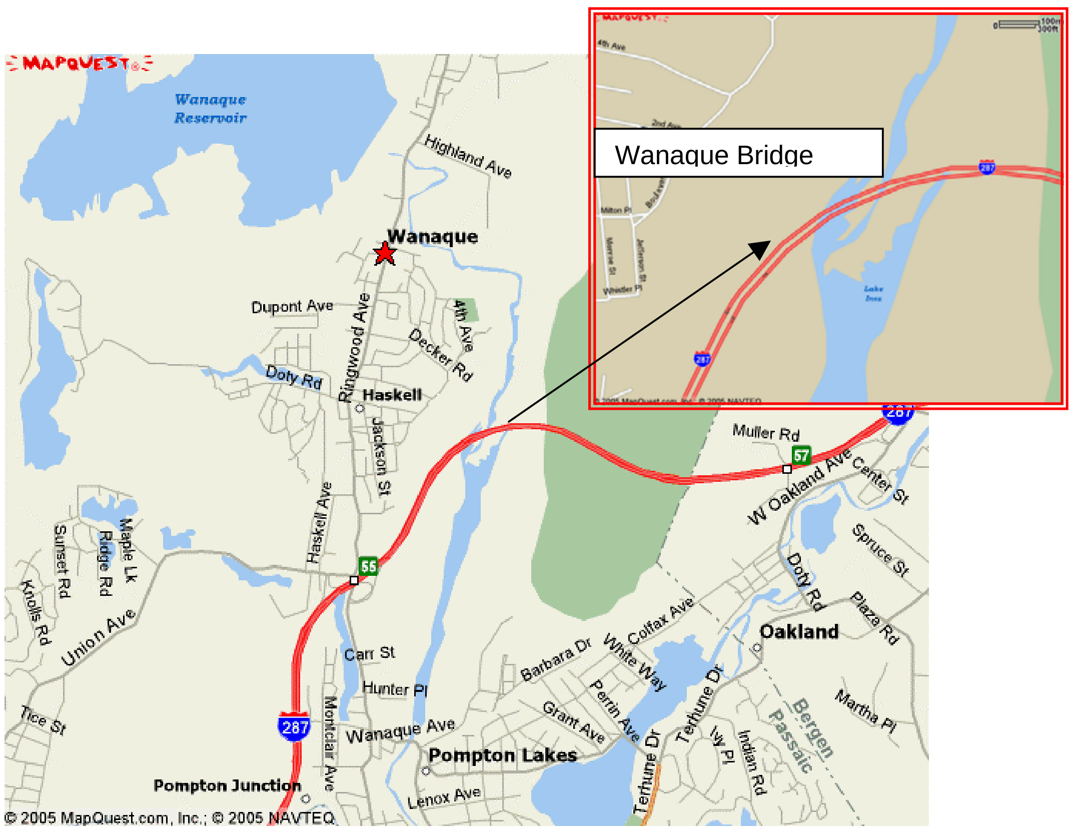

Figure 1. Wanaque Bridge Site Location on Route I-287 (Source: Mapquest)

NJDOT's long-term plan is to provide accurate and dependable weather information to all travelers in New Jersey. A short-term goal is to test the feasibility of this fog detection system and, if the conclusions are positive, to expand onto other roads where there are similar weather concerns. This new approach to information dissemination is being tested because of the limitations of the current system, which mainly relies on unchangeable, year-round signs or pre-canned highway advisory radio (HAR) messages. This static information approach falls short in the following ways:

- Lack of timely reporting
- Lack of location, traffic and weather related detail
- Insufficient information and geographical coverage
- Inaccuracies due to changing conditions

The new system will detect the presence of fog and send real-time information to the traffic operations center. This accurate real-time data can then be used to enact a response, mainly using a Variable message Sign (VMS) to alert the environmental conditions. Information can also be disseminated using pagers, e-mail, phones, or wireless devices available to the NJDOT personnel.

The objective of this study is to select and deploy an integrated weather/traffic detection system that can be used to gather information about real-time traffic and adverse weather conditions such as fog, ice, rain, and snow. The evaluation of the accuracy of the sensor data is another objective. Finally, evaluation of the effectiveness of this weather information disseminated to the drivers using “Variable Message Sign (VMS)” in preventing accidents caused by adverse weather conditions is among the original objectives of the study. However, this last objective was not realized due to an internal decision made by NJDOT.

Background

The site selected for the evaluation was a low visibility area in which several fog related accidents have recently occurred. It is expected that the frequency and total number of accidents can be reduced with an effective use of weather / traffic warning system. The system will also detect accidents in real-time using the information obtained from traffic sensors and incident management crews. The occurrence of incidents will be verified by using a CCTV camera installed on the bridge.

Improved traffic management is necessary for alleviating present and future congestion and safety problems on highways. Remote traffic surveillance, and consequently data transfer, is a required component of operational strategies to improve highway management. Surveillance, using CCTV, loop detectors, infrared cameras, or other sensors, provides information about a dangerous situation or an accident that has already occurred. In this project, monitoring traffic using CCTV verification is an important requirement. Visual evidence of the current traffic conditions will be used to develop effective measures for traffic management including hazard warnings and speed limit reductions through the use of Variable Message Signs at the project site. Effectiveness of these traffic management measures depends on effective surveillance that can be accomplished by transferring traffic and weather data from the site to the traffic control center managed by NJDOT. This data include, but is not limited to, vehicle counts, queue lengths, visibility, temperature, and weather conditions, specifically fog. Data will be transferred through a communication workstation that will allow users to upload and download data and instructions from the site to the Operations Center.

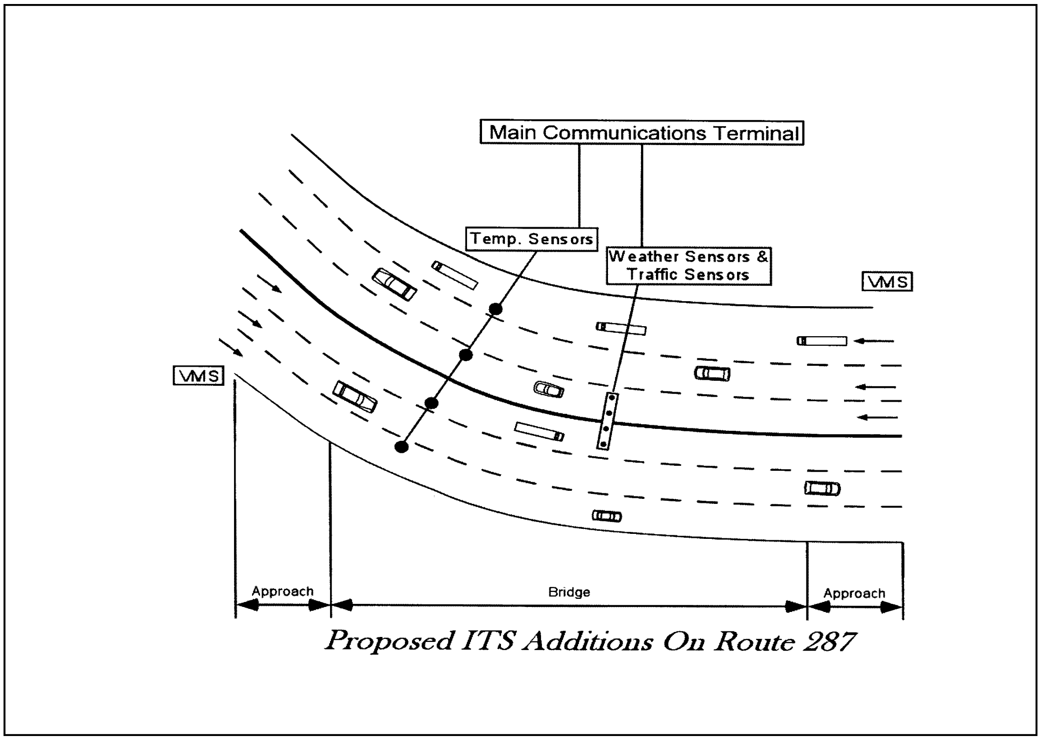

Figure 2. Schematic of the Proposed Weather System for Wanaque Bridge

Project Description

This project involves the selection, deployment and testing and evaluation of weather and traffic monitoring sensors on the Wanaque Bridge in Northern New Jersey (Figure 2). This project has two major objectives:

- <u>Selection, acquisition and installation of an integrated weather / traffic monitoring system.</u> A subcontractor was selected as a result of an evaluation process of the proposals submitted by interested companies. This involved the identification of companies that develop and deploy weather / traffic monitoring systems, development of a “Request for Proposals” that was then sent to companies identified as possible system developers, evaluation of the submitted proposals, and the selection of the subcontractor. The subcontractor, from whom the system was acquired, was also responsible for proper installation of the system as well the integration of the system with the existing NJDOT ITS equipment. As part of this first goal, necessary traffic management strategies such as the requirements for the dissemination of the reduced speed limit and other relevant information to drivers via variable message signs was also identified by NJDOT.

- Testing and Evaluation of the capabilities of the installed system. This phase includes testing the data transfer mechanisms and surveillance capabilities of the deployed system. All of the required system components described in this proposal must be present and functioning at service level. This included a training session by the subcontractor where the prospective users of the system were trained to use and maintain 1) the software system 2) the sensors. The first part of the training was held at a NJDOT location where access to the system software and data was possible. The second part of the training was held on site.

Both these training sessions held by the selected subcontractor are used as a means to also assure appropriate working of the software and hardware components of the deployed system. Originally, it was anticipated that after the system is used by the NJDOT to disseminate traffic advisory under severe weather conditions, the effectiveness of the installed system in reducing the number of incidents by providing the necessary information to drivers and the traffic management personnel at NJDOT would be tested using the data obtained from the system and NJDOT. However, this objective could not be realized because the system information was not used to generate and disseminate real-time information due to the final decision made by NJDOT.

Functional Requirements

Based on a functional analysis of the weather and traffic related data, requirements of integrated weather/traffic detection system also shown in Figure 2 are as follows:

1. Weather Detection System that has a capability of generating alarms for low visibility conditions.
2. In-Road Temperature Sensors that has a capability of generating alarms for adverse road surface conditions due to low temperatures.
3. Closed Circuit Television (CCTV) for assessing the weather conditions and the verification of traffic incidents.

4. Traffic Sensors for traffic monitoring and for the automatic detection of incidents along with an alarm capability.
5. Variable Message Signs that will be used to disseminate weather warnings and reduced speed limits to the drivers,

Weather Detection System detects hazardous driving conditions due to adverse weather such as fog, heavy rain or snow, and to alert the NJDOT traffic management center. When the visibility at the site is below a pre-defined threshold level, an automatic alarm will be issued by the system so that necessary traffic management strategies are taken. Road temperature sensors will permit the detection of ice, and subsequent slippery road conditions. Upon detection of such conditions, the system will send an alarm to the traffic control system and NJDOT maintenance crews.

A CCTV monitoring station and a fully integrated communication station were also designed and included in the system. The primary purpose of the CCTV monitoring station is to provide verification capabilities for viewing the prevailing weather and traffic conditions. The communication workstation provides the ability of remotely connecting to the site and its devices for the purpose of confirming alarms and monitoring real-time conditions. This communication workstation will be fully integrated with existing terminals at NJDOT traffic management center. The communication workstation which will control the weather / traffic monitoring system will be remotely accessible by the off-duty NJDOT personnel for the verification of alarms and data downloads. The communication of the system with the workstation will be regular telephone lines or another communication technology, such as wireless, that is readily available at the test site. A software solution does not require a stand-alone workstation dedicated to this system can also be considered as long as it satisfies all of the above requirements.

Speed, density, and volume of traffic will be detected using the traffic sensors. Using this information, occurrences of incidents will also be detected automatically. Remote Traffic Microwave Sensor (RTMS) sensors were selected by NJDOT as the most reliable type of sensors in such situations. Variable Message Signs will be provided and installed by NJDOT.

LITERATURE REVIEW

Fog-related crashes, like all crashes in general, are difficult to predict but may exhibit some tendencies associated with their occurrence. It has been generally concluded from National Transportation Safety Board (NTSB) investigations of major fog incidents that "fog-related crashes result because drivers have not maintained uniform reduced speeds during times of limited visibility"(6).

Dense fog that reduces visibility is a threat to the safe and efficient operation of motor vehicles. "Attempts are being made to prevent, abate, and disperse fog and to improve visibility and guidance through fog. Restricted driver visibility due to fog and its relationship to safe traffic operation, particularly on high-speed freeways, has been a national concern. Although fog crashes account for a relatively small portion of all crashes, when fog was a contributing cause or the prevailing weather condition at the time of fatal crashes, they can involve many vehicles in a chain-reaction pileup, which attracts much public attention. These poor visibility conditions increase stress on drivers and reduce their ability to react appropriately to sudden changes in roadway and traffic conditions"(6).

Brief History of Fog Detection Systems

Various agencies in United States have already deployed or are deploying different types of fog detection devices, but many areas are still relying on actual observation of fog by the Department of Transportation (DOT) and then reporting it. However, there are several relatively recent attempts by several DOT's to deploy and test weather information systems such as North Dakota and Virginia Departments of Transportation to name a few. CALTRANS is one of the DOT's that deployed fog detection systems in the fog-prone Central San Joaquin Valley of California. CALTRANS system is equipped with high performance sensors and data acquisition equipment installed at nine separate locations. The device provides real-time weather and visual range data for a large monitoring area. They include remote sensor assemblies consisting of pavement sensors, forward scatter fog sensors, wind speed and direction detectors, barometric pressure recorders, rain gauges etc., and a central processing unit. A master computer uses the data to assess conditions and provide reports of special weather conditions to drivers within the monitored area. The cost of the entire project was reported to be more than $3.6 million ($1.32 million for California Department of Transportation CALTRANS and $2.35 million for California Highway Patrol CHP)[15]

South Carolina installed weather-monitoring equipment consisting of fog detectors and weather stations. The system is equipped with five forward scatter type fog detectors at 500-foot intervals. The system also has a weather station to detect wind direction, wind speed, temperature, and humidity. These devices provide information to a data recorder and a central computer to correlate the prevailing field conditions with a set of pre-selected parameters to determine the appropriate countermeasures of reduced visibility.

During 1960s, the New Jersey Turnpike Authority (NJTA) contracted with a private weather forecasting service to provide three daily forecasts and additional forecasts when foggy conditions are expected. For a short period of time during the mid 1970s, the turnpike opted for a laser system for fog detection. In the middle of the 1970s, the turnpike opted for a laser system. However, "installation problems, coupled with components failure and difficulty in finding replacement parts, forced the turnpike to abandon the project. Instead, NJTA sought off-the-shelf detectors proven by other agencies, and purchased two fog detectors and complete weather stations" [7].

Following three severe chain reaction crashes (in 1978, 1979, and 1990) on I-75, Tennessee has developed a fog detection system. The I-75 system covers a 19-mile section of the highway identified as the fog-prone area. The system continually monitors the climatological and visibility conditions along the three-mile highway section with a history of severe fogging events. Eight forward scatter fog detectors integrated with two weather stations monitor visibility across the fog area. The weather stations measure temperature, wind speed, wind direction, and dew points. The information is processed by using the Management Information System for Traffic (MIST 2.0) developed by Farradyne Systems, Inc.

In the mid-1980s, few State Highway Agencies (SHA), such as Minnesota, Pennsylvania, New Jersey, Washington, and Wisconsin began testing pavement sensors. Research into the use of this technology in these states showed that snow and ice control decision makers could make their operations more efficient and effective by using weather and pavement condition information. Especially important was the ability to monitor pavement temperature and to compare temperatures with forecasts of pavement temperatures. In the past, snow and ice control personnel monitored air temperature and forecasts thereof. With pavement surface and subsurface temperature information now available, their attention was soon placed on the roadway, which is what has the major influence on how snow and ice behave on the pavement. In the investigation, the research considered all aspects of weather information, such as forecasts and communications, as well as in-road and roadside sensors, to be a part of Road Weather Information Systems (RWIS)[(1)].

According to a 1997 Virginia Department of Transportation (VDOT) report, VDOT has placed RWIS stations at 40 locations in the State. This report emphasizes the lack of and the need for studies to determine the system performance. The most important conclusion of this study is the need to identify system malfunctions and to repair these on a timely basis. Moreover, the study recommends the development of procedures for reporting malfunctions and the progress of repairs [(16)].

Several European countries are also making efforts to counter the adverse impacts of foggy conditions. Project DRIVE in the Netherlands has proposed to install an integrated system of nephelometers to assess road visibility. The nephelometers measure the physical structure of the clouds, including their concentration, and the shape of cloud particles. PROMETHEUS research program in Europe has developed a visibility monitoring system based on infrared laser beams (similar to the detector being tested in Idaho). The backscatter signals from the beam are processed to derive the visibility range. Motorway 25, which circles the city of London, is equipped with fog detection technologies to detect and forecast poor visibility conditions. The Automatic Fog Warning System (AFWS), equipped with backward scatter sensors, is designed to help drivers by providing real-time information on weather conditions.

Review of Visibility Factors and Equations [5]

Fog is identified by NJDOT as the main concern along the Wanaque Bridge on Route I-287. The traffic control center will have to determine safe speeds based on visibility calculations. The object on the road, and its contrast to the background, greatly affect the visibility, so all the equations in the forthcoming sections will center around a contrast coefficient (C*). Contrast varies with daylight, object luminance, and whether the observer's headlights are on. In light of this information, three cases need to be considered.

- CASE 1: Daylight, no lights on the target vehicle or the observer's vehicle
- CASE 2: Nighttime, taillights and headlights are on for both vehicles
- CASE 3: Daylight, Taillights and headlights are on for both vehicles

Case 1

Koschmieder's theory of "airlight" is applied for this case. The equation found through Koschmieder's research is as follows:

$$V = -\frac{1}{\sigma}\log\frac{\varepsilon}{C*} \qquad \textbf{(1)}$$

where

V= Visual range

σ= Atmospheric extinction coefficient (derived from transmissometer readings)

ε= contrast discrimination threshold

The recent standard approach is to assume that C* = 1 (black body viewed against white fog) and let ε = 0.06. This leads to a visual range that can be calculated from a reading on the trasmissometer. This resulting equation for visual range is as follows:

$$V = \frac{2.813}{\sigma} \quad \textbf{(2)}$$

Case 2

Visual range for this case relies on background luminance and object luminance. Therefore, Allard's law will be used to determine visibility. The equation governing this law is:

$$I_T \frac{e^{-\sigma V}}{V^2} = K_1(1 - K_2\sqrt{B_b})^2 \quad \textbf{(3)}$$

where

I_T = Taillight intensity

B_b = Background brightness

E_1, E_2 = Constants used to fit the observer luminance threshold data

Although this equation is not solvable in its given form, the Transportation Research Board report(5) provides appropriate values for all the variables. This enables the visual range to be computed.

Case 3

Case 3 can be split into two separate cases:

- Case 3a: The taillights of the leading car is seen first
- Case 3b: The body of the leading car is seen first

Case 3a can be approached in the same manner as case 2. All the conditions and variables, previously mentioned, apply in this sub-case. Since there is no measurable change in background luminance when headlights are on or off during the daytime, case 3b can be treated in the same manner as case 1.

Review of Operational Implementation Possibilities

Since fog is determined by NJDOT as the leading concern for the Wanaque Bridge along Route 287, some fog countermeasures in addition to Variable Message Signs (VMS) are briefly described below. If the user receives and understands the warning through a VMS, but fails to alter his / her behavior, other enforcement tactics can be employed. These tactics range from visual guidance systems to the threat of legal actions (for example, those who do not obey the reduced speed limit can be issued a ticket). It is important; however, to first make sure that the visual warning and the physical warning area are not separated by too large or too small of a distance. In fact, the National Cooperative Highway Research Program recommends that the sign be as close as 600 feet to the area of reduced visibility, if possible. This is done because drivers “forget” about the warning if it is communicated too far in advance. If the sign placement is correct and the driver receives and understands the warning while failing to alter their behavior, other measures need to be taken.

Initial tests of strobe lights mounted on the median barrier and angled towards the oncoming traffic, have also been shown to be successful. These lights are placed at a distance of 100 feet from one another and blink in succession. Incompliant users may not understand or respect the reduced visibility because they have no means of judging their visual range. This system will provide the user with the means of testing his/her own limitations, without being told what they are. As a result, it will increase the validity of the posted warnings and increase user compliance.

A second method can rely on enforcement and utilize minimal resources. If the user does not comply with posted regulations, they will be reprimanded. When a speed reduction is posted on the VMS, a second warning is also posted, such as, “Area under police patrol. Violators will be issued a ticket”. This system gives the users two reasons to adhere to the posted warnings. The frequency of actually patrolling the area in times of adverse conditions is left to the proper authorities as well as the extent of the fine.

Anti-collision systems are currently being pursued as part of the overall research problem described in the FHWA “Safety and Operations” web page(8). These include the use of vehicle-mounted radar. The radar systems have a range of about 300 feet, corresponding to a safe speed of 46 to 53 mph, depending on whether the pavement is wet or dry. One problem with the radar is that it is limited in that it cannot discern between a tree on the side of the road and a car that is in the same lane. A possible solution is a passive radar system, which includes a reflector on all vehicles. The radar would now respond only to reflector-equipped vehicles. Safe speed can be increased by increasing the radar's range and/or by connecting the radar to the breaking system, thus eliminating perception-reaction time.

SELECTION AND ACQUISITION OF THE SYSTEM

During Phase 1, the suppliers/system integrators that have an integrated weather/traffic detection sensor and that meet the specifications provided by the NJDOT were identified. A "Request for Proposals (RFP)" was sent to all of them. The names of the suppliers to whom the RFP was sent are shown in Table 1. Proposals that were received as a result of this RFP and the information that summarizes the responses were sent to NJDOT to select the finalists to be invited for a final presentation to NJDOT and the members of the research Team. After the final presentations, NJDOT in collaboration with Rutgers research team selected the supplier based on the submitted proposals and the presentations.

To summarize following steps were taken for the selection of the subcontractor for the system integration and installation.

1. RFP's were sent out to Companies shown in Table 1 that were identified as potential suppliers of the Weather / Traffic Information System described in the original NJDOT RFP.
2. Three companies responded. They were invited to give a presentation at the New Jersey DOT headquarters at Trenton.
3. After company presentations, a letter that provided further details about the requirements of the project were prepared and sent to the companies.
4. Responding companies were asked to submit a final and best offer. Final evaluations for the three submitters were obtained from the evaluators at NJDOT and Rutgers.

5. SSI was selected by NJDOT as the sub-contractor based on the evaluation results of the review panel. Arrangements for installation and traffic control were made.

Table 1. Names and the contact information of the suppliers

Image Sensing Systems, Inc. Adress/Contact: Durga Panda 500 Spruce Tree Centre, 1600 University Avenue West, St. Paul, Minnesota 55104-3825 USA Phone: 612.603.7700, Fax: 612.603.7795, Email: iss@imagesensing.com	**Pulnix** Adress/Contact: 1330 Orleans Drive Sunnyvale, CA 94089 Jim Alves, ITS Sales Manager Phone: 619.523.9220 Email: alves@funtv.com Chris Towne, ITS Sales Phone: 408.747.0300 x129 Toll Free: 800.445.5444 Fax: 408.747.0660 Email: ctowne@pulnix.com	**Denbridge Digital** Adress/Contact: 15095 Wicks Boulevard San Leandro California 947577 USA Tel: 510.614.1111 Fax: 510.614.0562
Odetics-ITS Adress/Contact: Greg McKhann Director of Marketing-714-780-7215 Sales phone: (888) 254-5487 Sales fax: (714) 780-7246 Sales email: vantage@odetics.com 1515 S. Manchester Avenue, Anaheim Ca. 92802-2907	**Pearpoint** Adress/Contact: 72055 Corporate Way Thousand Palms, CA 92276 U.S.A. (760) 343-7350 Tel (760) 343-7351 Fax Tom Schmandt - ext 231 Joan Stone - ext 241	**iMPATH Networks** Adress/Contact: Wayne Weisel Integral Sales 15813 Haynes Road Laurel, MD, 20707 Voice: 301 953 3212 Fax: 301 498 1206 Email: intsls@aol.com
Optelecom, Inc. Adress/Contact: Mark Pearlstein 9300 Gaither Road Gaithersburg, MD USA 20877 Tel: (301) 840-2121, fax: (301) 948-6357, 800-29-FIBER email: optelecom@optelecom.com	**International Road Dynamics, Inc. (IRD)** Adress/Contact: Corporate Office 702-43rd Street East, Saskatoon, SK CANADA S7K 3T9 Phone (306) 653-6600 Fax (306) 242-5599 Email info@ird.ca CONTACTS: Peter Kooy, Marles Kerns	**Nu-Metrics** Adress/Contact: Box 518 University Drive Uniontown, PA 15401 USA Phone (724) 438-8750 Toll Free 800-346-2025 Fax (724) 438-8769
Surface Systems, Inc. (SSI) Adress/Contact: Joe Kasperski Surface Systems, Incorporated 11612 Lilburn Park Road Saint Louis, MO 63146 314-569-1002 1-800-325-7226 1-314-569-3567- Fax	**Traffic engineering and Sales Inc.** Adress/Contact: Lisa Caelli 275 West Natick Road, Suite 300 Warwick, RI 02886-1130	

INTEGRATION AND INSTALLATION OF WEATHER INFORMATION / DETECTOR SYSTEM

RWIS System Components and Descriptions

A Road Weather Information System (RWIS) consists of multiple sites each containing a suite of sensors that gather weather data and then report to a central location where the information is displayed for the users. Specifically, each RWIS site contains pavement sensors imbedded in the pavement that measure temperature, moisture, form of moisture (snow/ice), and amount of deicing chemical present. Atmospheric sensors determine air temperature, relative humidity, wind speed and direction, precipitation and visibility.

All Sensors connect to a Remote Processing Unit (RPU), also adjacent to the highway/runway that transmits information to a server located at the main offices. The server collects and stores data from the remote units and forwards the data to a user display.

The meteorological sensors, which are located along the roadway, gather data on temperature, dew point, wind speed and direction, and precipitation. Still frame video cameras can also transmit current images of the specific site back to the user. The pavement sensors measure pavement temperature; evaluate whether the pavement is dry, wet, or ice covered; determine the relative concentration of deicing chemicals on the road surface; and calculate the temperature at which the moisture on the pavement surface would freeze. This data is then used to predict the site-specific conditions which are possible by analyzing the data as received through the sensors. The description of the main components of the system is as follows:

<u>Scan Server</u>

The SSI Scan server is the data collection device. It utilizes Microsoft NT (currently version 4.0) as the platform and SQL (currently version 6.5) as the database. The server polls the Remote Processing Units (RPU) using a scheduler that is configured as required by the customer. The communication options include telephone modem, radio, leased line modem, fiber optic, cellular phone, CDPD (cellular digital packaged data) and network (Ethernet)

The data is displayed using SSI's Scan Web software that is a web page housed on user's server that can be viewed using standard web browsers such as Internet Explorer or Netscape. A dual server configuration (one server performing both data collection and user display tasks) can poll up to 10 RPUs and provide viewing for up to 20 concurrent users. If a larger system is required then 2 servers, one for data collection and one performing the user display (Web) task are needed.

ESP- Remote Processing Units

The ESP-RPU platform is designed to provide a spectrum of configuration choices that range from cost effectiveness at one end to the ultimate in Intelligent Transportation System site hardware at the other.

The ESP-RPU is based upon an industry Standard Intel 32 bit 486-microprocessor architecture that has been used undersea and in outer space. The processor card, and all peripherals and options are housed in an aluminum card cage, which includes an ISA (Industry Standard Architecture) passive back plane. A solid-state flash ROM is used for permanent program and data storage. Further, the Sensor Interface card that collects data from pavement sensors and atmospheric sensors is an ISA bus card. The RPU is powered by a standard 120 VAC with optional solar power and battery backed sites.

SSI Pavement and Subsurface Sensors

The Surface Sensor (FP2000) is a single solid-state electronic device that is installed in the roadway pavement. It is composed of materials that have thermal characteristics similar to common pavement materials. The top of the sensor is approximately the roadway pavement color and texture and is installed with epoxy sealer so that top is flushed with the surrounding roadway surface.

The sensor is thermally passive, providing stable operation over a temperature range from -30°C to 50°C (-22°F to 122°F). The sensor and cable will withstand a temperature range of -37°C to 80°C (-35°F to 175°F) without sustaining damage.

The sensor is supplied with 46 m (150 ft) or 91 m (300’) of attached molded cable that is waterproofed and sealed as an integral part of the assembly. The sensor electronically samples the following pavement conditions:

- Surface temperature at the sensor head.
- Dry pavement condition.
- Wet pavement condition above 0°C (32°F).
- Wet but not frozen pavement condition at or below 0°C (32°F).
- Snowy or icy pavement condition at or below 0°C (32°F).

In addition, the pavement sensors supply data for determining the following pavement surface conditions when sufficient moisture is present:

- Freezing point temperature of the moisture/ice-control-chemical solution present on the surface of the pavement sensor for commonly used ice-control-chemicals.
- Depth of the moisture/ice-control-chemical-solution present on the surface of the pavement sensor up to a depth of 12 mm (0.5 inches).
- Percentage of ice particles present in the moisture/ice-control-chemical solution resident on the surface of the pavement sensor.

The ESP-RPUs standard configuration supports up to 4 surface sensors and 4 subsurface probes and can be expanded to 8 each with the addition of a Surface Sensor Expansion Kit. The maximum hardwired distance the sensors can be located from the RPU is 2500 feet.

Extended distances can be accomplished with the use of an Outpost. The Outpost is a remote station that supports up to 2 surface sensors and 2 sub probes. The Outpost communicates directly with an RPU via either spread spectrum radio 900Mhz or 2.4

GHz, leased line modem or fiber optic cable. If spread spectrum radios are used, a radio study is recommended to assure there is no surrounding interference (mainly paging towers or cellular phones which may run on the same frequencies)

Atmospheric Sensors

Connection is provided for the following atmospheric sensors:

- Air temperature sensor
- Wind speed sensor
- Wind direction sensor
- Relative Humidity sensor
- Precipitation classifier
- Water level sensor
- Visibility sensor

The ESP-RPU is capable of expanding to handle multiples of any of the atmospheric sensors listed above with the addition of the optional Sensor Interface Card.

Video Imaging

The ESP-RPU may be equipped to transmit video images over the communications link that exists for RPU/RWIS Server communications. The video option package comes with an ISA bus video capture card, a memory upgrade, power supply, 50' of cable, a B/W video camera, and an environmental housing with heater. A color camera with an integrated capture card is also available. Video imaging can be used for verification of road conditions, visibility; and verification of Variable Message Sign display.

RWIS Utilization

RWIS delivers real-time information on changing atmospheric and pavement temperatures, precipitation, and the amount of chemicals on the pavement. By analyzing the data collected from the sensors, the personnel can be notified using either pager or e-mail when pre-determined thresholds are crossed. When the information provided both by pavement sensors and meteorological sensors are combined, RWIS can analyze which roads need the real attention of crews, snow and ice operations can be efficiently planned and carried out. Moreover salt and deicing chemicals can be saved since they would be applied only to those sections that really need it.

WEATHER/TRAFFIC DETECTION SYSTEM FOR WANAQUE BRIDGE, NEW JERSEY

The installation location, Wanaque River Bridge in Wanaque Borough, Passaic County, had already been selected by the NJDOT, before the project began. The system was subsequently installed at this location. Figure 3 and Figure 4 show the various stages of the installation work.

Figure 3. Installation of the RWIS on the Wanaque Bridge

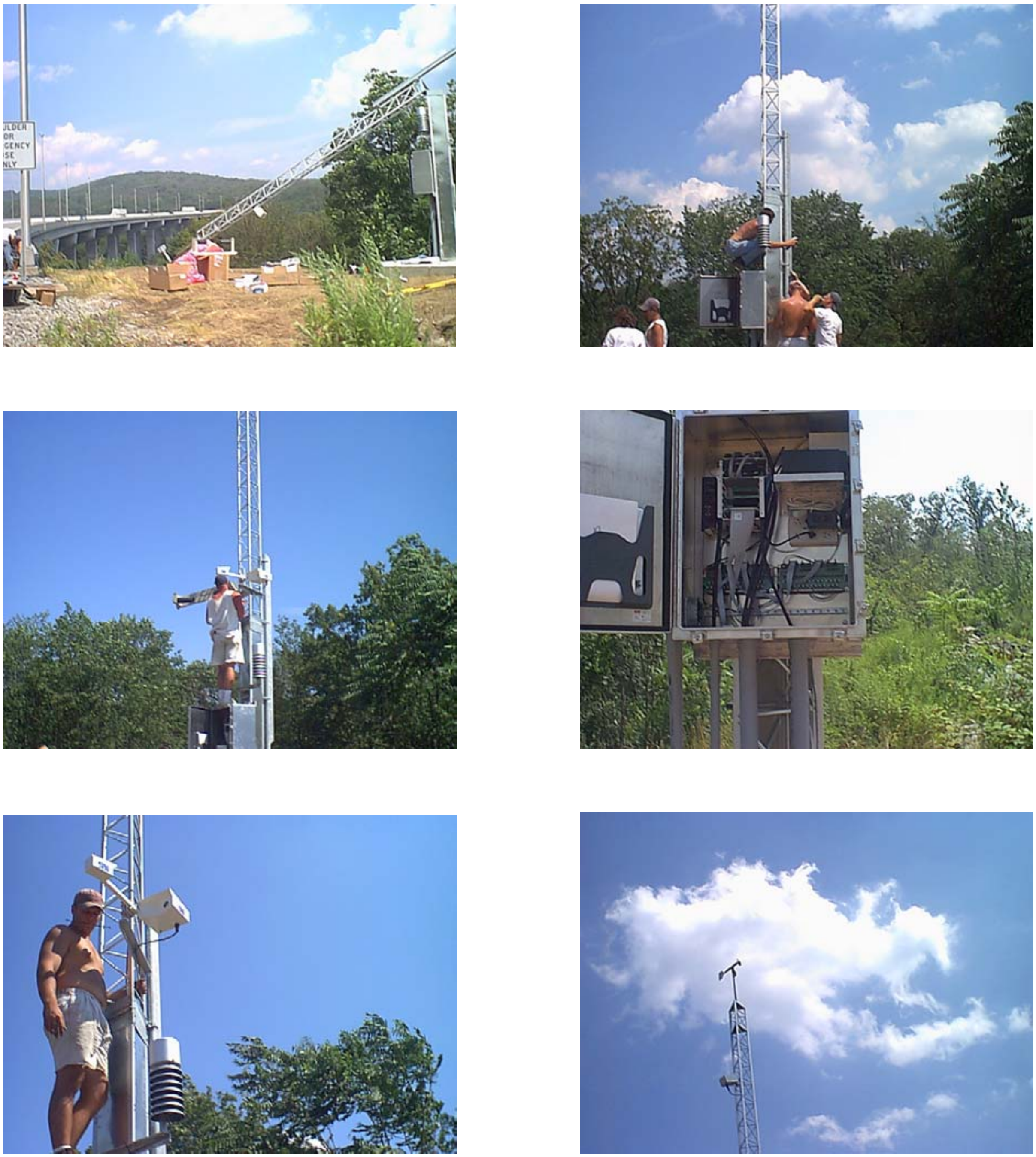

Figure 4. Details of the system components and installation steps.

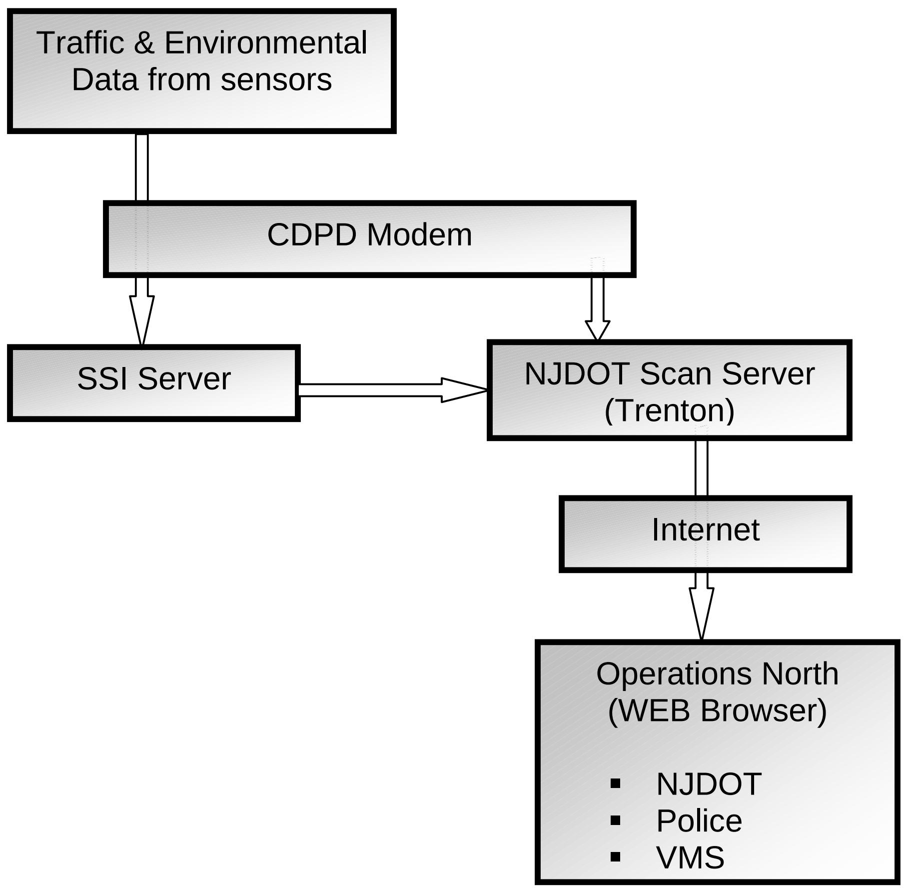

Figure 5. Schematic representation of the working of the deployed weather information system on the Wanaque Bridge

Figure 5 shows final configuration of the deployed system. Several decisions had to be made to ensure long-term uninterrupted performance of the system. The most important modification was the use of a CDPD modem instead of telephone lines to achieve continuous communications between the field sensors and the server. Using a phone connection to communicate with a server located in Trenton or at Traffic Operations Center North was determined to be an expensive option that could not be sustained in the long-run. Moreover, the connection through a phone modem could not be continuous since that would be prohibitive in terms of long- term costs. Thus, after considering various options, the use of CDPD modem was determined to be the best option mainly due to its ability to allow the field system to be continuously on-line for a very reasonable monthly fee. As seen in Figure 5, CDPD based communication model allows direct connection to Internet and thus to a web server. Thus, the second important decision was to upgrade the server located at Trenton that was already collecting RWIS data from other sited in New Jersey. This upgrade enabled not only the existing server at the NJDOT Trenton headquarters to be connected to this new system in addition to other existing weather sensors deployed throughout the State. This was a system-wide upgrade achieved for all the RWIS stations in New Jersey made possible by the project, Moreover, the new web server can be reached by any computer that is on the NJDOT backbone using a web browser. This approach eliminated the need to install a stand-alone server at the Traffic Operations Center North dedicated just to this system. It also enabled any NJDOT computer to see the information provided by the system. This was a cost saving and enhanced solution that improved access to the information.

Proposed Evaluation Plan of The System

The steps of the proposed evaluation plan are based on the plan proposed in a report published by Batelle researchers (3). The FHWA ITS field operational test guidelines are presented in the USDOT ITS report (10). In 1998, Batelle was chosen as the independent evaluator of the effectiveness of the FORETELL operational test in achieving its goals and objectives. “FORETELL is a multi-state initiative bringing ITS together with advanced weather prediction systems to create operational highway maintenance management and traveler information systems throughout North America”. Of course, this project is not comparable in size and scope to FORETELL process because it deals with a single integrated weather station and does not have the long-term implementation data that will make it possible to evaluate its time-dependent performance. However, in the following section the main guidelines adopted from FORETELL evaluation efforts and other similar studies are presented to outline a complete evaluation plan that can be used for conducting the evaluation of this and other ITS field operations in New Jersey. In fact, these guidelines are also very similar to FHWA's ITS field operational test guidelines presented in USDOT ITS report[10] and previously used by several studies including the evaluation of Garden State Bus Routing project [4,12]. Some of the major evaluation tasks that are considered in the current study can be listed as follows:

1. Testing and evaluation of the reliable functioning of the integrated system: This task is concerned with the evaluation of the reliable functioning of the system software and hardware. Each sub-system as well as the overall integrated system should be tested.
2. Evaluation of the accuracy of the detection system in terms of the measurements. This system collects various data such as traffic volume and speed, pavement temperature, fog detection, and CCTV camera capabilities. This task is concerned with the evaluation of the accuracy of the data.
3. Evaluation of the effectiveness of the system in reducing the accidents due to the adverse weather conditions. This task is planned to be developed to determine the integrated system's effectiveness in providing the motorists with useful early warnings to prevent accidents. This task will also determine the effectiveness of the system for improving incident detection times. Before and after traffic and accident data will be collected and analyzed to determine the systems effectiveness. The development of a survey that will determine user satisfaction was also proposed. However, as it was mentioned several times in the previous sections, this task was not performed since the system data was not used to generate and disseminate real-time advisories and the long-term data needed to perform this task was not available.

Evaluation Objectives and Guidelines

A weather/traffic information system was deployed to gather weather and traffic data and then to reduce number of weather-induced accidents by warning the drivers of adverse road conditions based on decision making steps that make use of the collected data. The main purpose of the evaluation is the testing of the systems' functionalities and then the evaluation of the effectiveness of this system. In order to achieve this overall goal, a well-documented, structured approach is needed to ensure meaningful results. A successful evaluation is needed to answer the following questions:

1. Does the system function reliably most of the time?
2. Does the system collect, transfer, and disseminate accurate information?
3. Does this system provide crucial information to the driver that is beyond what is currently available?
4. Does the conveyed information affect the driver's behavior in a positive way?

The success or failure of the system can be determined by measured outputs and outcomes. Output is the information that is collected and transferred from the system. It also includes the warning that may or may not be posted on the Variable Message Sign. The outcome is measured by driver compliance and accident prevention. Table 2 illustrates the steps that should be taken in this procedure.

Table 2. Information link to user decision and outcomes [3]

Information	Decision	Users	Results
Improved Roadway and Weather Information	• Post Warning • Nature of the Warning	• Increased Awareness • User Compliance	• Effectiveness • Decrease Number of Incidents • Increased Safety

Table 3. Goals, objectives, and expectations [3]

Goals	Objectives	Expectations
Safety	▪ Reduce frequency of crashes ▪ Reduce rate of crashes ▪ Reduce severity of crashes ▪ Reduce users exposure to unsafe conditions	▪ Reduce fog-related accidents and injuries ▪ Reduce the frequency, rate, and severity of crashes by providing timely and meaningful warnings to all users, potential and current ▪ Reduce users exposure to unsafe conditions by providing crucial information
Efficiency	▪ Reduce congestion and delay ▪ Improve vehicle routing ▪ Improve maintenance management	▪ Reduce cost of maintenance by optimizing deployment, number of workers, and special attention needs ▪ Reduce delay by providing information to an expected user
Environmental Conservation	▪ Reduce vehicle miles traveled ▪ Reduce emissions ▪ Reduce hazardous materials by proper responses	▪ Improve water and air quality by reducing VMT and cleaning hazardous materials timely, and properly

The goals and objectives presented in Table 3 are general evaluation goals for any ITS system.

Evaluation Plan for Measuring Performance of the Deployed System

The deployed RWIS system will collect data and send it to the Traffic Operations Center (TOC). Weather and road information will be disseminated and warnings will be disseminated through VMS. System performance of TOC relies on data accuracy, system availability, and overall effectiveness of the information provided. Thus, evaluation plan should focus on three areas:

- **System Availability:** Is the system running when and the way it is supposed to?
- **Hardware and Software Performance:** How accurate are the data that are prepared by the Traffic Management Center? How precise and timely is the road condition information provided by the Traffic Management Center?
- **System Reliability:** Is the system producing reliable output? In other words, does the system produce the same output from the given input?

A detailed list is provided to assist in data collection and comparison in order to evaluate the system's reliability, performance, and availability.

Table 4. System performance, objectives, and measurement methods[(3)]

Evaluation Goal	Evaluation Objectives	Measures
System Performance	**Accuracy** • Atmospheric sensor data vs. actual	• Precipitation type, rate, amount, start time, and finish time • High and low air temperature • High and low dew point temperature • Minimum visibility wind speed and direction
	• Road condition data vs. actual	• High and low pavement surface temperature • Pavement surface condition (wet, dry, freezing, frozen, presence of foreign material) • Snow or ice amount, type, start and finish time
	• Traffic center observation vs. final site observation	• Air temperature • Dew point temperature • Pavement surface temperature surface conditions
	Operational Availability • Atmospheric data updated on time? • Road conditions updated on time?	• Time data is available vs. time data is needed • Time data is available vs. time data is needed
	Operational Effectiveness • Information dissemination occurring on time?	• Time dissemination occurs vs. time required • % of time weather / road condition information is delivered on time

User Compliance

There are a few issues that need to be discussed when evaluating user compliance to the advisory information that will be generated by the system. First issue is whether the user is provided with clear and unambiguous information. The second issue is whether the user can make a timely and efficient decision. Table 5 will help answer these crucial questions:

- Did the user receive the information?
- Did the user understand it?
- Did it change the user's behavior?

For this particular system, information was planned to be disseminated to the user by the use of a Variable Message Sign. However, it is important to mention that, due to a NJDOT decision, the system's real-time information dissemination functions were never implemented. As a result, the user compliance cannot be tested and evaluated, however evaluation guidelines are given here to ensure completeness.

Table 5. User Compliance, objectives, and measurement methods[3]

Evaluation Goal	Evaluation Objectives	Measures
User Compliance	**Receipt of Information** • Was it received on time? • Was it in the form the user wanted? • Was it what the user wanted? • Was it presented unambiguously? • Did the user think that it was correct?	Survey and/or interview users
	Use of Information • Did the user understand the information? • Did the user know how to use the information? • Was the information there when they needed it?	Survey and/or interview users
	Behavior change • Did the user obey the caution? a) Reduce their speed? b) Decrease lane changing, tailgating, risky behavior?	• Record vehicle speed before and after the warning • Observe user behavior before and after the warning (by CCTV or on-site observation)

EVALUATION OF THE SYSTEM

The proposed evaluation plan presented above could not be fully implemented due to the internal decision made by NJDOT not to use the system as a real-time traveler information system. NJDOT decided to just archive the weather data for use with other weather data received from its RWIS stations deployed at various locations in the State. Thus, real-time decision support capabilities of the deployed system and its impact on the reduction of accidents could not be evaluated. On the other hand, system availability and system accuracy were two evaluation goals that were implemented. The first evaluation goal was to test the system availability and the second was the reliability and accuracy of the data received.

Before describing these two evaluation goals, it is important to mention some of the findings of other studies presented in the open literature. This will help in understanding some of the important points regarding the evaluation of the users' reactions to the systems similar to the one deployed in this project. FORETELL is described by the USDOT web page (17) as "a multi-state weather information network designed to reduce winter weather accidents by providing highway managers, trucking professionals, and transit operators with real-time and forecast roadway weather information derived from multiple sources". FORETELL is a multi-state weather information system created as a result of the collaboration of DOTs in Iowa, Missouri, Wisconsin and Canada. It collects weather data from various sources including the National Oceanic and Atmospheric Administration's National Weather Service, Environment Canada, Road Weather Information System (RWIS) stations, and sensors at airports and agricultural sites. The real-time weather data and advanced forecast information is disseminated to users via the Internet.

An effort to determine the impact of FORETELL on the individual weather-related activities of users before and after is deployment was made. The research approach was to conduct surveys first in November 1999, to collect baseline data. Next, follow-up surveys were conducted for two consecutive winters to determine after conditions.

Several interesting results were obtained. 30-40% of highway maintenance operators who represented over 90% of respondents surveyed, who used the system changed weather-related decisions based on the FORETELL information provided (e.g., wind speed/direction, precipitation, atmospheric temperature, pavement temperature, pavement condition, and dew point). According to the same survey results, greater than 50% of users said they wanted to continue using FORETELL in the future, and about 20% of users said they would pay for the service. However, these results are limited to the maintenance personnel and do not respond most of the questions in terms of drivers and their preferences when it comes to the type of information would like to receive and the way they would like to receive this information.

Research conducted by the University of Utah Traffic Laboratory (UTL) on the Road Weather Information System (RWIS) addressed some of these issues [(18)]. A survey was developed to determine "what people want in terms of the type, amount, and preferred delivery method of weather related road information". Commuters, truckers, recreational travelers, and long distance travelers were included in the survey. Variable message signs and radio are found to be the most popular form of RWIS information dissemination. Commercial radio and television reports were also found to be popular choices among all with the exception of the trucking industry dispatchers. They preferred Internet technology. New technologies such as, telephone, paging services, and in-car navigation systems were not ranked high by any group. The surveys indicated that road condition information was preferred by all groups over traditional travel information including information on alternate routes, travel times, and travel speeds. They also indicate that road conditions which alter driving habits, such as accumulating snow, fog, ice, wind, and road closures, are most important while rain, non-sticking snow, thunder storms, and snow flurries are less important. The preferred delivery time is while en route, making use of radio and variable message signs. The four groups were unanimous in preferring site specific and corridor information rather than information accuracy in any specific radius.

Another research project conducted in the Tampa area attempted to answer the question of the impact of real-time information on the fog related accidents. The main conclusion of this study was that programs that increase driver awareness of fog and for related accidents would be more effective than real-time information in terms of reducing fog related accidents [6].

Testing and Evaluation of System Availability

After the system was installed in addition to several field tests conducted by SSI technical people to ensure its adequate working, two workshops were conducted to train the NJDOT personnel as well as to demonstrate the system's working thus availability. The following training activities were done:

1. November 14th – 2001: 4-hour User Training with Gordon Bell
2. November 15th -2001 RTMS Training: 4-hour user and 4-hour technical

During these two sessions, the working of the both software and hardware systems were tested. Moreover, the attendants were trained in using and maintaining the software and hardware systems. The details of these workshops and availability tests are given in Appendix A.

SYSTEM ACCURACY

The research team conducted basic tests to evaluate the capability of the system to collect accurate traffic and weather data through its sensors and to transfer this data to the web server located at the NJDOT headquarters in Trenton. It was not possible for the research team to access the data by directly logging into the NJDOT server from a remote computer thus, a special arrangement between NJDOT, system developer, and the research team was made to obtain data in a CD-ROM and work on that data.

A site visit to NJDOT on January 8th, 2002 was also made to observe the working of the installed system and its remote access capabilities, including the CCTV. As a result of this visit, it was confirmed that the deployed system worked as proposed and the weather and the video data were continuously received without any problems. Below is a summary analysis of the data obtained from the sensors.

Evaluation of The System Data

There are 5 types of data in the file obtained from the server. Data cover a period of approximately 3 months, from 11/14/01 to 2/19/02.

Atmospheric Data

A) Air Data

The following data fields are available for the air data.

- Air Temperature- in degree Celsius and degree Fahrenheit.
- Dew point temperature- in degree Celsius
- Relative humidity- in percentage.

Figure 6 shows the variations in the air temperature in January 2002. Table 6 shows the statistics related to air temperature data for different time periods. The last column of Table 6 shows the average temperatures observed during the indicated months as predicted by weather channels. When compared to predicted, the air temperature measured on the site were generally higher than those predicted by the weather services.

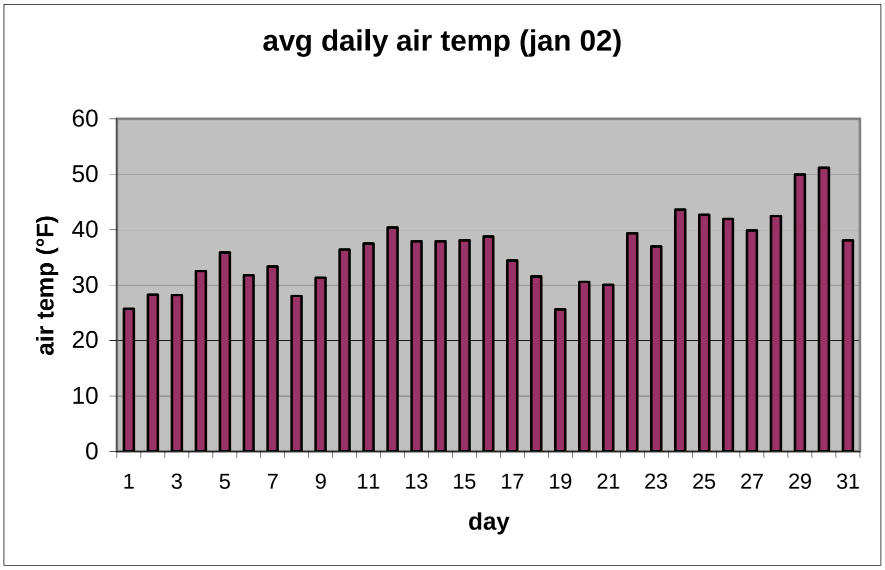

Figure 6. Air temperature measurements for January 2002

Table 6 Air temperature data statistics, °F

	Average	Maximum	Minimum	Standard Deviation	Average Temperature Forecast
November 2001	48.13	59.52	36.13	7.08	44.7
December 2001	41.08	62.03	24.64	9.58	35
January 2002	36.14	51.19	25.64	6.38	29.7
February 2002	34.85	44.43	25.62	5.62	32

Figure 7 shows the dew point temperature measurements for January 2002. Table 7 shows the average statistics of that data for different time periods.

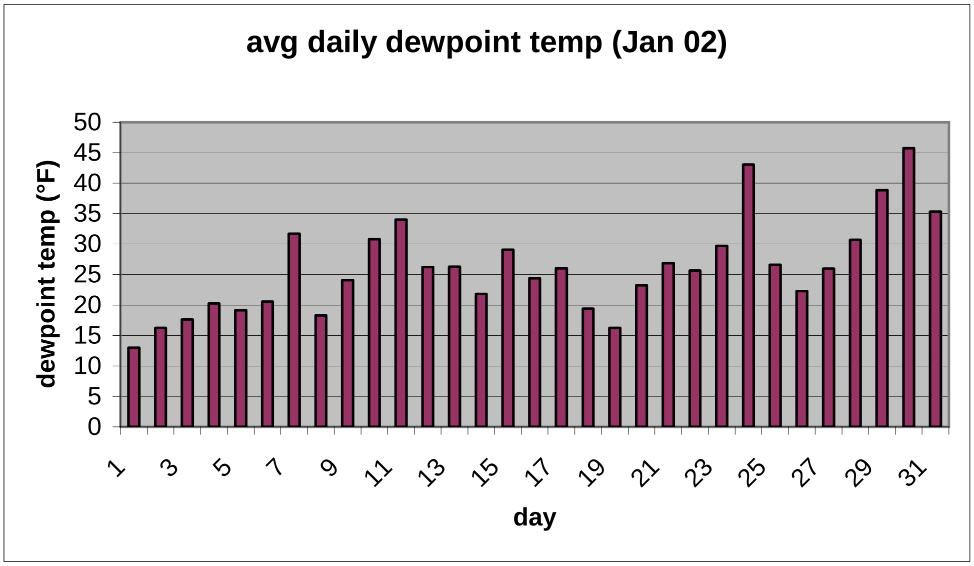

Figure 7. Dew point temperature measurements for January 2002

Table 7. Dew point temperature data statistics, °F

	Average	Maximum	Minimum	Standard Deviation
November 2001	40.64	55.13	25.62	8.72
December 2001	30.86	52.1	9.91	10.95
January 2002	26.11	45.73	13	7.72
February 2002	22.54	38.78	9.87	7.87

Figure 8 shows the relative humidity measurements for January 2002. Table 8 shows the statistics of that data for different time periods.

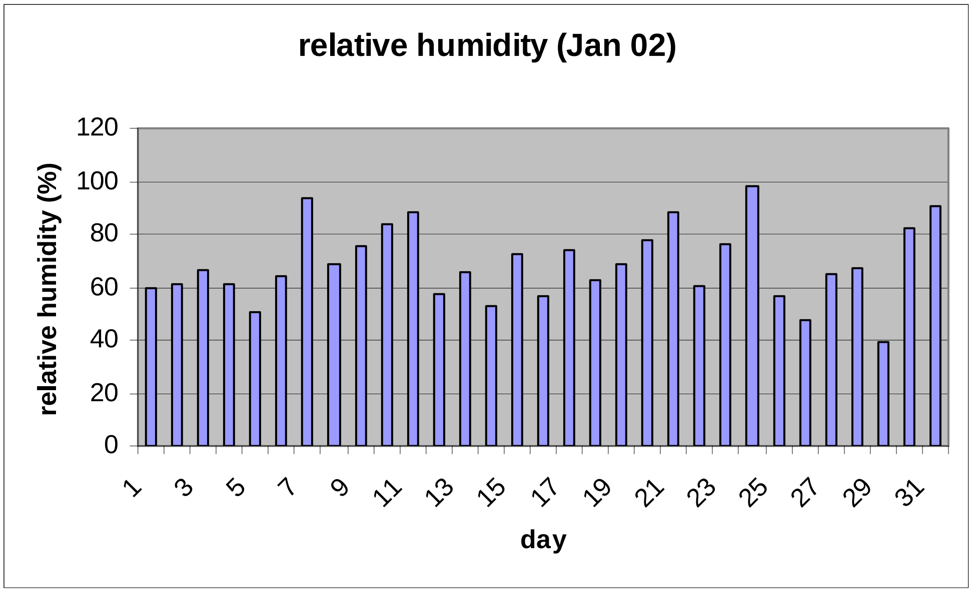

Figure 8. Relative humidity measurements for January 2002

Table 8. Relative humidity data statistics

	Average	Maximum	Minimum	Standard Deviation
November 2001	78.39	97.65	59.55	11.67
December 2001	70.54	98.52	52.4	13.89
January 2002	68.76	97.96	39.08	14.20
February 2002	63.25	94.67	46.28	12.32

Figure 9 shows comparison of air data (average values) for different months.

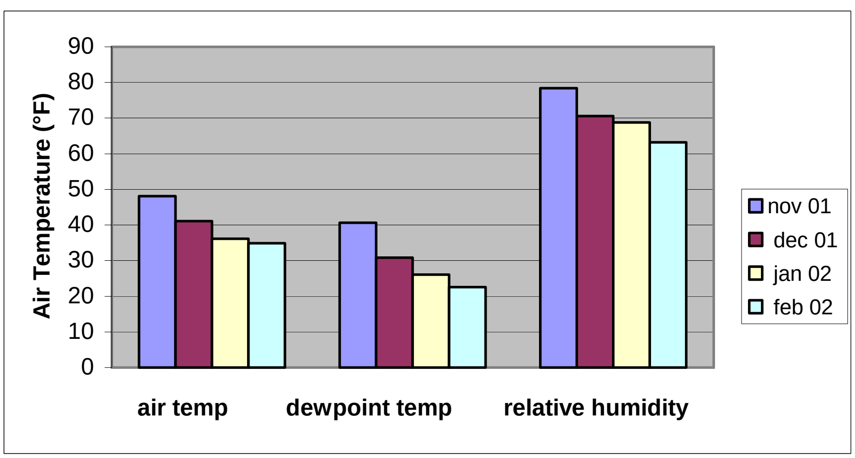

Figure 9. Comparison of air data for different months

B) Wind Data

The following data fields are available for wind data.

- Wind Speed Average- one-minute average in km/hr.
- Wind Speed Gust- one-minute maximum in km/hr.
- Wind Direction Average- one-minute average in degrees.
- Wind Direction Minimum- one-minute average in degrees.
- Wind Direction Maximum- one-minute average in degrees.

Figure 10 shows average wind speed values for January 2002. Table 9 shows data statistics and Figure 11 shows average wind speed measurements for different months.

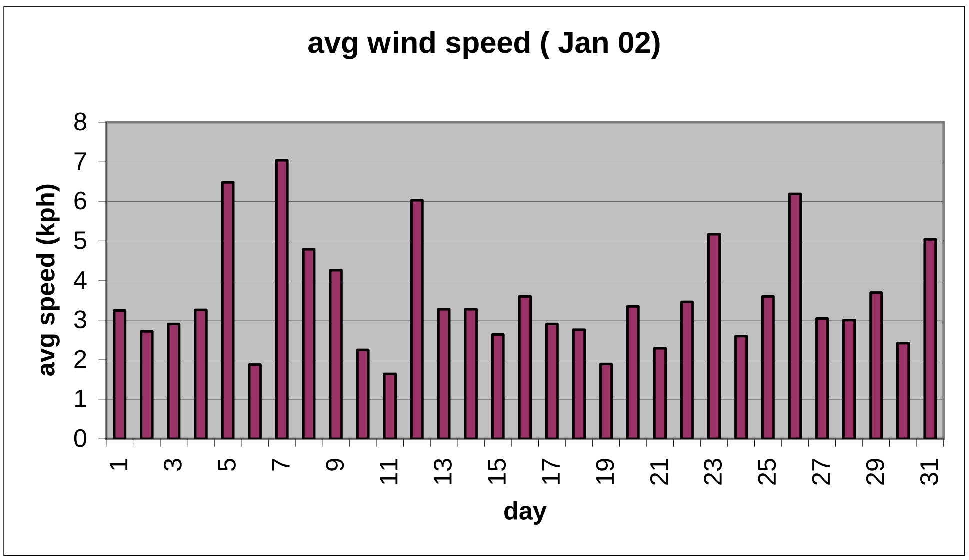

Figure 10. Average wind speed data for January 2002.

Table 9. Average wind speed data statistics, Kph

	Average	Maximum	Minimum	Standard Deviation
November 2001	2.95	4.52	1.13	0.91
December 2001	4.04	10.6	1.02	2.28
January 2002	3.57	7.04	1.64	1.41
February 2002	3.9	7.03	1.36	1.58

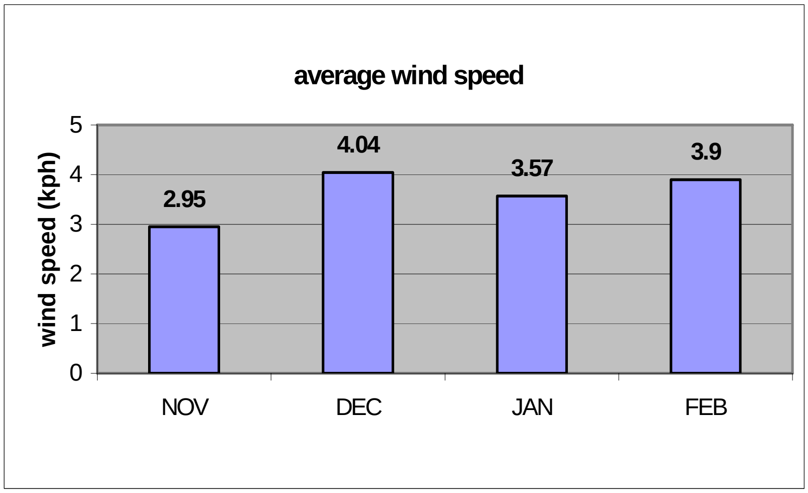

Figure 11. Average wind speed data for different months.

Precipitation Data

The following data fields are available for precipitation data.

- Precipitation Type- e.g. Rain, snow or Freezing Rain etc.
- Precipitation Intensity- e.g. light, moderate, heavy etc.
- Precipitation Rate-in mm/hr.
- Precipitation Accumulation- in mm over 24 hour starting at midnight local time.
- Time since precipitation has started, in minutes.

Surface Data

The following data fields are available.

- Surface Condition (pavement sensor reported surface condition)- e.g. dry, wet, damp, frost etc.
- Sub Surface Temperature- in degree Celsius
- Freezing Temperature- in degree Celsius.
- Chemical Factor- in integer (from 5 to 95)
- Chemical percent
- Depth of liquid solution on pavement sensor surface-in mm
- Ice percent

Figure 12 shows the surface temperature measurements for January 2002. Table 10 shows the summary of data statistics for the surface temperature measurements. Figure 13 shows the comparison of average monthly surface temperatures.

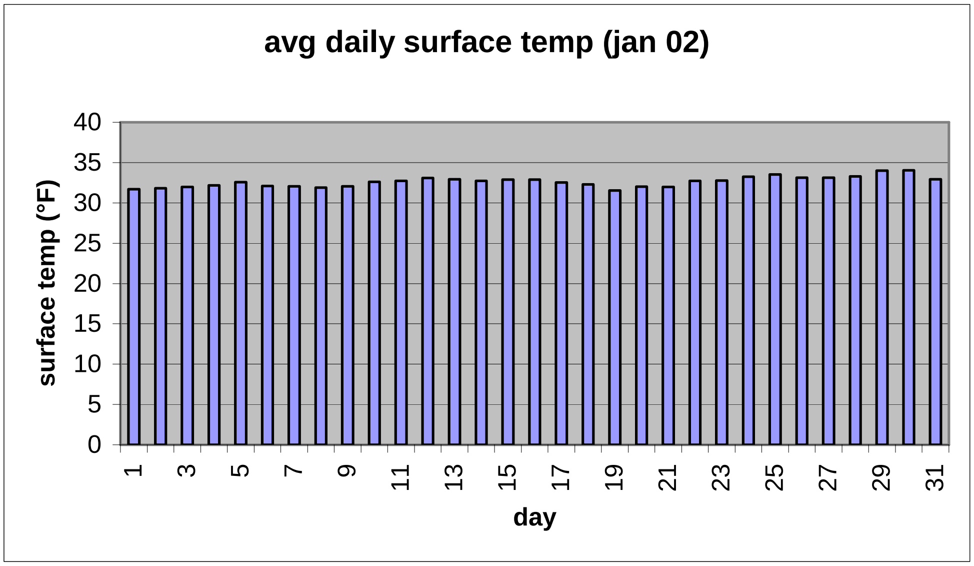

Figure 12. Average daily surface temperatures for January 2002.

Table 10. Average surface temperature data statistics, ^{o}F

	Average	Maximum	Minimum	Standard Deviation
November 2001	33.9	34.79	32.95	0.56
December 2001	33.17	35.09	31.60	0.87
January 2002	32.62	34.03	31.52	0.64
February 2002	32.65	33.67	31.88	0.53

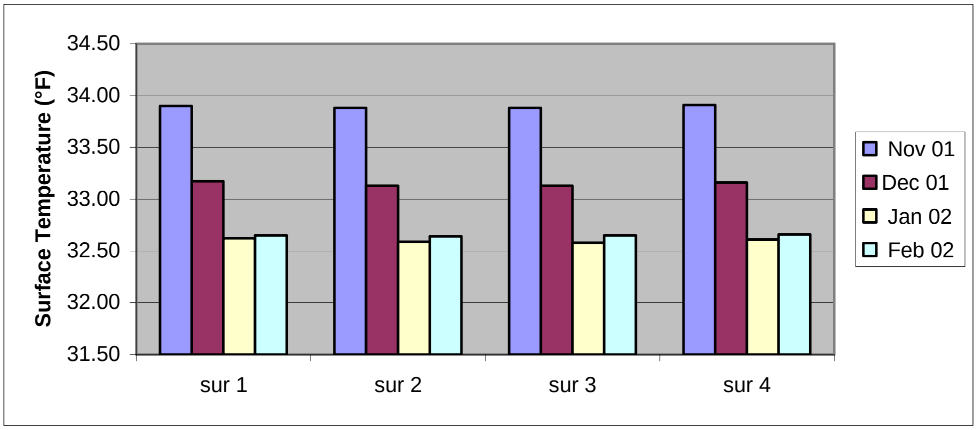

Figure 13. Comparison of average monthly surface temperatures

Table 11. Selected climatological data

DATE	Air Temp (°F)		Dew Point (°F)		Relative Humidity (%)		Wind Speed (Kph)	
	Sensor	State db	Sensor	State db	Sensor	State db	Sensor	State db
Nov. 16, 2001	58.98	61.1	45.2	41.3	62.08	NA	3.89	10.2
Nov. 21, 2001	36.13	34.5	25.62	22.8	68.92	NA	3.31	2.7
Nov. 26, 2001	53.06	52	49.5	47.7	89.34	NA	2.55	3.3
Dec. 5, 2001	58.71	58	43.36	43.8	65	NA	2.66	3.8
Dec. 16, 2001	34.47	33.1	22.83	21.1	63.3	NA	3.02	2.9
Dec. 24, 2001	41.68	37.5	35.77	34.2	82.42	NA	2.78	7.1
Jan. 1, 2002	25.73	25.7	13	11	59.41	NA	3.24	11.9
Jan. 12, 2002	40.4	39	26.21	24.7	57.4	NA	6.03	11.7
Jan. 27, 2002	39.85	43.7	25.99	22.6	64.96	NA	3.04	10.2
Feb. 4, 2002	32.63	32	22.72	20.8	70.5	NA	1.82	10.1
Feb. 10, 2002	37.99	41.2	33.52	47.6	84.72	NA	2.19	11.8
Feb. 15, 2002	34.72	38.5	21.92	26.5	61.42	NA	5.68	8
Average	41.20	41.36	30.47	30.34	69.12		3.35	7.81

SOURCE: STATE DATA BASE IS OBTAINED FROM WWW.WUNDERGROUND.COM

Table 11 for the selected days, the data collected by the sensors and the data collected independently by the State and posted at WWW.WUNDERGROUND.COM are found to be comparable given the point-wise nature of the data collected by the sensors on the

Wanaque Bridge. Moreover, the averages for several days are almost identical for both data sources. Relative humidity data was not available from the State database, thus it is not possible to compare this data with sensor data. The biggest difference between the average values of the sensor data and the data from the State database is observed for wind speeds. In general, the results of this descriptive data analysis show that the sensors at the Wanaque Bridge are working accurately.

Visibility Data

Visibility values for all four months (November to February) follow a steady pattern with the exception of several days with lower visibility. The average visibility distances are 1.85, 1.86 1.79 and 1.83 miles for November, December, January and February, respectively. Therefore, it can be said that visibility in these months follows a very similar pattern on the average. Most of the values that are different than the mean occurs in January 20, where the visibility drops to levels under 1 mile at late hours of January 19 and keeps its low value until the afternoon of January 20. This long low visibility period decreases the overall visibility average for January 20. In February low visibility periods are observed for four days. However if the scale of the y-axis in the plot is considered, those low visibility values are “relatively” low compared to February average, but not low compared to other months. Visibility values for February do not deviate from the monthly average by more than 0.1 miles, thus it can be concluded that February is an average month in terms of visibility. It should also be noted that December 29 data is missing in the data set.

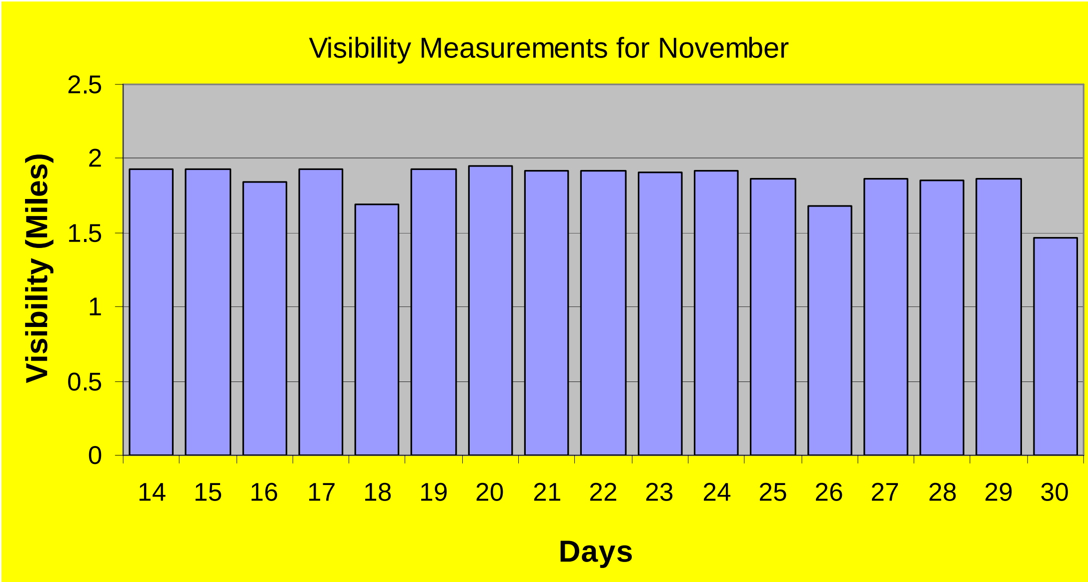

Figure 14. Visibility in miles for November

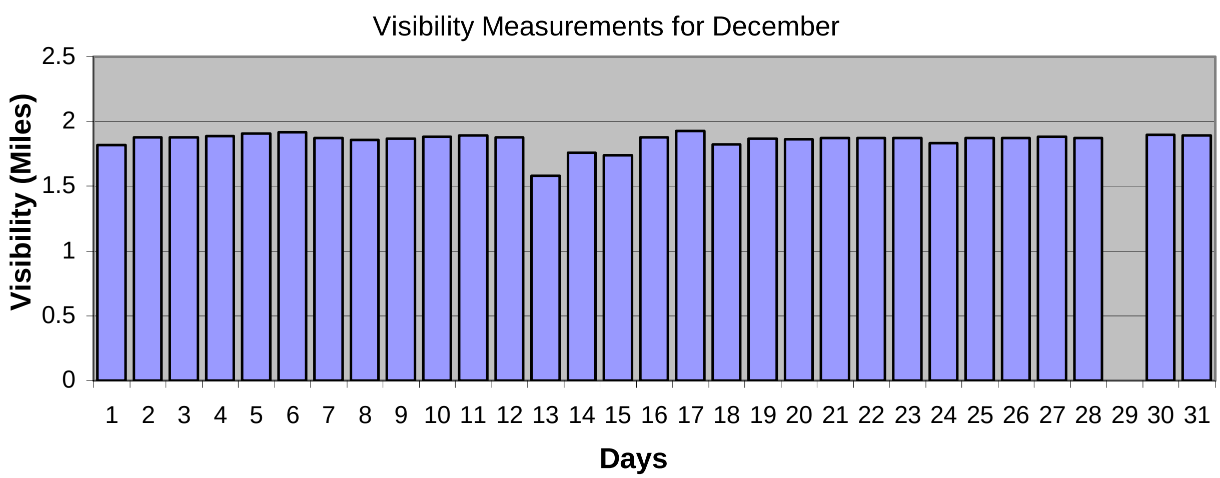

Figure 15. Visibility in miles for December

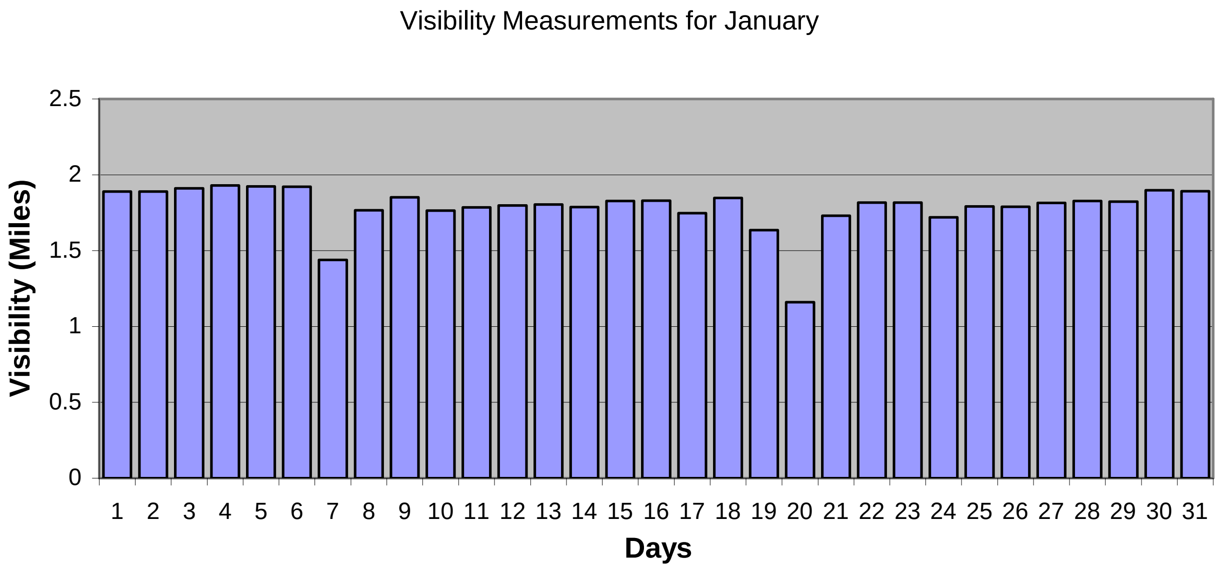

Figure 16. Visibility in miles for January

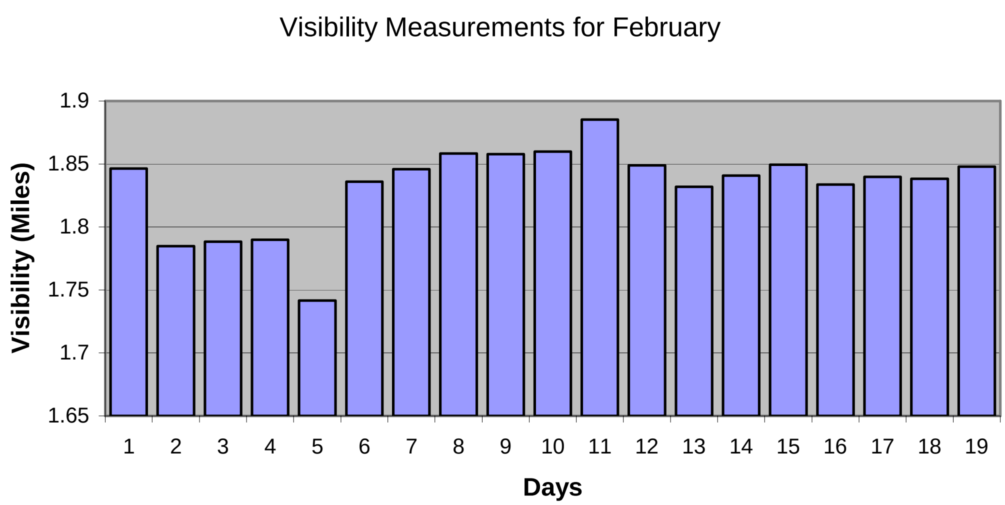

Figure 17. Visibility in miles for February

Traffic Data

The following data fields are available.

- Average speed –km/hr
- Average headway (secs)
- Volume (vphpl)
- Occupancy (percent)

Figure 18 - Figure 21 show the average speed measurements for November 01-February 2002 period. Table 12 shows the data statistics for average speed. Figure 22 shows the comparison of average monthly speeds. Figure 23 shows volume data for January 2002. Figure 24 shows occupancy data for several days in January 2002.

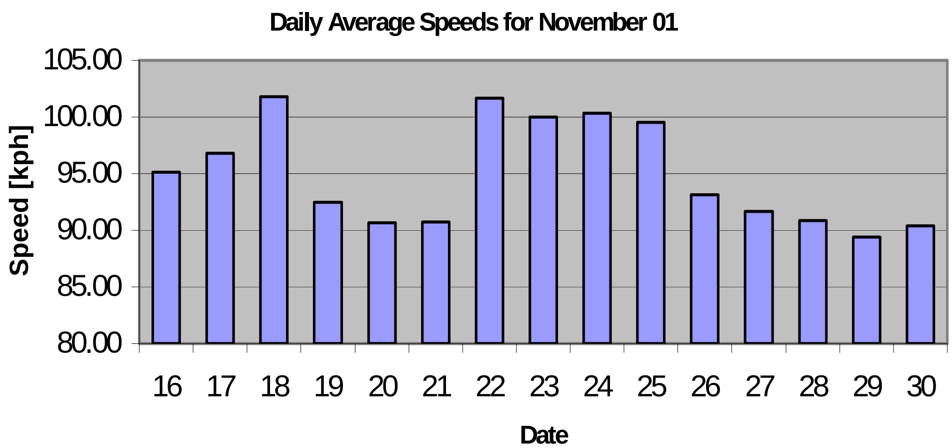

Figure 18. Average speed for November 2001

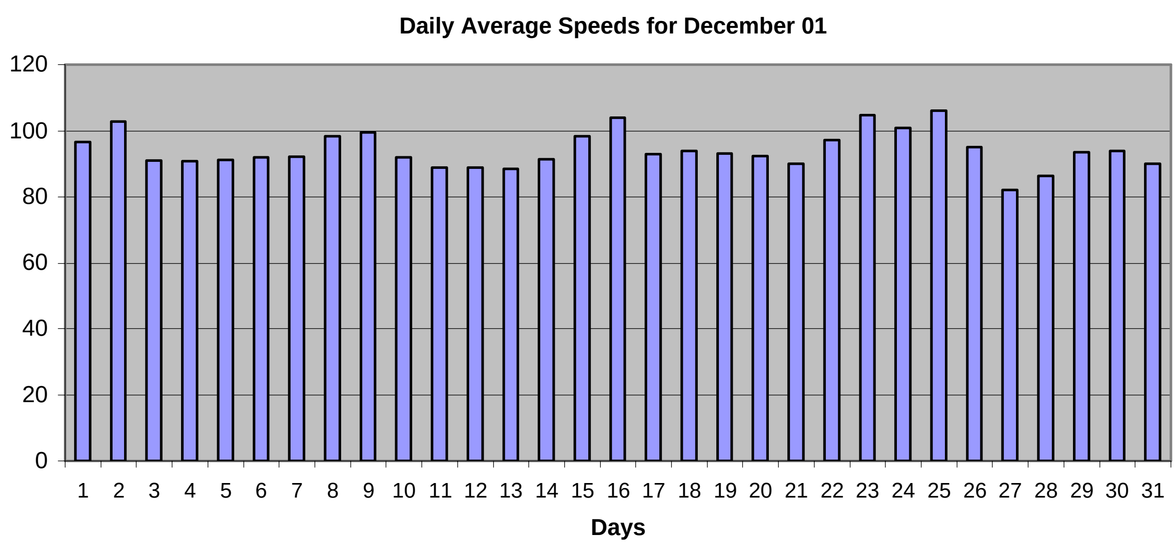

Figure 19. Average speed for December 2001

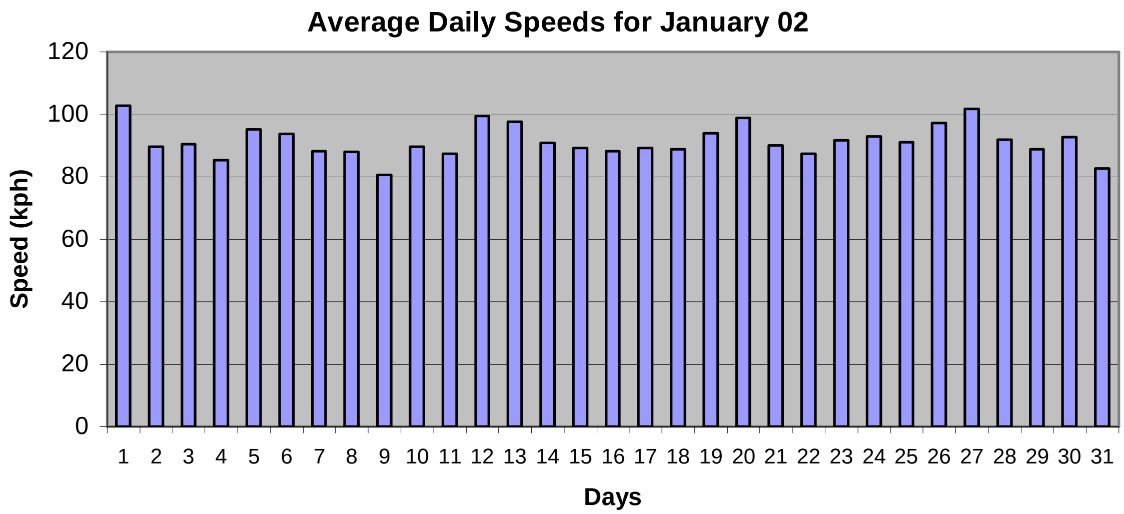

Figure 20. Average speed for January 2002.

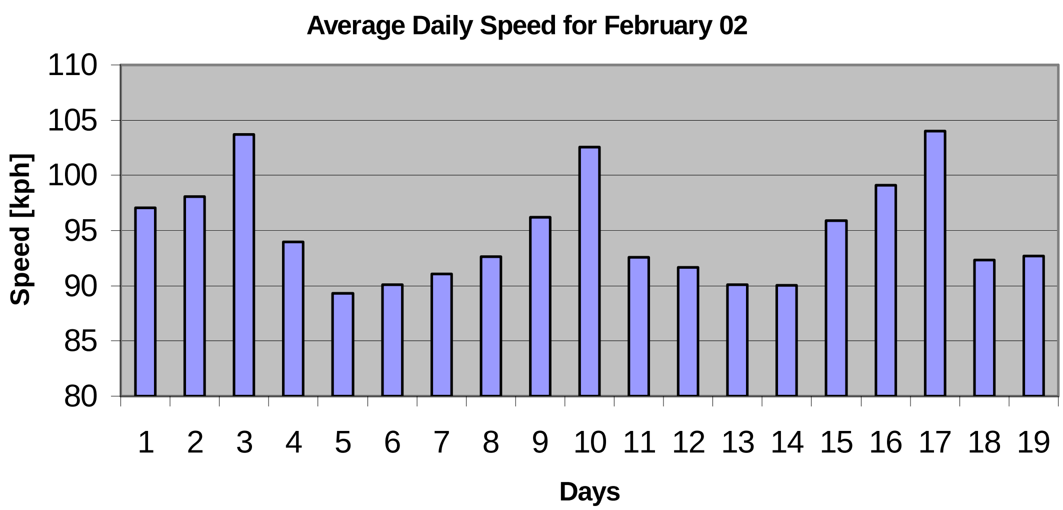

Figure 21. Average speed for February 2002.

Table 12. Average speed (kph) data statistics

	Average	Maximum	Minimum
November 2001	94	144	9
December 2001	92	144	3
January 2002	88	144	8
February 2002	93	144	12

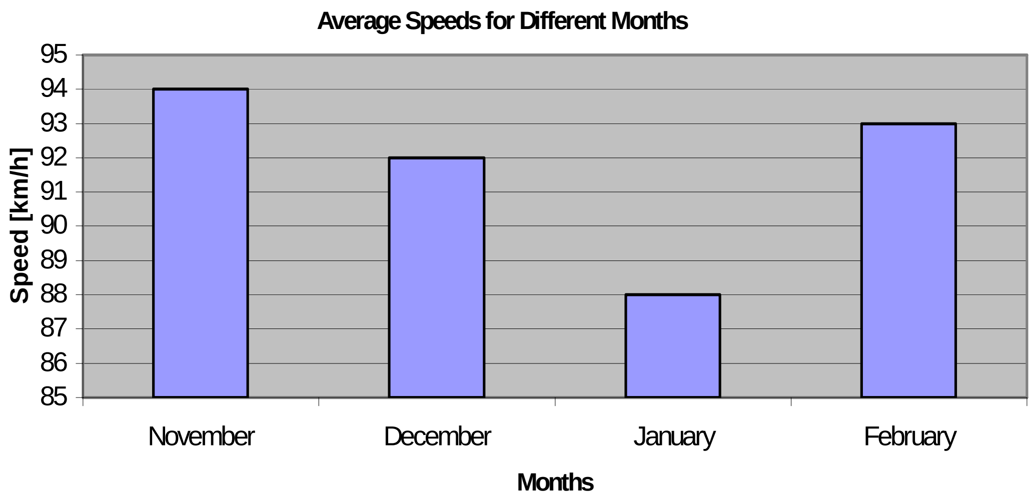

Figure 22. Average speed data for different months (kph)

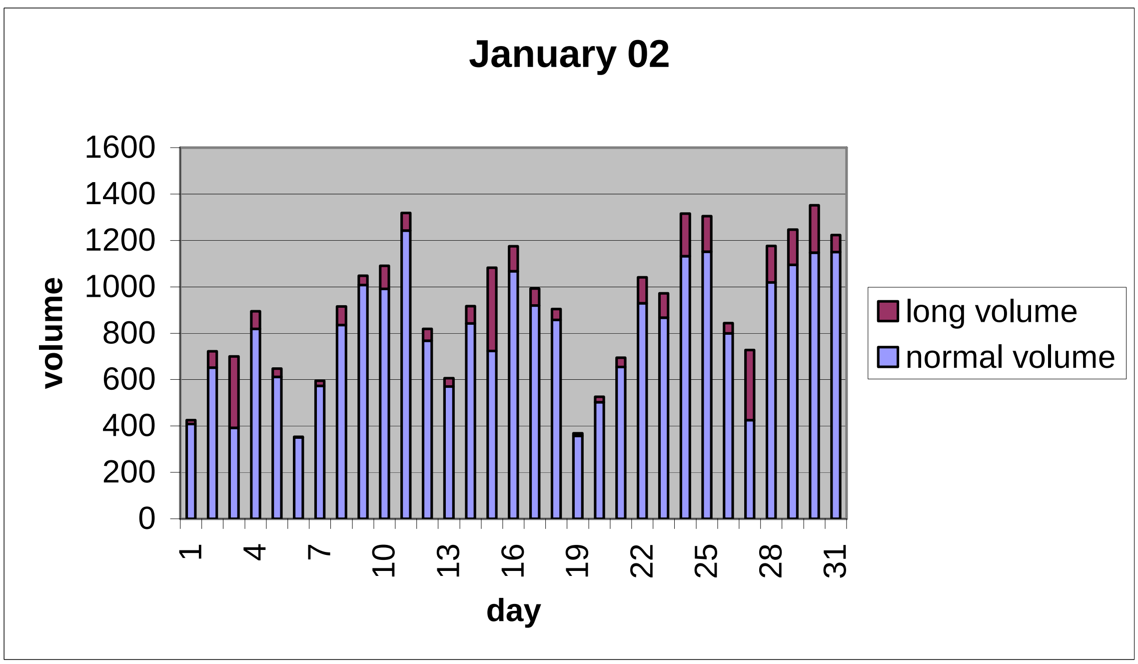

Figure 23. Volume for January 2002 (vphpl)

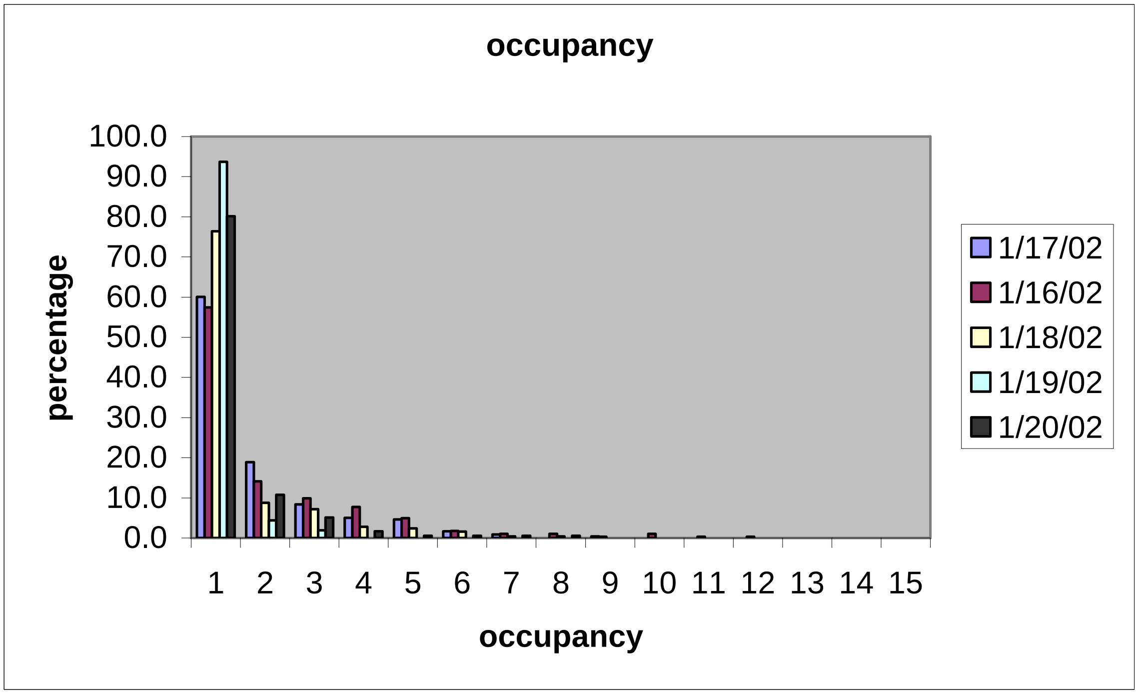

Figure 24. Percent occupancy for January 2002

The RTMS detector deployed as the traffic data collection sensor was carefully calibrated during the half day field training held by SSI in conjunction with the manufacturer of RTMS sensor namely, EIS of Canada. During the field calibration, the sensor was validated to collect reliable flow and speed data that is consistent with field measurements. The traffic data collected subsequently and presented above is also consistent with the expected traffic flow characteristics observed in the area. The speed data is found to be between 55 mph and 65 mph. The reason for speeds that are lower than 55 mph can be the existence of congestion and relatively higher percentage of truck volume. Higher average speeds are observed during the weekend days where traffic volumes are lower. This finding is consistent with well-known speed and volume relationship. Average occupancies are also found to be within the reasonable ranges of average values observed in the field. In general, occupancies are expected within the range of 1% to less than 10%. The occupancy data shown in Figure 24 depicts this expected trend. On the other hand, the frequency of higher occupancy percentages is remarkably very low, as expected. This descriptive analysis of the data obtained from the deployed sensors presented in the evaluation section supports the hypothesis that the system provides reliable and accurate data.

Accident Data

Table 13 shows the accident statistics reported in the NJDOT accident database as due to foggy weather. Since the accidents are rare events, it is hard to find statistically significant relationship between accidents and weather characteristics for a period of four months. However, as the table below shows, more accidents are reported when visibility is low than it is high. For November 2001, the maximum number of accidents coincides with the minimum visibility time period of the month. Likewise, for December, a similar occurrence is observed. (see Figure 15).

Table 13 Accident statistics due to foggy weather

Month	Day	Number of Accidents due to foggy weather	% Visibility Compared to max. of the month
November 2001	19	1	99%
	24	2	98%
	26	6	86%
	29	4	96%
	30	12 *	75% **
December 2001	7	1	97%
	9	1	97%
	13	4	82% **
	14	6 *	91%
January 2002	24	2	94%
February 2002	21	2	Not Available

* Maximum of the month, ** Minimum of the month

Overall statistics for accidents due to fog shows a declining trend for years 1999-2002 (see Figure 25). By 2002 the number of accidents drops to almost one third of the 1999.

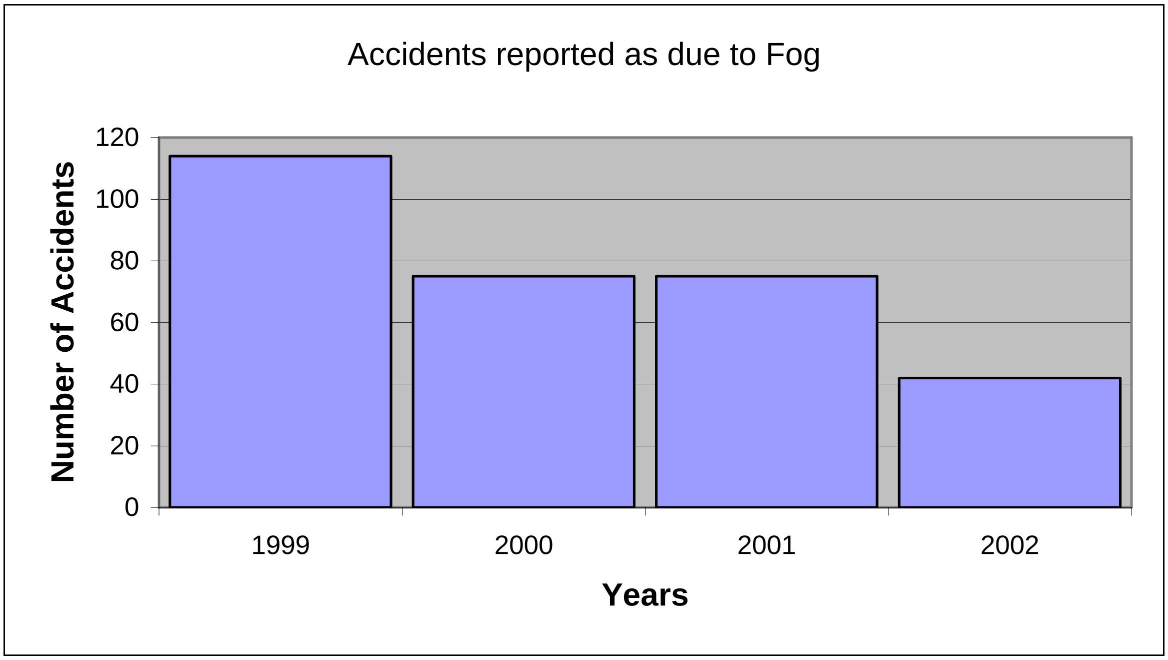

Figure 25 Accidents happened due to fog

CONCLUSIONS AND LESSONS LEARNED

Due to a departmental decision, NJDOT decided not to use the weather system deployed on the Wanaque Bridge to disseminate real-time data to the drivers via VMS. Instead, the system is currently used to collect and archive weather and traffic data from the sensors. The computer that collects this data resides at the NJDOT headquarters at Trenton.

SSI conducted the training of the system (half a day) and the software and field training of the RTMS sensor (1 day). Operations North personnel and two Rutgers researchers / students attended the software training. Only one Rutgers researcher attended the RTMS training. During the system training, SSI demonstrated the full functionality of the installed system. The details of these sessions are shown in Appendix A.

After the system has become fully functional, Rutgers did not have access to the database of the system for the evaluation purposes because only computers that are on the NJDOT backbone could get on-line access to the NJDOT server. SSI contacted the NJDOT Information Technology department to allow Rutgers to access the system on-line but this was not possible given the current set-up of the NJDOT firewall. Subsequently, three months of historical sensor data was extracted and sent to Rutgers Team in the form of an excel file which was summarized and analyzed in the previous section.

Before describing the lessons learned as a result of this project, it is important to mention findings of several studies that dealt with long-term issues that could not be dealt in this project mainly due to the limited length of the study period after the deployment of the project. A study by Virginia Transportation Research Council (VTRC) [(16)] identifies maintenance and repair as important activities to ensure accuracy and reliability of the data received from RWIS. The VTRC study recommends the use of well-established procedures and performance measures for maintenance and repair of the RWIS. It identifies various reliability and accuracy problems related to malfunctioning of the sensors. This finding is definitely applicable to the system deployed in this study and it emphasizes the need for having clear and enforceable preventive maintenance and repair procedures and performance measures.

Lessons Learned

Several problems were encountered after the installation of the system before it became fully functional. These are briefly listed below and they can be clearly used as valuable lessons learnt information for this study:

1. Power source on the bridge took considerable time to become functional and the same was true for the phone line. This experience shows that deployment of any ITS equipment can be delayed due to the delay in obtaining power and communication lines. Thus, this fact has to be taken into account when deployment schedules are developed.
2. Cost concerns about long distance phone calls created the need for an alternative communication solution such as, the possible use of Lantronix technology or a CDPD modem. Final communication solution that was adopted was the use of a CDPD modem mainly due to its low maintenance monthly cost, ability of unlimited

data transfer, and the availability of the CDPD service at the project site. It is thus important to understand the long-term communication costs of any ITS technology beyond the initial costs for acquisition, deployment, and training. However, it is also important to be able to adapt to the changes in technology during the course of the project. The decision for using CDPD modem and service instead of regular telephone saved the project considerable amount of money. More importantly, it made it possible for the DOT to have a continuous communication link to the sensors.

3. The server at NJDOT headquarters that would run SCANWEB server had to be upgraded and installed at Trenton based on the understanding that the RPU at Wanaque Bridge is going to be connected to this server. Moreover, through the use of a WEB Browser, the people at Operations North were able to log on to this server at Trenton. The advances in software and communication technology made it possible to have a central server at the NJDOT headquarters and still allow the remote users who are on the NJDOT backbone to use the system from their computers. This enabled the project team to reduce costs by obviating the need for having a separate server at Operations North. However, prospective users who are not on the NJDOT backbone i.e. who are outside the NJDOT firewall will not able to access the system. This of course limited wider use of the system data for research and other purposes.
4. The availability of Variable Message Signs, the details of communication between the system and the involved personnel, and the long-term maintenance of the deployed system were some of the major issues that emerged after the deployment of this system. Due to these issues, real-time advisory aspect of the original system was not implemented.

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APPENDIX A: RTMS TRAINING FOR INSTALLATION AND FIELD MAINTENANCE COURSE OUTLINE

Scope

The main purpose of this course is to train electronic technician personnel in the installation, setup, use and maintenance of the RTMS Remote Traffic Microwave Sensor. The course will last one day and includes formal classroom presentation and on-site training.

Pre-Requisites

Training participants should have the following pre-requisites:

Familiarity with traffic control

Knowledge of computer software

Will be actual person(s) tasked with installation and setup of RTMS product

Fluent in English

Access to a laptop computer

Course Structure

Classroom Training	Period
a. Overview of the RTMS sensor	30 min.
b. Principles of operation and performance specifications	30 min.
c. Installation procedure and configurations	30 min.
d. Setup and verification procedures	30 min.
e. Maintenance and trouble shooting	15 min.
f. Hands-on practice of the setup procedure	30 min.

On Site Field Training

The on-site field training is to be done at one of the sites, which has been specified for detection by the RTMS (unless another site is more appropriate). An RTMS unit is to be pre-mounted so that “hands on” instruction can begin.

Training will be done in small groups so that maximum exposure is supplied to the persons who will actually provide the setup and calibration of the RTMS units.

3 people maximum 3 hours

Required Equipment

For the class training:

- Classroom / boardroom
- Power Point projector or access to 20” monitor
- Whiteboard and markers
- for part (f), several PC computers of any kind, desktop, laptop etc. are required for the field people who will actually set up the equipment. Preferably one per trainee.

For the field training:

- a bucket truck,
- banding equipment and
- 12-24 VAC/DC power.

Written Material and Video

EIS will supply a User Manual, tips for setup procedures and trouble shooting. An introduction and training video will also be supplied if one has not already been given.