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South Jersey Real-Time Motorist Information System

FINAL REPORT

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Submitted by

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16. Abstract

In this project, NJDOT is interested in reducing traffic congestion in the Camden, NJ area, which is mainly caused by the traffic to Philadelphia during morning peak hours. For this purpose 5 traffic sensors are installed on Hwy 42, I-76 and I-676 on the north bound direction to monitor traffic volume, occupancy, and speed. Based on the data gathered from these 5 sensors, traffic congestion is detected and target drivers are informed about the congestion by pagers. The southern NJ highway network is modeled in Paramics microscopic simulation software. The simulation model is used to evaluate various configurations of sensor locations in accuracy of congestion detection.

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EXECUTIVE SUMMARY

Intelligent Transportation Systems (ITS) aim at reducing travel time by controlling the existing transportation infrastructure through use of state-of-the-art technology. One of the current emphasis areas in ITS is improved coordination of existing, as well as future infrastructure to improve the safety and reliability of surface transportation systems and to be able to restore the transportation system to normalcy in case of a disaster. Many ITS technologies, such as smart card technology, Global Positioning System (GPS) on cargo trucks, weigh stations, E-Z pass technology, traffic sensors, and wireless communication, which are aimed to increase the efficiency of the transportation services can now be used to ensure the security of the surface transportation system in the event of unexpected emergencies.

One of the similar efforts launched in New Jersey, by the New Jersey Department of Transportation (NJDOT) is the project entitled "South Jersey Real-Time Motorist Information System" aimed at rapid deployment of available ITS surveillance and communication technologies to monitor traffic on the basis of need at different locations in the South Jersey network. The proposed system is a highly mobile traffic surveillance system that is made of mobile self-sufficient systems called Sensor Processor and Communication Units (SPCU) and accompanying communication and data collection capabilities for sensor unit to exchange information with the traffic control center.

In this specific version of the system, congestion alerts are disseminated to selected motorists through pagers. In this proposed system, the basic novelty is to have portable sensor units that can be installed easily at any location on the transportation network without any delays for establishing power and communication connections to the infrastructure. This rapid deployment capability of the system is in accordance with the new efforts to develop easy to deploy traffic surveillance systems to better manage the transportation system during any type of disaster situation.

This system was first tested in a highly congested portion of the South Jersey highway network on highways I-76 and I-676 in New Jersey that lead to two major area bridges- the Walt Whitman and the Ben Franklin, which connect the cities of Camden and Philadelphia. In this paper, we present the technical overview and the advantages of this system, and its evaluation procedure as performed by the Rutgers researchers. We also present the problems faced during the implementation of such a prototype system, and finally list the lessons learned, along with future plans for deployment.

OBJECTIVES

Intelligent Transportation Systems (ITS) aims to reduce congestion by controlling the existing transportation infrastructure with state-of-the-art technology. One of its current areas of emphasis is to improve the safety and reliability of surface transportation system, especially in case of a disaster. Many ITS technologies, such as smart-card technology, the Global Positioning System (GPS) on cargo trucks, weigh stations, E-Z pass technology, traffic sensors, and wireless communication, which are used to increase the efficiency of the transportation services, can now be used to ensure the security of the surface transportation system in unexpected emergencies.

In response to this increased awareness of the need for better and more innovative surveillance systems, on June 13, 2002, USDOT issued a request for a model to augment the existing surveillance and monitoring system, thus increasing the security of surface transportation. In fact, this request issued emphasizes the need for more widespread and efficient use of "information-technology" solutions to improve surface transportation system security and reliability in specific situations and scenarios (ITS America Web Site).

Similarly, NJDOT launched a project entitled "South Jersey Real-Time Motorist Information System," the purpose of which was rapid deployment of available ITS surveillance and communication technologies to monitor traffic on a demand-by-demand basis at different locations in the South Jersey network. From historical observations, it is well known that southern New Jersey highways have already reached high traffic congestion levels because of the demand between Camden County and the Philadelphia business district.

The main objective of this project was to develop an easy-to-use traffic surveillance system and a real time motorist information system, as well as to test this system on highways I-76 and I-676 in NJ, which lead to 2 bridges—the Walt Whitman and the Ben

Franklin, which, in turn, connect the cities of Camden and Philadelphia. The parties involved with this project are:

- New Jersey Department of Transportation Bureau of Transportation Technology
- NJDOT, Traffic Operations – South Jersey Division
- Rutgers University, NJ
- New Jersey Institute of Technology
- L-3 Communications Inc.
- Cross County Connection Transportation Management Agency (CCCTMA)

Any type of major natural or man-made disaster necessitates rapid-response measures for effective management of the transportation network. The key for effective traffic management in such a scenario is real-time surveillance that will allow the traffic operation center (TOC) to understand the situation not only at the disaster location, but also in the whole network to evacuate people from the disaster area. For example, in the event of a hurricane, when a day or 2 is needed to evacuate the people, a real-time surveillance system can be used along the evacuation routes a short time after the evacuation decision becomes imminent.

Unfortunately, the deployment of existing surveillance systems with state-of-the-art technology takes an unacceptably long time because of the time required to provide power and communication for completely operational sensors. Moreover, the design and implementation of a central data gathering and processing system that can communicate with the sensors is a time consuming task not recommended for such time-dependent emergencies. Thus, a traffic surveillance system that can be deployed in less than a few hours is important for acquiring real-time surveillance at the key routes of the network.

The proposed system in this project is a highly mobile traffic surveillance system made of mobile self-sufficient systems called Sensor Processor and Communication Unit (SPCU) and accompanying communication and data collection capabilities for sensor units to exchange information with the traffic control center. The novelty of this proposed system is to have portable sensor units that can be installed easily at any location on the transportation network without any delays in establishing power and communication connections to the infrastructure.

In this specific demonstration project, the following steps were taken prior to deploying the proposed system:

- **Determination of the sensor locations in the test network**: Real-time and effective traffic advisory is only possible if the travel conditions over the test network are detected in a timely manner. This, in turn, depends on the effectiveness of the surveillance system. A careful selection of the sensor locations is very important for the accurate representation of travel conditions along the test network.
- **Development of an integrated traffic surveillance and communication Architecture**: A traffic surveillance and communication architecture that will ensure real-time traffic data acquisition, including traffic volumes, speed, and occupancy, was developed.
- **Development of real-time algorithms for estimating congestion levels**: The real-time data collected by the activated system were used to generate simple, yet useful, information to be sent to motorists traveling on this test network.
- **Dissemination of the motorist advisory information**: This can be accomplished using different information-dissemination techniques including cellular phones, pagers, a web page for pre-trip information, highway advisory radio, and variable message sign (VMS) for en-route information. In this specific version of the system, congestion alerts are disseminated to selected motorists via pagers. Pagers, being considerably inexpensive and commonly used when this idea was contemplated, proved that the necessary information could be disseminated successfully.

The following task was performed after the system had been deployed:

- **Evaluation of the effectiveness and feasibility of the system.** This task focuses on developing experiments, commuter surveys, and simulation analyses to measure the accuracy of the surveillance system and the congestion information.
  Table 1 shows the sections in this report where the above listed tasks are addressed.

Table 1. Section Numbers of the Project Tasks

Task Number	Task Description	Status
1.	Design a Surveillance / Communication System for Acquiring / Processing Real-Time Traffic-Congestion Information	SYSTEM DESCRIPTION and TECHNICAL OVERVIEW section Detailed in formation is given in L-3 Report [20]
2.	Deploy the Designed Surveillance / Communication System for Acquiring / Processing Real-Time Traffic-Congestion Information	WIRELESS TRAFFIC SENSOR EQUIPMENT section in L-3 Report [20]
3.	Development of Real-Time Traveler-Information Generation Algorithms	METHODOLOGY SECTION in NJIT Report [21]
4.	Dissemination of Traveler Information	THEORY OF OPERATION section in L-3 Report Report[20]
5.	Evaluate Effectiveness and Feasibility of the Deployed System and the Traveler Information	EVALUATION PLAN, SIMULATION ANALYSIS sections and Appendix B

In SYSTEM DESCRIPTION and TECHNICAL OVERVIEW section the various technical aspects of the proposed system are described. EVALUATION PLAN section outlines the system evaluation work conducted by the Rutgers University Team. Finally, CONCLUSIONS AND FUTURE WORK section discusses the future work and lessons learned.

SYSTEM DESCRIPTION and TECHNICAL OVERVIEW

Technical Overview

In anticipation of the need for the system described above, NJDOT, in cooperation with Rutgers University and L-3 communications Inc., has built a prototype system (Figure 1). The system has 3 principal components:

- Traffic Sensors
- Sensor Processor and Communications Unit (SPCU)
- Central Monitoring and Reporting Station (CMRS)

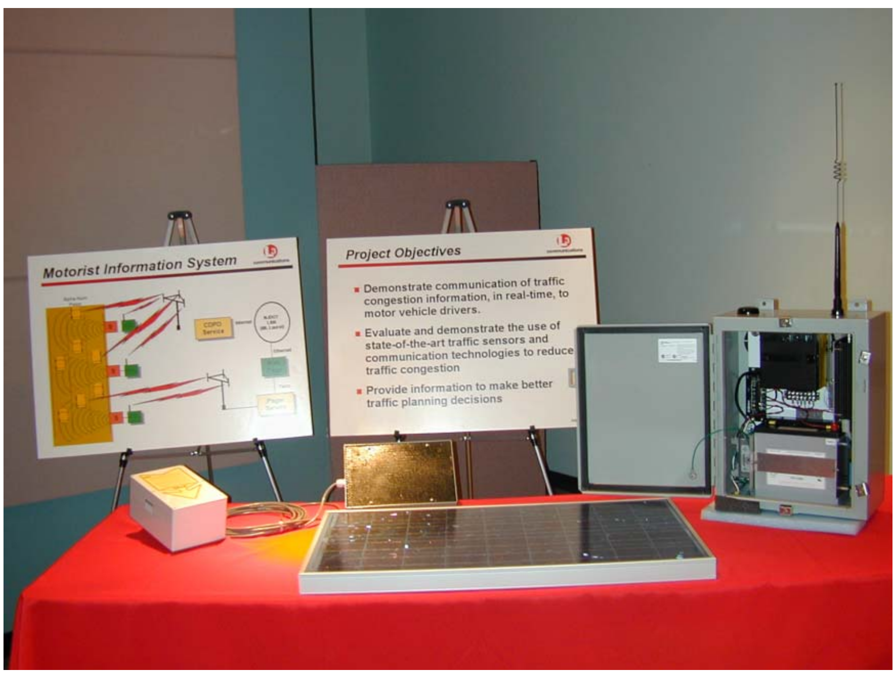

Figure 1. Prototype Sensor Processor and Communication Unit (SPCU)

Figure 2 is a picture of the existing system components, as well as the operation of its components. Roadside traffic sensors can view multiple lanes of traffic from an elevated mounting location at roadside and read traffic parameters, such as traffic volume, occupancy, and speed. Two types of traffic sensors are used in the system: remote traffic microwave sensors (RTMS) and acoustic sensors. Both types of traffic sensors can observe the traffic speed, occupancy, and volume.

The SPCU contains a cellular digital packet data (CDPD) modem and antenna (for wireless communication), batteries, and a solar panel for power, a Global Positioning System (GPS) for determining its current position, and a computer processor for on-site data processing and decision-making.

Each sensor connects to the SPCU via cable. The SPCU and the sensor are mounted on the same structure. The connection from the internal modem to any cellular-phone tower is established by a wireless connection using a cellular-phone antenna. The SPCU is capable of receiving configuration data and commands using the same wireless channel.

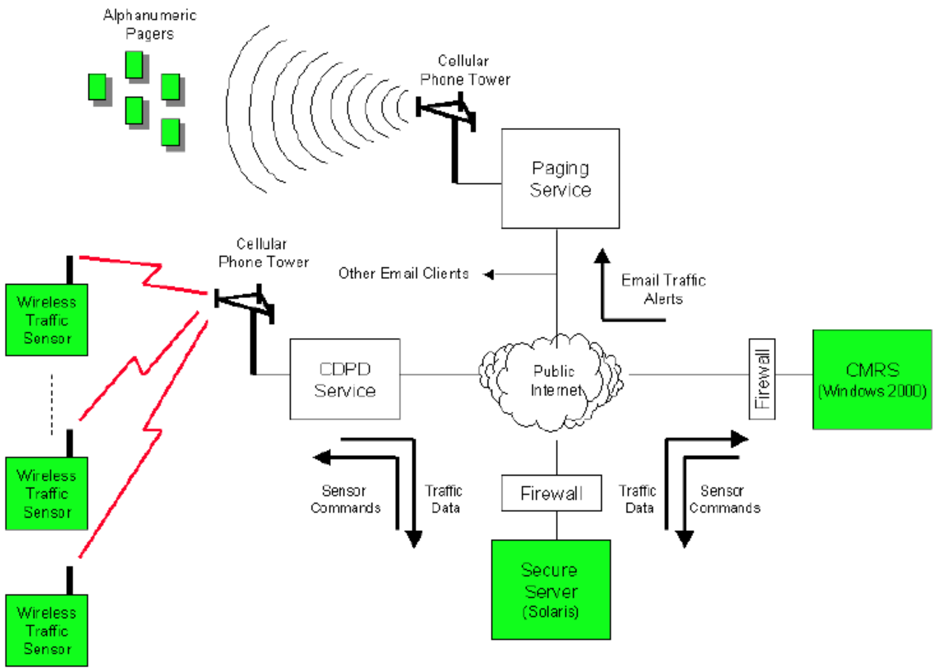

Figure 2. System Overview [20]

At the TOC, traffic sensor data received via the Internet access point is routed to a CMRS. It is a Pentium-class desktop PC running Microsoft Windows™ and a suitable web browser. As part of the current prototype system, a website developed by L-3 Communications Inc. collects, logs, and processes the incoming data and generates messages to be disseminated to motorists via pagers whenever traffic conditions change (See Detection of Congestion & Dissemination of Information by Pagers The website also provides access for the system administrator to configure and troubleshoot the system. Configuration includes functions such as adding or deleting traffic sensor stations, setting parameters remotely at the sensor stations, viewing a table of sensors and GPS locations, and interrogating sensors that appear to be faulty.

Figure 3 is a picture of a SPCU unit and a traffic sensor mounted on a pole on I-76.

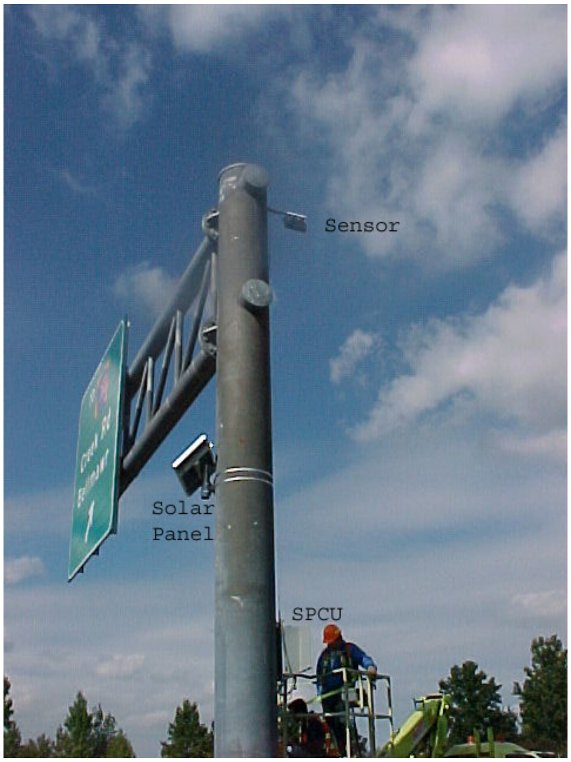

Figure 3. Surveillance System Picture

The existence of a central monitoring and reporting station enables the TOC to locate traffic sensors at any location in the network where traffic surveillance is required and to collect, log, and process data, as well as to disseminate traffic information without any time-consuming processes. This type of system architecture is well fit for highway-traffic safety and security, according to which rapid response measures need to be taken.

System Overview

Originally, 6 SPCU were installed in the system. However, 1 unit was damaged because of an accident after its installation, so currently, only 5 SPCUs exist in the network. Three of the sensors are *acoustic* and 2 are *radar* sensors. Figure 4 demonstrates the current locations of the sensors on the South Jersey highway network. The selection of these specific locations is based on the experience of the agencies involved in the project.

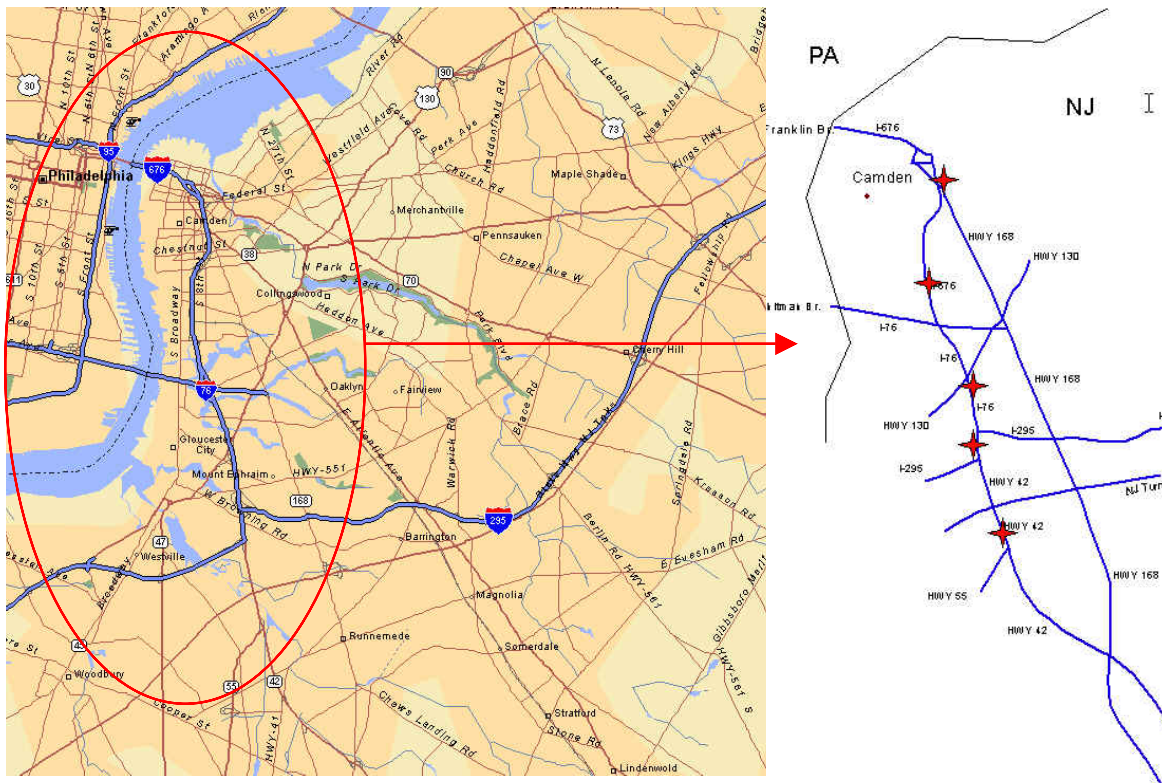

Figure 4. Current Sensor Locations

As seen in Figure 4, all 5 sensors are installed on I-76 and I-676, which lead to the Walt Whitman Bridge and the Ben Franklin Bridge, respectively. Because the project only deals with the peak morning traffic, the sensors are installed in the northbound direction. The exact sensor locations are:

Sensor 1. Route. 42 and Hwy 55 (Acoustic)

Sensor 2. I-76 and I-295 (Radar)

Sensor 3. I-76 and Hwy 130 (Acoustic)

Sensor 4. I-676 and Morgan Blvd. Exit (Radar)

Sensor 5. I-676 and Mickle Blvd. Exit (Acoustic)

Power Management

Traffic sensors can be scheduled to collect data at any time period with any desired frequency. These options can easily be changed from the CMRS configuration menu. Previously, the data-collection frequency was 30 seconds at every 5-minute and 10-minute interval for peak and off-peak periods, respectively. However, because of a power shortage in sensor operations, the frequency of data collection is set to a 30-second frequency at every 10-minute interval during rush hour and at every 30-minute interval during other times in this project.

An inevitable trade off exists between the accuracy of traffic information and the power consumption in traffic data collection. The total power used by the SPCU varies with the traffic-sampling rate. As samples are taken more frequently, power use increases. As stated previously, the SPCU is powered by a solar panel. The power used cannot exceed the average power provided by the solar panels; otherwise, the lead acid battery inside the SPCU will discharge, and the unit will stop working. A 50-W solar panel, used for this demonstration project, produces 7 Amp-hours to 9 Amp-hours per day of electric power. The lower and upper range corresponds to winter and summer operation, respectively. Table 2 lists typical SPCU power consumption for 2 different traffic sampling schedules and 2 different peak operating durations (L-3 Communications System, 2002). According to Table 2 a single 50-W panel cannot support a 5-minute peak and 15-minute off-peak data-collection frequency in wintertime. The demonstration project started in the beginning of Summer 2001; this explains why the data collection frequency had to be altered to a 10-minute peak and 30-minute off-peak frequency after Fall 2001.

Table 2. SPCU Power Consumption

Peak Sampling Interval (minutes)	Off-Peak Sampling Interval (minutes)	Peak Operating Hours/ Day	Radar Power (Amps-hr)	Acoustic Power (Amps-hr)
5	15	6	5.28	7.68
5	15	12	6.88	8.88
10	30	6	2.88	5.88
10	30	12	3.68	6.48

It is well known that higher frequencies of data collection will result in quicker detection of congestion. Possible remedies for the limitations of solar-power operations, without changing the data-collection frequency, are using bigger size solar panels or multiple solar panels in parallel.

Detection of Congestion & Dissemination of Information by Pagers

The sensors report actual vehicle speeds and traffic volume by lane. When any sensor reports a change in speed (i.e., a change in speed bin) the most recent speed sample from all sensors is reported in the pager message. Default speed-bin edges are set to Red: 0 mph to10 mph, Yellow: 10 mph to 30 mph, Green: > 30 mph. These can also be remotely changed from the CMRS configuration menu.

Hysteresis is applied to speed-bin edges to reduce nuisance reports when traffic speeds hover in the neighborhood of a bin edge. This prevents sending multiple pager messages to motorists. When the measured speed crosses a bin edge in the negative direction, that bin edge and all higher bin edges are increased by the hysteresis value. When the traffic speed crosses a bin edge in the positive direction, that speed bin edge and all lower bin edges are reset to the original value. The default hysteresis value is 10 mph and is remotely configurable from the CMRS. (For example, the following occurs when hysteresis = 10 mph. When speed changes from 45 mph to 5 mph, new bin edges are 40 [30 + 10] and 20 [10 + 10] for green and yellow boundaries. When traffic reaches

21 mph to 40 mph, the yellow bin edge is reset to 10 mph; when traffic exceeds 40 mph, the green bin edge is reset to 30 mph.)[1]

Whenever any of the sensors detect a change in the traffic-speed bin, an alert is sent to all pagers, listing the sensor location, color condition, and average speed, in parentheses, at each of the 5 locations. A typical pager message would appear as follows:

NJDOT TRAFFIC ALERT: 42N & 55 YELLOW (29**)---
42N & 295 GREEN (53) ---
42N & 130 GREEN (46) ---
676N & Morgan GREEN (59) ---

Figure 5. Motorist Pager Alert Message[2]

Because this was a demonstration project, the parties involved wanted to make sure that the information could be successfully delivered to the selected motorists. As mentioned earlier, the pagers were favored because they were inexpensive and widely used at the time this project was initiated. The information may also be transmitted to cellular phones, VMS signs with wireless access, and a web page designed for motorists.

EVALUATION PLAN

A system that is up-and-running must be used, and provision of reliable and useful information for motorists must be maintained. Accuracy and reliability of the system and the compliance of motorists are conditional in this type of systems. As soon as the motorists realize that the congestion information received is not valid, they start to lose their confidence in the system and disregard the information. This fact may result in total

[1] It takes only 5 seconds for the SPCU to transmit data to CMRS.

[2] 42N here refers to I-76 Northbound on the highway network.

failure of the system in a disaster scenario. Thus, the system must be evaluated comprehensively to assure system reliability.

This demonstration project is identified as an ITS deployment initiative. The Federal Highway Administration identifies 6 national goals for ITS projects (http://www.fhwa.dot.gov):

1. Improve safety of the nation's surface transportation system.
2. Increase the operational efficiency and capacity of the surface transportation system.
3. Reduce environmental costs associated with traffic congestion.
4. Enhance present and future productivity.
5. Enhance personal mobility, as well as the convenience and comfort of the surface transportation system.
6. Create an environment in which the development and use of ITS can flourish.

Table 3 shows the compliance of the project with the national ITS goals:

Table 3. Relationship between ITS Goals and the Project Goals

ITS Goals / Project Goals	Improve Safety	Increase Efficiency	Reduce Environmental Costs	Enhance Productivity	Enhance Personal Mobility	Promote ITS
Improve System[3] Performance	√	√	√	√	√	√
Improve System Reliability	√					√

The project mostly involved the design, development, and use of an innovative surveillance system as described above. However, as a demonstration project, the main objective in this project is to evaluate:

- System Performance
- System Reliability

[3] System here means the portion of the network used as the deployment area.

The steps taken to ensure the system performance and reliability are:

(1) The accuracy and performance of the installed sensors were evaluated to make sure that the collected data from the sensors match the actual traffic-flow characteristics. The evaluation of the sensors with ground truth data is presented in the following subsections.

(2) The system must be able to disseminate reliable traffic information to drivers in a timely manner. Surveys were conducted to determine whether the selected motorists received accurate information (See System-Wide Performance Test 2 (SWPT-2) section). The motorists were informed about the traffic conditions only by the speed bins. However, in the future, if the proposed system is used to disseminate travel-time information, the reliability of traffic information will be directly related to the accuracy of travel-time estimation. Hence, the travel-time–estimation accuracy was evaluated using a simulation model of the southern New Jersey highway network (See System-Wide Performance Test 1 (SWPT-1) section).

The following subsections provide a brief description of each evaluation test performed. Table 4 summarizes these tests and their goals.

Table 4. Evaluation and Testing of the Project Goals and Objectives

Goal 1	Evaluate System Performance	Tests
1.	Evaluate SPCU performance by testing how often the system fails to deliver traffic information	ST-1
2.	Evaluate the accuracy of each sensor using ground truth data	ST-2
Goal 2	Evaluate System Reliability	
1.	Evaluate the accuracy range of estimated route travel time by sensor data compared to ground truth data	SWPT-1
2.	Evaluate the correctness of congestion alert sent by pagers using commuter surveys	SWPT-2

Evaluation Tests and Results—Phase 1: Sensor Testing

<u>Sensor Testing 1 (ST-1)</u>

The sensor data is tested to detect failures related to the operation of the installed sensors. It is important to make sure that all the sensors are up-and-running regularly to avoid giving invalid information. This test is designed to evaluate the System Performance goal of this project. The trouble log is recorded by L3-Communications if any failure occurs with the operation of the sensors. The summary of this log is shown in Table 5.

Table 5. NJDOT Motorist Information System Trouble Log Summary

Failure Type	Equipment	Number of Failures	Duration of Failure (days)	Total Number of Site Visits for Maintenance (days)
Sensor Data	SPCU – all units	1	Various	6
Sensor Data	SPCU-Sensor 1	2	1	1
Sensor Data	SPCU- Sensor 2	4	19	4
Sensor Data	SPCU-Sensor 5	1	35	2
Server Failure	CMRS	6	17	-
No Pager Messages	CMRS	1	31	-
Power Outage	CMRS	1	5	1
Server Transfer	CMRS	1	1	-

The majority of system failures are caused by the initial calibration errors, information dissemination failures, and server failure. However, because the involved parties had become familiar with the system and its operation, the number of such failures was gradually reduced.

<u>Sensor Testing 2</u> (ST-2)

Three different types of data are collected by the sensors, namely vehicle counts, speed, and occupancy. Examples of sensor data (Table 6) are given in the following sections. Thirty-two station-wide readings are then reported for each roadway and station as a minute count. Because it is almost impossible to collect speed and occupancy values at the site, ground truth data (i.e., videotaping) was collected to ensure that the data obtained by the sensors were within a reasonable range of accuracy. The vehicle-count data was extracted from the video using an Image Processing Unit. The statistical results of this comparison are provided in Table 6.

Table 6. Sample Data Set from the Sensors

Acoustic 001		Tractor-Trailer					Truck-Volume					Total-Volume					Total-Occupancy										Avg.
42N & 55		–Volume Lane:					Lane:					Lane:					Lane:					Speed Lane:					Speed:
Date	Time	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
10/11/01	11:45PM	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	3	0	--	--	--	32	--	32
10/11/01	11:30PM	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	0	1	2	0	--	--	39	29	--	32
10/11/01	11:15PM	0	0	0	0	0	0	0	0	0	0	0	0	2	8	0	0	0	1	5	0	--	--	47	57	--	55
10/11/01	11:00PM	0	0	0	0	0	0	0	0	0	0	0	8	10	8	0	0	4	6	4	0	--	37	54	47	--	47
10/11/01	10:45PM	0	0	0	0	0	0	0	0	0	0	0	4	6	4	0	0	2	4	2	0	--	59	50	59	--	55
10/11/01	10:30PM	0	0	0	0	0	0	0	0	0	0	0	4	2	6	0	0	2	1	4	0	--	55	39	51	--	50
10/11/01	10:16PM	0	0	0	0	0	0	0	0	0	0	4	6	6	6	0	2	4	4	5	0	17	45	57	43	--	43
10/11/01	10:00PM	0	0	0	0	0	0	0	0	0	0	0	2	6	4	0	0	1	4	2	0	--	59	46	12	--	37
10/11/01	9:45PM	0	0	0	0	0	0	0	0	0	0	0	10	4	4	0	0	5	2	2	0	--	55	52	55	--	54
10/11/01	9:30PM	0	0	0	0	0	0	0	0	0	0	0	4	4	4	0	0	2	2	2	0	--	52	58	63	--	58
10/11/01	9:15PM	0	0	0	0	0	0	0	0	0	0	0	6	6	10	0	0	3	3	5	0	--	51	39	33	--	40
10/11/01	9:00PM	0	0	0	0	0	0	0	0	0	0	0	0	6	2	0	0	0	3	1	0	--	--	33	51	--	38
10/11/01	8:45PM	0	0	0	0	0	0	0	0	0	0	0	6	6	10	2	0	3	3	6	3	--	48	47	37	55	44

Table 7 contains summary information about the vehicle-count data for each sensor. For data from each sensor with the corresponding ground truth data, we performed a paired-*t* test and formed a 95% confidence interval for the mean of differences between each data set.

Table 7. Paired-*t* Confidence Interval for Ground Truth and Sensor Data Difference

	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5
Mean of Differences	-82.38	18.17	23.8	6.07	11.2
Number of Observation Points (Every 5-minutes)	13	6	15	15	15
Standard Deviation of Difference In Vehicle Counts	40.54	109.92	85.66	25.81	32.45
t-value (confidence interval is 95%)	2.179	2.571	2.145	2.145	2.145
95% Confidence Interval for Difference of Sample Means	[-106.88, -57.89]	[-97.21, 133.54]	[-23.64, 71.24]	[-8.23. 20.36]	[-6.77. 29.17]
Zero Covered?	NO	YES	YES	YES	YES

For example, regarding sensor 4, the paired *t*-test is performed as follows:

$\bar{x} = 6.07$ (sample mean)

$S = 25.81$ (standard deviation of the sample)

$a = 0.05$

$n = 15$ (number of data points)

$$\text{Confidence Interval (CI)} = \bar{x} \pm t_{n-1,1-\alpha/2} \frac{S}{\sqrt{n}}$$

$$\text{CI for sensor } 4 = 6.07 \pm 2.145.\frac{25.81}{\sqrt{15}} = [-8.23,\ 20.36]$$

It is observed in Table 7 that with a 95% probability, that the confidence interval constructed for Sensor 1 does not cover 0, whereas the other confidence intervals formed for the rest of the sensors cover 0.

It should be mentioned that the sensors used in the system are tested many times by the manufacturers before they are advertised in the market. Therefore, 3 possible factors that led to the insufficient results of our statistical analysis can be listed: (1) *Aggregation of Sensor Data*: As mentioned before, sensors collect data for 30-second time frames and aggregate it for 1 minute at every 5 minutes.[4] On the other hand, ground truth data reflects averages of continuous traffic counts at every 5 minutes. In short, sensor data is actually a 30-second data sampling from a continuous traffic aggregated to 5-minute intervals. This fact obviously affects the results. (2) *Normality Assumption*: The confidence interval formed by the paired-*t* test is exact when the sample size approaches infinity[5]. Because few observations were made, the confidence intervals formed for each sensor could be far from the 95% confidence level[6] (3) *Ground Truth Data*: Owing to the hardships of data collection along I-76 and I-676 (i.e., limited shoulder width at sensor locations), the ground truth data is not sufficient to perform a satisfactory statistical analysis.

Evaluation Tests and Results—Phase 2: System Wide Testing

System-Wide Performance Test 1 (SWPT-1)

This test involves the evaluation of the travel-time estimation accuracy of the current system using a simulation model of the southern New Jersey highway network. Detailed information about the test is provided in Analysis part in SIMULATION ANALYSIS section.

System-Wide Performance Test 2 (SWPT-2)

To verify the validity of the information sent to the pagers, the Rutgers Team designed a survey for selected volunteer commuters and NJDOT emergency vehicle drivers. This survey was used to gather information about day-to-day experiences of users with the pagers that were programmed as part of this project. These drivers, who are familiar with the Camden Philadelphia highway network, were asked to complete a daily survey form to compare the experienced traffic conditions with the traffic conditions estimated

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[4] As mentioned earlier, the evaluation sensors were collecting data at every 5 minutes. Later, because of power limitations, a 10-minute interval was used.
[5] *T*-test uses the central-limit theorem, which states that if the sample size is sufficiently large, the averages of the samples will be approximately distributed as standard/normal.
[6] See Law and Kelton [(5)] pp. 535-536 for examples of the variation in confidence level with different sample sizes.

by the system. The participants included the South Jersey Emergency Service Patrol, Delaware Valley Regional Planning Commission (DVRPC) and CCCTMA staff. The basic idea behind the survey was to examine the information disseminated to the pagers. Basically, as they received messages on the pagers warning of congestion, the volunteer drivers would verify the current traffic condition if they were driving on the congested area under alert. They also would specify any congested conditions, including their average speeds, even if the page did not give a congestion alert. This way, the system was evaluated from the drivers' point of view. A copy of these commuter surveys is presented in Appendix A.

As observed during the project, the pagers disseminate correct congestion information when the system is up and running. However, during the majority of the survey period, the system was down because of server/surveillance problems as indicated in Table 5. Moreover, because of the initial problems with the system, during the time surveys were conducted, the survey forms were not helpful in obtaining surveyors' opinions. Later, enough survey results existed to verify the operational and content accuracy of the pagers and information. It was, thus, safely concluded that the pagers performed well as soon as the initial problems with the system were resolved.

SIMULATION ANALYSIS

Background

Real-time and effective traffic advisory is possible only if the route-travel times are accurately estimated. Accurate route-travel–time estimation depends, in turn, on the effectiveness of the surveillance system. Aside from the accuracy of the system components regarding the collection of traffic data, a careful choice of the amount of sensors and their locations is equally important for the accurate estimation of travel times.

Real-time traffic advisory systems are mostly needed during incidents. An efficient advisory system should be able to detect the incident quickly with the help of the surveillance system and disseminate reliable advisory information to travelers. Minimizing the incident-detection time is a challenge. The surveillance system can identify the effect of the incident only when the shockwave caused by the incident reaches one of the sensors. The timing of this event is clearly related to the speed of the shockwave. Therefore, the closer the sensor is to the incident, the shorter the detection time will be. However, incidents are random events, and it is impossible to predict their locations. This phenomenon is illustrated in Figure 6.

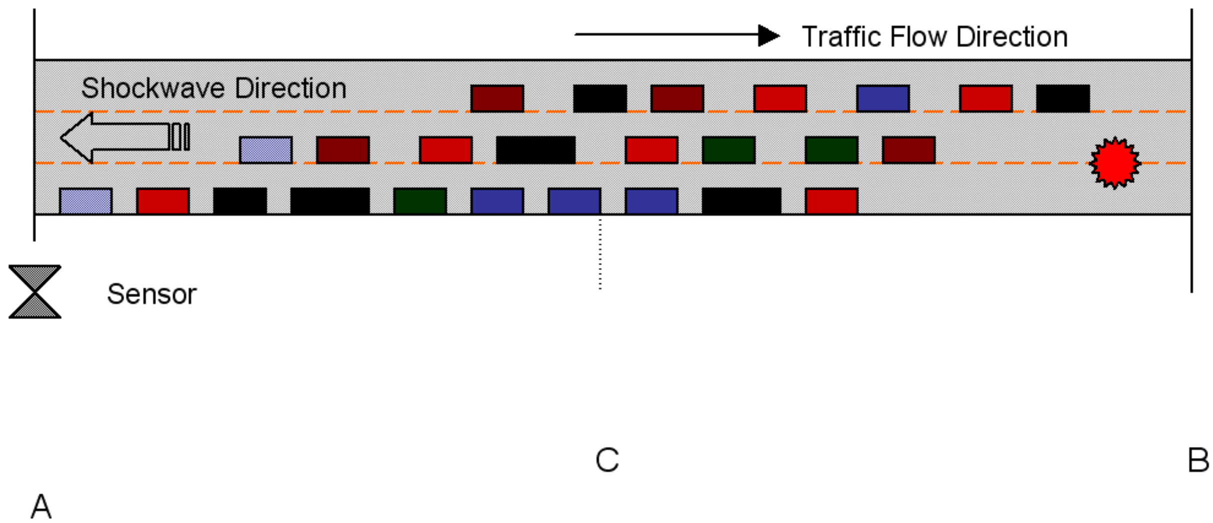

Figure 6. Incident Detection

A time lag between the time of occurrence of the incident and the time when the sensor detects the queue (caused by the incident) has to be expected. Determining the optimal configuration of sensors to minimize this time lag is the ultimate goal. In Figure 6, if consider a sensor configuration where one of the sensors is installed at point B is considered, the incident will not be detected until the queue reaches the next upstream sensor. Clearly, an additional sensor at point C would decrease this time lag.

In short, timely detection of incidents depends on several factors: (1) incident location, (2) Number of sensors, (3) location of sensors and, (4) traffic flow characteristics. In this section, the way travel time estimations are affected with the second and third factors was analyzed. This type of analysis is essential before actual implementation of the system.

To evaluate the effectiveness of each possible sensor, realistic traffic-flow characteristics must first be established. Therefore, only a microscopic traffic simulation model can capture the dynamic nature of traffic flow and demand within a certain time interval.

Network Model

The highway network model used for the simulation must closely represent the actual network characteristics, which can be grouped into 3 main categories:

- Network Components, including links, intersections, interchanges, ramps, and zones.
- Geometric aspects and limitations, including accurate representation of roadway alignment, gradient, number of lanes, lane width, speed limits, signposting distances, stop signs, visibility, 1-way roads, and right and left turn lanes.
- Origin–destination (O-D) demands, including the demand between each O-D pair for a given time period.

Comprehensive modeling of network components with accurate geometric features ensures realistic representation of traffic flow in the network. An O-D–demand matrix is used to generate traffic flows in the model network. Obtaining correct O-D–demands is also ensures valid traffic flows as a result of simulation runs. Even a minor flaw in modeling may lead to inaccurate representation of the actual network characteristics. Therefore, utmost attention should be spent to ensure the development of a valid network model.

In this report, the South Jersey highway network is modeled using PARAMICS simulation software. PARAMICS is a suite of high-performance software tools for microscopic traffic simulation. Individual vehicles are modeled in fine detail for the duration of their trip, providing accurate traffic-flow and congestion information, as well as enabling the modeling of the interface between drivers and ITS (Abdulhai et al, 1999). In addition to being an effective microscopic traffic simulator, PARAMICS has several advantages over other traffic-simulation tools:

- Excellence in modeling highly congested networks and ITS infrastructures
- Advanced vehicle-following and lane-changing simulation capability
- Capability of incorporating driver-performance and vehicle-performance measures
- Batch-mode operations for statistical studies
- Application Programming Interface (API) option, which enables users to modify the simulation routine for testing their own models.

The network used for simulation purposes is extracted from the larger network shown in Figure 7. The area under consideration is approximately 90 square miles. Only major highways and freeways are included in the model, whereas the secondary roadways are modeled as demand connectors to the major highways.

The following are the steps followed to generate the South Jersey network in PARAMICS:

- Skeleton Network Coding**:** A skeleton network defines the position of the nodes and links in the network model. First, it is ensured that the node positions match the overlay intersections. Then, simply by connecting the nodes, the skeleton network model is developed. This step also contains detailed, effort-intensive tasks to model geometric aspects of the network model, such as roadway alignment, draw curves, interchanges, on and off-ramps, and highway merges.
- Detailed Network Coding: This step involves coding the rest of the geometric aspects and limitations of the highway network, such as number of lanes, highway type, speed limit, and line width. This information can be gathered either by site

visits or by available resources. In this report, the information given in “NJDOT Straight Line Diagrams” is used.

- O-D Demands: South Jersey–Philadelphia-highway travel-demand matrices are created for different time periods of the day and the corresponding zone locations. The data for the matrices are obtained from the Delaware Valley Regional Planning Commission (DVRPC). The demand matrices are aggregated for 137 zones in the network for modeling purposes.

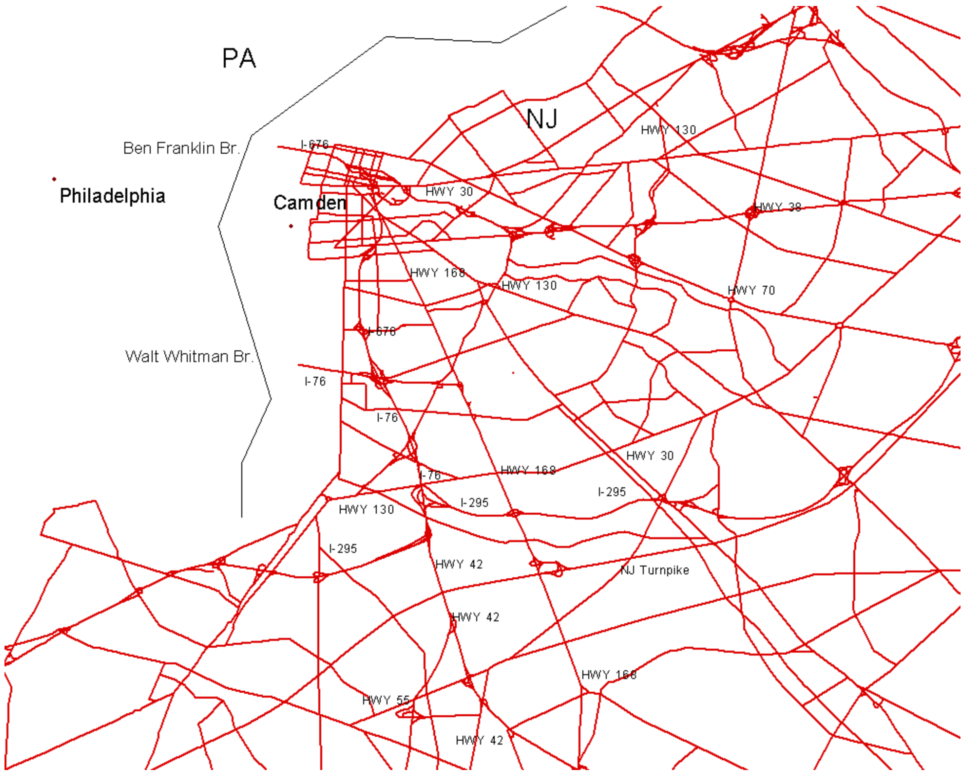

Figure 7. South Jersey Highway Network

Figure 8 shows the screenshot of the modeled highway-network model in PARAMICS. The simulation network model contains 2162 nodes, approximately 4,000 links, and 137 demand zones.

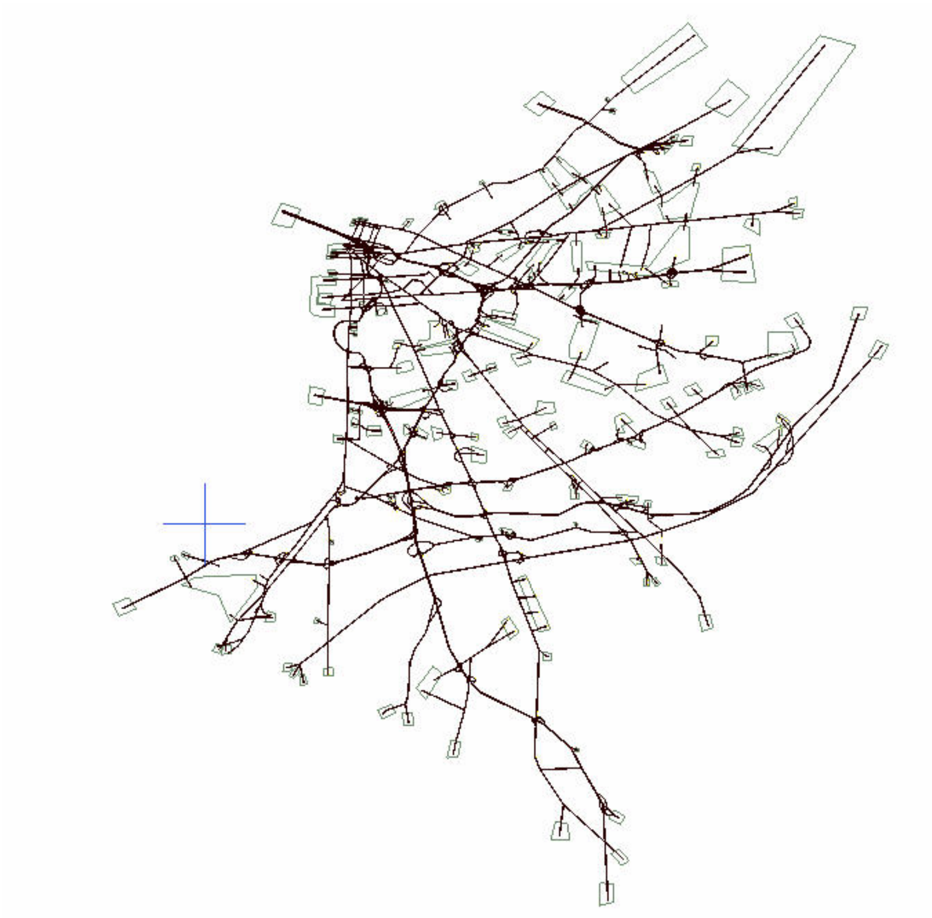

Figure 8. Highway Network modeled in PARAMICS

Model Calibration/Validation

Calibration is the modification process of initial model input parameters to attain the actual traffic characteristics in the network as represented by various network outputs. Model input parameters vary for each simulation tool but, in general, include driver characteristics, mean headway, mean reaction time, and route cost equations. Network outputs usually connote vehicle counts, mean speed, and route-travel time. A 3-level calibration/validation process is used. First, the developed network model is calibrated based on vehicle counts at 27 important locations provided by NJDOT. Second, individual vehicle runs were performed to determine total trip times along the major routes in the study area. These route-travel times were compared with those generated by the simulation. Finally, real-time traffic data, which was obtained from 5 sensors along a corridor included in the simulation network, was also used to validate the flow and travel-time estimations obtained from the simulation model. Table 8 shows the actual vehicle counts obtained from field observations, as well as counts gathered by the simulation runs at 32 locations.

Table 8. Calibration Results of the SJ Highway Network Simulation Model[7]

Location	Highway Name	Simulation Counts	Ground-Truth Data Range	
			Min	Max
1	River Rd	32.47	13.93	20.90
2	Hwy 168	16.19	23.49	35.24
3		15.24	27.27	40.90
4		44.93	34.37	51.56
5		36.42	27.81	41.72
6		39.66	34.29	51.44
7	I-295	88.89	89.33	134.0
8		88.90	86.03	129.05
9		127.9	138.50	207.75
10		131.93	156.31	234.46
11		134.56	129.06	193.59
12	Hwy 130	48.80	37.93	56.90
13		63.27	35.35	53.02
14		67.30	51.25	76.88
15	Hwy 30	82.26	75.41	113.11
16		85.44	93.06	139.59
17		49.09	13.21	19.82
18		24.32	29.17	43.76
19	Hwy 70	54.22	57.59	86.39
20		51.71	63.74	95.60
21		48.54	61.27	91.90
22		45.72	72.04	108.06
23	Hwy 38	95.36	110.10	165.14
24		51.78	61.17	91.76
25		33.62	68.42	102.63
26	Federal St	16.76	8.48	12.72
27		13.43	14.96	22.44
28	I-76	84.88	75	100
29	&	78.52	67.2	85.4
30	I-676	78.28	67.6	85.6
31		34.79	26.6	34.8
32		31.06	19.8	27.4

At each step, necessary adjustments were made to obtain flows and travel times similar to those observed from the measurements of the real system.

[7] Vehicle counts given for locations 28 through 32 are obtained from traffic sensors.

Analysis

The system evaluation procedure as explained in EVALUATION PLAN section also involves validating the accuracy of the travel-time/congestion information generated by the traffic data gathered from the sensors. Although this demonstration does not consider travel-time estimations, SWPT-1 (See System-Wide Performance Test 1 (SWPT-1) section) is needed to observe how well the sensors operate with travel-time/congestion estimation algorithms for the study network.

The various practical and methodical limitations to real-time travel-time collection include (1) the high number of data required to statistically validate the evaluation results and (2) synchronization of the collected data with the sensor data. Therefore, this evaluation process was decidedly executed using simulation. PARAMICS traffic-simulation software is used to simulate the study network. The simulation network modeled for Ozbay and Bartin[(5)] is adopted for the present analysis.

To evaluate the system using simulation, the detectors in the simulation model should give traffic data readings that are similar to the actual sensor readings. For this purpose, the simulation was run for n = 6 times to construct a 95% confidence interval for the means of the selected performance measures, namely route-travel time and average network-travel time (Note that with n = 6 replications, the mean of each performance measure is assured a 97.5% confidence interval based on *Bonferroni Inequality*. (See Law and Kelton[(6)] pp. 560 and Banks and Carson[(7)] pp. 467-468 for details).

Table 9 shows the comparison of detector speed and vehicle counts gathered by simulation and by the actual sensor readings obtained from the database. The intervals given in the table are the 95% confidence intervals for the means of each data source. The simulation readings are sufficiently similar to the actual sensor readings.[8]

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[8] Only Sensor 2 shows lower speed values; however the offset is not large enough to significantly affect the travel-time estimation.

Table 9. Confidence Interval for Sensor Data and Simulation

	Speed (Simulated)	Speed (Sensor Data)	Counts (Simulated)	Counts (Sensor Data)
Sensor 1	[44.01, 52.21]	[47.24, 50.87]	[89, 102]	[94, 108]
Sensor 2	[33.98, 45.85]	[59.48, 62.82]	[54, 97]	[66, 80]
Sensor 3	[50.71, 51.26]	[53.98, 57.12]	[76, 85]	[75, 90]
Sensor 4	[63.73,67.62]	[62.14, 67.96]	[30, 50]	[25, 33]
Sensor 5	[63.29, 65.12]	[60.44,64.86]	[14, 30]	[17, 25]

As mentioned earlier, the sensors, at the desired frequency, collect traffic data over a thirty-second observation window and aggregate it for 1 minute at every 5 minutes during peak period. The detectors in the simulation model were set at the exact locations at which they were currently used. Detectors were coded to simulate the sensors with the same frequency and type of data collection, using the API functions of PARAMICS: Every time the sensor detects a vehicle, the speed and vehicle-count data are collected for the lane in which the vehicle is traveling.

$S_{i,j,k}$: Average Speed (veh/hr)

$V_{i,j,k}$: Vehicle Count (veh/t)

where, i : detector index

j : lane index

k : time period index

t : length of time period (mins)

For the current deployment $i = 1,2,...,5$ and the desired data collection frequency is $t = 5\,\text{min}$. At the end of each time period, k, the average speed of the detector i, $\overline{S}_{i,k}$, is the weighted average of the average speeds at each lane:

$$\overline{S}_{i,k} = \frac{\left(\sum_{j=1}^{n} S_{i,j,k} V_{i,j,k}\right)}{\sum_{j=1}^{n} V_{i,j,k}} \qquad (1)$$

Next, a very simple travel-time–estimation function suggested by Rice and van Zwet (2002) was assumed:

$$T(k) = \sum_{i=1}^{m-1} \frac{2d_i}{\bar{S}_{i,k} + \bar{S}_{i+1,k}} \qquad (2)$$

where, $T(k)$ = estimated travel time for time period k (seconds)

d_i = distance between sensor i and i-1 (miles)

m = number of sensors in the system

A Note on Travel Time Estimation Methodology

Equation (2) computes the average of each $\bar{S}_{i,k}$ and assumes a constant-speed profile between 2 consecutive detectors. The constant-speed–profile approach yields erroneous results if the traffic flow changes considerably between the detectors. A hypothetical speed profile is shown in Figure 9; the fluctuating line represents an actual speed profile on a freeway segment at time period k, whereas the straight line is the estimated average speed profile between sensors. The fluctuating speed profile is often encountered on freeways where heavy traffic merges from an on-ramp, causing lower speeds on the freeway upstream (see 0 to 0.2 miles on x-axis). The real travel-time value, which was computed based on the actual speed profile shown in Figure 9, is 3.12 minutes, whereas the estimated value is 1.63 minutes. Clearly, the closer the estimated speed profile is to the actual speed profile, the more accurate the estimation will be. Gazis and Knapp[14] attempt to define a more complex speed profile represented by polynomial functions, using the available sensor data. Coiffman[16] attempts to estimate vehicle trajectories with loop detectors; the author extrapolates local traffic condition from the detectors and extends it for the link. A myriad of studies in the literature is dedicated to travel-time estimation/prediction, most of which focus on filtering the sensor readings or using historical observations to improve travel-time function. (For details 9,11,1213,14,15 and 17)

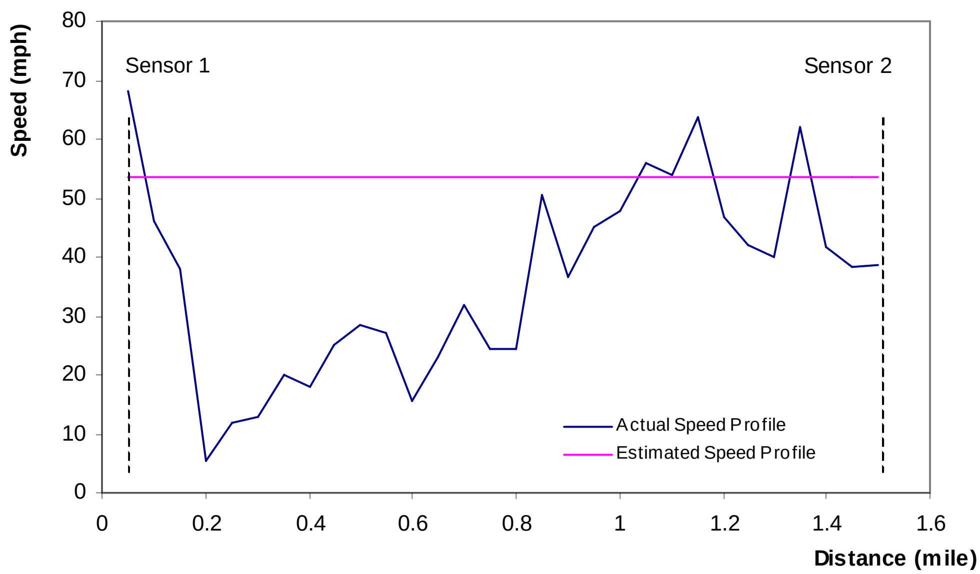

Figure 9. A Hypothetical Freeway Speed Profile

However, the accuracy of estimation is not always based on the travel-time–estimation algorithm. It also depends on the selected locations and the amount of sensors. Suppose, an additional sensor existed at x = 0.2 miles; using equation (2), the estimated travel time would yield 3.31 minutes, an approximately 40% increase in accuracy compared with the 2-sensor configuration. On the other hand, if the additional sensor was placed at x = 0.8 miles, the estimated travel time would yield 2.30 minutes. In short, no matter how good the estimation method is, the location and number of sensors are important factors in accurate travel-time estimation. Only a few studies in the literature are dedicated to determining the optimal number and location of traffic sensors. Yang and Miller-Hooks[(10)] and Sherali et al.[(18)] approach the problem as maximizing the coverage of real-time information. They weigh the candidate location of sensors with the travel-time variability of that location. The basic idea in the problem formulation is that sensors are not required on freeway segments where the travel-time variance is not significantly large. The problem is then to select amongst the links where travel time highly varies to maximize the benefit. This approach is promising in finding the right number and location of sensors, only if we have accurate knowledge of travel times on selected links once monitored. As shown in Figure 9, depending on the speed profile, this assumption might fail. Sherali et al.[18] uses Automatic Vehicle Identification (AVI) reader technology, which collects real travel-time data from equipped vehicles. Using AVI technology, the results present optimal locations; however, the system is not as widely used as loop detectors or RTMS sensors. Yang and Miller-Hooks[10] ,on the other hand, do not explicitly use a travel-time–estimation methodology.

This paper does not deal specifically with determining the optimum number and location of sensors. The system performance is presented for travel-time–estimation accuracy with the current system capabilities. However, several simulation analyses were performed to emphasize the importance of this problem.

Table 10, as well as Figure 10 and Figure 11, provide the results of our simulation analysis for 2 sensor configuration scenarios under incident and no-incident cases during a 3-hour peak period. The second configuration with 2 additional sensors is analyzed to observe if the system gains any benefits regarding better travel-time estimation. As mentioned in OBJECTIVES section, traveler information systems are mostly needed for irregular traffic characteristics. To analyze the system performance under such conditions, both configurations were simulated with the presence of a 25-minute incident on I-76. Despite the random nature of incidents, the geometric aspects and traffic characteristics of certain links make them more susceptible to incidents. The selection of a link for sensors is based on NJDOT's annual crash rates report [22]; if a link has an incident-occurrence rate of 12.8% or greater, it is selected.

Table 10. Confidence Intervals of Absolute Error ($\bar{\varepsilon}$) in Route-Travel–Time Estimation

Scenarios	No Incident	Incident
(1) Current Configuration - 5 Sensors	[21.57, 24.18]	[91.08, 100.35]
(2) Modified Configuration - 7 Sensors	[27.61, 30.64]	[92.45, 104.10]

Notes: (1) The results are based on 90% confidence interval for $\bar{\varepsilon}$ and 8% relative error with respect to real error, μ. (2) The route distance is approximately 7 miles. (3) The values are in seconds

The results provided in Table 10 represent the confidence interval of absolute error between the estimated route-travel time, $T(k)$ and the average actual travel time, $\overline{T_A}(k)$. $T(k)$ is calculated using equation (2). $\overline{T_A}(k)$ is collected by probe vehicles in simulation. For each time period k = 5 minutes, the absolute difference (ε) between $T(k)$ and $\overline{T_A}(k)$ is calculated for vehicles that start their journey within that time period. The simulation was run with random number seeds till a 90% confidence level for the expected $\bar{\varepsilon}$ with a relative error of 8% was obtained.[9] The results of this study show that the error in travel-time estimation is between 36 and 41 seconds, as well as 156 and 180 seconds, for no-incident and incident cases, respectively. Figure 10 and 11 show the plots of travel-time estimation for each scenario.

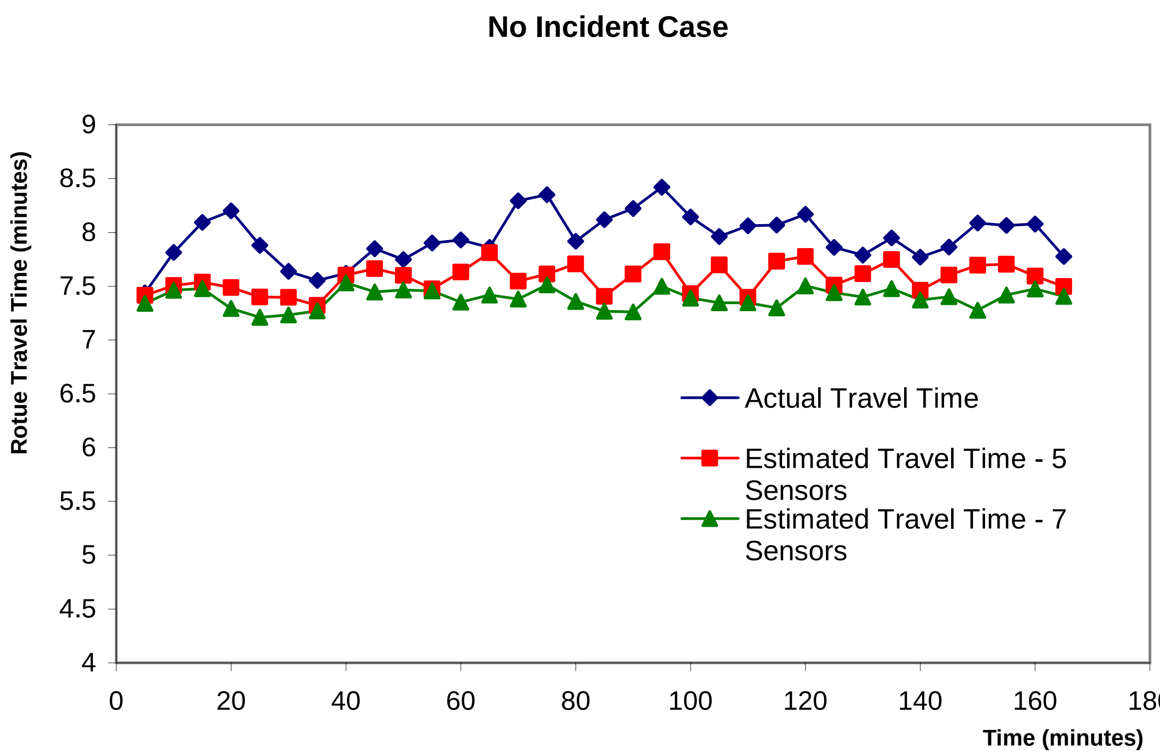

Figure 10. Comparison of Travel-Time Estimation—No Incident (Current vs. Modified Configuration)

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[9] If 100 independent 90% confidence intervals are constructed based on other independent simulation runs, $\bar{\varepsilon}$ would be expected to have a relative error of 8% (at most) for the unknown real mean (μ) in approximately 90 out of 100 cases. In the remaining ~10 cases, the relative error of $\bar{\varepsilon}$ would be greater than 8%.

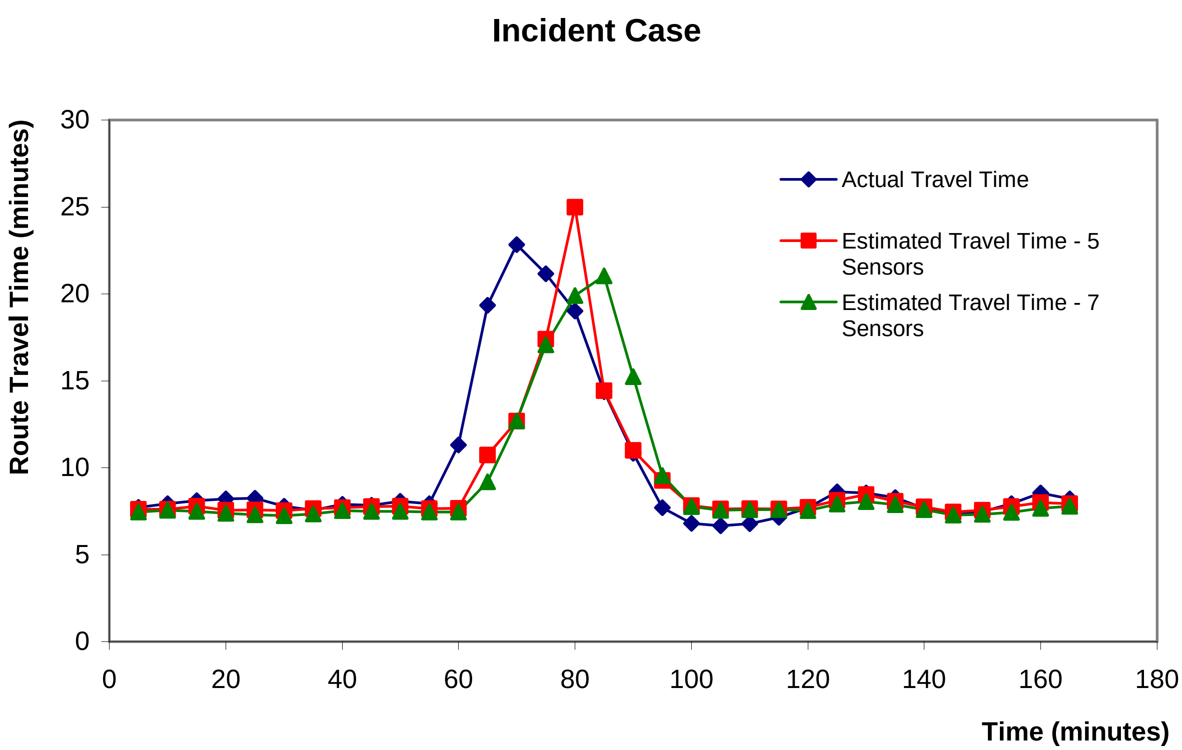

Figure 11. Comparison of Travel-Time Estimation - Incident (Current vs. Modified Configuration)

The results show that the improvement caused by 2 additional sensors is insignificant both in incident and no-incident scenarios. Nevertheless, these results will vary considerably with (1) *Incident Characteristics*: These would include location, duration, or severity degree; (2) *Sensor Locations*: Depending on the vehicle-speed profile along the route, a different selection of sensor locations would yield different results; and (3) *Travel-Time Function*: Different travel-time functions will yield different results. Equation(2) was used because of its simplicity and accuracy as stated by Rice and van Zwet[(9)].

Therefore, a more comprehensive simulation analysis should consider all these factors simultaneously. However, for large simulation network models, such as the one analyzed in this report, the number of replications needed to construct a desired confidence interval for $\bar{\varepsilon}$ may be a lot higher than expected. For example, approximately

50 replications were conducted in this study to obtain a 90% confidence level for each result provided in Table 10.[10]

In conclusion, the simulation analyses indicate that increasing the number of sensors does not always improve the accuracy of travel-time estimation. Therefore, simulation analyses are very useful in testing the performance of sensor configurations under various traffic characteristics.

CONCLUSIONS AND FUTURE WORK

As mentioned earlier, this project is aimed at evaluating the effectiveness and accuracy of the implemented motorist information system. Currently the developed system is rather limited in the number of mobile units, 5 in total; however, it is significant as a proof of concept that helps us understand the system characteristics and the possible problems that might be faced in the future. Therefore, during the first step of this project, all participating agencies involved in the study have had enormous experience regarding the potential of the proposed system and several practical issues, such as problems associated with using pagers for information dissemination and calibration of the sensors.

Now that the system is deployed and tested, and any potential technical problems are known, additional units can be built to cover major alternative routes to divert motorists in the event of non-recurrent congestion. There are still several tasks that have to be conducted to ensure an effective and system:

(1) In order to best estimate / predict route travel times in a study area, optimal number and location of sensors need to be determined prior to the deployment
This is a network-oriented task and should be analyzed with a powerful simulation tool first. For any selected route in this particular network, the designed surveillance system

[10] One replication takes approximately 25 minutes on a Dell Workstation PWS530, 2.20GHz computer.

can be simulated and the optimal number of sensors and their locations can be estimated under various traffic characteristics.

(2) Frequency of data collection needs to be studied and suggestions need to be made for the existing / future surveillance system and power limitations. As mentioned earlier, the time frame and frequency of sensor data collection can be remotely changed from a central monitoring and reporting station located at the TOC. However, due to power limitations, the duration and frequency of data collection were held at a minimum rate. Although the power shortage problem is resolvable, it will still be necessary to determine an optimal data collection frequency where both power usage is minimized and route travel times can be estimated accurately.

(3) Information dissemination capabilities of the system have to be further studied and enhanced in cooperation with the participating agencies. In this project, the system deployed has proven to effectively detect congestion and disseminate alerts to motorists by pagers. In order to provide information to a greater number of motorists, other means of dissemination have to be studied. For example, Ozbay and Bartin[(5)] showed the positive impact of VMS information on marginal costs of drivers on the southern NJ highway network. Similarly, Goel et al.[(19)] reported some promising improvements in travel time savings with the proposed vehicle-to-vehicle travel time dissemination technology in the same highway network. These studies show that there are potential benefits of deploying traveler information systems on this network.

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APPENDIX A

COMMUTER SURVEYS

APPENDIX B

NJDOT MOTORIST INFORMATION SYSTEM TROUBLE LOG

Ref #	Date	Time	Equipment	Description of Problem	Resolution/Action	Remarks/Status
1	9/27/01	Various	SPCU-all units	Incorrect Red/Yel/Green classification of traffic speeds. Reported speeds are OK.	10/18: Fixed SPCU software errors in speed classification routine and km-to-mph conversion for radar sensors. 10/19: Installed new software at 42N/55 location on 10/19 (acoustic sensor); Testing confirms problem fixed. Will verify update other sensors. 11/7: Installed new software at 676N/Mickel site (acoustic sensor). Testing confirms problem fixed. 11/7: Installed new software at 42N/295. Fix did not work. Investigation showed radar section of code had not been updated, only acoustic section. Radar section of code subsequently updated. Will install on 11/27. Traffic speed measurements continue to be ok, only bin reporting is non-operational. 11/14: Removed CPU boards from sensors at 42/130, & 676/Morgan to L-3 for software update. 11/27: Installed software fixes in sensors at 42/295, 42/130, 676/Morgan. Confirmed all sensors working normally.	First time system has been tested with variable speed traffic. CLOSED.
2	10/15/01	3:55 PM	SPCU-Radar SN002 (42N/295)	Stopped sending data.	10/19: Checked sensor: battery voltage OK, processor and CPU green lights on. Cycled power to modem & CPU; unit returned to normal operation.	CLOSED

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3	10/16/01	10:30 AM	CMRS	Cannot logon to CMRS after rebooting system; password previously used no longer works	10/18: Obtained system admin password from Brian Margerum at OIT, changed user password, and restarted system. System operating OK.	CLOSED
4	10/31/01	5:50 PM	SPCU-Radar SN002 (42N/295)	Stopped sending data.	11/7: CPU board swapped out. Sensor working normally.	CLOSED
5	11/14/01	11:00 AM	CMRS	Traffic sensors will not accept configuration commands containing the number "10" in the command string.	11/16: Problem traced to PERL code I/O service subroutine in CMRS. Subroutine treated binary data as ASCII and interpreted "10" as a line feed character, which interrupted transmission of configuration command to sensors. Code modified to use different I/O function that is data independent. System tests verify problem solved.	CLOSED
6	11/30/01	6:00 PM	CMRS	CMRS stopped sending pager messages.	12/3: Modified code that filters out messages on low traffic volume. One message missed in subsequent testing. 12/4: Increased time allowed for Windows 2000 to process messages. System working normally after modifications.	Low traffic volume filter is an added enhancement, not required by specs. CLOSED.
7	12/4/01	8:35 AM	SPCU – Acoustic SN001 (42/55)	Stopped sending data.	12/4: Reset sensor from CMRS. Data reporting resumed normal operation.	CLOSED
8	12/10/01			CMRS removed from service to prepare for delivery	CMRS delivered to CCCTMA on 12/14.	SYSTEM ADMIN NOTICE

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9	12/14/01	4:00 PM	CMRS	CMRS unable to communicate with Internet	12/19: DSL modem reprogrammed from dynamic to fixed IP addressing mode. 12/21: Identified incorrect firewall rule. L-3 firewall address updated to accept CMRS at new location.	CLOSED

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10	12/21/01	12:00 AM	SPCU	Data not being received from 3 sensors @ 55, 295, Mickel locations	1/2/02: Confirmed data not received from sensors at server. Scheduled field visit w/NJDOT to check/ reset sensor units. 1/8/02: Dead batteries found in all three non-responding units. Coordinated with NJDOT to swap battery and/or charger unit from spare SPCU (unit #6) on 1/14/02 (earliest available date for road crew support) to determine which has failed. 1/17/02: Battery swapped on sensor at 42/55. Sensor data being received. Charger appears to be working. Problem attributed to lower solar panel output in Winter not keeping battery charged. Traffic sensor sampling rate reduced to reduce power consumption. Battery change out on remaining two sensors rescheduled to 1/22 and TBD (two visits) due to unavailability of NJDOT road crew/equipment. 1/22/02: Repair rescheduled by NJDOT to 1/23. 1/23/02: Battery replaced in sensor at 42/295. Battery removed for charging at 676/Mickel. 1/25/02: Battery Replace in sensor at 676/Mickel. All sensors operating properly.	CLOSED

Ref #	Date	Time	Equipment	Description of Problem	Resolution/Action	Remarks/Status
11	12/24/01	3:30 AM	CMRS	Pager messages not reaching pagers	1/2/02: Retest mail server after all sensors are operating. (Mail server interface previously verified OK on 12/21.) 1/8/02: Mail server will not operate with empty database. Database inadvertently emptied when data archived on 12/21/01. Null records placed in database and server restarted. 1/25/02: Error in traffic volume filter corrected in CMRS software. (Filter blocks messages when speed and volume are both low. Incorrect volume parameter was being used by filter.)	CLOSED
12	1/12/02		CMRS	CMRS Outage	1/17: Site visit determined outage caused by power outage at CCCTMA. CMRS software restarted.	CLOSED
13	1/17/02		CMRS	Two Viruses detected on CMRS	1/17: Viruses quarantined by Norton Antivirus. No impact on system performance.	CLOSED
14	1/22/02	8:00 am	CMRS	Server not reachable from Internet	1/23: Confirmed DSL network outage at CCCTMA. 10:30 am: DSL service restored at CCCTMA.	CLOSED
15	1/28/02		SPCU	Sensor data from 42/295 location is not correct.	1/30: Schedule repair visit with NJDOT to check sensor. Spare sensor from uninstalled SPCU can be used as replacement unit if needed. 2/4: Sensor at 42/295 repositioned and calibrated. Sensitivity increased. Vehicle counts match observed traffic +/- 10%. 2/5: Sensor at 42/55 recalibrated. Vehicle counts match observed traffic +/- 10%.	CLOSED