FINAL REPORT

Evaluation of Intelligent Transportation Infrastructure Program (ITIP) in Pittsburgh and Philadelphia, Pennsylvania

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EVALUATION OF INTELLIGENT TRANSPORTATION INFRASTRUCTURE PROGRAM (ITIP) IN PITTSBURGH AND PHILADELPHIA, PENNSYLVANIA

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Disclaimer

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EXECUTIVE SUMMARY

The Transportation Equity Act for the 21st Century (TEA-21) Public Laws 105-178 and 105-206, Title V, Section 5117(b) (3) provides for an Intelligent Transportation Infrastructure Program (ITIP) to advance the deployment of operational intelligent transportation infrastructure system activities to aid in transportation planning and analysis. The U.S. Department of Transportation (DOT) is interested in developing an ability to measure the operating performance of the roadway system at a national level. The U.S. DOT is also interested in state and local transportation agencies having access to roadway system performance data to assist in their planning, evaluation, and management activities. To be useful for the purposes described, roadway system performance data must be measured continuously, and be available in both real-time and archived formats. The deployment of this program was initiated in the two largest metropolitan areas in the Commonwealth of Pennsylvania, Pittsburgh and Philadelphia. For each location, the U.S. DOT provided $2 million in federal funds and the Pennsylvania DOT provided $500,000. Implementation of this program is a public-private partnership between the U.S. DOT and a private Consortium led by Mobility Technologies (formerly Traffic.com). Mobility Technologies designed, owns, operates, and maintains the traffic information system to provide an Integrated Surveillance and Data Management Infrastructure (ISDMI). The objectives of the ISDMI program are to provide real-time and archival traffic information services along with the integration of an existing surveillance infrastructure.

Systems Description

The ISDMI systems are made up of two functional areas: (i) a data gathering function, i.e., Metropolitan Traffic Area (MTA) and (ii) a data processing and storage function application, the National Transportation Data Center (NTDC). The primary purpose of the MTA is to gather traffic information from various sources within a defined region and transmit those data back to the NTDC. The NTDC data reporting system processes, stores, and reports on the information from the data gathering system. The NTDC processes the data to provide real-time traffic condition information, and maintains a data storage or warehouse facility for archived data. Both the public and private sectors have access to the real-time and archival databases at the NTDC through a web-based enterprise system.

The system consists of a network of sensors located across a metropolitan area and connected via a communications network to the NTDC. Each sensor collects information in real time, continuously monitors the roadway, and communicates to the NTDC on a regular basis (currently configured at intervals of 60 seconds) sending all of the information gathered in that period. The data, which are processed at the NTDC, are used for both real-time distribution and data archive purposes. Typical traffic sensor attributes, such as volume, occupancy, and speed, are retrieved from the device for each of the defined detection zones and stored as raw sensor data in the NTDC database by time of day and date. These data are used by ISDMI systems software to compute data elements such as traffic congestion and traffic density.

Currently, there are 114 sensors in the Pittsburgh area and 178 in the Philadelphia area. These sensors are installed along urban freeways and major arterials. Acceptance testing of the ISDMI systems was conducted in Pittsburgh in May 2001 and in November 2001 in Philadelphia.

Evaluation Goals and Framework

The primary purpose of the evaluation is to demonstrate the technical and institutional feasibility, costs, and benefits of the primary Intelligent Transportation Systems (ITS) user services in the areas of traveler information, route guidance, traffic control, incident management, and archived data functions, and to further encourage deployment of the systems in other cities. The expected outcomes of the evaluation are analyses and documentation of the benefits that are of interest to various stakeholders. These include cost savings and customer satisfaction with the traffic data generated by the ISDMI systems.

The framework for conducting the evaluation consists of four interrelated building blocks. First the evaluation goal areas were identified and prioritized during an evaluation workshop. The evaluation workshop was conducted to obtain stakeholder inputs in terms of consensus on goals and objectives of the evaluation effort and opportunities for data collection. Key features and expected changes following the deployment of the ISDMI systems were identified. Initial priorities of evaluation goals and objectives were also established at the evaluation workshop. Second, measures for evaluating the various goal areas were identified. Collectively, these measures are considered to be key to the evaluation effort. Third, the hypotheses that will be used to evaluate the expected changes associated with each goal area were developed. These hypotheses reflect the overall objectives of the evaluation and the expected changes associated with the implementation of the systems. Finally, methods were identified for collecting relevant data on the measures to test the hypotheses and to help evaluate the success of the goal areas.

Five major goal areas were evaluated: systems performance, mobility, productivity and efficiency, safety, and institutional issues. In evaluating these goal areas, the following six studies were conducted to test the hypotheses of each goal area.

1. ***Technical effectiveness*** – This study area focuses on the system performance goal area. Measures in this study evaluated the ability of the systems to perform the intended functions.

2. ***Customer satisfaction*** – This study addresses productivity and efficiency and mobility goal areas. The objective of this study is to identify levels of satisfaction and identify areas of the systems in which users find improvements desirable.

3. ***Congestion*** – This study primarily addresses the mobility goal area. The objective of the congestion study is to examine the effects of the availability of accurate and reliable real-time traffic condition data with a wide coverage area offered by ISDMI systems on traffic.

4. ***Cost*** – This study addresses the productivity and efficiency goal area. The cost analysis is intended to quantify the non-recurring and recurring costs associated with deploying, operating, and maintaining the systems.

5. ***Safety*** – The objective of the safety study is to identify potential safety benefits that could be associated with the deployment of the ISDMI systems.

6. ***Institutional Issues*** – The objective of the institutional issues study is to identify the policy issues and institutional arrangements that were likely to affect the deployment and operation of the new technology.

Evaluation test plans were developed and used in conducting each of these studies. Table ES-1 shows the goal areas, studies conducted, and the hypotheses tested.

Table ES-1. Evaluation Goals, Hypotheses, and Studies

Goal Areas	Study	Hypotheses	Data on measures collected?
System Performance	• Technical effectiveness	• Accurate, complete, and reliable traffic data • Less costly to collect, store, and share data • Faster to process and distribute data • Ability to provide real-time and archived traffic data	Yes Yes Yes Yes
Productivity and Efficiency	• Customer satisfaction • Cost	• Less costly and faster collection and processing of traffic data • Improved data quality (timely, accurate, accessible) for planning and other purposes • Improved efficiency in data collection, processing and reporting	Yes Yes Yes
Mobility	• Congestion • Customer Satisfaction	• Improved traveler information to road users • Reduced delay and congestion to road users • Improved trip planning • Improved customer service to transit and other road users	Yes Yes Yes No (See 1)
Safety	• Safety	• Improved incident detection and response • Better risk management	Yes (See 2) No (See 3)
Institutional Issues	• Institutional issues	• Improved interagency interaction • Easy to share and exchange data • System is portable to other places	Yes Yes Yes

1. No information was available during evaluation period.
2. Qualitative assessment only. No quantitative data available during evaluation period
3. No information was available during evaluation period

Findings

This report presents the findings from the six studies in Pittsburgh and Philadelphia. Highlights of the findings are presented in the following sections.

Technical Effectiveness

The technical effectiveness component of the evaluation includes an assessment of the ability of the systems to capture, process, store, and report traffic data accurately, completely, and of acceptable quality for the various applications. Quantitative assessments of accuracy and completeness of archived sensor data and qualitative assessment of the ability to capture, process, and report good quality real-time data were performed.

Archived Data Accuracy

The purpose of the data accuracy analysis is to examine the ability of the ISDMI sensors to capture, process, and store traffic volume data accurately. This is achieved by comparing archived traffic volume data with automatic traffic recorder (ATR) and manual volume counts, which represent the status quo or legacy systems for, traffic volume data collection. It should be recognized that the ATR and manual counts also have inherent measurement errors. The following are the main observations from the statistical analyses.

ISDMI Sensors vs. ATR Counts: Statistical analyses were conducted to characterize the accuracy of the sensors in capturing and recording traffic volume data. The analysis shows that the ISDMI sensors recorded lower traffic counts than the ATR counts in approximately 81% of the readings. The absolute differences between the ATR and sensor readings increase with increasing traffic volume. However, the relative differences (i.e., differences expressed as a percentage of the ATR counts) decrease with increasing traffic volume. At the 95% confidence level, precision of the sensor data ranges from ± 74% for ATR traffic volumes less than 500 vehicles per hour to ± 7% for ATR traffic volumes greater than 2,500 vehicles per hour.

In Philadelphia, the analysis shows that the ISDMI sensors recorded higher traffic counts than the ATR counts in approximately 81% of the readings and that the sensor counts remained fairly constant (± 175) for all levels of traffic volume. At the 95% confidence level, precision of the sensor counts range from ± 124% for ATR traffic volumes less than 500 vehicles per hour to ± 6% for ATR traffic volumes greater than 2,500 vehicles per hour.

There is no clear explanation for the differences in accuracy of traffic volume data between Pittsburgh and Philadelphia. Although Pittsburgh analysis included data collected before the systems had undergone acceptance testing, the results indicate that the quality of data before and after the acceptance testing are comparable. The differences could be attributed to several factors. A possible reason is that, the sensors were deployed in Pittsburgh before Philadelphia. Therefore, experiences with the sensors and lessons learned in Pittsburgh might have been taken into account in the Philadelphia deployment.

ISDMI Sensor vs. Manual Counts: Sensor records of traffic volume were also compared with manual counts conducted at 10 different test locations in Pittsburgh. Each field test consisted of 2 or 3 hours of manual traffic counts in one direction of travel. The field tests were conducted by officials of PennDOT Bureau of Planning and Research (BPR). It was found that the ISDMI sensors recorded lower traffic volume counts than the manual counts in 18 of 25 measurements (72%). Also, the difference between ISDMI sensor records and manual counts ranges between -20% and +16% relative to the manual counts. These results are consistent with the ATR comparisons.

Archived Data Completeness

The purpose of the data completeness analysis is to examine the ability of the ISDMI sensors to capture, process, and store traffic data completely. The data used to characterize the completeness of the archived data collected by the ISDMI sensors consist of volume, occupancy, and speed values reported at 5-minute intervals.

For the Pittsburgh data, it was found that completeness improves from January through June 2001 but decreased between June and September 2001. The overall average percentage complete for all three variables is around 70%. Specifically, about 30% of all the potential 5-minute intervals data were missing for each of the three quantities (29% for volume, 27% for occupancy, and 31% for speed). Volume and speed data were simultaneously missing approximately 3% of the time, with all three values missing about 27% of the time. In general, the speed values appear to be missing slightly more often than the volume or occupancy values.

The data for Philadelphia were found to be 98% complete. Obviously, the sensors in Philadelphia are capturing, processing and storing a higher percentage of the expected amount of data than in Pittsburgh. Despite the differences in data completeness between the two cities, the results compare favorably with other archived ITS data. For example, a recent study (Lomax et al., 2001) showed that completeness ranged from 38% to 93% for 10 different cities in the U.S. A value of 70% complete for Pittsburgh would be on par with several other cities. A value of 98% complete for Philadelphia is much better than the current maintenance levels of most data archives. Realistically, 100% completeness is not expected, and there is no established acceptable threshold value to distinguish between good and poor quality archived traffic data. In the absence of such a threshold the only reference for gauging the quality of archived ITS data would be evidence from similar studies or systems.

Real-Time Data Qualitative Assessment

Only qualitative assessments of the systems and real-time data were made based on discussions with the users of real-time data in Pittsburgh. The stakeholders in Philadelphia were not accessing data from the ISDMI systems at the time of evaluation data collection and therefore were unable to provide information on the quality of real-time data. Officials of the Traffic Management Center (TMC) of Pennsylvania Department of Transportation (PennDOT) District 11 in Pittsburgh noted that the ISDMI systems are performing their intended functions of providing timely traffic information to traffic operators to help manage traffic in the Pittsburgh area, and providing traveler information to the general public. Officials of TMC made the following pertinent observations:

- Data from ISDMI sensors supplement information from the cameras, and the data are readily accessible to the staff of the TMC.

- The traffic flow map and announcer functionalities of the ISDMI systems interface give detailed information on traffic conditions at any given time. Moreover, the ISDMI systems cover a wider area compared to the cameras and therefore the TMC is now able to provide traffic information on routes not monitored by cameras.

- The ISDMI systems have a trigger mechanism that alerts TMC personnel in the event of an incident. The TMC personnel believe that this functionality reduces time required for incident detection and response. In addition, the TMC can provide timely and accurate messages to motorists relating to incidents on the highways.

It could be concluded that the systems are operating as expected in collecting, processing, and storing traffic data non-intrusively and on a continuous basis. While the quality of archived data, measured in terms of accuracy and completeness, is comparable to results from studies elsewhere, there is room for improvement. The results indicate that sensors and communication systems are capable of capturing, processing, and transmitting real-time traffic data in required format to users. The systems are also capable of generating customized reports from archived databases.

Customer Satisfaction

Customer satisfaction studies were conducted to measure the opinions of three groups of customers: the public (including the general public and current subscribers to the Mobility Technologies website), stakeholders, and media houses. Random telephone surveys of the general public were conducted to evaluate awareness, access, and acceptance and an Internet survey of actual users (subscribers to the Mobility Technologies website) were conducted with a focus on use and value associated with the ISDMI system. Note that in the customer satisfaction survey questions, Traffic.com or TrafficPulse was used to reference the actual website of ISDMI information. Two media houses in Pittsburgh and three in Philadelphia were surveyed.

In general, the public and media houses accept the data generated by the ISDMI systems. Over 95% of the general public indicated their willingness to continue using the information, and all media houses expressed satisfaction with the traffic information and indicated that they would recommend this source of traffic information to other potential customers. These users find overall performance of the systems to be acceptable and the information useful for their needs. On the other hand, stakeholders are slow to begin using the data from the ISDMI systems, and so it is impossible to offer any meaningful concluding remarks regarding stakeholder satisfaction with the data from the ISDMI systems. The few stakeholders that are currently accessing the data express satisfaction with the data.

Specific findings from each of the three groups of customers are presented below.

General Public

Awareness: According to the telephone survey, 28% of Pittsburgh residents and 23% of Philadelphia residents had heard of Traffic.com. The Internet surveys indicate that Traffic.com website users heard about the systems mostly from television or radio advertisements (32%) in Pittsburgh, and mostly by word of mouth in Philadelphia (35%).

Out of the people who responded to the Internet survey, 58% in Pittsburgh and 69% in Philadelphia knew that Traffic.com provides information on point-to-point travel times. More users (70% to 81%) were aware of the information on route-specific travel speeds and maps in both Pittsburgh and Philadelphia.

Access: About 65% of the households in the Pittsburgh area and 77% in the Philadelphia area have access to the Internet. Access to the Internet is used as a proxy for access to Traffic.com information. Thus, 65% to 77% of the population in these two cities could access the website if they desire.

Acceptance: Almost all Internet survey respondents (95% in Pittsburgh and 97% in Philadelphia) plan to continue using Traffic.com traffic information in the future. This is a clear indication that current users find the information useful and will continue to use it.

Use: About 16% of the Traffic.com information users in the Pittsburgh population compared to 44% in the Philadelphia population checked for traffic on specific routes and 6% (Pittsburgh) versus 9% (Philadelphia) check for current travel times. About 84% of Internet respondent users in both cities indicated that they check for traffic on specific routes.

Value: According to the Internet survey results, 68% of users in Pittsburgh and 86% in Philadelphia changed their original travel route at least once because of Traffic.com information, while 47% (Pittsburgh) and 66% (Philadelphia) changed their original time of travel. The effect on the choice of transportation mode is less noticeable, i.e., 6% in Pittsburgh and 2% in Philadelphia changed their original mode of transportation.

About 75% of commuters from the Internet survey in Pittsburgh and 43% in Philadelphia feel that their commute time has remained about the same. However, 18% (Pittsburgh) and 47% (Philadelphia) of the commuters feel that Traffic.com information helped to decrease their commute time.

The results seem to indicate that the real-time traffic information provided by the Traffic.com systems is helpful to motorists in making their trip planning decisions. At the time of the survey, less than 10% of the users in Pittsburgh and 27% in Philadelphia indicated their willingness to pay for the services provided.

The Internet survey results indicate that the majority of the users believe the system performs well. Seventy percent (70%) of the users in both Pittsburgh and Philadelphia think the website is easy to navigate through; 75% believe the information is easily understood; about 65% feel the information is reliable; and about 73% indicated that most or all of the routes they wanted to check for traffic were included in the system.

The customer satisfaction studies indicate that members of the general public who are aware of the Traffic.com website use and value the information provided in making their travel decisions. The results indicate that the levels of satisfaction expressed by users in both cities are similar. More than half of the users indicate that the information meets their needs. Although the numbers of respondents in the surveys are small, the results clearly indicate that the information from the Traffic.com website impacts travelers' choices of travel routes more than the time of travel. It is noted that the system is relatively new and usage will increase with time.

Stakeholders

At the time of customer satisfaction data collection, only two of the five stakeholders in Pittsburgh, PennDOT District 11 TMC and BPR, were actually accessing and/or using the ISDMI data. In Philadelphia, only the TMC was accessing the ISDMI data on a limited basis at the time of data collection in April 2002. Some possible reasons why all stakeholders are currently not accessing or using the information from the ISDMI systems at the time of evaluation data collection could include: (i) lack of knowledge about data quality (ii) stakeholders' lack of preparation for the data generated from the ISDMI systems, (iii) availability of similar data from alternative sources such as legacy systems; (iv) the fact that the ISDMI system is not currently integrated with stakeholder legacy systems. Due to the limited use of the data, a comprehensive assessment of the stakeholder satisfaction with data generated by the ISDMI systems was not possible.

Expressions of satisfaction presented in this report are those of a few stakeholders, and these expressions may not necessarily be true reflections of all the stakeholders in the two cities. This is because each stakeholder uses real-time or archived traffic data for different applications. It is interesting to note that the TMC staff in Pittsburgh and Philadelphia have divergent impressions about the data from the ISDMI systems. For example, the TMC staff in Pittsburgh noted that (i) the ISDMI systems improve coverage of highway systems and therefore improve traffic surveillance and incident management (emergency response), and that (ii) the system of data collection is convenient and useful because it is non-intrusive and continuous. The TMC staff in Philadelphia, on the other hand, expressed concerns about the reliability and accuracy of data generated by the ISDMI systems for incident detection. In Philadelphia, they feel that information generated from the ISDMI systems is not useful for incident management purposes.

Stakeholders who currently access data from the ISDMI systems all agree that the Internet interface is user-friendly and facilitates access to the data. Also, they find the Internet interface more useful than the PC-based interface software provided by Mobility Technologies.

Media Houses (Radio and TV Stations)

Two media houses in Pittsburgh and three in Philadelphia were surveyed to determine their satisfaction with the information obtained from Traffic.com. On average, the media houses access real-time traffic information via ISDMI systems 3 to 9 times during each peak period every day. The media houses expressed satisfaction with the quality of the data in terms of the format of data delivery, accuracy, timeliness, completeness, and reliability. It is observed that the new systems offer a more convenient and easier way to obtain traffic information via the Internet compared to faxes, the legacy form of data access.

Congestion

The primary objective of the congestion study is to examine the potential impacts of the availability of traffic information from the ISDMI systems on traffic congestion. It is recognized that there is no direct linkage between changes in traffic speed and volume and the availability of traveler information to travelers. The results of the congestion analysis only provide indications of possible effects of the availability of traveler information on congestion.

In Pittsburgh, traffic speed and volume characteristics at two historically congested locations were compared between two points in time. Data from the ISDMI archived database and video recordings of traffic movements were used. A similar analysis was conducted in Philadelphia, but no video data were used.

Significant improvements in average speeds during the evening peak period were noticed at one location in Pittsburgh. There was a corresponding decrease in traffic volume at this location during the evening peak period. The average speed and traffic volume during the morning peak period remained about the same. At the second location, however, average speeds stayed practically the same during morning and evening peak periods and in both directions of travel. In Philadelphia, the results indicate that average morning peak period speed increased but the conditions at the second location remained relatively constant. These results are inconclusive to directly attribute any changes in speed or volume at these locations to the availability of traveler information to travelers.

TMC personnel in Pittsburgh observed that changes in traffic congestion in the Pittsburgh area in general were marginal. It was noted that congestion seemed to have improved on corridors without camera coverage. This is probably the result of providing motorists with traffic information through variable message signs (VMS) and highway advisory radio (HAR) on those corridors and through commercials and radio information provided by Mobility Technologies. The end result is better information to a greater number of motorists, particularly during the peak periods or in the event of an incident. Thus, availability of timely traffic information improves the traffic management operations of the TMC and assists motorists in trip-making decisions. The officials of Philadelphia's TMC also observed that no noticeable changes in congestion had taken effect since the implementation of the ISDMI systems.

Due to the several factors affecting traffic flow, the direct impact of the ISDMI systems on congestion could not be conclusively and quantitatively established. Moreover, the time between deployment and evaluation was not long enough to capture any noticeable effects of the ISDMI systems on congestion. However, it is probable that the availability of accurate and complete real-time traffic information, providing wide coverage for the traffic managers and travelers, improves route choice decisions and consequently impacts congestion.

Cost Analysis

The ISDMI project, being a private-public sector partnership, has a unique financing arrangement. Consequently, certain cost items such as non-recurrent and capital costs incurred by the private entity are considered proprietary and therefore not available to the evaluation team. The U.S. DOT incurred $2 million and PennDOT incurred $500,000 as non-recurrent expenditure in the implementation of the ISDMI systems. There are no recurring costs to the public sector. The private partner assumes all recurring costs. The focus of the cost analysis therefore is to determine the cost savings to the various stakeholders in terms of data collection, processing, storage, and retrieval for legacy versus ISDMI systems. The cost analysis was limited to estimating the cost savings to the stakeholders assuming that they rely entirely on data provided by the ISDMI systems.

The cost savings to stakeholders are essentially the non-recurrent costs of deploying new data collection systems and the recurring costs of operating and maintaining the existing legacy and new systems. Even for stakeholders such as Pittsburgh's TMC, who consider data from the ISDMI systems as supplemental to their legacy sources, each stakeholder will potentially realize some cost savings if they rely entirely upon the ISDMI systems for their traffic data needs.

The following potential cost savings to various stakeholders were estimated:

- TMC Pittsburgh– the estimated non-recurring capital cost estimated at $570,000 (i.e., 57 detectors at $10,000 each) for deploying a new traffic detection system and annual maintenance cost estimated at $57,000 would not be incurred if the TMC relies on ISDMI systems to complement traffic information obtained with the existing cameras. The ISDMI sensors are not substitutes to the cameras; therefore, the annual recurring costs for the legacy camera systems will remain.

- BPR – the annual recurring cost of $63,580 for the legacy data collection (i.e., ATRs), processing, storage, and reporting would potentially be saved if the BPR relies on the ISDMI systems for its data needs. In addition, the cost of deploying new double loop ATRs estimated at a minimum of $184,000 per site (63 sites total), i.e., $11,592,000 and the annual recurring costs of $12,000 per site could be potentially saved.

- Southwestern Pennsylvania Commission (SPC) Pittsburgh – a potential cost saving to the SPC, the local Metropolitan Planning Organization (MPO), is part or all of the annual recurring cost of $130,000 for traffic data collection, processing, and reporting. This amount includes labor, vehicles, maintenance, equipment replacement, and other operating costs associated with data collection and reporting.

- TMC, Philadelphia – Data on the cost of equipment and operations and maintenance were not available to the evaluation team to allow a detailed estimation of cost savings. However, should the TMC access and use real-time traffic data from the ISDMI systems to supplement information from the cameras, the minimum potential cost savings would be $90,000 per month or $1,080,000 annually, being the cost of real-time data from secondary sources, including the cost of development and distribution of traveler information through telephone and internet systems.

- Delaware Valley regional Planning Commission (DVRPC) – It was estimated that the annual cost of traffic data collection, processing, analysis, and reporting is approximately $600,000 including salaries and equipment purchasing. This amount represents a potential cost savings if DVRPC should rely entirely on ISDMI systems for its traffic data needs.

- City of Philadelphia, Streets Department – The estimated annual cost for data collection is $90,000 in Federal funds. It is possible the City could save this amount if it is determined that the nature and quality of data from the ISDMI systems meet their needs.

Safety

Information on safety impacts is anecdotal and qualitative. TMC personnel observed a reduction in the number of secondary incidents, which they considered to be a major safety benefit of access to real-time traffic information offered by the ISDMI systems. This observed reduction in secondary incidents is directly attributed to improvements in incident management practices through availability of timely traffic condition and incident information to the TMC that is subsequently relayed to motorists via VMS and HAR in a timely fashion. This is also due to the fact that the ISDMI systems have a wider coverage of the highway network, whereby the TMC is able to monitor traffic over a wider area than with the cameras only. The information alerts motorists of incidents ahead and allows them to react accordingly and prepare before getting closer to the incident location. It also allows motorists to make decisions regarding alternative routes, thus avoiding congestion and delays caused by incidents. Overall, TMC personnel claim to be able to perform the incident management functions better with the availability of the ISDMI systems.

Even though the TMC personnel in Philadelphia did not provide any specific information on safety impacts, the observations in Pittsburgh regarding wider coverage and reduced secondary incidents are expected to be applicable to Philadelphia as well.

Institutional Issues

No major institutional issues have been identified with the deployment and usage of the systems in the Pittsburgh and Philadelphia areas. The ISDMI project is unique in terms of the public/private partnership in its design and implementation. As such, certain institutional issues are not likely to surface at this time but may become evident in the future. These issues may include data quality and the recourse available to the public in the event of erroneous or incomplete data, and public rights to the data (though not an issue to date). In turn, competitors may be discouraged from trying to provide identical data.

Operational changes in the BPR in terms of traffic data analysis and projection are expected to occur with availability of data from ISDMI systems. The technical approach for doing so, the level of detail, and accuracy will change because data from ISDMI systems are more comprehensive in terms of spatial and temporal coverage. For example, the assumptions underlying the development of traffic growth and expansion factors will be refined.

With the implementation of ISDMI systems, data collection responsibilities may change. Currently, the MPOs in Pittsburgh and Philadelphia collect traffic data for the DOT. This change may result in more efficient use of resources.

Data that were hitherto unavailable to stakeholders will now be available and therefore analyses and decisions based on the outputs of those analyses would be based on larger data sets – hence resulting in more confidence in decisions based on such data. For example, traffic data for all lanes on freeways and throughout the day are captured by the ISDMI systems and are available.

CHAPTER 1: INTRODUCTION

1.1 Background

According to the Transportation Efficiency Act for the 21st century (TEA-21) Public Laws 105-178 and 105-206, Title V, Section 5117(b) (3) under the Transportation Technology Innovation and Demonstration Program, the Intelligent Transportation Infrastructure Program (ITIP) is intended to advance the deployment of an operational intelligent transportation infrastructure system for data services for the measurement of various transportation system activities to aid in transportation planning, analysis, and maintenance while making a significant contribution to the ITS program under this title. The program is expected to meet the following objectives:

- Build an infrastructure for the measurement of various transportation system metrics to aid in planning, analysis, and maintenance of the transportation system, including the build out, maintenance, and operation of more than 40 metropolitan area systems with a cost not to exceed $2,000,000 per metropolitan area. For the purposes of this demonstration initiative, a metropolitan area is defined as any area that has a population exceeding 300,000 and that meets several of the criteria established by the Secretary in conjunction with the ITS corridors program.

- Provide private technology commercialization initiatives to generate revenues that will be shared with local departments of transportation.

- Collect data primarily through wireless transmission along with some shared wide area networks.

- Aggregate data into reports for multi-point data distribution techniques.

- Utilize an advanced information system designed and monitored by an entity with experience with the Department of Transportation in the design and monitoring of high reliability, mission-critical voice and data systems.

The U.S. Department of Transportation (DOT) is interested in developing an ability to measure the operating performance of the roadway system at a national level. The U.S. DOT is also interested in state and local transportation agencies having access to roadway system performance data to assist in their planning, evaluation, and management activities. In addition, the U.S. DOT is interested in facilitating public/private partnerships and the commercialization of traveler information data to create the opportunity for self-sustained systems that attract capital. To be useful for the purposes described, roadway system performance data must be measured continuously, and be available in both real-time and archived formats.

The path to achieving these objectives presents an opportunity to serve public agency needs in true public/private partnerships. It is recognized that the same data that are useful to the public transportation agencies also have value for commercial traveler information applications. Such a partnership was envisioned in TEA-21 Section 5117(b)(3). To this end, the U.S. DOT and a private sector consortium led by Mobility Technologies (formerly Traffic.com) have initiated the implementation of the program in the two largest metropolitan areas in the Commonwealth of Pennsylvania, Pittsburgh and Philadelphia.

In implementing this program, Mobility Technologies (MT), a private enterprise, designed, owns, operates, and maintains a traffic information system to provide an Integrated Surveillance and Data Management Infrastructure (ISDMI). MT invested its own capital to build the initial infrastructure and is responsible for the design, implementation, and long-term management of the system. The ISDMI project is intended to demonstrate the enhancement of existing surveillance infrastructure through integration, along with strategic deployment of supplemental surveillance infrastructure. The project utilizes the Intelligent Transportation Systems National Architecture (ITSNA) as a guide for implementation of the data services. Within the ITSNA guidelines, MT is a service provider of information that can be used toward the following ITSNA User Services and Market Packages for the Pittsburgh and Philadelphia metropolitan areas:

- **Pre-Trip Traveler information** will be available as it applies to Current Situation Information on the major roadways in the Pittsburgh and Philadelphia areas. The information gathered will provide input into the Broadcast Traveler Information (ATIS1), Integrated Transportation Management/Route Guidance, and Traffic Prediction and Demand Management market packages.

- **Route Guidance** will be assisted through the sharing of data with the local Pittsburgh and Philadelphia traffic management centers (TMCs) to provide current road condition information. This information will be made available to both public and private sectors and will mainly impact the Broadcast Traveler Information market package.

- **Traffic Control** will be enhanced through the Traffic Surveillance information and the Provide Information functions. Specifically, by sharing sensor data with the Pittsburgh and Philadelphia TMC and the other public agencies, traffic control capabilities will be enhanced.

- **Incident Management** will be enhanced through the synergy gained by locating and linking the Mobility Technologies Metropolitan Traffic Area (MTA) system with the Pittsburgh TMC. This will allow the sharing of planned and non-planned incident data and the early dissemination of that information through the Broadcast Traveler Information application.

- **Archived Data Function** will provide guidelines for the creation of a data warehouse. This user service describes the types of data and data elements that will be useful for short- and long-term data sharing among both public and private sectors.

To ensure that the program goals and objectives are realized and document the benefits and costs of the program, an independent evaluation of the various components and elements of the infrastructure was required. This interim report presents preliminary findings in Pittsburgh and summarizes the baseline situation in Philadelphia. No conclusions of the evaluation are presented in this interim report. The report also presents an overview of the ISDMI systems design and highlights the evaluation strategy and approach.

1.2 Evaluation Project Objectives and Scope

The primary purpose of the evaluation is to demonstrate the technical and institutional feasibility, costs, and benefits of the primary Intelligent Transportation Systems (ITS) user services provided by the ISDMI systems in the areas of traveler information, route guidance, traffic control, incident management, and archived data functions, and to further encourage deployment of comparable systems in other cities. The expected outcomes of the evaluation are analyses and documentation of the benefits that are of interest to various stakeholders. These include cost savings and customer satisfaction with the traffic data generated by the ISDMI systems. The system is evaluated in a number of categories, including the efficiency of the system to gather, process, and archive traffic data required for maintenance and operation of the transportation system; user satisfaction; cost savings over traditional data collection approaches; and institutional issues associated with the systems deployment.

1.3 Organization of Report

The remainder of this report is divided into several chapters:

Chapter 2 presents an overview of the system deployments. It describes the major components of the system architecture and user services. This chapter also describes the status of system deployment in Pittsburgh and Philadelphia.

Chapter 3 presents the evaluation strategy and approach. This chapter identifies the evaluation goals, measures, the hypotheses tested, and the technical approach of the evaluation. The same approach was used in Pittsburgh and Philadelphia.

Chapter 4 presents the findings of the evaluation in Pittsburgh and Chapter 5 presents the findings in Philadelphia. In each of these chapters, a separate section is devoted to each study area: technical effectiveness, customer satisfaction, congestion, cost analysis, and safety. A discussion of institutional issues is presented at the end of Chapter 5.

The findings are presented by city and not by study area because of the differences in the nature of the ISDMI systems deployment, in each city. Also, this presentation format is intended to highlight the differences between the two cities in terms of stakeholder and general public perceptions of the usefulness of data generated from the systems as well as the nature of the data used in the evaluation analyses.

Chapter 6 presents a general discussion of findings from the two cities and some concluding remarks.

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CHAPTER 2: SYSTEM DESIGN AND DEPLOYMENT

2.1 System Design

2.1.1 Introduction

This chapter describes the essential elements of traffic information system infrastructure deployed in Pittsburgh and Philadelphia. Detail descriptions can be found in *"System Requirements Definition- Pittsburgh"* Final Report, issued in January 2001 (Traffic.com, 2001a) and *"System Requirements Definition- Philadelphia Metropolitan Area"* Final Report, issued in March 2001 (Traffic.com, 2001b). The status of the deployment in these two cities is also described in this chapter. Implementation of the ISDMI systems consists of data gathering, also known as the Metropolitan Traffic Area (MTA), and data processing and storage at the National Transportation Data Center (NTDC). The NTDC may physically reside at one or more data centers around the country. Currently there is one main data center located in Philadelphia. The primary purpose of the project is to gather traffic information from various sources within a defined region and transmit those data back to the NTDC. The NTDC processes the data to provide real-time traffic conditions and provide a data storage or warehouse facility for the archived data. The system is designed such that additional cities can be quickly added once the concept and design have been proven.

The system consists of two major components (Traffic.com, 2001a, 2001b):

- **Data gathering** – A system that gathers traffic-related data from strategic locations throughout the Pittsburgh and Philadelphia metropolitan areas, and

- **Data distribution** - The NTDC data reporting system that stores and reports on the information from the data gathering system.

Both the public and private sectors have access to the real-time and archival databases at the NTDC through the web-based stakeholder system. Users can access the system through assigned user names and passwords that control access and privilege levels. Any public sector PC or workstation that has an Internet connection and is running Microsoft Internet Explorer browser version 5.0 or above can be used.

Pennsylvania Department of Transportation (PennDOT) and Mobility Technologies have an agreement to share raw sensor data from the installed sensor devices for public agency internal operations and planning. The raw sensor data are shared through direct access phone lines or other communication means available to PennDOT.

2.1.2 MTA Data Gathering

Data for the Pittsburgh and Philadelphia MTAs are gathered from the sensor units installed as part of this project and the current legacy system of PennDOT. The system uses microwave radar and acoustic based units.

2.1.2.1 Traffic Sensor Data

Sensor data include volume, lane occupancy, speed, lane density, and classification (large or small vehicles) data to the extent they are available from the devices. These data are processed at the NTDC to highlight real-time area traffic maps with colored links that indicate the status of traffic flow on the system. These data also provide input into the congestion detection portion of the system in order to provide alerts to both public and private users of the system.

2.1.2.2 Legacy System Data

The ability to include data from existing systems is a key feature of the data warehouse. Incorporating the data into a common warehouse at the NTDC serves both public and private sector interests. The system is designed to incorporate multiple legacy systems in the future; however, for this project, only one legacy system interface is provided for each city or MTA.

PennDOT supplies the initial Legacy System data. The Legacy System implements the National Transportation Communication/Internet Protocol (NTCIP) center-to-center communications protocol for the exchange of data. NTCIP is listed in the ITSNA as a standard to be used under the Broadcast Traveler Information (ATIS1) market package. As more agencies move to NTCIP-based systems, more data will become available for archiving.

Part of this implementation includes a definition of the message sets for the interchange of the sensor data. Mobility Technologies shares the following data items:

Raw Data: Mobility Technologies shares raw data from the sensors within an MTA's legacy system to enhance the coverage and effectiveness of both systems. Data are transmitted through the available communication lines between the TMC and the NTDC.

Planned Incident Data: Planned incidents are known events—such as construction reports and major events—that may affect traffic flows on the system. Initially, this information is entered manually. Specific data elements and formats will depend upon availability of the data and are defined during the software development process.

The information is displayed on a map of each city that shows sensor locations and color-coded conditions at the sensor locations. PennDOT has access to the real-time and archival database in order to support their freeway surveillance and incident management activities. TMC can export their data into the NTDC and extract live data from the NTDC by using local Internet connectivity. The interface at the NTDC is supplied and maintained by Mobility Technologies.

2.1.3 NTDC Data Sharing and Storage

A key function of the NTDC system is the implementation of ITSNA standards that allows the public sector partners to share the information gathered by the system. Data are received from the sensors and processed to determine the current status of the roadway. Current status is represented on a "real-time map" available through the Internet. The data used to determine the status are stored at the NTDC and are available to the public sector through the Internet. The real-time map data are also used in the private sector to provide information through Internet technologies to subscribers of the data on a fee basis.

Data are stored in a historical data warehouse and made available to public sector users and subscribers approved by Mobility Technologies. Specific data types include the following.

- **Raw Data** - Unprocessed data received directly from a sensor or other traffic-sensing device. Some agencies may prefer to have this kind of data in native format instead of summarized or processed sensor data. Data received from the legacy system may be in a raw or processed format depending on agreements and standards used. For example, raw data on volume, occupancy, speed, and classification can be provided as received from the sensor at the time the data is polled from the device.

- **Processed Data** - Data derived from the raw data. Processed data may include summarized totals for certain time periods and congestion detection data resulting from processing the raw data. Traffic data generated for display on graphic maps or for other public consumption are also considered processed data. The specific nature of these data is well defined and adheres to the ITSNA standards where applicable.

2.1.4 NTDC Data Reporting

The NTDC system provides a variety of reports in both online and offline mode. The online reports provide a snapshot of traffic and device status at the time of the request. The offline reports are available through the data warehouse function. The system reporting features available to the public sector partners include:

- Preformatted and customized reports
- Ad hoc reporting capability
- Data downloading from historical or archived warehouse.

2.1.5 NTDC Operations and Maintenance

The NTDC system is designed with security and availability as key aspects of operations and maintenance. A password-based logon facility is controlled by a Mobility Technologies administrator that allows multiple levels of system access based on the system users' needs and responsibilities.

2.1.6 User Needs

Public sector stakeholders are expected to realize short- and long-term benefits from the NTDC system including access to a repository of historical information available for roadway and transit projects. The user needs identified below are represented by the User Services in the ITSNA. While this is not intended to be an exhaustive comparison, representative ITSNA User Services are shown with each identified user need. Specific public sector stakeholder needs and benefits include the following (Traffic.com, 2001a, 2001b):

PennDOT Central Office expressed a need to have access to the traffic count information, produced by the system, on a 24-hour, 7-day basis with counts totaled on a 15-minute basis. The system will be able to provide this information. There was also a discussion to include the Statewide Automatic Traffic Recorder (ATR) information as a part of the system. This could be accommodated in the future, as the one legacy system for this project has already been chosen. Currently, Mobility Technologies provides customized output reports and data formats consistent with the PennDOT Highway Performance Monitoring System (HPMS) statewide reporting requirements and ADUS. **ITSNA User Service – Archived Data User Services (ADUS)**

PennDOT District 11-0 is interested in sharing sensor data in order to enhance their roadway coverage to improve their operations and better benefit the traveling public in the Pittsburgh area. They have a need for access to the raw sensor data on a real-time basis. They also see a benefit to using the historical data for planning purposes. **ITSNA User Service – Pre-Trip Traveler Information, Traffic Control, and Incident Management**

Port Authority of Allegheny County public transit system would like to have access to incident and congestion data for the purpose of notifying bus operators of traffic conditions. The system may be able to provide some of that information. The Port Authority also sees a benefit to having access to count information in order to plan new routes and projects such as park-and-ride lots. **ITSNA User Service – Pre-Trip Traveler Information and Route Guidance**

The Southwestern Pennsylvania Commission (SPC) expressed an interest in the historical data for use in planning for and prioritizing future traffic-related projects. They would like to have online access to the data warehouse reporting facility. **ITSNA User Service – Archived Data User Services (ADUS)**

City of Pittsburgh would like to use traffic count information for planning purposes in areas where the sensors are covering city arterials. They also feel that with the implementation of a new traffic control system that is currently in the procurement stage the city will be able to take further advantage of and share additional information with the Mobility Technologies system. **ITSNA User Service – Traffic Control and ADUS**

Pennsylvania Turnpike Commission (PTC) currently has very extensive count information with their fare collection system. This information can be input into the archived data warehouse in the future. The PTC is also interested in having current information on incidents and congestion around the turnpike interchanges. This would allow them to notify the travelers of conditions at those exits. **ITSNA User Service – Pre-Trip Traveler Information, Route Guidance, and Incident Management**

2.2 System Architecture

The Mobility Technologies system is one of the initial systems developed to demonstrate the cooperation between the public and private sectors as they implement ITS technologies that will cross-jurisdictional boundaries. The system architecture, based on ITSNA standards, is designed to promote data sharing between existing (legacy) systems, new systems such as the Mobility Technologies system, and future information technology systems in order to improve traffic flows and traveler information. This design is consistent with the intent of the TEA-21, Section 5208 ITS Integration Program. Detailed system descriptions are provided in *"System Requirements Definition – Pittsburgh"* Final Report, issued in January 2001.

The system design also reflects the need to provide an evolutionary, cost-effective integration path within a metropolitan area. This means using existing systems and infrastructure to the extent practical, while implementing the ITSNA standards in an evolutionary manner. The ITSNA User Services and Market Packages based on this implementation have been identified in Section 2.1 of this report. Recognizing that it is impractical to implement all new standards immediately, this design allows the region to begin working with and learning about the architecture while gaining some practical benefits.

The system consists of a network of sensors located across a metropolitan area and connected via a communications network to the NTDC. Each sensor, used to collect information in real time, continuously monitors the roadway and communicates to the NTDC on a regular basis (currently configured at intervals of 60 seconds) sending all of the information gathered in that period. The data, which are processed at the NTDC, are used for both real-time distribution and data archive purposes.

The NTDC is a multi-tiered, distributed processing system with interfaces out to the Internet as required. The Mobility Technologies system sends data to the ISDMI Internet interface and the PC-based interface software system at the NTDC. Both the MTA systems and the PC-based interface software system process the data in real-time and maintain a congestion map of the MTA area. The MTA system data are then passed to the data warehousing portion of the NTDC. This allows the shortest implementation time and optimal use of existing and proven off the shelf hardware and software.

The PC-based interface software supports multiple operator interface workstations capable of concurrent system access and control. In addition, remote operator interface workstations are supported.

The NTDC system is a Center Class system in ITSNA terms and will consist of the following elements as shown in Figure 2-1:

- Data Collection subsystem
- Data Warehousing subsystem
- Data Processing subsystem
- Links to roadside sensors (Roadside Class)
- Links to Pittsburgh legacy system (Center Class)
- Links to the Mobility Technologies distribution and presentation system (Reporting), consisting of Web sites and other applications (Traveler Class).

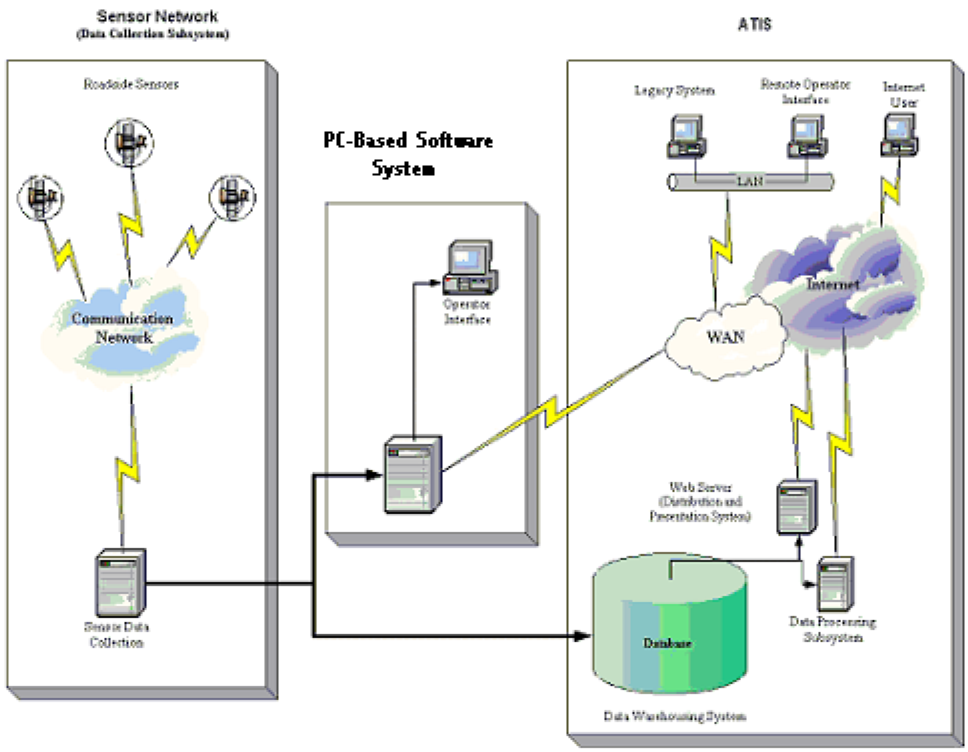

Figure 2-1. Mobility Technologies Model System Architecture
(Source: Systems Requirements Definition – Pittsburgh Final Report, Jan 2001)

2.2.1 NTDC System Requirements

Requirements for the NTDC system focus on data storage, retrieval, and reporting as well as operational and training issues. Specifically, the requirements fall into the following six categories:

- Data Retrieval and Storage
- Congestion Detection
- Data Warehouse
- Data Reporting
- Operations and Maintenance
- Training.

2.2.2 Data Retrieval and Storage

One of the main purposes of the system is to retrieve traffic-related data and store the data for both real-time and archival use. The following sections cover the retrieval and storage of data including Sensor Data and Legacy System Data.

2.2.3 Sensor Data

This section details the collection process and storage requirements for data retrieved from the sensors. It also identifies the specific data elements that can be retrieved from the sensors.

2.2.3.1 Sensor Data Collection Process

The part of the sensor network located along the roadside is designed to communicate with the sensor device via any communication media (twisted pair copper, telephone dial-up, radio, cellular, fiber-optic) that will support RS-232 protocols. The system is capable of supporting multiple communications rates or media within the same system. These rates are configurable by individual communications channels within the sensor device itself. Many sensors, such as the RTMS units, typically communicate at 9600 baud, but the MTA system supports device speeds from 1200 baud to 56 KBPS, as provided by the wireless carrier.

The sensor data collected along the roadside over the RS-232 channel is communicated from the roadside back to the NTDC over a standard Internet protocol (TCP/IP). Sensors collect traffic data continuously along the roadway and are configured to send that data to the NTDC at regular intervals. Time intervals need to be kept short to improve the value of the real-time data. Time intervals are optimized to improve data quality reported by a sensor. Initial systems target 60-second time intervals to provide an efficient balance between real-time data, communication requirements, and sensor averaging. However, the time intervals may vary to optimize the performance of the system components. Sensor data are expected for all detection zones defined on a device. This data are forwarded to the NTDC system for processing and storage.

2.2.3.2 Sensor Data Elements

Typical traffic sensor attributes, such as volume, occupancy, and speed, are retrieved from the device for each of the defined detection zones and stored as raw sensor data in the NTDC database by time of day and date. These data are used by ISDMI systems software to compute data elements such as traffic congestion and traffic density. Table 2-1 describes the types of stored sensor data.

Table 2-1. Stored Sensor Data Elements

Data Element	Description
Long Vehicle Count	Count of the number of long vehicles (over 50') detected during the previous detection period.
Volume	Count of all vehicles detected by the sensor during the previous detection period
Occupancy	Percentage time of vehicle presence in the respective detection zone in the preceding counting period.
Speed	Average speed of vehicles in the respective zone during the detection period.
Device ID	A unique ID for the sensor providing the data. This can then be associated with a specific location.
Congestion	Comparison of actual speeds from the sensors to historical or user-specified speed thresholds computed other application systems located at the NTDC.
Density	The number of vehicles occupying a given length of lane or roadway averaged over time. It is usually expressed as vehicles per mile or vehicles per mile/per lane. The accuracy of this calculation with the initial system implementation will depend on the quality and quantity of the data available for the calculation.

2.3 System Deployment Status

2.3.1 Pittsburgh

At the time of evaluation data collection, 111 sensors were installed along urban freeways and major arterials in the Pittsburgh area. The systems have been operational in Pittsburgh, gathering, processing, and storing traffic data since September 30, 2000. Table 2.2 shows the corridors and the sensor identification numbers on each corridor. Training sessions were conducted for stakeholders in Pittsburgh in December 2000 and February 2001. This was followed by a system acceptance testing conducted in May 2001.

Mobility Technologies also uses helicopters, vehicles, and listening scanners to get up-to-date real-time traffic information that is transmitted via radio and Internet. The scanners capture information on incidents and events, which are then provided to the broadcast partners. Different free-web access is provided to enable stakeholders and the general public to access real-time traffic condition data. Information available at the stakeholder website is more comprehensive than what is available at the general public website. Stakeholders are also able to access the archived database. Most stakeholders in Pittsburgh requested and were provided with Internet access usernames, passwords, and a PC-based user interface software. In addition, value-added commercial services are provided on a fee basis to media houses that operate radio and TV stations. Currently, two media houses operating ten AM and FM radio stations and two TV stations in Pittsburgh obtain their traffic information from Mobility Technologies.

Table 2-2. Location of Sensors by Corridor in Pittsburgh Area

Corridor / Route Number	Number of Sensors Prior to 10/01/01	Number of Sensors after 1/31/02	Sensor IDs
1005	2	2	613, 633
3020	1	1	283
28B (SR 1001)	2	2	40, 253
I-279	15	24	8[1], 9[1], 10[1], 11, 16[1], 17, 18, 26[1], 27, 29, 293, 294, 374, 1633, 1634, 2635[2], 2636[2], 2637[2], 2638[2], 2655[2], 2656[2], 2657[2], 2658[2], 2675[2], 2676[2], 2595[3], 2598[3], 2599[3], 2615[3]
I-376	8	13	32, 33, 34, 35, 36, 270, 1631, 1632, 2557[3], 2559[3], 2575[3], 2596[3], 2597[3]
I-579	2	2	416, 417
I-79	10	10	19, 20, 21, 22, 24, 25, 28, 30, 31, 42
PA-121	1	1	373
PA-2040	2	0	281[4], 282[4]
PA-228	2	2	276, 278
PA-28	7	10	37, 39, 43, 47, 49, 267, 268, 2560[3], 2563[3], 2576[3]
PA-380	1	1	393
PA-50	1	0	418[4]
PA-51	6	6	5, 255, 258, 259, 260, 263[4], 272, 284[4]
PA-60	3	3	13, 14, 413
PA-65	5	5	1, 2, 6, 269, 271
PA-8	7	4	44, 45[4], 46, 48, 254, 419[4], 420[4]
PA-837	1	1	7
PA-88	3	2	52, 53[4], 280
PA-885	5	5	264, 265, 266, 274, 275
PA-910	2	2	38, 41
SR 19	9	5	256[4], 261[4], 262, 273, 277[4], 279, 285[4], 414, 415
US-22	4	4	12, 15, 23, 56
US-30	2	1	58
SR 3104	2	2	3, 4
SR 3069	2	2	653, 673
SR 2048	2	2	54, 55
SR 4003	2	2	50, 51
Total	111	114	

Notes:

[1] *These sensors were removed and replaced with new sensor numbers*
[2] *These sensors were added to replace the ones removed*
[3] *These are new sensors*
[4] *These sensors were removed – actual removal of site.*

These changes were part of an improvement project conducted from October 2001 through January 2002. There were 111 sensors at the time of evaluation of data collection.

2.3.2 Philadelphia

The system deployment in Philadelphia followed the deployment in Pittsburgh. The system design is essentially the same as for Pittsburgh. About 50 sensors were installed, mainly for the Republican Party national convention, in August 2000. A total of 178 sensors were installed in the Philadelphia area. Table 2-3 shows the locations of the sensors by corridor. System acceptance testing was completed on November 1, 2001, and stakeholder training was conducted on November 28 and 29, 2001.

Similar to the system in Pittsburgh, Mobility Technologies provides information via radio and Internet. Stakeholders are provided Internet access to the web applications. In addition, value-added commercial services are provided on a fee basis to media houses that operate radio and TV stations. Currently, three media houses operating seven AM and FM radio stations and the NBC TV station in Philadelphia obtain their traffic information from Mobility Technologies.

Table 2-3. Location of Sensors by Corridor in Philadelphia Area

Corridor / Route Number	Number of Sensors	Sensor IDs
Route 202	11	1830, 1831, 1832, 1833, 1835, 1836, 1837, 1838, 1839, 1840, 1841
I-476	28	353, 433, 434, 453, 454, 493, 753, 793, 1930, 1931, 1932, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040, 2041, 2042, 2043, 2044, 2045, 2046
I-95	72	513, 514, 533, 534, 553, 554, 773, 1113, 1133, 1153, 1193, 1213, 1233, 1293, 1313, 1473, 2047, 2048, 2049, 2050, 2051, 2052, 2053, 2054, 2055, 2056, 2057, 2058, 2059, 2060, 2061, 2062, 2063, 2064, 2066, 2067, 2068, 2069, 2130, 2131, 2134, 2135, 2136, 2137, 2138, 2139, 2140, 2141, 2142, 2143, 2144, 2145, 2146, 2147, 2148, 2149, 2150, 2151, 2152, 2153, 2154, 2155, 2156, 2157, 2158, 2230, 2482, 2483, 2484, 2485, 2487, 2488
I-76	42	813, 833, 853, 873, 893, 913, 933, 953, 973, 993, 1013, 1033, 1053, 1073, 1093, 1253, 1273, 1393, 1413, 1433, 1453, 2489, 2490, 2491, 2492, 2493, 2494, 2495, 2496, 2497, 2498, 2499, 2500, 2501, 2502, 2503, 2504, 2505, 2506, 2507, 2508, 2509
Penrose Avenue (PA-219)	4	713, 2519, 2520, 2521
I-676	2	693, 1173
Route 1	3	2510, 2516, 2517
Route 63	1	2518
Route 422	8	2522, 2523, 2524, 2525, 2526, 2527, 2528, 2529
Route 309	7	2530, 2531, 2532, 2533, 2534, 2535, 2536
Total	178	

CHAPTER 3: EVALUATION STRATEGY AND APPROACH

3.1 Introduction

This chapter presents the evaluation strategy and approach. The evaluation goals, measures, and hypotheses to be tested as well as the technical approach of the evaluation are described. A complete discussion of the evaluation plan is contained in the "*Evaluation Plan*" (Battelle, 2001a) issued in January 2001. Additional details, including the designs of specific studies that were carried out (congestion, technical effectiveness, safety, customer satisfaction, and institutional issues), are provided in *Test Plans* (Battelle, 2001c, 2001d) for each study identified in this evaluation project.

3.2 Purpose and Scope of the Evaluation

As noted in Chapter 1 of this report, the primary purpose of the evaluation is to demonstrate the technical and institutional feasibility, costs, and benefits of the primary ITS user services in the areas of traveler information, route guidance, traffic control, incident management, and archived data functions, and to further encourage deployment of the systems in other cities.

The ITS evaluation goal areas relative to the ISDMI systems deployment defined below reflect the expectations of the effects of ISDMI systems on traffic management and operations by both state and local transportation agencies.

System Performance – This goal area evaluates the ability of the ISDMI systems to perform their intended functions of capturing, processing, storing, and delivering accurate and timely traffic data to all potential users.

Mobility – This goal area evaluates the ability of road users to move from one point to another on the road network with minimal delay. The ability to do so will be enhanced by having access to real-time traffic condition information. Such data allow the trip maker to plan trips and access route guidance information. Mobility will also be improved for public transport operators to provide accurate information to customers on schedules and delays.

Safety – This goal area evaluates the impacts of availability of real-time traffic information to motorists and public stakeholder agencies on safety. This information may contribute to reducing the number of crashes on the roadway system. However, this study does not attempt to assess the system's impact on numbers of crashes. Instead, the study focuses on changes in incidence response times due to improved access to real-time traffic data. Safety is a system-level outcome impacted by the mobility and system performance goal areas.

Productivity/Efficiency – This goal area evaluates the effects of using the ISDMI systems on the costs, time, reliability, and throughput relating to data collection, processing, storage (archiving), and reporting facilities.

Institutional Issues - This goal area identifies the institutional issues that need to be addressed to successfully deploy the ISDMI systems.

3.3 Evaluation Strategy

The evaluation strategy and plan was developed in two steps. First, an evaluation workshop was conducted to obtain stakeholder inputs in terms of consensus on goals and objectives of the evaluation effort and opportunities for data collection. In this step, key features and expected changes following the deployment of the ISDMI systems were identified. Initial priorities of evaluation goals and objectives were also established at the Evaluation Workshop conducted in Pittsburgh in March 2000. The major anticipated changes are based on input from stakeholder representatives at the evaluation workshop. The expected changes are grouped into two functional areas and summarized in Table 3-1. The workshop provided the opportunity to identify potential data collection opportunities of the measures to evaluate the goal areas and to identify key contacts for coordination during the evaluation effort. Workshop participants included representatives of key stakeholders including the FHWA, Pennsylvania Department of Transportation (PennDOT), Southwestern Pennsylvania Commission (SPC) – the metropolitan planning organization for the Pittsburgh area, Allegheny County Port Authority (ACPA), Beaver County Transit Authority (BCTA), and the City of Pittsburgh.

Table 3-1. Expected Changes Due to ISDMI Systems Deployment

Traffic Data Gathering	Traffic Data Usage

- Enhanced and supplemental data gathering
- Faster and simpler traffic data collection and archiving
- Easy access to real-time traffic condition data
- Accurate traffic data to public
- Reduced traffic data collection costs
- Availability of archived data
- Easier, faster, and more detailed traffic data, e.g., traffic per lane (for facility usage assessment and planning purposes)
- More efficient use of infrastructure and resources
- Faster and lower cost production of preformatted, customized, and ad hoc reports.
	- More efficient incident detection and response (i.e., improved incident management)
	- Improved traffic control and surveillance (larger coverage area)
	- Improved public traveler information
	  - better customer service (transit operators)
	  - complaint response
	  - trip planning and best route – route choice decisions
	  - bus schedules (why bus is late? how late? alternative bus route?) – trip planning and customer service
	- Better risk management
	- Ability to identify traffic usage patterns year-round more easily
	- Ability to monitor changes in traveler behavior, e.g., mode change
	- Better traffic forecasting

In order to establish evaluation priorities, the participants reviewed and prioritized the evaluation goal areas according their perceived importance as they pertain the to the ISDMI systems deployment. Each stakeholder representing a key user group was asked to distribute 100 total points among the five goal areas. The total assigned to each goal area was used to rank the goal area. Table 3-2 shows the ranking of the various goal areas. The mobility and safety goal areas were identified to be mostly impacted by the deployment of ISDMI systems. This is followed by the system performance goal area and then the productivity and efficiency goal area. The institutional issues goal area relating to interagency cooperation was not considered to be significantly impacted by the ISDMI systems deployment.

Table 3-2. Ranking of Evaluation Goals by Stakeholders

Goal Area	Stakeholder*					Average Score
	PennDOT Central	PennDOT Dist - 11	PA Port Authority	SPC	FHWA	
Safety	40	40	35	20	20	31
Productivity/ efficiency	10	5	5	20	20	12
Mobility	40	40	35	20	20	31
System Performance	5	10	20	20	20	15
Institutional issues	5	5	5	20	20	11

* - *stakeholders present at the evaluation workshop*

The second step in the evaluation strategy was to finalize the preliminary evaluation strategy based on outputs from the evaluation workshop. This involved identification of measures for evaluating the various goal areas. The hypotheses that were used to evaluate the expected changes associated with each goal area were then developed. Methods were then identified for collecting relevant data on the measures to test the hypotheses and to help evaluate the success of the goal areas. A detailed description of the evaluation strategy is provided in the *"Evaluation Plan"* (Battelle, 2001a).

A presentation of the evaluation plan was made to the stakeholders in Philadelphia on July 10, 2001, at the Institutional Coordination of ITS in the Delaware Valley Technical Task Force meeting. The presentation highlighted the scope and objectives of the evaluation effort and provided an update of the evaluation effort in Pittsburgh. Key contact persons representing the various stakeholders were identified for data collection purposes. Stakeholders included representatives of PennDOT District 6, PennDOT Bureau of Planning and Research, Delaware Valley Regional Planning Commission (DVRPC), FHWA-Philadelphia office, Pennsylvania Port Authority, Delaware River Joint Toll Bridge Commission, Delaware River Port Authority, SEPTA-Transit Authority, and the City of Philadelphia.

3.4 Evaluation Study Areas

This section outlines the technical approach for evaluating the five major goal areas. Six study areas are identified. Details of the tests conducted are described in the *Test Plans* (Battelle, 2001c, 2001d) developed for each study.

3.4.1 Technical Effectiveness Study

The technical effectiveness study area focuses on the system performance goal area. Measures in this study evaluated the ability of the systems to perform the intended functions. The technical effectiveness study attempted to address the following types of questions:

- What difficulties are encountered in collecting and processing, archiving, retrieving, and reporting of traffic data with the new systems?
- What is the quality of data from Mobility Technologies' sensors and archived databases?
- Are systems capable of generating customized reports from archived databases?
- Are sensors and communication systems capable of capturing and transmitting accurate and timely traffic data in the required format to all users?

Data for the technical effectiveness study were gathered through key informant interviews and operational data analysis. All stakeholders were interviewed to provide information that can be used to address the above questions. These interviews were designed to provide qualitative and quantitative assessments of the interfaces, the quality of data, and reliability of systems. Information from these interviews was also related to the customer satisfaction study.

Analyses were conducted to assess the accuracy and quality of data collected with ISDMI sensors by comparing with data collected using manual and automatic methods. PennDOT Bureau of Planning and Research (BPR) conducted field tests to compare manual traffic volume counts with archived ISDMI data. These tests were undertaken as a means of evaluating the accuracy of data outputs from Mobility Technologies' sensors and database systems. System operational data analyzed were in three parts as described below.

1. First, manual traffic volume counts were compared with archived data from the ISDMI systems archived database. The objective is to examine the accuracy of the sensors in capturing traffic volume data.

2. Second, sample automatic traffic recorder (ATR) data were compared with traffic data downloaded from the archived database. The purpose is to examine the accuracy of the sensors and archived database in recording and processing traffic volume data relative to the ATR values.

3. Third, comprehensive data quality analyses of archived data for all sensors in Pittsburgh and a sample of sensors in Philadelphia were conducted. These data were downloaded from the ISDMI archived data base and subjected to a number of statistical analyses designed to assess the quality of the traffic data gathered, stored, and processed by the ISDMI systems. The quality tests were performed for traffic volume, traffic speed, and lane occupancy records for

5-minute data records. The 5-minute data records represent the finest level of archived data reporting available.

3.4.2 Customer Satisfaction

For purposes of this study, three groups of customers are identified (1) stakeholders, (2) the public (including the general public and known ISDMI subscribers), and (3) commercial entities or media houses (e.g., radio and TV stations). The customer satisfaction study assesses the benefits identified by these customers. These are subjective satisfaction levels expressed by each user affected by the system's deployment. Customer satisfaction is essential to successful adoption of new technology applications. Expansion and even retention of the system requires that customers be satisfied that the system is meeting their needs and represents an improvement over previous methods. The objective of the customer satisfaction study is to collect customer satisfaction information in two forms, qualitative and quantitative, for the convergent purposes of identifying levels of satisfaction and identifying areas of the systems in which users find improvements desirable. This study was designed to obtain information that can be used to address questions such as:

- How well are the data accepted and used by customers?
- Do customers find traffic information accurate and reliable?
- Are customers satisfied with the overall performance of the systems?
- What is the added value of the products offered by the system?
- What aspects are considered more useful or beneficial than other aspects?

Stakeholder satisfaction was assessed through key informant interviews. Customer satisfaction data from commercial entities, e.g., media houses, were obtained through a survey. Two media houses operating in the Pittsburgh area and three in Philadelphia area provided information relating to their qualitative assessments of satisfaction with and usefulness of traffic data provided by ISDMI systems.

- In conducting the customer satisfaction study for the general public, the focus is on gathering information on awareness, access, acceptance, use, and value. This is based on previous customer satisfaction studies that have employed the following model (Cluett, 2000):

  – Awareness level of the product or service
  – Access to the product or service
  – Acceptance (stated preference of product or service)
  – Use behaviors (revealed preference of product or service)
  – Valuation (willingness to pay for product or service).

While Mobility Technologies information is beginning to be disseminated to the public in the Pittsburgh and Philadelphia through the Internet and other media sources (e.g., television, radio, etc.), it is too early in the deployment of the system to evaluate these other sources of Mobility Technologies information. Therefore, this component of the customer satisfaction study is concerned only with evaluating the customer satisfaction of the information available to the public on the Mobility Technologies website, as well as the performance of the website.

In order to capture information to address the five components of the customer satisfaction model as it pertains to the Mobility Technologies (Traffic.com) website, two surveys were conducted: random telephone surveys of potential users (the general public) and an Internet survey of actual users. Using the two types of surveys allowed the measurement of awareness of the site, as well as satisfaction with the site and its information. Data from completed surveys were put into a database and analyzed statistically using the SAS software package.

There were several underlying assumptions. For example, the success of the test depended upon a sufficient number of respondents completing the survey. A total of 250 telephone surveys were completed in each city.

3.4.3 Congestion Study

The congestion study primarily addresses the mobility goal area. Congestion is directly related to mobility. Mobility was identified by the stakeholders to be the most important goal area to the system's deployment, and the changes expected are mainly related to mobility. The primary objective of the congestion study is to examine the effects of the availability of accurate and reliable real-time traffic condition data with a wide coverage area offered by ISDMI systems on traffic congestion. Real-time traffic data are required by the Traffic Management Center (TMC) of PennDOT District 11 in Pittsburgh and District 6 in Philadelphia to provide current traffic condition information to motorists via variable message signs (VMS) and highway advisory radios (HAR). Availability of pre-travel information is intended to help road users plan trips so as to avoid congested routes or routes where construction or non-recurring incident delays are expected. Similarly, timely and accurate traffic data are expected to help manage incidents efficiently to avoid delays and congestion.

The congestion study was designed to obtain information that can be used to address questions such as:

- What is the percent reduction in vehicle delays on the roadways, especially during peak hours?
- What are the changes in travel time between selected points on the roadway network?
- How have average operating speeds on congested streets changed with the system's deployment?

This study involves collecting and analyzing data to test the hypothesis that the availability of traffic condition and improved traveler information to road users will result in reduced delays and congestion to road users. The systems are expected to provide traffic managers with access to accurate, real-time traffic information in order to advise the traveling public through appropriate media such HAR and VMS. Similarly, traveler information available via the Internet, radio, and TV is expected to result in improved trip planning and route choice decisions by the traveling public.

The steps involved in data included site visits and observation of traffic flow data using video recordings of traffic conditions at selected sites in the network monitored by the traffic monitoring and surveillance systems of PennDOT's TMC, in Pittsburgh and Philadelphia. Also, archived traffic volume and speed were downloaded and analyzed. Data of interest for the congestion study includes parameters such as travel time, speed, and traffic volume. The purpose of the analysis is to examine changes, if any, in congestion at the locations and determine the approximate proportion of these changes that can be attributed to ISDMI systems.

3.4.4 Cost Study

The cost study addresses the productivity and efficiency goal area. The cost analysis was intended to quantify the non-recurring and recurring costs associated with deploying, operating, and maintaining the systems. The evaluation measures were chosen based on the premise that the ultimate goals of deploying ITS technologies are to improve operational efficiency and increase productivity. The cost study was designed to obtain information that can be used to address questions such as:

- What are costs associated with ISDMI systems deployment and operations (both MTA and NTDC components)?
- What are costs of data collection, processing, and archiving?
- Does the technology reduce or increase the time required to collect and process traffic data?
- What costs and implications are associated with real-time data access?

Cost data were collected through stakeholder interviews and operational data analysis. System deployment cost data was not available. The cost data gathered were limited to stakeholder costs for collecting, processing, and reporting data using their legacy systems.

3.4.5 Safety Study

Safety was prioritized as the second most important goal area that will be impacted by the system's implementation. However, it is recognized that it is practically impossible to measure any direct effects of the systems on safety. The objective of the safety study therefore is to identify potential safety benefits that could be associated with the deployment of the ISDMI systems. The safety study attempted to obtain information that can be used to address questions such as:

- Does the system improve incident management (detection and/or response times)?
- What are the potential impacts of improved incident management on safety?

Data necessary to evaluate safety impacts were collected through key informant interviews of stakeholders, particularly the TMC. Data on changes (perceived or actual) on incident detection and incident response times were gathered. For purposes of the evaluation, incident detection time was defined as the time between the occurrence of an incident and the time that the incident management team receives a report. Similarly, incident response time was defined as the time between detection of an incident and the arrival on the scene of the incident management team. Given that records of incident detection and response times were not kept, and the recognition that it is impossible to link any changes in safety measures directly to the ISDMI systems, the evaluation of safety impacts was limited to anecdotal inferences and perceived impacts based on the experiences of the officials of the TMCs.

3.4.6 Institutional Issues

The objective of the institutional issues study is to identify the policy issues and institutional arrangements that were likely to affect the deployment and operation of the new technology. Non-technical issues that impede as well as those that support the development and deployment of the technologies were identified. Any institutional changes (laws, regulations, and organizational structure) that might be affected by the deployment of the technologies as well as the portability of the technology to other locations were identified. The study was designed to obtain information that can be used to address questions such as:

- What are the institutional issues associated with the deploying the systems?
- Are there institutional and non-technical impediments or supports to the systems' deployment?
- What institutional structures are required to ensure system portability?

The institutional issues study was conducted through interviews of stakeholders and officials of Mobility Technologies. Information on institutional issues from stakeholders was gathered during the post-deployment interviews. This is because stakeholders would then have had the opportunity to use the system and be in a better position to provide information on the institutional issues in their respective agencies. In the case of the Mobility Technologies, the institutional issues interviews were conducted in February 2001, at a time when the systems had been fully operational in Pittsburgh.

CHAPTER 4: FINDINGS – PITTSBURGH

4.1 Introduction

This chapter describes the results of the studies identified in the evaluation plan and discussed in Chapter 3 of this report. Discussions presented in this chapter focus on the findings from Pittsburgh. The first data collection effort was carried out in Pittsburgh in November 2000 to gather baseline information against which to estimate the changes resulting from the deployment of the ISDMI systems. Post-deployment data were collected in Pittsburgh in April through August 2001. The baseline situation is first summarized followed by discussions of the findings from each study.

4.2 Summary of Baseline Situation

This section describes the baseline situation against which the changes resulting from ISDMI systems deployment are evaluated. Also, key stakeholder initiatives in deploying similar technologies designed to improve their respective traffic data gathering, analysis, and information activities are discussed in this section. These initiatives are important in evaluating the changes such as cost savings, technical effectiveness, and customer satisfaction. The stakeholder technologies were at various levels of deployment at the time of the ISDMI systems evaluation. These initiatives are also relevant in identifying any conflicts with the goals and expectations from the ISDMI systems. The following sections summarize the baseline situations by stakeholder.

4.2.1 PennDOT District 11-0 Traffic Management Center (TMC)

The primary functions of the TMC of PennDOT Dist 11-0 are freeway surveillance and incident management. The TMC provides traveler information to motorists through 20 VMS and 8 HAR stations. The TMC relies on information from 61 cameras installed at various locations on the freeways in the Pittsburgh area to monitor traffic flow in real-time and on a continuous basis. The TMC also provides incident information to the State Police and emergency services as part of their incident management activities. Typically, traffic data are not stored, but surveillance video can be recorded if requested for incident management purposes. The TMC does not exchange real-time traffic data with other organizations. The TMC does not monitor signal operations and does not archive traffic data.

The safety-related activity of the TMC is incident detection. When an incident is detected, the State Police are contacted. Motorists usually call TMC using cellular phones when they observe an incident. The TMC staff then calls the State Police with the information. The State Police handle all subsequent contacts. The TMC may also provide a video of the incident to the State Police when requested (for locations covered by the cameras). The State Police have access to the TMC with map display facilities and are able to view incident locations.

PennDOT District 11-0 Traffic Division uses archived ATR data to study traffic trends. This information is used to examine expansion options on the highway systems and also to advise maintenance crews on movement and scheduling of maintenance activities.

4.2.2 PennDOT Bureau of Planning and Research (BPR)

The Bureau of Planning and Research (BPR) of PennDOT collects traffic data using automatic traffic recorders (ATRs) at 63 locations on freeways and arterials. Of this number, 28 are installed on 2-lane highways, 21 on 4-lane highways, and the remaining 14 on 6- and 8-lane highways. The kinds of traffic data collected include traffic pattern, peak hour traffic, 30^{th} hour, speed, and vehicle classification. The data are stored on a mainframe computer. The BPR processes these data and forwards them along with summaries and 5-year annual average daily traffic (AADT) to PennDOT district offices. The information is usually compiled into a traffic data book, which is made available on the web. ATRs have 6% downtime, primarily for quality control purposes involving preventive maintenance and re-calibration of equipment. Traffic data from ATRs are usually collected between April and October of every year. The traffic data are not used for crash analysis. One staff (1 FTE) is solely responsible for reducing and compiling traffic data obtained from the ATRs. The BPR is currently working with an independent consultant to review the data editing process to make it more efficient.

4.2.3 Beaver County Transit Authority (BCTA)

Beaver County Transit Authority (BCTA) serves Beaver County and certain parts of Allegheny County. The BCTA does not monitor traffic conditions, except for conducting on-time studies for their vehicles using an automatic vehicle location (AVL) system. The BCTA collects travel time and time point data. These data are analyzed for the purposes of (i) random review of contractor performance; (ii) general quality of service analysis, and (iii) review of complaints. The BCTA uses spreadsheets to analyze planned versus actual schedules for quality monitoring purposes. Bus location information can be obtained in real time, when customers call in to get information on current bus location (typically in inclement weather). Real-time data are used to address customer service inquiries such as bus arrival times and schedules.

The existing AVL system, installed in 1991, was expected to be replaced with GPS by the end of 2000. The system is used for time, location, and speed data collection. Other data obtained include passenger counting, boarding times, especially for special needs customers, and engine performance. The new system is expected to have the functionality to respond to customer inquiries and provide accurate information on bus locations relative to customers' location. The BCTA does not interact with other agencies for traffic data sharing. The BCTA does not transmit any real-time information to other agencies.

The BCTA uses real-time data as well as archived data stored on hardcopy. The only kind of archived data are bus travel time and location data that are stored for 90 days only. The current system does not permit electronic data storage.

4.2.4 Allegheny County Port Authority (ACPA)

Allegheny County Port Authority (ACPA) operates light rail, bus (busway systems), 2 inclined plane railways, and paratransit (for elders and disabled). The ACPA operates about 1,000 buses, 55 light rail vehicles (28 more ordered), and about 100 paratransit vehicles. The ACPA conducts about 5,000 to 6,000 revenue vehicle-trips per day, with 2,000 to 3,000 time points. There are about 2,000 operators. In addition to the revenue vehicles, they operate non-revenue vehicles for maintenance and monitoring purposes. There are about 15,000 bus stop shelters and transit stations interfaced with the street system. Scheduling for their vehicles is computerized. Because of the electronic fare collection, there is 100% coverage for passenger counts. Bus location is monitored through GPS devices. Bus drivers have radios and they report to a centralized location (two-way communication). There is no other real-time monitoring.

Passengers call in to a customer service center for information on bus locations, in case of inclement weather. The ACPA does not collect or store vehicle location data. In terms of archived data, the agency conducts a system-wide passenger survey every 6-8 years. Data are stored in electronic format. The agency is in the process of installing new AVL devices on their vehicles for conducting on-time studies.

4.2.5 Southwestern Planning Commission (SPC)

Southwestern Planning Commission (SPC) is the local metropolitan planning organization (MPO) in the Pittsburgh area. The agency collects traffic data for the department of transportation and also conducts congestion management studies. Congestion management studies are conducted periodically using travel time studies to collect traffic condition data.

4.2.6 Competing Deployments

Some of the stakeholders were in the process of deploying new technologies or upgrading their traffic data collection systems at the same time that the ISDMI systems were implemented. These developments should be taken into account in reviewing the benefits that may result from the implementation of the ISDMI systems. The following are examples of systems to be deployed by various stakeholders.

- PennDOT Dist 11-0 TMC is installing its own vehicle detection system that consists of detectors using microwave technology capable of collecting traffic data across all lanes. The TMC planned to install 57 detectors by the end of 2001.

- The BPR had invited bids for the installation of double loop ATRs to replace the existing 63 ATRs. In addition, the BPR is currently working with consultants to upgrade their data editing software.

- The BCTA invited bids for the installation of new AVL systems and kiosks to provide traveler information to bus passengers.

4.3 Technical Effectiveness

The technical effectiveness component of the evaluation includes an assessment of the ability of the systems' components to perform their intended functions and an analysis of the quality of archived data. This analysis is designed to evaluate the ability of the systems to capture, process, store, and report traffic data accurately, completely, and of acceptable quality for the various applications. In defining data quality, the following attributes are used:

- Illogical or improbable data values that do not fall within expected ranges or meet established principles or rules;
- Expected data values that are missing because of hardware and/or software malfunction, quality control edits, or maintenance; or
- Data values that are systematically inaccurate (but within the range of plausible values) because of equipment measurement error (e.g., equipment improperly calibrated).

The following sections discuss results of analyses of accuracy and completeness of archived data from the ISDMI systems and an assessment of the quality of real-time data. Archived data from April through August 2001 were used for accuracy analysis and data from January through September 2001 were used for data completeness analysis. Some data used in the analyses were collected and archived prior to the system acceptance testing on May 9, 2001. MT was testing and fine-tuning the system during this time in Pittsburgh.

4.3.1 Archived Data

Two types of data were used in the data quality analysis. First, ATR data for the months of April through August 2001 were compared with archived data collected by sensors at the same location as the ATR. Second, manual traffic counts were compared with ISDMI sensor counts. Statistical analyses were conducted to characterize the accuracy of the sensors in capturing and recording traffic volume information. The manual and ATR counts are considered to be the standards to which data from ISDMI sensors are compared. Therefore, the data accuracy analysis compared traffic counts collected from ISDMI sensors to both the ATR and manual counts. It is important to note that these other data collection methods also possess some error. However, the point of the analysis was to compare the ISDMI sensors to an accepted standard, rather than absolute truth. Therefore, the error associated with the ATR readings and manual counts was not explicitly accounted for in the analysis. The analyses are discussed in the following sections.

4.3.1.1 Data Accuracy

This section describes the analysis that primarily examined accuracy, but first addressed aspects of reliability by considering when the ISDMI sensors appeared to be working properly. Hourly counts of the traffic volume were collected from ISDMI sensor 33 (location 3062) and from an ATR at a similar location. The two sites are in close proximity to each other and are located in Allegheny County on Interstate 376, 2.2 miles west of Pennsylvania Route 48, Exit #16. The traffic counts were collected hourly from the westbound lanes of traffic during the months of

April, May, June, July, and August 2001. These traffic counts were summed across each day to create daily traffic volume totals for these months as well and analyzed separately.

A primary goal of the technical effectiveness study is to characterize the accuracy of the traffic counts from the ISDMI sensors. Accuracy is comprised of two components: bias and precision. A bias represents a systematic difference in the data collection process, while precision quantifies how close individual measurements are to the average value. If the bias or precision inherent in the data collection process changes over time, the process is unstable. In order to adequately characterize the accuracy of the ISDMI sensor data, the process must first be in a state of statistical control. Thus, the analysis consists of two basic phases. The first phase is to remove any obvious patterns or gross measurement errors that are caused by an unstable measurement process, which is not in a state of statistical control. The second phase is to characterize the precision of the ISDMI sensor counts relative to the ATR readings and the manual counts. This analysis assumes that the ATR readings and manual counts are accepted as truth and are equivalent standards. Any known bias in these two data collection methods should be taken into account when interpreting the results of this analysis.

ISDMI Sensor vs. ATR -- Hourly Traffic Volume: First, hourly traffic counts obtained from the ISDMI sensor were compared with the ATR counts for the months of April through August 2001. In general, the two data collection methods agree quite well. However, a closer examination reveals some significant differences. These differences are most clearly illustrated by the absolute differences between the sensor and ATR readings, as shown in Figure 4-1. The absolute difference is simply the difference between the ATR and the sensor readings as distinct from the relative difference, which is the difference expressed as a percent of the ATR reading. The reference line at zero indicates the level around which the differences are expected to cluster. It can be seen that the readings from the two sources are often quite different, with many obvious excursions from the reference line.

The first step is to determine the stability of the data capture process. Upper and lower control limits were established as the mean plus or minus 3 standard deviations of the absolute differences between the ISDMI and ATR counts (Figure 4-1). Any differences falling outside these limits were discarded and the process repeated until the change in the percentage of the differences falling outside the limits was less than one half of a percent (0.5%).

Figure 4-2 shows the same graph after the outliers (i.e., spikes beyond the control limits) were removed from the data set and the control limits recalculated. Seven iterations of outlier removal and control-limit calculations were completed before the absolute differences reached this level of stability. In addition to these outliers, the data for April 1, 2001 (Sensor number 33) were removed. This is because the ISDMI sensor recorded no traffic volume for 10 hours on that day.

Although the sensor had been operational before the beginning of April, these readings are obvious indications that the sensor was not working properly at those times. It was determined that the erroneous data were probably due to sensor malfunction or MT downtime for routine maintenance, testing, or equipment fine-tuning.

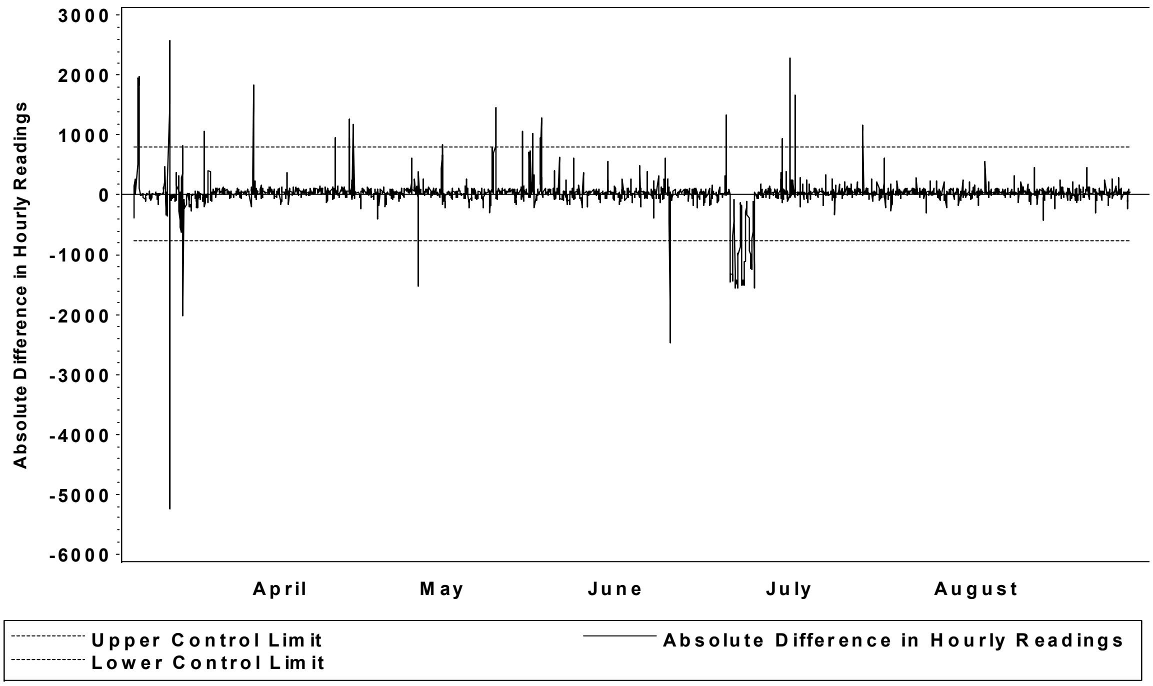

Figure 4-1. Absolute Differences between Sensor and ATR Hourly Traffic Volume Counts, Including Control Limits

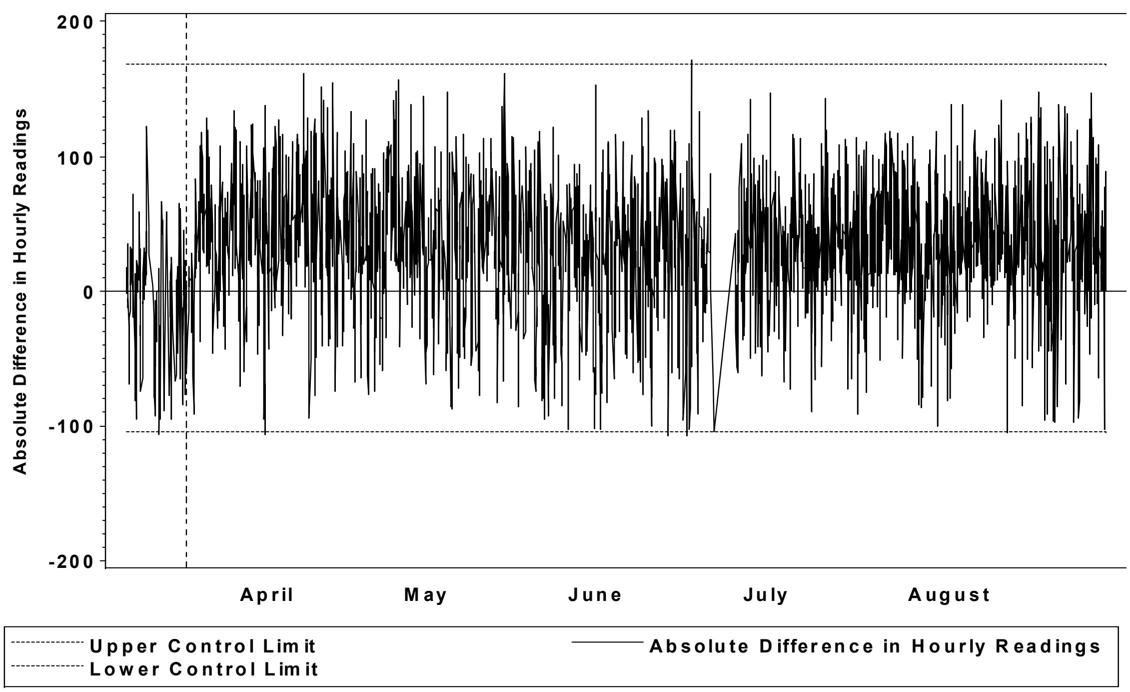

Figure 4-2. Absolute Differences between Sensor and ATR Hourly Traffic Volume Counts – Outliers and Zero-Readings Removed

Figure 4-3 shows that once the outliers and zero-readings are removed, the absolute differences appear to follow a fairly random pattern. In all, 338 points (11% of the data) were removed from further analysis. Figure 4-3 illustrates that the absolute differences follow a much more consistent pattern. However, the 81% of the differences that are positive indicate that the ISDMI sensor consistently underestimates the ATR count.

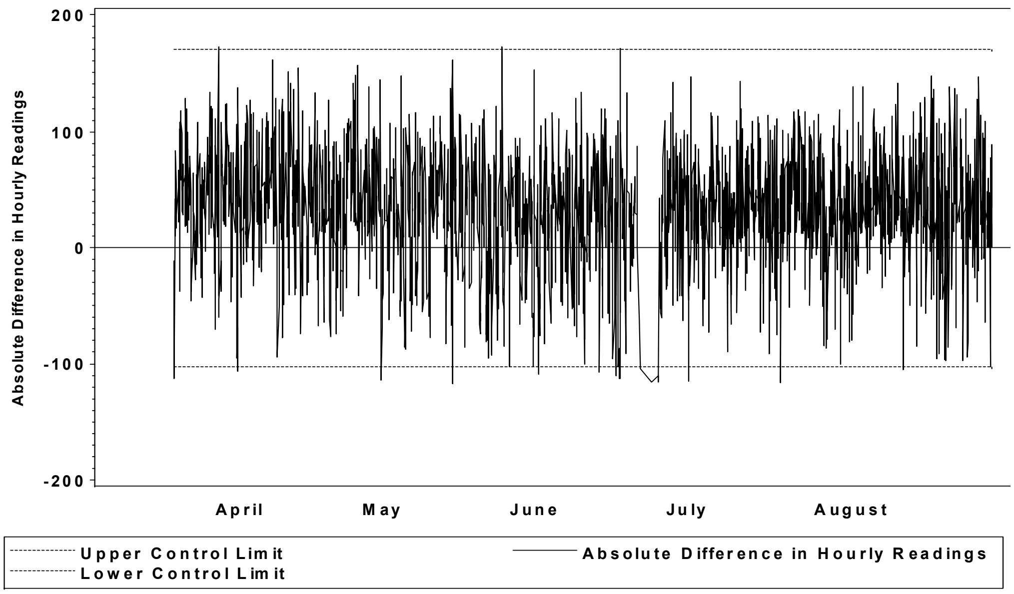

Figure 4-3. Absolute Differences between Sensor and ATR Hourly Traffic Volume Counts – All Unstable Data Removed

Having stabilized the process, the next step is to assess the precision of the sensor counts by examining the differences between the sensor recordings and ATR counts. Figure 4-4 displays the absolute differences versus increasing traffic count, as measured by the ATR. The patterns in the graph indicate that there may be significant variations in the absolute differences depending on the actual traffic volume. In order to explain the relationship further, a weighted piece-wise linear regression model was fitted to the absolute differences versus the ATR counts. The resulting model predictions and their associated approximate 95% prediction bounds are shown in Figure 4-5 along with the model-input data. Prediction bounds are defined as the limits that, on average, will include 95% of predictions. The prediction bounds in Figure 4-5 represent the precision associated with the absolute difference at a given ATR count. For ATR counts between 0 and 600, the precision ranges from (± 9.4 to ± 82.4). For counts of 600 to 1,700 the precision is (± 82.6 to ± 138.7). For counts of 1,700 to 2,300 the precision is (± 138.8 to ± 161.3) and for counts of 2,300 to 3,200 the precision is (± 161.5 to ± 189.8).

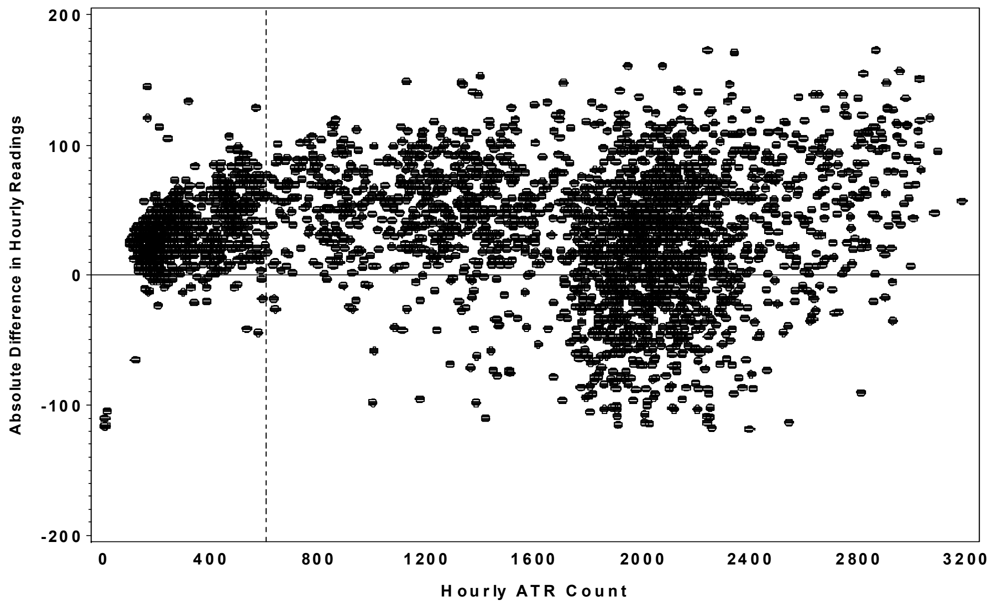

Figure 4-4. Absolute Differences between Sensor and ATR Hourly Traffic Volume Counts vs. Hourly ATR Count

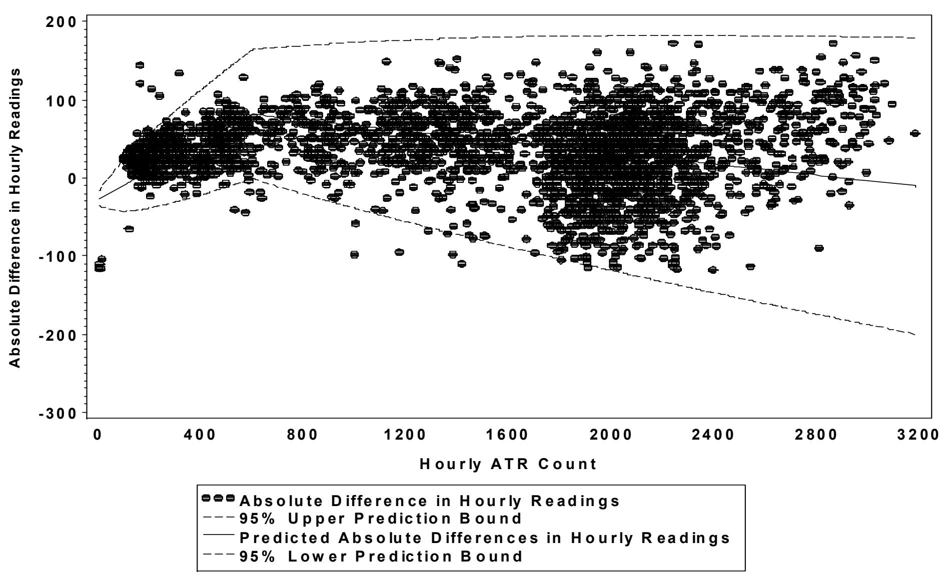

Figure 4-5. Weighted Piece-wise Regression Results of the Absolute Difference versus the ATR Readings – Approximate 95% Prediction Bounds Plotted

Now that the absolute differences have been adjusted for the variations in the traffic volume level, these differences can be expressed as relative differences, as shown in Figure 4-6. The relative differences are the absolute differences expressed as a percentage of the ATR count. Examining the differences in this way allows for a more direct standard of comparison. For instance, an absolute difference of 10 for an ATR reading of 100 (10%) is more problematic than an absolute difference of 10 for an ATR reading of 1000 (1%). However, a 10% difference carries the same weight regardless of the ATR reading. There are a few points that have extremely high positive values. Figure 4-7 illustrates the relative differences versus increasing traffic counts on a finer scale, without those extreme points. For ATR counts below 600, the relative difference ranges from approximately –11% to 87%. The range tightens dramatically at higher traffic levels. For instance, the relative difference ranges from –5% to 7% for ATR counts between 2,300 and 3,200. This is an indication that the sensor readings are more accurate at higher traffic volumes (i.e., smaller relative differences).

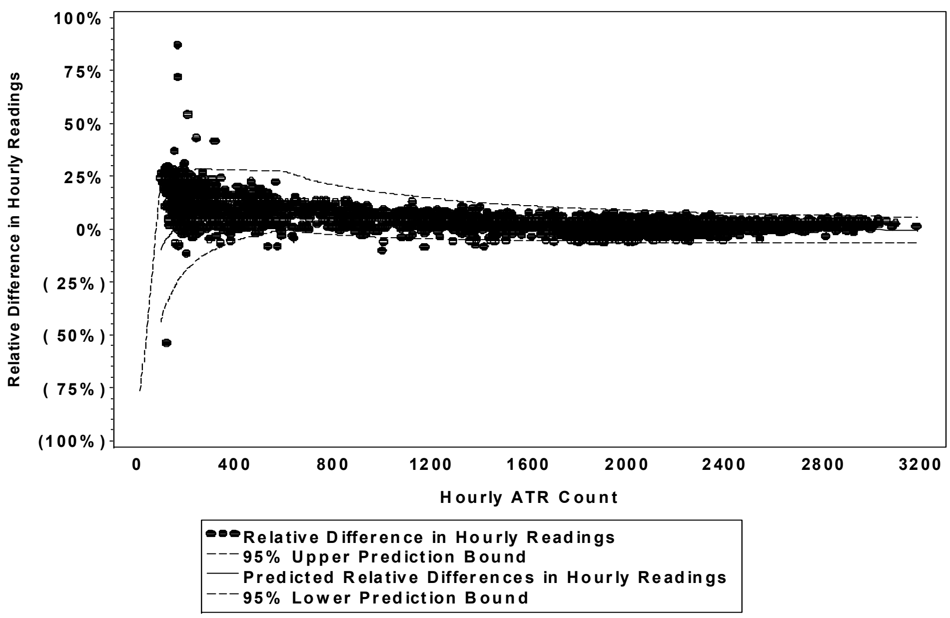

Figure 4-6. Relative Differences between Sensor and ATR Hourly Traffic Volume Counts versus Hourly ATR Count

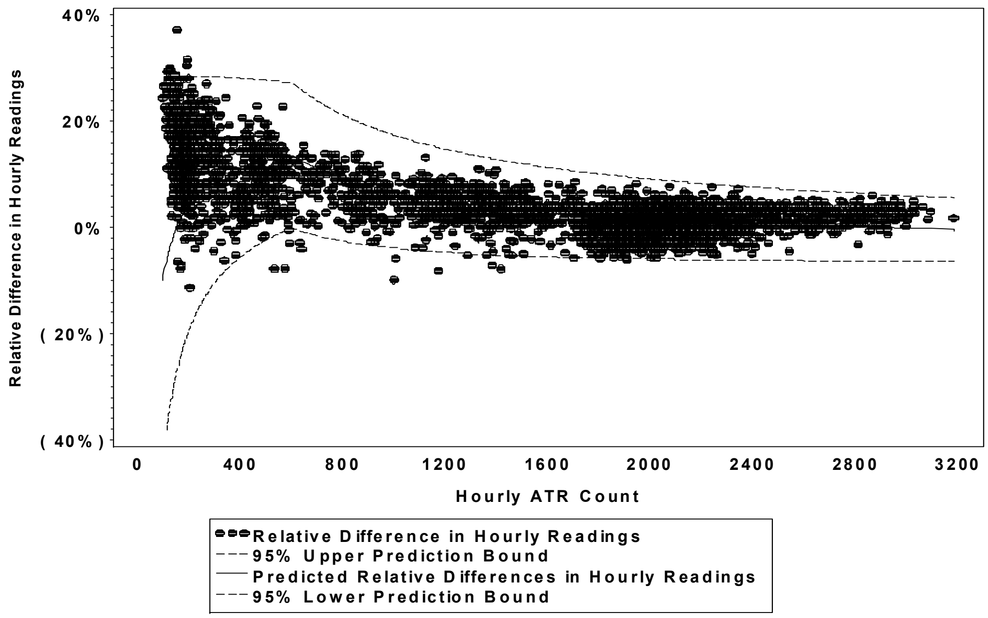

Figure 4-7. Relative Differences between Sensor and ATR Hourly Traffic Volume Counts vs. Hourly ATR Count – Finer Scale

Table 4-1 shows the average precision bounds for both the absolute and relative differences at a 95% confidence level. Table 4-1 shows the ranges and midpoint of the precision bounds relative to the ATR reading. The absolute differences between the ATR and sensor readings increase with increasing traffic volume. However, the relative differences decrease with increasing traffic volume recorded by the ATR (i.e., increased precision).

Table 4-1. Summary of Precision Bounds for ISDMI Data

Traffic Volume by ATR	Precision at 95% Confidence	
	Absolute Difference	Relative Difference
Minimum and Maximum Precision for Suggested Ranges		
0 - 500	± 9 to ± 75	± 15% to ± 133%
500 - 1500	± 75 to ± 130	± 9% to ± 15%
1500 - 2500	± 130 to ± 168	± 7% to ± 9%
> 2500	± 168 to ± 190	± 6% to ± 7%
Midpoint of Minimum and Maximum Precision for Suggested Ranges		
0 - 500	± 42	± 74%
500 - 1500	± 103	± 12%
1500 - 2500	± 149	± 8%
> 2500	± 179	± 7%

ISDMI Sensor vs. ATR Counts – Daily Traffic Volume: The next step in the analysis was to compare the ISDMI sensor and the ATR readings on a daily basis. The hourly readings were summed by day for April through August of 2001. Ninety-eight (98) of the 141 days contained at least one hourly statistical outlier. These days were removed from the daily analysis due to insufficient data. The absolute differences were calculated for the remaining 43 daily values and are plotted in Figure 4-8, which shows a plot of the absolute daily traffic volume differences against ATR counts. It is noted that all 43 points fall well above the zero reference line. This indicates that the daily counts recorded by the ISDMI sensors are lower than the ATR counts. Figure 4-9 shows the relative daily differences, ranging from (0.4% to 6%), versus the daily ATR totals. Since the results are identical to the hourly count analyses, no further analysis was performed on the daily traffic count data.

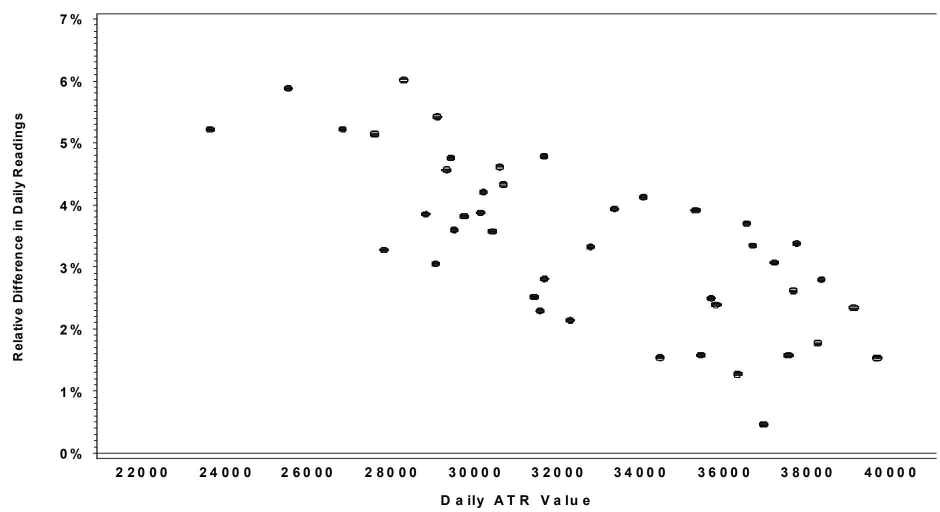

Figure 4-8. Absolute Difference between Sensor and ATR Daily Traffic Volume Counts vs. Daily ATR Count

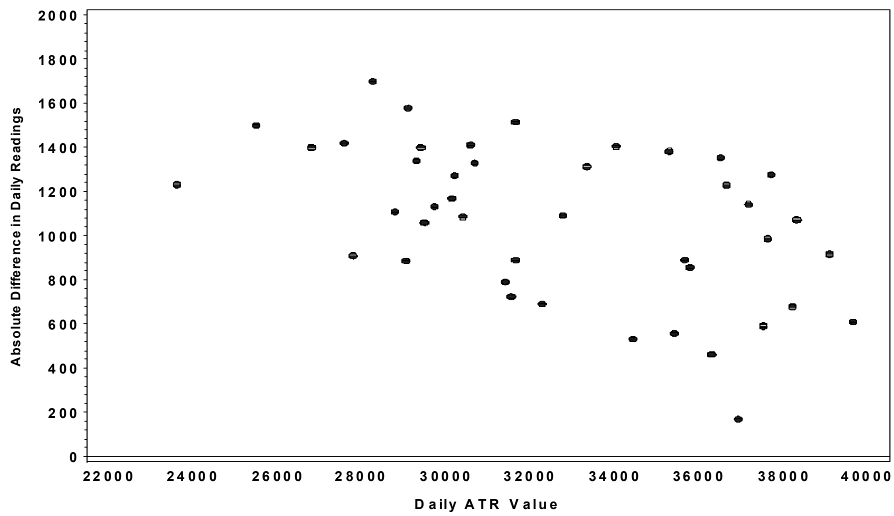

Figure 4-9. Relative Difference between Daily Traffic.com Sensor and ATR Readings

***ISDMI Sensor vs. Manual Counts – Hourly**:* The ISDMI sensor readings and manual counts of the traffic volume were also compared using data from ten (10) different test locations. Officials of the BPR conducted these field tests. The traffic counts were collected during various times from December 11 to 19, 2000. Each of the tests consisted of manually counting traffic volume for 2 or 3 hours at a given site for one direction of traffic. Table 4-2 provides a listing of the test sites. The test data consist of the ISDMI sensor counts and the manual counts for the same locations and times. Due to data limitations, simple descriptive analysis was performed. Figure 4-10 displays the ISDMI sensor data downloaded from the archived database and manual counts for each of the ten test sites.

The relative differences are shown in Figure 4-11, with different symbols denoting various traffic volume levels. It is observed that:

- ISDMI sensors generally underestimate the manual counts. In 18 of the 25 measurements (i.e., 72%), the ISDMI sensors recorded lower traffic volume counts than the manual counts.
- The difference between ISDMI sensor records and manual counts range between -16% and +20% relative to the manual counts.
- The relative difference is less than 10% for 76% of the tests conducted.
- The relative differences in sensor and manual counts are generally higher for manual counts greater than 1,500 vehicles per hour.

Table 4-2. Test Locations for ISDMI Sensor Counts vs. PENNDOT Manual Counts

Test #	Sensor ID	Location (Test Site)	Test Date	Counting Period	Traffic Direction
1	33	SR 0376 btw Ramp 8022 and SR2066 (#3062)	12/11/2000	1:00 – 4:00 PM	Westbound
2	33	SR 0376 btw Ramp 8022 and SR2066 (#3062)	12/12/2000	8:00 – 11:00 AM	Eastbound
3	50	Truck Route 19 btw Ramp 8079 and SR 4018 (#3084)	12/13/2000	1:00 – 4:00 PM	Northbound
4	50	Truck Route 19 btw Ramp 8079 and SR 4018 (#3084)	12/13/2000	1:00 – 4:00 PM	Southbound
5	28	SR 0079 btw SR 0022 and SR 0060 (#3096)	12/14/2000	8:00 – 10:00 AM	Southbound
6	28	SR 0079 btw SR 0022 and SR 0060 (#3096)	12/14/2000	11:00 AM – 1:00 PM	Northbound
7	265	SR 0885 btw SR 2040 and SR 2045 (#3084)	12/14/2000	2:00 – 4:00 PM	Southbound
8	22	SR 0885 btw SR 2040 and SR 2045 (#3084)	12/15/2000	11:00 AM – 1:00 PM	Northbound
9	22	SR 0079 btw SR 4011 and Ramp 8023 (#3061)	12/18/2000	9:00 – 11:00 AM	Southbound
10	33	SR 0376 btw Ramp 8022 and SR2066 (#3062)	12/19/2000	11:00 AM – 2:00 PM	Eastbound

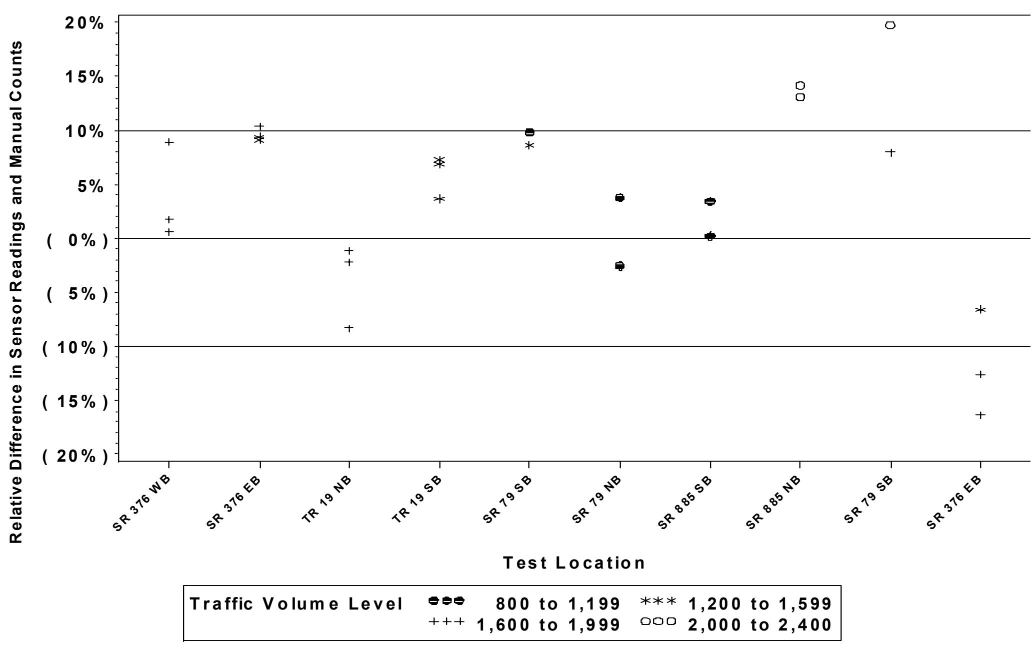

Figure 4-10. Actual Hourly Sensor Readings and Corresponding PENNDOT Manual Counts for Various Sites in the Pittsburgh Metropolitan Area

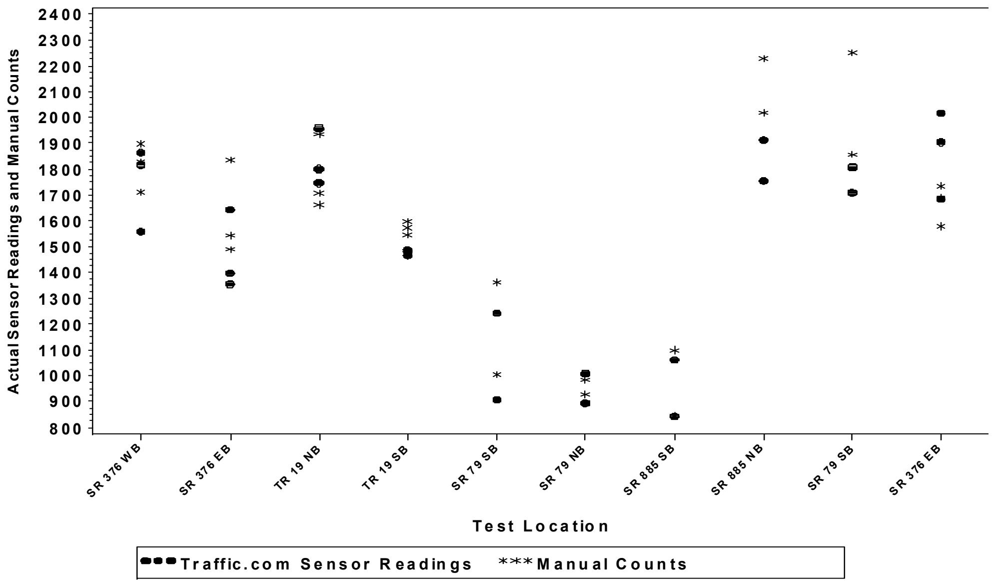

Figure 4-11. Relative Differences between Sensor Readings and Corresponding PENNDOT Manual Counts by Varying Traffic Volume Levels

4.3.1.2 Data Completeness

Another aspect of the technical effectiveness study is to characterize the completeness of the archived data collected by the ISDMI sensors. The data used for this analysis consists of volume, occupancy, and speed values reported at 5-minute intervals from January 1 through September 30, 2001, from the 111 ISDMI sensors in the Pittsburgh area. The sensor locations are shown in Table 2-2. Sensors record the volume, speed, and occupancy of individual or multiple lanes, and for some corridors, in multiple directions.

Each volume record represents the count of all vehicles detected by a sensor during a reporting period and the speed value represents the average speed of all vehicles detected. An occupancy reading represents the percentage of time a sensor detects a vehicle during a reporting period. The ISDMI database interface is structured such that archived data reports can be generated for reporting periods of 5-minute, 15-minute, 1-hour, and 24-hour intervals. The analyses presented in this report were performed on 5-minute data, which represents the smallest unit of reporting.

Analysis: Due to the large volume of data available (more than 10.7 million records of 5-minute intervals), this analysis is largely descriptive in nature. The primary objective of the completeness analysis is to assess the ability of the sensors to capture all possible data points. Data completeness refers to the number of actual data values compared to the number of expected values. As an example of data completeness, consider the following. In the analysis, traffic data at 5-minute reporting period intervals were used. Therefore, for each sensor, the expected number of records per day would be 288 (i.e., 1,440 minutes per day divided by 5-minute periods equals 288 records). The total number of records for each sensor for the January 1 through September 30, 2001, analysis period would be 288 multiplied by the number of days. The percent missing is the number of expected data points that were observed to be missing, expressed a percentage of the total number of expected records. Thus the percent complete is 100 less the percent missing. This does not take into consideration the percent of data missing due to system maintenance.

Summary statistics were calculated for each variable of interest (volume, speed, and occupancy), along with some qualitative summaries such as the number and percent of values that are missing, zero, or negative. In an attempt to gauge the validity and consistency of the reported variables, the data were compared to specific bounds derived from assumed relationships among the three measures. Summaries were constructed by corridor and aggregated over all months. The negative traffic volumes and the corresponding occupancy and speed records were included in the calculation of the average, standard deviation, and median values shown in Table 4-3. The purpose of this analysis is s to characterize the data collected and therefore, it is appropriate to include all records. In any case, the impact of including (or removing) the negative volumes has a negligible effect on the calculated statistics because there are so few of them.

To examine the consistency of the data among different time intervals, the 5-minute interval data from one corridor (I-376 with 16 sensors) and for one day (June 1, 2001) were aggregated to 15-minute, 1-hour, and 24-hour intervals and compared to the corresponding archived data downloaded directly from the ISDMI archived database. Similarly, the 15-minute data were aggregated to 1-hour and 24-hour intervals for comparison. Finally, the 1-hour data were aggregated to 24-hour intervals for comparison, as well.

Discussion of Results: Table 4-3 presents descriptive statistics in terms of minimum, maximum, average, standard deviation, and median for the traffic volume, speed, and occupancy values recorded by the ISDMI sensors. The results are aggregated by corridor and also by month of the year. It is noted that 10 sensors recorded two or more negative traffic volumes. However, negative speed and occupancy values were not recorded when negative traffic volumes were recorded. The negative volumes were reported during January through May 2001 only, i.e., prior to systems acceptance testing in Pittsburgh. These are obviously erroneous readings that could be attributed to equipment malfunction. The problem has since been identified and corrected. Sensors on 9 of the 26 corridors (or 35%) reported negative traffic volume values. However, only 232 traffic volume records (or 0.002%) were negative, indicating that this is not a significant problem.

Table 4-3. Summary Statistics for the Reported Volume, Occupancy, and Speed

Summary Level	Statistic	Volume	Occupancy	Speed
Overall	Minimum	-99.00	0.00	1.00
	Maximum	999.00	100.00	92.00
	Average	83.32	2.81	51.06
	Standard Deviation	79.25	6.92	13.98
	Median	60.00	1.00	54.00
January	Minimum	-94.00	0.00	1.00
	Maximum	992.00	100.00	92.00
	Average	85.02	3.33	52.55
	Standard Deviation	81.59	9.79	14.34
	Median	60.00	1.00	56.00
February	Minimum	-99.00	0.00	1.00
	Maximum	995.00	100.00	92.00
	Average	94.21	2.66	54.38
	Standard Deviation	87.37	6.49	13.30
	Median	69.00	1.00	58.00
March	Minimum	-93.00	0.00	1.00
	Maximum	998.00	100.00	92.00
	Average	93.00	2.76	53.15
	Standard Deviation	84.19	6.21	13.25
	Median	69.00	1.00	56.00
April	Minimum	-99.00	0.00	1.00
	Maximum	999.00	100.00	92.00
	Average	83.22	2.78	49.62
	Standard Deviation	80.66	6.06	14.28
	Median	59.00	1.00	52.00
May	Minimum	-94.00	0.00	1.00
	Maximum	809.00	100.00	92.00
	Average	79.33	3.04	48.93
	Standard Deviation	76.79	7.94	14.47
	Median	57.00	1.00	51.00
June	Minimum	1.00	0.00	1.00
	Maximum	922.00	100.00	92.00
	Average	80.42	3.17	49.20
	Standard Deviation	76.58	8.41	14.74
	Median	58.00	1.00	51.00
July	Minimum	0.00	0.00	1.00
	Maximum	721.00	100.00	92.00
	Average	80.00	2.39	51.68
	Standard Deviation	75.98	4.81	13.33
	Median	58.00	1.00	54.00
August	Minimum	0.00	0.00	1.00
	Maximum	809.00	100.00	92.00
	Average	82.81	2.57	51.52
	Standard Deviation	78.00	5.25	13.33
	Median	60.00	1.00	54.00

Table 4-3. Summary Statistics for the Reported Volume, Occupancy, and Speed (Continued)

Summary Level	Statistic	Volume	Occupancy	Speed
September	Minimum	0.00	0.00	1.00
	Maximum	823.00	100.00	92.00
	Average	79.05	2.48	51.36
	Standard Deviation	75.03	5.33	13.13
	Median	58.00	1.00	53.00
1005	Minimum	1.00	0.00	4.00
	Maximum	263.00	68.00	91.00
	Average	33.16	0.75	56.64
	Standard Deviation	32.22	1.90	12.75
	Median	27.00	0.00	55.00
28B	Minimum	0.00	0.00	1.00
	Maximum	761.00	99.00	89.00
	Average	41.98	2.80	40.40
	Standard Deviation	38.76	7.91	10.97
	Median	37.00	1.00	42.00
3020	Minimum	-12.00	0.00	1.00
	Maximum	489.00	100.00	67.00
	Average	60.60	5.98	29.53
	Standard Deviation	46.35	10.68	7.74
	Median	58.00	3.00	30.00
I-279	Minimum	-86.00	0.00	1.00
	Maximum	999.00	100.00	92.00
	Average	117.86	3.57	57.25
	Standard Deviation	99.30	7.13	11.64
	Median	98.00	2.00	59.00
I-376	Minimum	-99.00	0.00	1.00
	Maximum	990.00	100.00	91.00
	Average	145.41	4.10	57.22
	Standard Deviation	96.06	7.23	10.28
	Median	147.00	2.00	59.00
I-579	Minimum	0.00	0.00	1.00
	Maximum	508.00	100.00	85.00
	Average	67.04	0.81	63.43
	Standard Deviation	66.35	3.13	7.64
	Median	60.00	0.00	63.00
I-79	Minimum	-43.00	0.00	1.00
	Maximum	962.00	100.00	92.00
	Average	94.22	2.23	56.84
	Standard Deviation	75.96	4.15	10.91
	Median	78.00	2.00	60.00
PA-121	Minimum	0.00	0.00	1.00
	Maximum	377.00	100.00	73.00
	Average	43.94	3.73	25.51
	Standard Deviation	32.90	9.06	7.28
	Median	44.00	2.00	24.00

Table 4-3. Summary Statistics for the Reported Volume, Occupancy, and Speed (Continued)

Summary Level	Statistic	Volume	Occupancy	Speed
PA-2040	Minimum	1.00	0.00	1.00
	Maximum	225.00	72.00	73.00
	Average	25.59	1.19	32.75
	Standard Deviation	17.32	1.63	6.79
	Median	26.00	1.00	33.00
PA-228	Minimum	1.00	0.00	1.00
	Maximum	572.00	100.00	89.00
	Average	54.19	12.77	33.09
	Standard Deviation	49.64	27.24	11.49
	Median	50.00	1.00	36.00
PA-28	Minimum	-88.00	0.00	1.00
	Maximum	892.00	100.00	89.00
	Average	62.74	2.30	54.90
	Standard Deviation	51.90	6.09	12.21
	Median	53.00	1.00	57.00
PA-380	Minimum	-54.00	0.00	1.00
	Maximum	978.00	100.00	82.00
	Average	58.64	8.19	42.91
	Standard Deviation	68.05	17.94	12.31
	Median	41.00	1.00	42.00
PA-50	Minimum	0.00	0.00	1.00
	Maximum	385.00	64.00	91.00
	Average	38.86	1.97	38.11
	Standard Deviation	32.05	4.04	11.46
	Median	33.00	1.00	37.00
PA-51	Minimum	0.00	0.00	1.00
	Maximum	926.00	100.00	91.00
	Average	48.74	1.82	44.95
	Standard Deviation	40.88	4.91	11.66
	Median	39.00	1.00	44.00
PA-60	Minimum	0.00	0.00	1.00
	Maximum	827.00	63.00	92.00
	Average	81.54	1.27	58.54
	Standard Deviation	58.07	2.28	11.25
	Median	75.00	1.00	62.00
PA-65	Minimum	0.00	0.00	1.00
	Maximum	983.00	100.00	91.00
	Average	66.41	1.31	62.25
	Standard Deviation	45.97	2.54	7.62
	Median	61.00	1.00	63.00
PA-8	Minimum	0.00	0.00	1.00
	Maximum	732.00	80.00	91.00
	Average	44.49	1.64	46.13
	Standard Deviation	42.36	4.29	12.47
	Median	36.00	1.00	45.00

Table 4-3. Summary Statistics for the Reported Volume, Occupancy, and Speed (Continued)

Summary Level	Statistic	Volume	Occupancy	Speed
PA-837	Minimum	0.00	0.00	3.00
	Maximum	803.00	60.00	90.00
	Average	87.93	2.25	47.40
	Standard Deviation	56.05	2.59	6.57
	Median	82.00	1.00	47.00
PA-88	Minimum	0.00	0.00	3.00
	Maximum	341.00	65.00	67.00
	Average	33.23	1.95	39.98
	Standard Deviation	24.42	2.97	8.59
	Median	31.00	1.00	40.00
PA-885	Minimum	0.00	0.00	1.00
	Maximum	536.00	92.00	91.00
	Average	38.90	2.18	42.24
	Standard Deviation	28.90	3.97	10.75
	Median	35.00	1.00	42.00
PA-910	Minimum	-94.00	0.00	1.00
	Maximum	452.00	100.00	68.00
	Average	27.76	1.38	36.05
	Standard Deviation	24.77	6.49	10.58
	Median	22.00	1.00	35.00
SR 19	Minimum	-93.00	0.00	1.00
	Maximum	882.00	100.00	91.00
	Average	109.21	3.67	58.12
	Standard Deviation	64.00	6.56	10.12
	Median	111.00	2.00	60.00
US-19	Minimum	-71.00	0.00	1.00
	Maximum	850.00	99.00	91.00
	Average	53.92	3.52	40.28
	Standard Deviation	51.50	8.70	13.56
	Median	42.00	1.00	40.00
US-19T	Minimum	0.00	0.00	1.00
	Maximum	464.00	100.00	89.00
	Average	62.21	2.39	33.89
	Standard Deviation	48.53	4.80	9.45
	Median	56.00	1.00	32.00
US-22	Minimum	0.00	0.00	1.00
	Maximum	996.00	100.00	91.00
	Average	94.38	2.53	54.82
	Standard Deviation	76.88	5.18	10.86
	Median	80.00	1.00	56.00
US-30	Minimum	1.00	0.00	1.00
	Maximum	981.00	99.00	89.00
	Average	108.41	2.46	50.45
	Standard Deviation	90.22	3.35	11.99
	Median	73.00	1.00	51.00

The overall minimum speed reported by the sensors was 1 mph on 23 of the 26 corridors (or 88%). The maximum speed reported among the 26 corridors ranges from 67 mph to 92 mph and the median speed is 54 mph, ranging from 24 mph to 64 mph among the corridors. In this type of analysis the median is considered a more informative measurement than the average, since the average can be greatly affected by extreme observations.

The overall median occupancy rate is 1%. This implies that half of the occupancy values reported are 0% or 1%. Those percentages seem to be low considering that 1% of a 5-minute interval is 3 seconds. The sensors also reported at least one full occupancy reading (100%) during each month of the analysis. Fifteen of the 26 corridors exhibited 100% occupancy at some point during January through September 2001. Table 4-4 summarizes the statistics on the completeness of archived data recorded by the ISDMI sensors. The number and percent of the traffic volume, speed, and occupancy values that are either negative, zero, or missing are presented. It is noted that just under a third of all the potential 5-minute intervals contain missing values for each of the three quantities (29% for volume, 27% for occupancy, and 31% for speed). In order words, the overall percent completeness for traffic volume is 71%; speed, 69%; and occupancy 73%. Figure 4-12 shows the variation of percent of data missing by month and Figure 4-13 shows the variation by corridor. It is noted that the percentage steadily decreases from January through June, from roughly 47% to around 10%, then increases to about 29% in September. The corridor with the highest percentage of missing values is SR-19, with roughly 73% missing volume and speed records. The lowest percentage is found on PA-121, ranging from 1.2% to 3.9%. In general, the speed values appear to be missing slightly more often than the volume or occupancy values.

Given that the sensors capture volume, speed, and occupancy data simultaneously, it was reasoned that if one of the values were missing, then the other two values would be missing as well. Table 4-5 summarizes the amount of simultaneous missing values for pairs of the quantities, as well as all three variables. Table 4-5 indicates that occupancy is never missing unless volume and speed are also missing. Volume and speed are simultaneously missing approximately 2% of the time, while all three values are missing about 27% of the time. Again these numbers decrease steadily on a monthly basis through May, and start to climb again in June to 29% in September. The corridor with the highest percentage for all three variables missing is 1005, with 72%, while PA-121 exhibits the smallest percentage at about 1%.

Table 4-4. Number and Percent of the Volume, Occupancy, and Speed Values that are Missing, Zero, or Negative

Summary Level	Statistic	Volume	Occupancy	Speed
Overall	Number Missing	4,749,121	4,402,849	5,038,997
	Percent Missing	29.32%	27.18%	31.11%
	Number Zero	103,852	3,329,426	0
	Percent Zero	0.91%	28.23%	0%
	Number Negative	232	0	0
	Percent Negative	0%	0%	0%
January	Number Missing	848,085	745,060	875,003
	Percent Missing	46.11%	40.51%	47.58%
	Number Zero	0	380,676	0
	Percent Zero	0%	34.79%	0%
	Number Negative	42	0	0
	Percent Negative	0%	0%	0%
February	Number Missing	758,547	699,972	776,968
	Percent Missing	45.66%	42.14%	46.77%
	Number Zero	0	294,948	0
	Percent Zero	0%	30.69%	0%
	Number Negative	46	0	0
	Percent Negative	0.01%	0%	0%
March	Number Missing	773,495	710,525	789,783
	Percent Missing	42.06%	38.63%	42.94%
	Number Zero	0	329,195	0
	Percent Zero	0%	29.17%	0%
	Number Negative	90	0	0
	Percent Negative	0.01%	0%	0%
April	Number Missing	442,477	402,365	463,410
	Percent Missing	24.86%	22.61%	26.04%
	Number Zero	0	388,935	0
	Percent Zero	0%	28.24%	0%
	Number Negative	25	0	0
	Percent Negative	0%	0%	0%
May	Number Missing	173,891	132,362	199,321
	Percent Missing	9.45%	7.20%	10.84%
	Number Zero	0	471,688	0
	Percent Zero	0%	27.64%	0%
	Number Negative	29	0	0
	Percent Negative	0%	0%	0%
June	Number Missing	204,637	164,576	231,982
	Percent Missing	11.50%	9.25%	13.03%
	Number Zero	0	428,342	0
	Percent Zero	0%	26.52%	0%
	Number Negative	0	0	0
	Percent Negative	0%	0%	0%

Table 4-4. Number and Percent of the Volume, Occupancy, and Speed Values that are Missing, Zero, or Negative (Continued)

Summary Level	Statistic	Volume	Occupancy	Speed
July	Number Missing	532,186	532,186	588,969
	Percent Missing	28.94%	28.94%	32.02%
	Number Zero	39,644	349,595	0
	Percent Zero	3.03%	26.75%	0%
	Number Negative	0	0	0
	Percent Negative	0%	0%	0%
August	Number Missing	501,738	501,738	557,321
	Percent Missing	27.28%	27.28%	30.30%
	Number Zero	38,854	349,415	0
	Percent Zero	2.91%	26.13%	0%
	Number Negative	0	0	0
	Percent Negative	0%	0%	0%
September	Number Missing	514,065	514,065	556,240
	Percent Missing	28.88%	28.88%	31.25%
	Number Zero	25,354	336,632	0
	Percent Zero	2%	26.59%	0%
	Number Negative	0	0	0
	Percent Negative	0%	0%	0%
1005	Number Missing	113,607	112,520	116,729
	Percent Missing	72.25%	71.56%	74.23%
	Number Zero	0	25,432	0
	Percent Zero	0%	56.86%	0%
	Number Negative	0	0	0
	Percent Negative	0%	0%	0%
28B	Number Missing	94,804	91,390	99,418
	Percent Missing	30.14%	29.06%	31.61%
	Number Zero	1,118	80,690	0
	Percent Zero	0.51%	36.17%	0%
	Number Negative	0	0	0
	Percent Negative	0%	0%	0%
3020	Number Missing	105,206	98,952	105,455
	Percent Missing	66.90%	62.93%	67.06%
	Number Zero	0	13,752	0
	Percent Zero	0%	23.59%	0%
	Number Negative	1	0	0
	Percent Negative	0%	0%	0%
I-279	Number Missing	221,668	169,072	286,028
	Percent Missing	9.40%	7.17%	12.13%
	Number Zero	14,885	546,984	0
	Percent Zero	0.70%	24.98%	0%
	Number Negative	7	0	0
	Percent Negative	0%	0%	0%

Table 4-4. Number and Percent of the Volume, Occupancy, and Speed Values that are Missing, Zero, or Negative (Continued)

Summary Level	Statistic	Volume	Occupancy	Speed
I-376	Number Missing	79,321	77,288	86,576
	Percent Missing	6.31%	6.14%	6.88%
	Number Zero	175	147,070	0
	Percent Zero	0.01%	12.46%	0%
	Number Negative	149	0	0
	Percent Negative	0.01%	0%	0%
I-579	Number Missing	126,125	109,142	152,224
	Percent Missing	53.47%	46.27%	64.54%
	Number Zero	26,051	69,383	0
	Percent Zero	23.74%	54.75%	0%
	Number Negative	0	0	0
	Percent Negative	0%	0%	0%
I-79	Number Missing	276,589	267,638	290,417
	Percent Missing	15.99%	15.47%	16.79%
	Number Zero	5,008	313,123	0
	Percent Zero	0.34%	21.42%	0%
	Number Negative	2	0	0
	Percent Negative	0%	0%	0%
PA-121	Number Missing	5,317	1,950	6,196
	Percent Missing	3.38%	1.24%	3.94%
	Number Zero	368	47,355	0
	Percent Zero	0.24%	30.49%	0%
	Number Negative	0	0	0
	Percent Negative	0%	0%	0%
PA-2040	Number Missing	204,248	183,492	205,626
	Percent Missing	64.94%	58.34%	65.38%
	Number Zero	0	51,018	0
	Percent Zero	0%	38.94%	0%
	Number Negative	0	0	0
	Percent Negative	0%	0%	0%
PA-228	Number Missing	178,460	154,740	185,152
	Percent Missing	56.74%	49.20%	58.87%
	Number Zero	0	57,221	0
	Percent Zero	0%	35.82%	0%
	Number Negative	0	0	0
	Percent Negative	0%	0%	0%
PA-28	Number Missing	129,914	114,046	161,786
	Percent Missing	13.77%	12.09%	17.15%
	Number Zero	3,442	248,464	0
	Percent Zero	0.42%	29.96%	0%
	Number Negative	4	0	0
	Percent Negative	0%	0%	0%

Table 4-4. Number and Percent of the Volume, Occupancy, and Speed Values that are Missing, Zero, or Negative (Continued)

Summary Level	Statistic	Volume	Occupancy	Speed
PA-380	Number Missing	69,035	68,738	71,506
	Percent Missing	43.90%	43.71%	45.47%
	Number Zero	163	31,482	0
	Percent Zero	0.18%	35.57%	0%
	Number Negative	2	0	0
	Percent Negative	0.00 %	0%	0%
PA-50	Number Missing	4,775	2,290	6,618
	Percent Missing	3.04%	1.46%	4.21%
	Number Zero	772	59,820	0
	Percent Zero	0.51%	38.60%	0%
	Number Negative	0	0	0
	Percent Negative	0%	0%	0%
PA-51	Number Missing	401,494	351,474	422,500
	Percent Missing	30.04%	26.30%	31.61%
	Number Zero	3,991	351,717	0
	Percent Zero	0.43%	35.70%	0%
	Number Negative	0	0	0
	Percent Negative	0%	0%	0%
PA-60	Number Missing	71,139	70,944	73,783
	Percent Missing	15.08%	15.04%	15.64%
	Number Zero	170	115,695	0
	Percent Zero	0.04%	28.87%	0%
	Number Negative	0	0	0
	Percent Negative	0%	0%	0%
PA-65	Number Missing	182,685	182,073	184,044
	Percent Missing	38.73%	38.60%	39.01%
	Number Zero	4	68,377	0
	Percent Zero	0%	23.61%	0%
	Number Negative	0	0	0
	Percent Negative	0%	0%	0%
PA-8	Number Missing	412,551	380,312	462,258
	Percent Missing	43.73%	40.31%	48.99%
	Number Zero	37,224	265,658	0
	Percent Zero	7.01%	47.17%	0%
	Number Negative	0	0	0
	Percent Negative	0%	0%	0%
PA-837	Number Missing	38,768	38,748	39,360
	Percent Missing	24.65%	24.64%	25.03%
	Number Zero	1	17,440	.
	Percent Zero	0%	14.72%	0%
	Number Negative	0	0	0
	Percent Negative	0%	0%	0%

Table 4-4. Number and Percent of the Volume, Occupancy, and Speed Values that are Missing, Zero, or Negative (Continued)

Summary Level	Statistic	Volume	Occupancy	Speed
PA-88	Number Missing	157,182	155,872	165,419
	Percent Missing	49.98%	49.56%	52.60%
	Number Zero	1,082	40,437	0
	Percent Zero	0.69%	25.49%	0%
	Number Negative	0	0	0
	Percent Negative	0%	0%	0%
PA-885	Number Missing	413,996	398,728	417,047
	Percent Missing	43.88%	42.26%	44.20%
	Number Zero	908	167,005	0
	Percent Zero	0.17%	30.66%	0%
	Number Negative	0	0	0
	Percent Negative	0%	0%	0%
PA-910	Number Missing	64,938	57,170	79,479
	Percent Missing	20.65%	18.18%	25.27%
	Number Zero	3,458	116,063	0
	Percent Zero	1.39%	45.10%	0%
	Number Negative	23	0	0
	Percent Negative	0.01%	0%	0%
SR 19	Number Missing	114,891	113,774	115,318
	Percent Missing	73.06%	72.35%	73.34%
	Number Zero	0	8,156	0
	Percent Zero	0%	18.76%	0%
	Number Negative	27	0	0
	Percent Negative	0.06%	0%	0%
US-19	Number Missing	542,085	480,272	549,595
	Percent Missing	57.46%	50.90%	58.25%
	Number Zero	2,558	166,012	0
	Percent Zero	0.64%	35.84%	0%
	Number Negative	17	0	0
	Percent Negative	0%	0%	0%
US-19T	Number Missing	360,533	352,464	362,782
	Percent Missing	57.32%	56.04%	57.68%
	Number Zero	546	93,590	0
	Percent Zero	0.20%	33.84%	0%
	Number Negative	0	0	0
	Percent Negative	0%	0%	0%
US-22	Number Missing	150,031	147,710	163,217
	Percent Missing	19.08%	18.79%	20.76%
	Number Zero	1,928	172,465	0
	Percent Zero	0.30%	27.01%	0%
	Number Negative	0	0	0
	Percent Negative	0%	0%	0%

Table 4-4. Number and Percent of the Volume, Occupancy, and Speed Values that are Missing, Zero, or Negative (Continued)

Summary Level	Statistic	Volume	Occupancy	Speed
US-30	Number Missing	229,759	222,050	230,464
	Percent Missing	48.70%	47.07%	48.85%
	Number Zero	0	55,017	0
	Percent Zero	0%	22.03%	0%
	Number Negative	0	0	0
	Percent Negative	0%	0%	0%

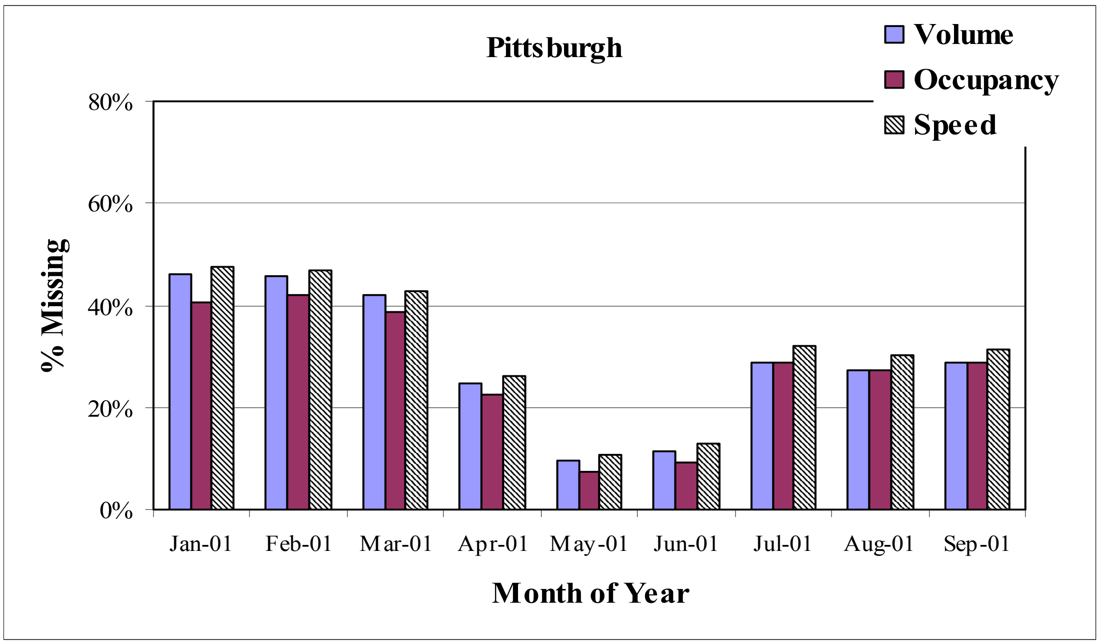

Figure 4-12. Percentage of Missing Data by Month

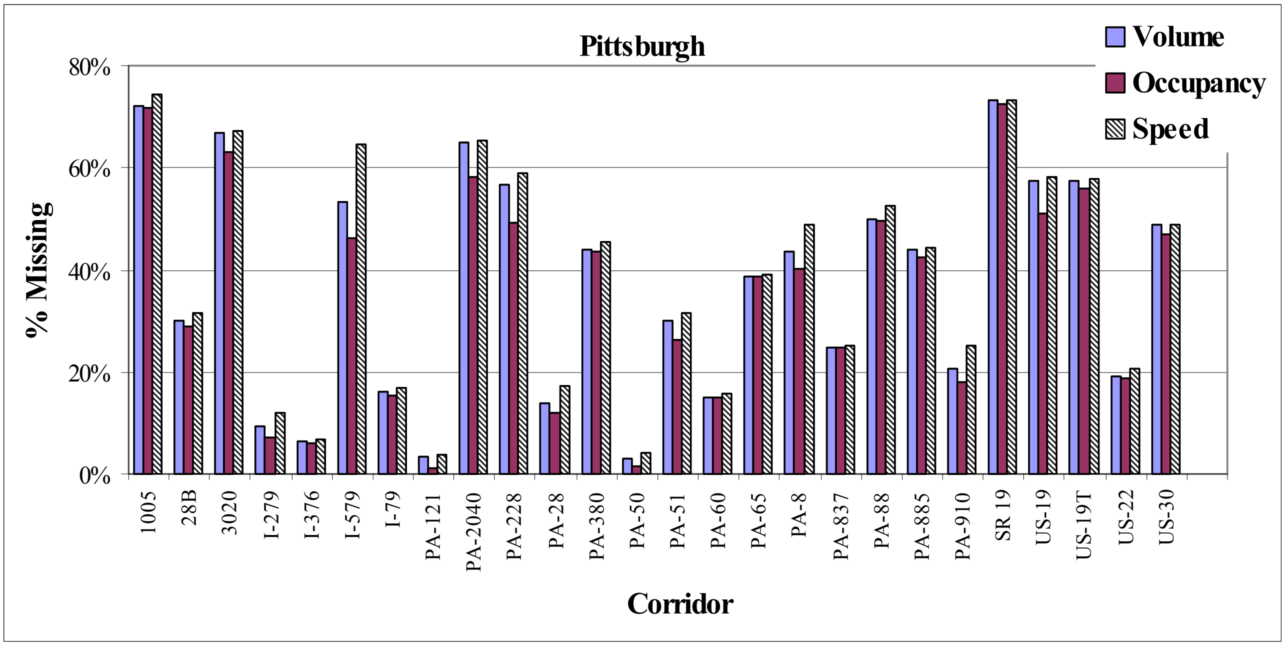

Figure 4-13. Percentage of Missing Data by Corridor

Finally, the analysis dealt with comparing the data aggregated from smaller time intervals to larger time interval data downloaded directly from the ISDMI archived database for the 8 sensors (2 directions of travel) on the I-376 corridor for one day. The volume readings for each sensor were simply summed across the time intervals, while the speed and occupancy values were averaged. The purpose of this part of the analysis was to determine how "complete" the larger interval data values are, by determining how the values are created. For example, if the 1-hour interval data are created by summing the 5-minute data and there are several missing data values for the 5-minute data in any given hour, the 1-hour data could be underestimating reality.

Table 4-6 presents the results of the comparison. Column 1 indicates the data that were aggregated for comparison to data downloaded directly from the ISDMI archived database (indicated in Column 2). Column 3 lists the number of time intervals per sensor that were available for each comparison. The remaining columns present the number and percent of the time intervals that were different by the specified quantity (i.e., 10 vehicles, 5 mph, and 5% occupancy). The results indicate that simply summing or averaging the values taken from the 5-minute data can create the larger interval data values. As noted above this can cause a problem for users of the larger interval data since it will underestimate the actual volume, occupancy, and speed if there is a significant amount of missing data. It was later determined that a communication carrier outage occurred from 2:30 AM until 5:40 AM on June 1, 2001. However, this is not expected to affect the results of the analysis presented in Table 4-6.

Table 4-5. Number and Percent of the Volume, Occupancy, and Speed Values that Are Missing in Conjunction with One or More Other Values

Summary Level	Number Missing (Percent Missing)			
	Volume and Occupancy	Speed and Occupancy	Speed and Volume	Volume, Occupancy, and Speed
Overall	N/A	N/A	346,272 (2.14%)	4,402,849 (27.18%)
January	N/A	N/A	103,025 (5.60%)	745,060 (40.51%)
February	N/A	N/A	58,575 (3.53%)	699,972 (42.14%)
March	N/A	N/A	62,970 (3.42%)	710,525 (38.63%)
April	N/A	N/A	40,112 (2.25%)	402,365 (22.61%)
May	N/A	N/A	41,529 (2.26%)	132,362 (7.20%)
June	N/A	N/A	40,061 (2.25%)	164,576 (9.25%)
July	N/A	N/A	N/A	532,186 (28.94%)
August	N/A	N/A	N/A	501,738 (27.28%)
September	N/A	N/A	N/A	514,065 (28.88%)
1005	N/A	N/A	1,087 (0.69%)	112,520 (71.56%)
28B	N/A	N/A	3,414 (1.09%)	91,390 (29.06%)
3020	N/A	N/A	6,254 (3.98%)	98,952 (62.93%)
I-279	N/A	N/A	52,596 (2.23%)	169,072 (7.17%)
I-376	N/A	N/A	2,033 (0.16%)	77,288 (6.14%)
I-579	N/A	N/A	16,983 (7.20%)	109,142 (46.27%)
I-79	N/A	N/A	8,951 (0.52%)	267,638 (15.47%)
PA-121	N/A	N/A	3,367 (2.14%)	1,950 (1.24%)
PA-2040	N/A	N/A	20,756 (6.60%)	183,492 (58.34%)
PA-228	N/A	N/A	23,720 (7.54%)	154,740 (49.20%)
PA-28	N/A	N/A	15,868 (1.68%)	114,046 (12.09%)
PA-380	N/A	N/A	297 (0.19%)	68,738 (43.71%)
PA-50	N/A	N/A	2,485 (1.58%)	2,290 (1.46%)
PA-51	N/A	N/A	50,020 (3.74%)	351,474 (26.30%)
PA-60	N/A	N/A	195 (0.04%)	70,944 (15.04%)
PA-65	N/A	N/A	612 (0.13%)	182,073 (38.60%)
PA-8	N/A	N/A	32,239 (3.42%)	380,312 (40.31%)
PA-837	N/A	N/A	20 (0.01%)	38,748 (24.64%)
PA-88	N/A	N/A	1,310 (0.42%)	155,872 (49.56%)
PA-885	N/A	N/A	15,268 (1.62%)	398,728 (42.26%)
PA-910	N/A	N/A	7,768 (2.47%)	57,170 (18.18%)
SR 19	N/A	N/A	1,117 (0.71%)	113,774 (72.35%)
US-19	N/A	N/A	61,813 (6.55%)	480,272 (50.90%)
US-19T	N/A	N/A	8,069 (1.28%)	352,464 (56.04%)
US-22	N/A	N/A	2,321 (0.30%)	147,710 (18.79%)
US-30	N/A	N/A	7,709 (1.63%)	222,050 (47.07%)

Table 4-6. Number and Percent of Differences Between the Aggregated Data and the Downloaded Data

Aggregated Data	Downloaded Data	Number of Time Intervals (per sensor[1])	Number Different (Percent Different)		
			Volume Different by 10 Vehicles[2]	Speed Different by 5 mph	Occupancy Different by 5%
5 minutes	15 minutes	1,296 (81)	0 (0%)	2 (0.16%)	2 (0.15%)
	1 hour	336 (21)	0 (0%)	0 (0%)	0 (0%)
	24 hours	16 (1)	0 (0%)	0 (0%)	0 (0%)
15 minutes	1 hour	336 (21)	0 (0%)	3 (0.90%)	1 (0.30%)
	24 hours	16 (1)	0 (0%)	0 (0%)	0 (0%)
1 hour	24 hours	16 (1)	0 (0%)	0 (0%)	0 (0%)

[1] *Number of time intervals per sensor - eight sensors and 2 directions of travel.*
[2] *All of the compared volume values were exactly equal.*

The data quality analysis has uncovered some problematic areas with the archived sensor data. These include missing data (roughly 30% missing or 70% complete), along with the impact that missing data have on values reported in larger time intervals. In addition, a significant amount of 0% occupancy values were reported by the sensors (nearly 30%), and negative traffic volumes were reported by the sensors (less than 0.01%). Following the analysis it was discovered that the ISDMI sensors truncate the occupancy values. Therefore, some of the zero-occupancy values may not truly represent zero occupancy. For example, 0.9% would be recorded as 0%. This may still be a problem if small, non-zero occupancy values are informative. The truncation of the occupancy values suggests that there may be a need to re-evaluate the current algorithms and/or data display of the occupancy values from the ISDMI sensors.

4.3.2 Real-Time Data

Due to data limitations, no quantitative analysis was conducted for the real-time traffic data. However, some qualitative assessments were made based on discussions with the users of real-time data in Pittsburgh. The focus of the analysis is to evaluate the effectiveness of the systems in delivering good quality (accurate and reliable) real-time traffic information. Various stakeholders made the following observations:

- The Traffic Management Center (TMC) of PennDOT District 11 in Pittsburgh currently accesses ISDMI real-time data and traffic data from the cameras used for traffic surveillance and incident management purposes. Data from ISDMI sensors supplement information from the cameras and the data are readily accessible to the staff of the TMC.

- The traffic flow map and announcer functionalities of the ISDMI interface give detailed information on traffic condition at any given time. Moreover, the ISDMI systems cover a wider area compared to the cameras and therefore TMC is now able to provide traffic information on routes not monitored by cameras.

- TMC is also able to relay more comprehensive and accurate information on traffic conditions to motorists

- The ISDMI systems have a trigger mechanism that alerts TMC officials in the event of an incident. This functionality reduces the time required for incident detection and response. In addition, TMC can provide timely and accurate messages to motorists relating to incidents on the highways.

- ISDMI systems offer useful information to the transit agencies in providing customer service information to bus riders about bus delays.

Generally, the ISDMI systems are performing their intended functions of providing timely traffic information to traffic operators to help manage traffic in the Pittsburgh area. The interfaces also allow users (traffic management officials, motorists, and media houses) to access traffic conditions in real time.

4.4 Customer Satisfaction

As noted in Section 3.4.2 of this report, the customer satisfaction study was conducted to measure the opinions of three groups of customers: stakeholders, the public (including the general public and current subscribers to the Mobility Technologies website), and media houses that provide traveler information via radio and TV. The findings are categorized by each group and presented below.

4.4.1 General Public

This section presents the results of the customer satisfaction analysis based on data gathered from the general public on awareness, access, acceptance, use, and value. ISDMI information is being disseminated to the Pittsburgh public through a variety of media sources, including the Internet, television, and radio. The analysis focused on potential users of and current subscribers to the ISDMI (Traffic.com) website.

Since the ISDMI information is a relatively new product, it was not possible to obtain one sample of respondents that could assess all levels of the customer satisfaction model. Therefore, two separate samples were employed: one to address the awareness of, access to, and acceptance of the ISDMI information and the other to address the use and value of that information. The *potential* users, i.e., the general public, were surveyed for awareness, access, and acceptance, while the *actual* users were surveyed for use and value.

Telephone surveys were completed with 250 potential users of the ISDMI website in the Pittsburgh area. The surveys were conducted via Computer Assisted Telephone Interviews (CATI) from May 16 through May 23, 2001. From May 22 through June 6, 2001, users of the ISDMI website were surveyed via a web-based questionnaire. An email message with a link to the survey was sent directly to 326 registered ISDMI users from the Pittsburgh area. A maximum of two follow-up emails was sent to potential respondents, asking them to complete the survey if they had not done so already. The questions contained in the telephone and Internet surveys are presented in the *Customer Satisfaction Test Plan* (Battelle, 2001b). Traffic.com or TrafficPulse was used in the survey questions to refer to the actual website of ISDMI information.

The telephone survey response rate was approximately 20%, and the Internet survey completion rate was 42%. The procedures for response rate calculation for the telephone survey are based on the guidelines established by the Council of American Survey Research Organizations (CASRO, 1982) in defining a response rate. The final response rate for the telephone survey was obtained using the following formula:

$$\text{Response Rate} = \frac{\text{Completed HH Interviews}}{\left(\text{HHs In Scope} + \left[\text{Scope Undetermined} * \frac{\text{HHs In Scope}}{\text{HHs In \& Out of Scope}}\right]\right)}$$

where the numerator is the total number of completed household (HH) interviews and the denominator is the total number of in-scope telephone numbers (i.e., eligible households) plus the number of the "Scope Undetermined" telephone numbers (i.e., type of establishment unknown) estimated to be in-scope.

The completion rate for the Internet survey is simply the ratio of the number of completes to the number of solicitations. The ISDMI Internet survey had a 42% completion rate (i.e., 137 completes out of 326 solicitations).

4.4.1.1 Analysis

The two types of interviews were conducted in order to address each of the five issues of the customer satisfaction model. Each of the survey questions was designed to characterize the respondents in terms of their awareness of, access to, acceptance of, use of, and perceived value in the ISDMI website. Descriptive statistics such as frequencies and percentages were used to characterize the survey responses. Separate analyses were conducted for the telephone and Internet surveys since the respondents represented different sectors of the population (i.e., potential users vs. actual users). In addition, analysis weights were applied to the telephone survey responses to ensure that the results from the sample are representative of the target population. The weighting process included adjustments for non-response, multiple telephone lines, multiple people in a household, post-stratification to the age and gender distribution of the target population, and trimming of any extreme weights.

4.4.1.2 Discussion of Results

The results of both survey efforts indicate that the telephone survey respondents are quite different demographically from the Internet survey respondents. The telephone survey respondents include a higher percentage of older women, while the Internet respondents tended to be younger males. Table 4-7 provides the unweighted frequencies and percentages for selected descriptive variables for respondents of both surveys.

The following sections summarize the findings related to the major components of the customer satisfaction model: awareness, access, acceptance, use, and value. The telephone survey attempts to address each of these phases. However, due to the nature of the data collection, it is assumed that the Internet survey respondents are aware of, have access to, and have accepted the ISDMI information. Therefore, the primary use of the Internet survey is to address the usefulness and value of the system.

Awareness: In the context of the customer satisfaction model, awareness is concerned with the question: "Does the customer know that the product or service exists?" At the time of the CATI survey, 28% of the Pittsburgh area residents had heard of Traffic.com. The Internet survey indicates that Traffic.com users heard about Traffic.com most often from a television or radio advertisement (32%). This may suggest that a good way to market the site to the general public would be through these media, which is already part of the deployment plan.

These awareness results are consistent with the make-up of the telephone sample. Less than half of the telephone survey sample is comprised of daily commuters who are not looking for relief from traffic congestion. Of all commuters, the vast majority (about 73%) has commute times of 30 minutes or less. About 26% have commute times of 10 minutes or less, compared to 58% (75 out of 130) of the Internet survey commuters who indicated having a commute time of more than 30 minutes.

In addition to the awareness of the website itself, users may or may not be aware of several of its useful features. Of the 137 people who responded to the Internet survey, 58% knew that Traffic.com provides information on point-to-point travel times. A larger portion of the users was aware of the information on route-specific travel speeds and maps, 78% and 81% respectively. The telephone survey results could not adequately assess the user awareness of specific website features since only 9 of the 250 respondents (3.6%) visited the site.

Access: Obviously, the respondents to the Internet survey have access to the Traffic.com information because they are registered users of the site. Access for potential users can only be measured by how many "customers" in the population have access to the Internet. Roughly 65% of the households in the Pittsburgh metropolitan area have access to the Internet, either at home, at work, or someplace else. This figure does not indicate how much of the population has visited the Traffic.com website. It simply indicates that only 65% of the population could access the website if they wanted to.

Table 4-7. Unweighted Frequencies and Percentages for Demographic Variables from Both the Telephone and Internet Surveys

Demographic Variable	Number (Percentage)	
	Telephone Survey	Internet Survey
Age		
Refused	1 (0.4 %)	2 (1.4 %)
18 - 20 Years Old	7 (2.8 %)	1 (0.7 %)
21 - 30 Years Old	25 (10.0 %)	30 (21.9 %)
31 - 40 Years Old	35 (14.0 %)	55 (40.1 %)
41 - 50 Years Old	67 (26.8 %)	33 (24.1 %)
51 - 60 Years Old	44 (17.6 %)	13 (9.5 %)
Over 60 Years Old	71 (28.4 %)	3 (2.2 %)
Gender		
Refused	0 (0%)	1 (0.7 %)
Male	97 (38.8 %)	111 (81.0 %)
Female	153 (61.2 %)	25 (18.2 %)
Education		
Refused	2 (0.8 %)	2 (1.4 %)
Less than High School	14 (5.6 %)	1 (0.7 %)
High School Graduate/GED	102 (40.8 %)	7 (5.1 %)
Technical School/Professional Business School	14 (5.6 %)	16 (11.7 %)
Some College	29 (11.6 %)	27 (19.7 %)
Community College Graduate	21 (8.4 %)	6 (4.4 %)
College Graduate	42 (16.8 %)	57 (41.6 %)
Post-Graduate Degree	26 (10.4 %)	21 (15.3 %)
Frequency of Internet Use		
No Access	99 (39.6 %)	N/A
Everyday	57 (22.8 %)	118 (86.1 %)
Occasionally	63 (25.2 %)	18 (13.1 %)
Rarely	24 (9.6 %)	1 (0.7 %)
Never	7 (2.8 %)	N/A
# Days per week travel during weekday morning rush hr[1]		
None	103 (41.2 %)	7 (5.1 %)
Once	13 (5.2 %)	7 (5.1 %)
2-3 Days	15 (6.0 %)	13 (9.5 %)
4-5 Days	119 (47.6 %)	110 (80.3 %)
Length of one-way morning trip[1]		
Do Not Commute	103 (41.2 %)	7 (5.1 %)
Less than 5 Minutes	5 (2.0 %)	2 (1.5 %)
6 - 10 Minutes	33 (13.2 %)	6 (4.4 %)
11 - 30 Minutes	70 (28.0 %)	47 (34.3 %)
31 Minutes to 1 Hour	37 (14.8 %)	64 (46.7 %)
Over 1 Hour	2 (0.8 %)	11 (8.0 %)

Table 4-7. Unweighted Frequencies and Percentages for Demographic Variables from Both the Telephone and Internet Surveys (Continued)

Demographic Variable	Number (Percentage)	
	Telephone Survey	Internet Survey
# Days per week travel during weekday evening rush hr		
Refused	1 (0.4 %)	N/A
None	104 (41.6 %)	
1 Day	13 (5.2 %)	
2 Days	16 (6.4 %)	
3 Days	15 (6.0 %)	
4 Days	7 (2.8 %)	
5 Days	94 (37.6 %)	
Length of one-way evening trip		
Do Not Commute	105 (42.0 %)	N/A
Refused	1 (0.4 %)	
Less than 5 Minutes	6 (2.4 %)	
6 - 10 Minutes	31 (12.4 %)	
11 - 30 Minutes	67 (26.8 %)	
31 Minutes to 1 Hour	34 (13.6 %)	
Over 1 Hour	6 (2.4 %)	

Note: No distinction was made between morning and evening peak hours in the Internet survey. The question was worded differently in the two surveys.
N/A – Not Applicable

Acceptance: In the customer satisfaction model, the acceptance phase is marked by the customers' stated preference for the product or service. In relation to the Traffic.com website, the registered users (i.e., the Internet survey respondents) are assumed to have already accepted the information. Two questions in the telephone survey solicit information about whether the respondent has ever visited the Traffic.com website, and if not, if he/she thinks Traffic.com would be something he/she would use in the future. These two questions pertain to user acceptance of the Traffic.com website among the general public in the Pittsburgh metropolitan area. Sixty-five percent (65%) of the Pittsburgh population that have not used the Traffic.com website expect to do so in the future. Of those who would *not* use it in the future, over half do not need traffic information or do not commute during rush hour when it may be of the greatest benefit. Almost 25% of the population would not use it because they do not have a computer from which to gain access. However, one would expect the percentage of households with computers to increase over time. About 95% of the Internet survey respondents planned to continue using Traffic.com information in the future.

Use: While acceptance is measured by the number of customers that indicated they would use Traffic.com website, use is measured by the number of customers who actually do use it and its various features. The Traffic.com website can be used to gather information on the traffic for specific routes, as well as to check for accidents, current travel speeds, and current travel times. It also provides tools to aid in these searches, such as the point-to-point travel times, route-specific travel speed, and map features.

Note that only 9 of the 250 people (3.6%) surveyed via telephone had ever used Traffic.com website. This number is too small to draw any strong conclusions. However, since the Internet survey respondents were all registered users of the Traffic.com website, 100% of the respondents have used the site. Unfortunately, the results for the two survey efforts cannot be combined due to the weighting of the telephone survey responses. Therefore, the usefulness of the Traffic.com information will be characterized primarily by the Internet survey results.

Figure 4-14 shows the percentage of users from each of the surveys in relation to *how* they used the site. The Internet survey respondents used Traffic.com information for various reasons. Eighty-four percent (84%) of the Internet survey respondents checked for traffic on specific routes, 34% checked the current travel speeds, 61% checked for accidents, and 38% checked current travel times. Sixteen percent (16%) of the users in the Pittsburgh population checked for traffic on specific routes, and 6% checked for current travel times.

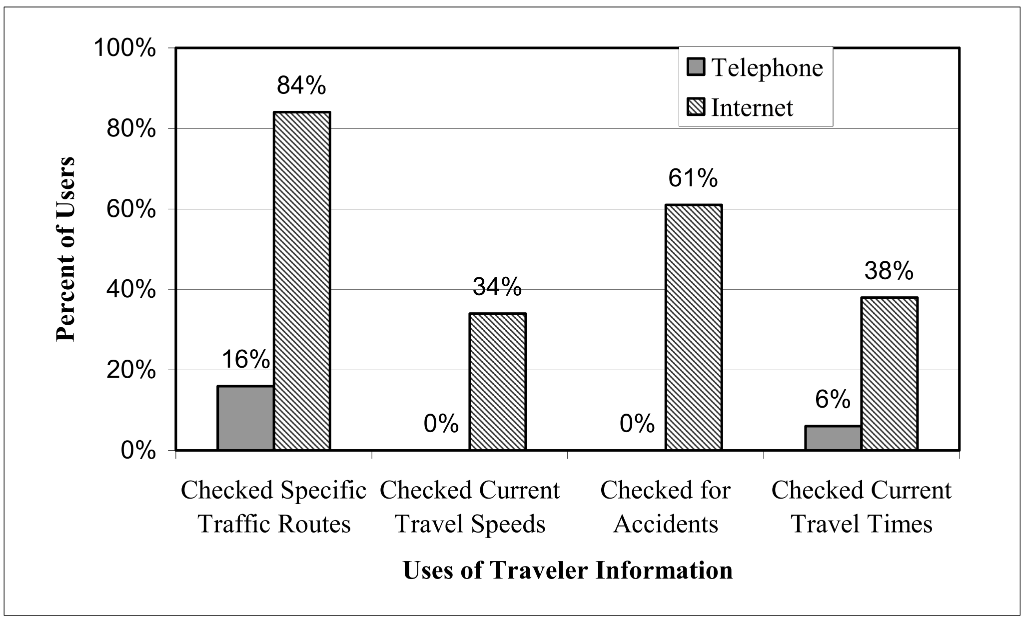

Figure 4-14. Percentage of Users from the Telephone and Internet Surveys That Used Traffic.com for the Listed Reasons

Value: The final phase of the customer satisfaction model is value of the traveler information. Many questions in the two surveys were directed at the value the respondent placed on certain aspects of the Traffic.com information, including their willingness to pay for the service. Figure 4-15 displays the percentage of users from the telephone and Internet surveys that changed their original travel route, time of travel, or mode of transportation because of the information received from Traffic.com website. From the Internet survey, 67% of users changed their travel route, 47% changed their time of travel, and 6% changed their mode of transportation. Among the general public, 68% changed their original travel route and 30% changed their original time of travel, and mode of transportation. These percentages could be an indication that the general public finds the information useful in making their travel decisions.

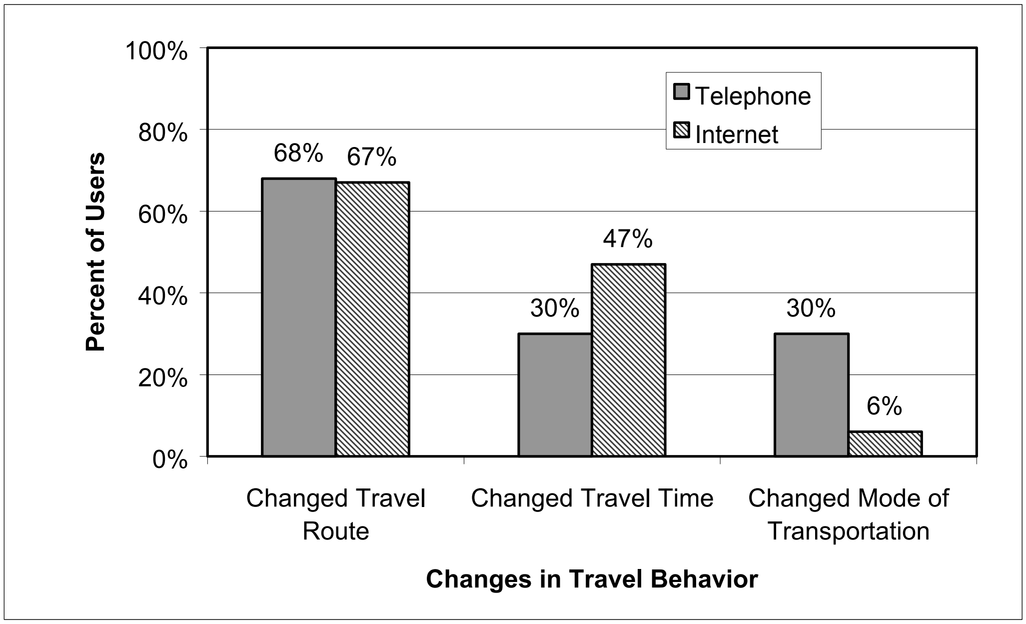

Figure 4-15. Percentage of Users from the Telephone and Internet Surveys That Changed Their Travel Behavior Based on Traffic.com Information

Fifty-seven percent (57%) of the 137 Internet survey respondents agree that the Traffic.com information is sufficient for their needs. Of the 29 who said the information did not meet their needs, 17 offered suggestions for improvement. The top three suggestions were:

- Provide more details on accidents or lane restrictions, such as which lanes are congested and which lanes are blocked by the accident, construction, or special event;
- Provide suggestions for alternate routes;
- Set up an account where traffic messages could be sent to cell phones or palm pilots.

The Internet survey results also indicate that 18% of the commuters feel that Traffic.com information helped to decrease their commute time. However, the majority of the commuters (75%) feel that their commute time has remained the same. On the other hand, all of the point-to-point travel-time-users indicated that this feature was helpful in some way and 97% of both the route-specific travel-speed-users and map-users indicated they were helpful in general. These results clearly suggest that the users value the Traffic.com traveler information they receive. However, less than 10% indicated that they would be willing to pay for the services provided.

System Performance*:* The final segment of this analysis addresses the system performance. That is, how well does the Traffic.com systems perform the intended use? The Internet survey results indicate that the majority of the users believe the system performs well. Seventy percent (70%) think the website is easy to navigate through; 73% believe the information is easily understood; 60% feel the information is reliable; and 72% indicated that all or most of the routes they wanted to check for traffic were included in the system.

Conversely, there were some comments provided to the survey administrator via email that suggested some problem areas. These are summarized below.

- The initial format of displaying information on the Internet was considered to be much better and easier than the format at the time of the survey. Clicking on the alert symbols or links on the right side of the traffic box does not work with the new format.
- It would be helpful to provide the speed information and time on the map page. It is inconvenient to go to 2, sometimes 3 screens to get the needed information.

4.4.1.3 Commentary

The results of the telephone survey indicate that at the time of the survey, much of the general public in the Pittsburgh area was unaware of the Traffic.com website. As other areas of the system deployment progress, this will likely change for the better. In addition to helping awareness, the continued deployment of the Traffic.com information via television, radio, and promotions will aid in the amount of potential users that can access the information. Only 65% of the general public in the Pittsburgh area had Internet access at the time of the survey.

The acceptance of the Traffic.com information is not yet widespread in the Pittsburgh area. Even though 65% of the population that has not used Traffic.com website plans to use it in the future, about 25% of the general public would not find the information necessary, applicable, or available to them. As for the website itself, the results seem to indicate that the information is helpful; however, use of it doesn't necessarily translate into reduced travel times. More than 70% of the registered users surveyed indicated that their travel time stayed about the same, while roughly 7% indicated that use of the Traffic.com information actually increased their travel time. The actual reasons for increases in travel times were not captured in the survey. However, it is probable that this group of users changed their travel periods or routes based on the traveler information which might have resulted in higher travel times.

Lastly, the surveyed users did not indicate a willingness to pay for the service, although this is a difficult area to assess accurately. Perhaps implementation of some of the specific suggestions provided in the system performance section above could boost the website's value to customers.

4.4.2 Stakeholders

Two of the five stakeholders in Pittsburgh, PennDOT District 11 TMC and BPR were actually accessing and or using the ISDMI data at the time of the post-deployment interviews in August 2001. Therefore, impressions deduced from the information gathered should be considered preliminary. This is because the stakeholders do not have prolonged exposure to the data at this time and it should be expected that their perceived levels of satisfaction with the ISDMI systems might change with time. The model used for assessing the level of satisfaction is the same as the one used for the general public. However, the issue of access is not relevant to evaluating stakeholder satisfaction. This is because all stakeholders are given free access to the databases and, unlike the general public, stakeholders are able to access both real-time and archived databases. In addition to the Internet interface, stakeholders have PC based interface software designed purposely to allow stakeholders access to the archived database and to generate customized reports for their specific applications. The preliminary satisfaction levels expressed by the stakeholders are summarized below:

TMC uses the ISDMI real-time data on a continuous basis as a supplemental source of traffic data. TMC finds the data useful for a number of reasons:

- Data improve coverage of highway system
- Useful source of data for traffic management operations as well as planning and scheduling maintenance activities
- Data allow improved incident management (emergency response).

BPR offered the following assessment of the archived data from the ISDMI systems:

- The system of data collection is convenient and useful because it is non-intrusive.
- The system allows for more coverage spatially and temporally.
- It is easy to access and download archived data from the ISDMI archived database. It eliminates data processing and storage requirements.
- The ability to generate FHWA required HPMS reports was noted as a major advantage of the ISDMI archived database over the legacy systems.
- The major concern with traffic data from the ISDMI systems is accuracy and quality compared to the legacy systems.

BCTA was not accessing or using data from the ISDMI systems at the time of post-deployment data collection.

ACPA was not using the data on a continuous basis and not for any specific operational application at the time of the evaluation data collection. However, officials of the agency had the opportunity to access and review the data. The preliminary impression was that the data have great potential in assisting the agency in monitoring traffic, planning, and bus routing purposes. ACPA was not in the position to provide substantive customer satisfaction inputs into the evaluation effort.

At the time of post-deployment data collections and several weeks following, SPC was not accessing or using data from ISDMI. This was not because SPC did not find the data useful. Rather, it was due to some institutional arrangements within SPC that need to be resolved.

4.4.3 Media Houses

Information on customer satisfaction was obtained from two media houses operating in the Pittsburgh area. These are Steel City Media operating FM radio stations (i.e., WLTJ and WRRK), and Sheridan Broadcasting that operates AM and FM radio stations (e.g., WAMO). These media houses obtain traffic information from Mobility Technologies for a fee and provide traveler information to motorists especially during the morning and evening peak periods.

Access: Both media houses access real-time traffic data directly online in their studios through the Traffic Pulse producer (Mobility Technologies) application via the Internet. On the average, the media houses access real-time traffic information via the ISDMI systems 3 to 4 times during the morning peak hour between 6 and 10 AM and 3 to 4 times during the evening peak between 3 and 7 PM. In addition, traffic information is accessed throughout the day as needed. The media houses indicated that they do not experience any difficulties accessing data.

Use: The traffic information is used purely for broadcast purposes to listeners in the entire city of Pittsburgh. The media houses do not archive the traffic information after broadcast. On the question of whether the media houses receive feedback from the public on the traffic advisory information that they broadcast, one media house noted that sometimes listeners call to say that they saved a lot of time due to real-time traffic reports provided on the air.

Acceptance and Value: The quality of data is characterized as good and satisfies their needs in terms of the format of data delivery, accuracy, timeliness, completeness, and reliability. The media houses noted that the new systems offer a more convenient and easier way to obtain traffic information via the Internet compared to faxes, which is the legacy form of data access. It was noted that traffic information from the Mobility Technologies system is much more reliable and specific in terms of drive times.

An aspect of the traffic information system that was found to be more useful included the color-coded maps showing different levels of traffic conditions on the routes, making it easy to read and relay to motorists. Also, the Internet user interface is easy to use and user friendly.

Both media houses expressed satisfaction with the traffic information and indicated that they would recommend this source of traffic information to other potential customers. This is because this service has totally changed the way the media houses deliver traffic information to listeners and it is believed that it truly saves the traveling public time on the road.

In terms of potential improvements, the media houses recommended that more key route information such as drive times should be added.

4.5 Congestion

In evaluating the potential impacts of the ISDMI systems on congestion in the Pittsburgh area, two historically congested sections were identified. These locations are monitored with cameras. These are I-376 Beechwood Blvd during the evening peak hour, 3 to 6 pm (outbound or eastbound), and the I-279 Rosslyn Farm during the morning peak hour 6 to 9 am (inbound or southbound). Mobility Technologies' sensors 36 and 11 serve these locations, respectively.

The congestion analyses were conducted on data from two different sources, ISDMI archived database and video recordings. The video data were collected by recording traffic movements at these locations during morning and evening peak periods on Tuesday through Thursday for one week in November 2000 and one in August 2001. The archived data were downloaded from the ISDMI archived database over the same period. It was assumed that traffic conditions are fairly stable between Tuesday and Thursday of any given week. The November 2000 data served as the baseline and the August 2001 data represent the post-deployment situation.

Traffic parameters used for evaluating congestion are speed and volume (from archived data) and travel time between two points (from video recordings). These parameters were compared between November 2000 and August 2001 at the two locations to examine the potential impacts of ISDMI systems on traffic congestion. These discussed in Sections 4.5.1 and 4.5.2 below.

In interpreting the results of the congestion analysis, it is important to note that changes in travel speed could be the result of several factors including location, time of day, direction of travel, weather, season, volume of traffic, occurrence of incident, availability of alternative routes, and also prior knowledge of traffic conditions at the location. No seasonal effects were accounted for in the analysis because there are no data to show how traffic volume and speed changes with season at the selected sites. It is therefore difficult to attribute any changes in travel speed and travel time directly to the effect of the availability of traveler information on congestion at any given location. For the purposes of this analysis, it was hypothesized that the availability of traveler information to road users would affect congestion assuming all other factors remaining unchanged. The traveler information includes traffic condition information to motorists via Internet, VMS, and HAR.

4.5.1 Archived Data

Archived data on travel speed and traffic volume recorded by the sensors at the two locations were downloaded and analyzed. Traffic data were generated at 5-minute intervals. Data for the same dates in November 2000 as those for the baseline video recording were compared with data for other months through August 2001. Data for some intermediate months (February, April, and May) were also analyzed to examine the trend of traffic conditions at these locations. Analyses of archived data provide a more credible quantitative assessment of the impacts of the new ISDMI systems on traffic conditions compared to the video data. It is assumed that the quality and reliability of the archived traffic data are consistent in time and space.

With the 5-minute interval traffic data reports, 36 data points for each 3-hour peak period were analyzed for each month. The results are summarized in Table 4-8 and Figure 4-16. Table 4-8 shows the average speed and traffic volumes plus or minus 1 standard deviation, and the overall change between November 2000 and August 2001 expressed as a percentage of the November 2000 value. Negative values indicate decreases and positive values indicate increases above the November 2000 values, respectively. Figure 4-16 presents the average peak hour speeds by month for both directions of travel for the two locations. Figure 4-17 presents the average peak hour traffic volumes by month for both directions of travel for the two locations.

It is noted that average speeds during the evening peak period in the congested direction of travel at the Beechwood Blvd location has increased by only 9% between November 2000 and August 2001. The morning peak period in the congested direction did not show any significant noticeable improvement in average speed (1% increase). The average speeds in the non-congested directions stayed practically the same during morning and evening peak periods (about 1% increase). It is also noted in Figure 4-14 that average peak period speeds at this location did

Table 4-8. Summary Statistics of Speed and Volume – Archived Data

Average Speed (mph)				
Beechwood Blvd.				
Month	Congested Direction		Non-congested Direction	
	AM (WB)	PM (EB)	AM (EB)	PM (WB)
November	60.8 +/- 3.1	27.7 +/- 5.7	57.0 +/- 2.6	62.3 +/- 1.8
February	58.7 +/- 5.2	28.2 +/- 6.1	58.1 +/- 2.4	61.8 +/- 2.0
April	58.9 +/- 4.6	30.5 +/- 6.5	57.5 +/- 2.9	60.6 +/- 1.7
May	53.8 +/- 10.1	32.2 +/- 3.5	57.4 +/- 2.3	61.5 +/- 1.7
August	61.6 +/- 2.2	30.2 +/- 4.5	57.7 +/- 3.0	62.8 +/- 2.0
Overall Change	1.3%	9.0%	1.3%	0.8%
Rosslyn Farm				
Month	Congested Direction		Non-congested Direction	
	AM (SB)	PM (NB)	AM (NB)	PM (SB)
November	44.3 +/- 5.2	34.3 +/- 8.5	46.9 +/- 3.3	46.5 +/- 1.5
February	55.6 +/- 2.0	37.8 +/- 9.6	61.0 +/- 2.7	50.8 +/- 2.3
April	52.9 +/- 6.3	52.6 +/- 4.9	56.9 +/- 6.9	55.7 +/- 1.8
May	50.7 +/- 2.5	63.5 +/- 6.6	44.3 +/- 10.0	65.3 +/- 2.2
August	45.6 +/- 4.8	66.4 +/- 2.3	46.4 +/- 3.6	61.9 +/- 2.0
Overall Change	3.0%	93.8%	-1.2%	33.0%
Traffic Volume				
Beechwood Blvd.				
Month	Congested Direction		Non-congested Direction	
	AM (WB)	PM (EB)	AM (EB)	PM (WB)
November	286 +/- 23	364 +/- 37	201 +/- 41	226 +/- 29
February	293 +/- 26	370 +/- 29	197 +/- 40	222 +/- 28
April	289 +/- 16	349 +/- 35	204 +/- 38	231 +/- 18
May	251 +/- 31	301 +/- 22	200 +/- 33	233 +/- 19
August	275 +/- 20	367 +/- 23	181 +/- 27	203 +/- 22
Overall Change	-3.9%	0.7%	-9.9%	-10.0%
Rosslyn Farm				
Month	Congested Direction		Non-congested Direction	
	AM (SB)	PM (NB)	AM (NB)	PM (SB)
November	327 +/- 49	308 +/- 38	270 +/- 33	363 +/- 36
February	311 +/- 47	293 +/- 37	248 +/- 36	359 +/- 28
April	319 +/- 40	306 +/- 29	257 +/- 24	358 +/- 27
May	325 +/- 46	247 +/- 26	262 +/- 40	325 +/- 28
August	324 +/- 40	241 +/- 20	262 +/- 33	338 +/- 24
Overall Change	-0.9%	-21.7%	-2.7%	-7.0%

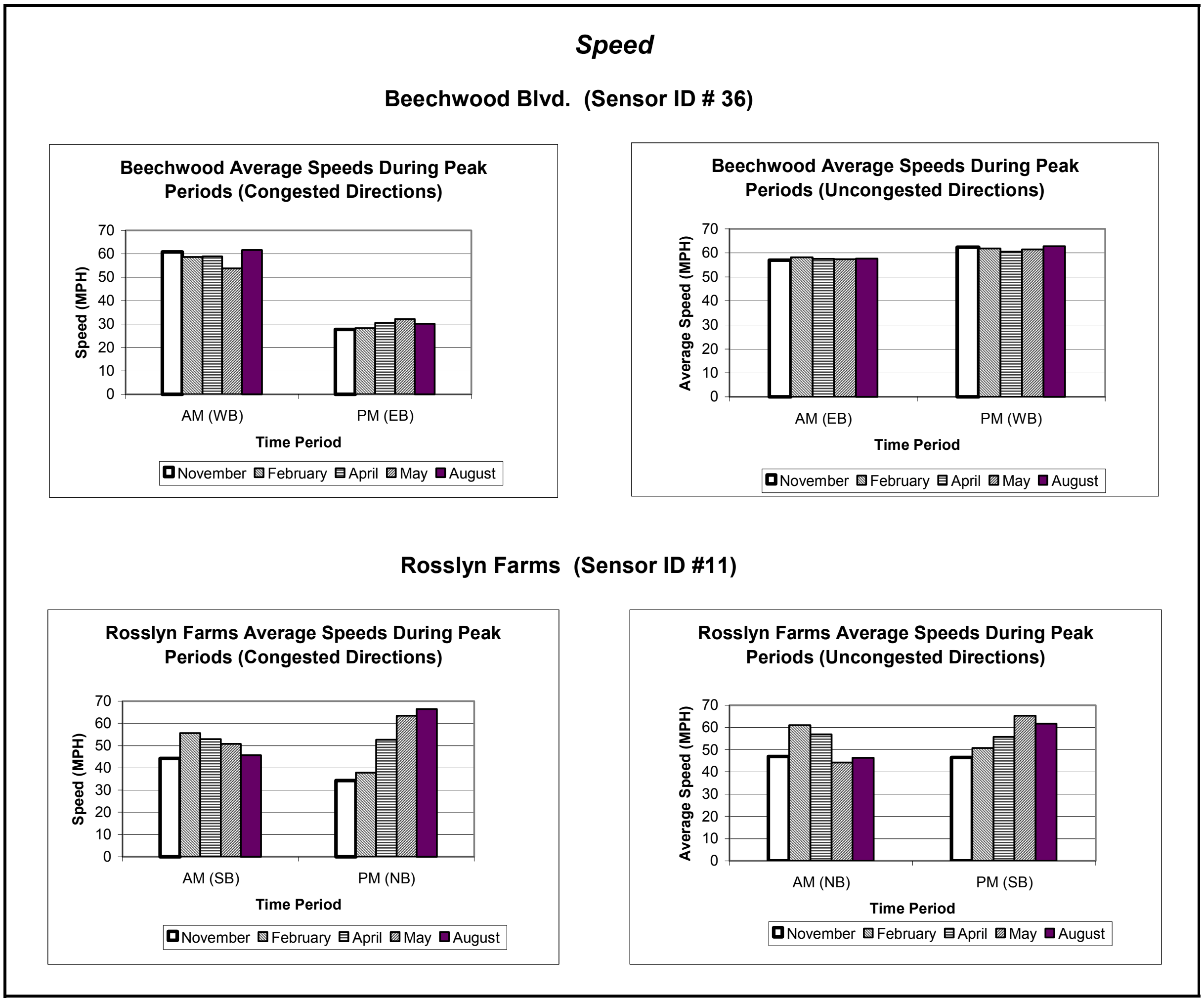

Figure 4-16. Average Peak Hour Speeds – (Archived Data)

not fluctuate significantly from November 2000 through February, May, and August of 2001. Similarly, the average volume stayed the about same during this period (Figure 4-17). Between November 2000 and August 2001, however, the average traffic volume at this location decreased by 10% during in the non-congested direction of travel in each peak period.

The Rosslyn Farms location, on the other hand, showed significant improvement in peak hour speed between November 2000 and August 2001. It was noticed that the average speeds during the evening peak period increased significantly, 94% in the congested and 33% in the non-congested directions of travel, respectively. The traffic volume at this location during the evening peak period reduced by 22% in the congested and 7% in the non-congested directions of travel. It is interesting to note that this corresponds to the highest increase in speed. The average speed and traffic volume during the morning peak period remained about the same. An examination of Figure 4-14 revealed that the increase in evening peak period average speed is steady from November 2000 through February, May, and August of 2001. The change in traffic volume during the same period is less noticeable (Figure 4-17).

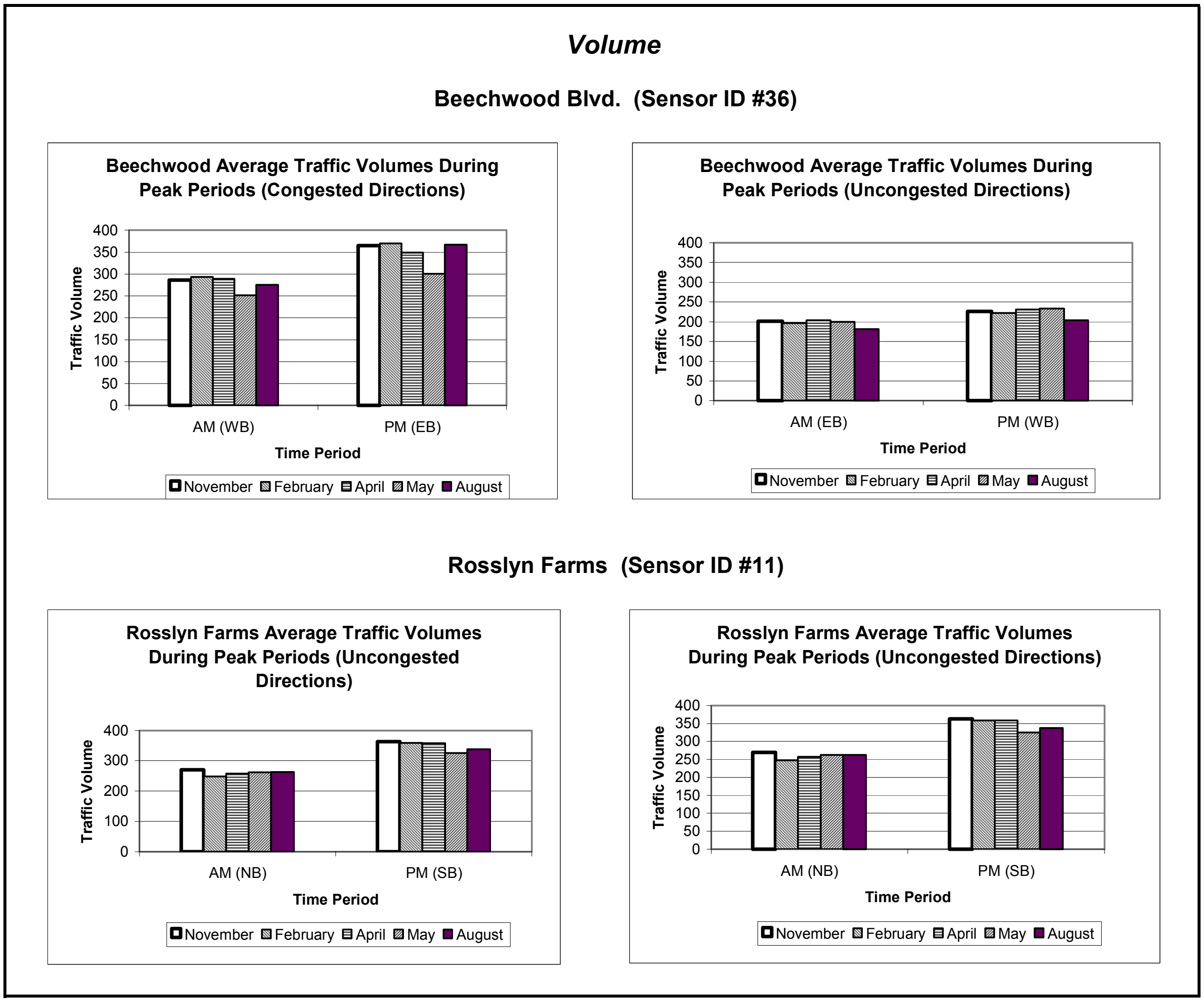

Figure 4-17. Average Peak Hour Volume – (Archived Data)

Improvements in traffic speed and reduction in traffic volume during the peak periods at these locations suggest that the observed changes may be attributed in part to improved traveler information to motorists. Although inconclusive, the results seem to suggest that the availability of real-time traveler information may in fact influence trip making decisions and therefore congestion. Furthermore, the results suggest that availability of timely traffic condition information may improve the traffic management operations of TMC and help motorists make trip planning decisions.

In order to get a better understanding of the impact of ISDMI on congestion, the results of the customer satisfaction study were also reviewed. The results indicate that 16% of the traveling public does check real-time traffic information in making travel decisions. Also, about 67% of motorists interviewed reported changing their route and 47% changed their original time of travel based on traffic information accessed on the Internet. While it is not possible to relate these changes to the use of highway sections served by the two sensors examined, the results suggest that availability and access to real-time traffic information influences making trip decisions and consequently congestion.

4.5.2 Video Recorded Data

Travel time estimates were derived by timing the travel time between two imaginary points from the video data. This was done for both the congested and non-congested directions of travel. Descriptive statistics of travel time (mean and standard deviation) were determined. The results from the video data analysis are crude and are used to provide a general indication of the changes in traffic conditions at the two locations between November 2000 and August 2001. Furthermore, the video data were used to verify information recorded by the sensors.

The results of the analysis are summarized in Table 4-9. It shows the average travel time plus or minus 1 standard deviation, and the overall change between November 2000 and August 2001 expressed as a percentage of the November 2000 value. Negative values indicate decreases and positive values indicate increases relative to the November 2000 value respectively. Also, an increase in travel time implies a reduction in speed at that location and vice versa.

Table 4-9. Summary Statistics of Travel Time (Seconds) – Video Data

Beechwood Blvd.				
Month	**Congested Direction**		**Non-congested Direction**	
	AM (WB)	PM (EB)	AM (EB)	PM (WB)
November 2000	13.4 +/- 1.0	23.5 +/- 7.3	11.9 +/- 1.1	11.7 +/- 0.6
August 2001	12.8 +/- 1.1	71.5 +/- 19.3	11.9 +/- 1.5	12.7 +/- 1.2
Overall Change	-4.5%	203.5%	-0.2%	8.7%
Rosslyn Farms				
Month	**Congested Direction**		**Non-congested Direction**	
	AM (SB)	PM (NB)	AM (NB)	PM (SB)
November 2000	4.4 +/- 0.5	6.7 +/- 2.8	3.8 +/- 0.5	6.0 +/- 0.8
August 2001	4.7 +/- 0.9	5.7 +/- 1.0	5.3 +/- 0.8	4.4 +/- 0.7
Overall Change	8.4%	-14.8%	40.7%	-26.7%

For the Beechwood Blvd. location, morning peak vehicle travel time in the congested direction of travel decreased by less than 5% between November 2000 and August 2001. The evening peak vehicle travel time, however, increased by more than 200% during the same period. It was noted that the vehicles were virtually at a standstill between 3:30 and 6:00 pm on one of the days that the traffic data were video recorded in August 2001. A review of the incident summary for that date revealed that an incident occurred near that location and it took about 2 hours to clear. An examination of the archived speed data over the same period and location indicated that the sensor recorded higher speeds than those observed in the video – the vehicles were be virtually stationary in the video, while the archived speed data showed speeds higher than 35 mph for that same location and time. Also, the speeds were inconsistent with the incident summary stored in the archived database. No plausible explanation can be offered for this discrepancy.

At the Rosslyn Farms location, evening peak travel times in the congested direction decreased by about 15% (i.e., average speed increased) and decreased by 27% in the non-congested direction of travel. The morning travel times at this location showed increases. These results are consistent with the results of the archived speed data analysis for this location presented in the previous section. These results support the hypothesis that the availability of real-time traveler information may in fact influence trip making decisions and therefore congestion. Also, there is evidence from the customer satisfaction study that the availability of real-time traffic information does influence trip making decisions and impacts congestion. It is expected that as awareness, access, and usage of the systems increase, the impact on congestion will become more visible.

4.5.3 Qualitative Assessment by TMC

TMC personnel, however, observed that even though changes in traffic congestion in general were marginal, some noticeable improvements were observed. For example, congestion seemed to have improved on corridors without camera coverage. This is probably the result of providing motorists with traffic information through VMS, HAR, and commercial radio reports including lane restrictions on affected corridors. Also, since TMC does not have cameras on all highways, the ISDMI sensors provide a wider coverage of the highway system and therefore allow the TMC to provide traffic advisories on links that are not serviced by cameras. The end result is better information to a greater number of motorists, particularly during the peak periods or in the event of an incident.

4.6 Cost Analysis

The cost analysis of ITS system deployment is designed to determine the recurring and non-recurring costs associated with the deployment of the systems. The ISDMI project, being a private-public sector partnership, has certain unique financing arrangements. The systems were designed, deployed, operated, and maintained by a private entity. Consequently, certain cost items are considered proprietary and therefore not available to the evaluation team and are not reported in this analysis. According to the information provided by Mobility Technologies, non-recurrent costs related to data collection, processing, and archiving are $2 million in Federal funds and $500,000 in state funds. There are no recurring costs to the public sector. The private partner assumes all recurring and capital costs.

The focus of the cost analysis of this evaluation therefore is to determine the cost savings to the various stakeholders in terms of data collection, processing, storage, and retrieval. These cost savings exclude system deployment costs. The cost analysis was limited to estimating the cost savings to the stakeholders assuming that they rely entirely on data provided by the ISDMI systems. In other words, the differences in the costs of using the legacy systems and ISDMI systems are estimated to reflect the potential cost savings to the stakeholders. The recurring maintenance and operation costs of the legacy systems and estimated costs of anticipated technology deployments by the various stakeholders are presented in the following sections.

4.6.1 PennDOT District 11-0 Traffic Management Center (TMC)

For the TMC, the deployment of PennDOT's own detectors whereby the department would be capturing and offering similar traffic information to the traveling public may conflict or duplicate the outputs of the ISDMI systems. However, when carefully planned, these data sources could complement each other. Since PennDOT's systems were not fully operational at the time of the evaluation it is difficult to speculate the potential cost effects of deploying and operating dual systems. Table 4-10 shows a breakdown of the operating costs of cameras currently used and the equipment costs for the new detectors. The non-recurring, one-time capital cost of deploying the new detectors, fiber optics, VMS, and HAR is estimated at $21,788,000 and the annual maintenance costs was estimated at 10% of the equipment cost (i.e., approximately $57,000). The annual operating and maintenance costs of the new systems were estimated at $957,000. Part of the new system costs would not be incurred if the TMC relies entirely on ISDMI systems to meet its traffic data needs including the kinds of traffic information that the detectors are expected to generate.

The ISDMI systems are not seen as replacements to the cameras. Rather, they supplement traffic information captured by the cameras. Therefore, no recurring cost savings from operating and maintaining the cameras are expected.

Table 4-10. Summary of Cost for TMC Traffic Information Gathering

Description	Number	Non-recurring Cost	Recurring Cost / Year
Legacy systems			
Cameras (CCTV)	61	}	
Variable Message Signs (VMS)	20	}$21,648,000	
Highway Advisory radio (HAR)	8	}	
Microwave Detectors ($10,000 each	57	}	
Fiber optics (miles)	37.5	}	
Vehicle detection & traffic management software		$140,000	
Maintenance cost @10% of equipment cost			$57,000
Operating cost			$900,000
Total (new systems)		**$21,788,000**	**$957,000**

4.6.2 PennDOT Bureau of Planning and Research (BPR)

BPR is planning to replace the existing 63 ATRs with double loop detectors. Table 4-11 shows the deployment and annual maintenance costs for each ATR site to be about $182,000 (i.e., 11,592,000 for 63 sites) and $12,500 per site respectively. These estimates are based on a bid from a potential contractor, which happens to be the lowest bid received by BPR. The closest bid was noted to be about 30% higher.

Table 4-11 also shows a breakdown of current annual data processing and editing, communication, ATR maintenance, and operations costs (i.e., legacy system). The total recurring cost for the legacy systems is $63,580. The cost savings to BPR resulting from the deployment of the ISDMI systems are the costs of data collection, processing, and storage using the legacy systems. In addition, the cost of replacing existing traffic data gathering equipment would also be saved. For the BPR, the recurring cost savings is about $64,000 per year less the time and effort required to download and process traffic data from the ISDMI archived database. This cost saving is based on the assumption that the BPR discards its legacy data collection systems and relies entirely on the archived data provided by the ISDMI systems. If a dual system were maintained (i.e., the legacy and ISDMI systems) the cost savings could be less than $64,000 per year in recurring costs. In addition, the one-time capital costs of new equipment would be saved. For example the cost of replacing all 63 sensors at $182,000 per site could be saved.

Table 4-11. BPR Equipment, Operation, and Maintenance Costs

Description	Non-Recurring Cost Per Site	Total Recurring Cost / Year
Non-recurring (new ATR)		
In-pavement double loop system	$181,574[1]	
Maintenance cost		$12,404
Operation and Maintenance (Legacy system)		
Data processing and editing	$500	$31,500
Equipment inspections	$250	$15,750
Maintenance and protection		
- 2-lane highways (38)	$160	$6,080
- 4 or more -lane highways (25)	$400	$10,000
Communication costs	N/A	$200
Data archiving (10 CDs)	$5 per CD	$50
Total (legacy system)		$63,580

1- Lowest bid from a potential contractor - about 30% lower than the next higher bid.

4.6.3 Beaver County Transit Authority (BCTA)

For BCTA, there are no potential cost savings because the information obtained from the ISDMI systems is supplemental to data from their legacy systems. Moreover, BCTA is not planning to deploy any system to generate similar kinds of information. The capital cost of the existing AVL system and other data gathering equipment is $285,000 with an annual maintenance and operating cost of $6,900. Obviously, traffic data collection does not constitute a major part of BCTA costs. The agency is planning to replace the legacy AVL system with a new one at a cost of $750,000.

4.6.4 Allegheny County Port Authority (ACPA)

ACPA did not provide any cost data. It is therefore not possible to speculate on the cost savings that might accrue to the agency.

4.6.5 Southwestern Planning Commission (SPC)

SPC spends $130,000 annually on traffic data collection, processing, and reporting. This amount includes labor, vehicles, maintenance, equipment replacement, and other operating costs associated with traffic data collection and reporting. The agency collects traffic data for other agencies such as PennDOT. SPC is currently not accessing or using data from the ISDMI archived database and therefore they are not in a position to provide any cost information that would allow estimation of potential cost savings. If SPC relies on ISDMI systems for its traffic data needs, then it could save up to $130,000. SPC also conducts periodic congestion management studies along some 100 corridors in the Pittsburgh area. While some of their studies occur on corridors that ISDMI does not cover, the nature and quality of data generated from the ISDMI systems could also help facilitate SPC's overall congestion management.

4.7 Safety

As noted in Section 3.4.5 of this report, information on safety impacts is anecdotal and qualitative. The TMC officials observed that one of the major safety benefits offered by the ISDMI systems is that access to real-time traffic information from the ISDMI systems resulted in a reduction in the number of secondary incidents. The TMC officials were not able to provide any numbers to back this claim. This is directly attributed to improvements in incident management practices through availability of timely traffic condition and incident information to the TMC and the provision information to motorists via VMS and HAR.

Since the ISDMI systems have a wider coverage of the highway network, the TMC is able to monitor traffic over a wider area than with the cameras only. The information alerts motorists of incidents ahead and allows them to react accordingly and prepare before getting to the incident location. It also allows motorists to make decisions regarding alternative routes, thus avoiding congestion and delays caused by incidents. Overall, TMC claims to be able to perform the incident management functions better with the availability of the ISDMI systems. It is important to note the overlap between the impacts on congestion and safety.

The ISDMI systems have a trigger mechanism that alerts TMC officials immediately when an incident occurs. This functionality reduces incident detection and response time. In this way, TMC can provide timely and accurate messages to motorists relating to incidents on the highways.

4.8 Institutional Issues

Because of their similarities, the discussions of institutional issues for both Pittsburgh and Philadelphia are combined and presented in Section 5.8 of this report.

CHAPTER 5: FINDINGS - PHILADELPHIA

5.1 Introduction

This chapter describes the findings in Philadelphia. The baseline data were collected in July and August 2001. This information serves as the baseline against which to estimate the changes resulting from the ISDMI systems deployment in Philadelphia. Post-deployment data collection in Philadelphia was completed in April 2002. First, the baseline information is presented in Section 5.2. This is followed by detailed discussions of the findings organized by study area. Since the same evaluation approach was used for Pittsburgh and Philadelphia, detailed descriptions of the steps involved in the analysis of data are not repeated in the discussions for Philadelphia.

5.2 Summary of Baseline Situation

A total of four interviews were conducted in Philadelphia between July and August 2001 with representatives of the following stakeholders:

1. PennDOT District 6 - Traffic Management Center – District 6
2. FHWA Philadelphia office
3. Delaware Valley Regional Planning Commission (DVRPC)
4. City of Philadelphia, Streets Department.

These were the only stakeholders that provided information to the evaluation team. The four agencies have different objectives and therefore different traffic data needs. For the TMC, it is very important to obtain real-time, accurate data, while the other three agencies use primarily archived data. TMC does not archive data (except incident logs), FHWA does not collect its own data, while DVRPC and the City of Philadelphia collect, process, archive, and share various types of traffic data with the other agencies.

General problems reported for legacy traffic data collection methods include equipment accuracy, failure of the equipment for specific applications, and vandalism. Regarding data sharing, the most important issue is common referencing systems, particularly regarding geographic information systems (GIS) and geolocation issues. The following sections provide details on the stakeholders.

5.2.1 Delaware Valley Regional Planning Commission

Delaware Valley Regional Planning Commission (DVRPC) is a two-state agency (Pennsylvania and New Jersey). DVRPC's major road traffic related activity is to collect traffic data and provide them to various agencies. The types of traffic data include: 24-hour volumes, loop counts, classification, and turning movements. Each year, PennDOT requests counts at about 2,000 locations. District 6-0 typically requests collection of manual turning movement counts at intersections for traffic engineering projects (i.e., changes in signal control, classification studies for resurfacing, etc.) Most of the requests for counts come from PennDOT and the City of Philadelphia and a few by the county (townships route their requests through the county).

DVRPC owns and maintains its own counting equipment. Typically, DVRPC does not obtain traffic data from other agencies. Data are collected at the 2,000 locations. When manual turning movement counts are conducted, the data are reported in 15-min volumes during the peak hour. DVRPC follows the Federal traffic manual guide for collecting and reporting traffic data.
A total of five (5) staff are responsible for traffic data collection (4 operate portable recorders and 1 conducts the manual counts). In addition, students are employed as seasonal temporary help. For data processing, analysis, and reporting, DVRPC uses one (1) computer staff for reporting, one (1) staff for data input, and a manager. The approximate annual budget is $600,000 including salaries and equipment purchasing.

With regards to coordination with other agencies, the most significant issue identified is the amount of money available to DVRPC for data collection – the agencies ask for an increasing number of counts for the same budget. As a result DVRPC tries to "bunch" the assignments given to the staff so that all the counting locations are close to each other.

Traffic Data Usage: DVRPC typically stores historical data for traffic monitoring and for checking equipment malfunctions. DVRPC uses archived data for its transportation applications, comparative analysis, identification of trends, and development of traffic growth factors. The agency does not collect or use any real-time data.

The data collection staff downloads historic traffic data from the roadside DVRPC equipment every Friday. The weather conditions and other unusual conditions observed at the site (i.e., work zones in the vicinity of the data collection location, etc.) are also reported with the traffic data. Data are very seldom collected over the weekend.

A notable problem that faces DVRPC in accessing archived data from other agencies is that electronic access is not available. Data collected by consultants are not recorded according to the requirements of the FHWA manual, particularly with respect to location information. Thus, DVRPC has difficulty verifying traffic information from other sources. A benefit of ISDMI data includes a common system for reporting traffic data to allow agencies to share data more efficiently.

Unlike Pittsburgh's MPO, DVRPC's traffic data collection unit does not conduct congestion management studies. The ISDMI data are valuable to DVRPC since the agency no longer collects data on interstates due to unsafe conditions when installing the counting tubes on interstates and freeways. While DVRPC collects traffic data on ramps, the agency does not collect accident data.

Data Quality and Problems: Traffic data collection problems experienced by DVRPC without ISDMI data are those that are common to all urban areas. These include: parked vehicles on tubes, vandalism, failure of the tube because of heavy truck traffic, and street cleaning vehicles damaging the tubes. Sometimes citizens or the police report disconnected tubes or vandalism. These problems are not documented, but generally they occur once or twice a week.

There are also problems with inaccurate vehicle classification devices whereby DVRPC data collection staff have to conduct vehicle classification counts manually. No problems with handling, storing, and reporting data were reported from manual tube collection.

5.2.2 PennDOT District 6 - Traffic Management Center

The major road traffic-related activity of PennDOT District 6 - TMC is surveillance and incident management for limited access facilities around Philadelphia. Data are typically not collected and saved, as the agency is interested only in real-time traffic conditions and incident detection.

Existing data sources are an incident log and a set of loop detectors. The incident log includes the type and duration of an incident, through the district's service patrol operation. When the State Police is involved and there is no dispatching of vehicles from the district, there would be no record of the incident at PennDOT. Loop detectors were installed to collect speed data along I-476, or *The Blue Route*, but these were not operational at the time of the ISDMI evaluation baseline data collection due to lack of functional software. These detectors were intended to be used for the ramp metering system. The district plans to install 24 detectors on I-95 (RTMS, similar to the ones used by Mobility Technologies) and the information will be processed using the TRANSDYM software obtained from Georgia DOT. The detectors will be installed along an 11-mile section of I-95 north of the Vine Street Expressway. The primary purpose is incident detection; however, the detectors will also be used to collect speed, flow, occupancy, and vehicle classification information by lane. This information will be transmitted to the TMC via a T-1 communications line.

TMC also obtains incident information from private traffic information providers such as Express Traffic, Metro Traffic, Smart Traveler (up to February 2002), and TRANSCOM. Additional information is sometimes obtained through the I-95 corridor coalition (Maine to Virginia), when the borders with other states are affected (New Jersey and Delaware).

With regards to coordination issues in working with other agencies, accuracy, timeliness, and completeness are TMC's most important issues. The TMC needs to know when the incident starts and also when it has been removed. There is a very well established list of contacts once an incident is detected.

Regarding costs to collect these data, it is very difficult to separate the data collection costs from the information dissemination costs. There are now 5 people working at the TMC – 4:30 am to 8:30 pm, 5 days a week. It is important to note that these 5 staff members do not work exclusively on traffic surveillance and incident management activities.

***Traffic Data Usage**:* The primary use of the data is for incident management. Video is the agency's primary means of gathering incident related information. Currently there are 46 cameras, and a total of 90 cameras are expected to be installed by the end of 2002. The data are transmitted via T-1, phone lines, fax, and the I-95 corridor coalition PC network. The system follows a protocol for sending messages to other agencies, depending on whether the effects of an incident or event are local or regional.

TMC paid $90,000 per month to Smart Traveler for traffic information – the contract ends February 2002. Smart Traveler obtains its traffic information from probes and they also have their own aircraft.

The agency does not archive data, and there are no recordings of the video received. The incident log is the only source of archived data, and it is available in hard copy. TMC transmits traveler information to the public via 10 permanent VMS boards and 13 portables.

In cases of congestion, TMC posts messages as appropriate via the VMS. When there are special events, the TMC operates extra hours, and provides options to travelers on routes and exits. When applicable, road closures are posted on scoreboards (during games). Even though alternate route information is not provided, TMC indicates where unusual congestion/delay may be expected. Sections with recurring congestion are: I-95 NB, Ben Franklin Bridge to Girard Avenue (2:30 - 6:30 pm) and I-95 SB, Bridge Street to Callow Hill (6:30-8:30 am), and I-676 both directions (1 ¼ mile long – 5 interchanges).

Data Quality and Problems: Problems identified with data quality captured from PennDOT's devices are mostly false detector or sensor alarms. Consequently, these data capturing devices cannot be relied upon exclusively but can be used as a trigger mechanism, which then needs to be verified by the cameras. As a result, the cameras are an important component of the real-time data gathering systems. The cameras malfunction at a rate of about 1 to 2 cameras per month.

Limitations of the current data collection approach include lack of central software to control all components. The operator needs to conduct several logs.

5.2.3 FHWA – Philadelphia Office

The FHWA office in Philadelphia has an oversight role for design and construction projects that are over $1 million. PennDOT has an agreement with FHWA and is responsible even when the city or municipality is concerned. When the project is operational, PennDOT takes over. Within this arrangement, data used by FHWA include traffic volumes, capacity information, and accident records. Their primary concerns are to determine how the ISDMI systems will operate in the future and whether the system will be able to handle the future demand.

FHWA does not collect any data; it relies on DVRPC and PennDOT for its data needs. FHWA requests data from these agencies only when related to a specific project in which FHWA is involved. DVRPC is certified for that purpose every year regarding the procedures to use in collecting traffic data. FHWA obtains ready-to-use archived data from DVRPC in electronic format. PennDOT processes the information and FHWA reviews the reports.

FHWA has not been able to continuously check traffic projections provided by DVRPC. The ISDMI systems are expected to help the FHWA with that, so that they can consider up-to-date information during the project construction.

5.2.4 City of Philadelphia, Streets Department

The City of Philadelphia is responsible for the operation and maintenance of the streets, excluding pavements. Types of data collected by the agency include traffic volumes by hour, average annual daily traffic (AADT), and crash data that are stored in Microsoft Access. The City is in the process of building a management information system that will code crash information and AADT in geographic information systems (GIS). The City conducts manual traffic counts on request for specific studies. They also collect traffic speed data. DVRPC is contracted annually for a portion of their data collection needs. The City started encoding reportable crashes in 2000. Their crash data come from the 911 systems.

On contract, DVRPC conducts traffic counts at about 250 locations annually. Citywide counts are carried out once every 6 years. Occasionally, the City conducts spot speed studies for particular projects. Such projects may involve changes in traffic control at an intersection, or signal upgrades.

When DVRPC collects data for PennDOT within Philadelphia, the information is also made available to the City. For the City's internal data collection procedures, manual counting boards are used in addition to automatic volume counters and radar guns for speed studies. The City is in the process of establishing a Traffic Control Center (TCC), which will include ITS elements (fiber communication to cameras installed in the field, VMS, and signal control). It is anticipated that these new developments will have greater coordination and interoperability needs. The agency provides data to consultants for specific studies. The most important coordination issue is differences in the geolocation or centerline reference that various agencies use. This creates problems with data sharing.

The estimated annual cost for data collection is $90,000 in Federal funds provided to the agency. The City of Philadelphia uses only archived data at this time. Real-time data will be used when their TCC becomes operational.

Traffic Data Usage: Archived data for the agency's activities include AADT and crash data. The primary use of these data is for traffic and safety studies. Typically, data are received electronically, but reformatting is usually required due to geolocation issues from GIS. DVRPC provides tube counts electronically in a pre-specified format. It is not expected that data from ISDMI sensors would conflict or overlap with their data collection practices. This is because the agency operates streets and not freeways.

Data Quality and Problems: The main problem for data collection is vandalism – some locations cannot be counted at all due to that problem. Also, locations with light rail or parking cannot be counted because the tubes cannot be installed. Another problem has been with Hi-Star devices, which could not accurately detect low speeds. Regarding processing and handling, the main problem has been the geo-location differences among agencies. An anticipated new system for data management will address all related issues very soon.

5.3 Technical Effectiveness

The following sections discuss results of analyses of accuracy and completeness of archived data from the ISDMI systems in Philadelphia. Archived data from 75 sensors from November 1, 2001, through January 31, 2002, were used in data completeness analysis. For these analyses, each direction was treated as if it was from a different sensor and no adjustments were made to the data to account for multiple lanes. Manual traffic count data were not available for Philadelphia. Data accuracy analysis was based on archived traffic volume data from two sensors (#2230 and #2482) compared with data from one ATR (#377).

Two types of data were used in the data quality analysis. First, ATR data were compared with archived data collected by sensors at the same location as the ATR. Statistical analyses were conducted to characterize the accuracy of the sensors in capturing and recording traffic volume information. Second, the archived data were analyzed to determine the ability of the systems to capture and store traffic volume, speed, and occupancy data completely.

5.3.1 Data Accuracy

Hourly counts of the traffic volume were collected from the ISDMI sensors and from ATRs at the same locations. The sensor and ATR sites are in close proximity to each other. In Philadelphia, the sites are located in Bucks County along Interstate 95, 2.5 miles south of US1/PA413. The traffic volume counts were collected hourly for northbound and southbound lanes of traffic during November 2001. The hourly readings were summed across each day to create daily traffic volume totals. The ATR data were provided by PennDOT's BPR. Archived data were downloaded from the ISDMI system database. This section describes the analysis that primarily examined accuracy, but first addressed aspects of reliability by considering when the ISDMI sensors appeared to be working properly.

The analysis consists of two basic phases. The first phase is to remove any obvious patterns or gross measurement errors that are caused by an unstable measurement process, which is not in a state of statistical control. The second phase is to characterize the precision of the ISDMI sensor counts relative to the ATR readings. This analysis assumes that the ATR readings are accepted as truth. Any known bias in these two data collection methods should be taken into account when interpreting the results of this analysis.

5.3.1.1 <u>ISDMI Sensor vs. ATR -- Hourly Traffic Volume</u>:

First, hourly traffic counts obtained from the ISDMI sensor were compared with the ATR counts. Figures 5-1a and 5-1b present the absolute differences in the sensor and ATR counts, along with the calculated control limits. The absolute difference is simply the difference between the ATR and the sensor readings as distinct from the relative difference, which is the difference expressed as a percent of the ATR reading. Five iterations of outlier removal were required for sensor #2230 and six iterations were required for sensor #2482 before the processes reached the desired level of stability. The southbound lanes contained more outliers than the northbound lanes, particularly at the end of November.

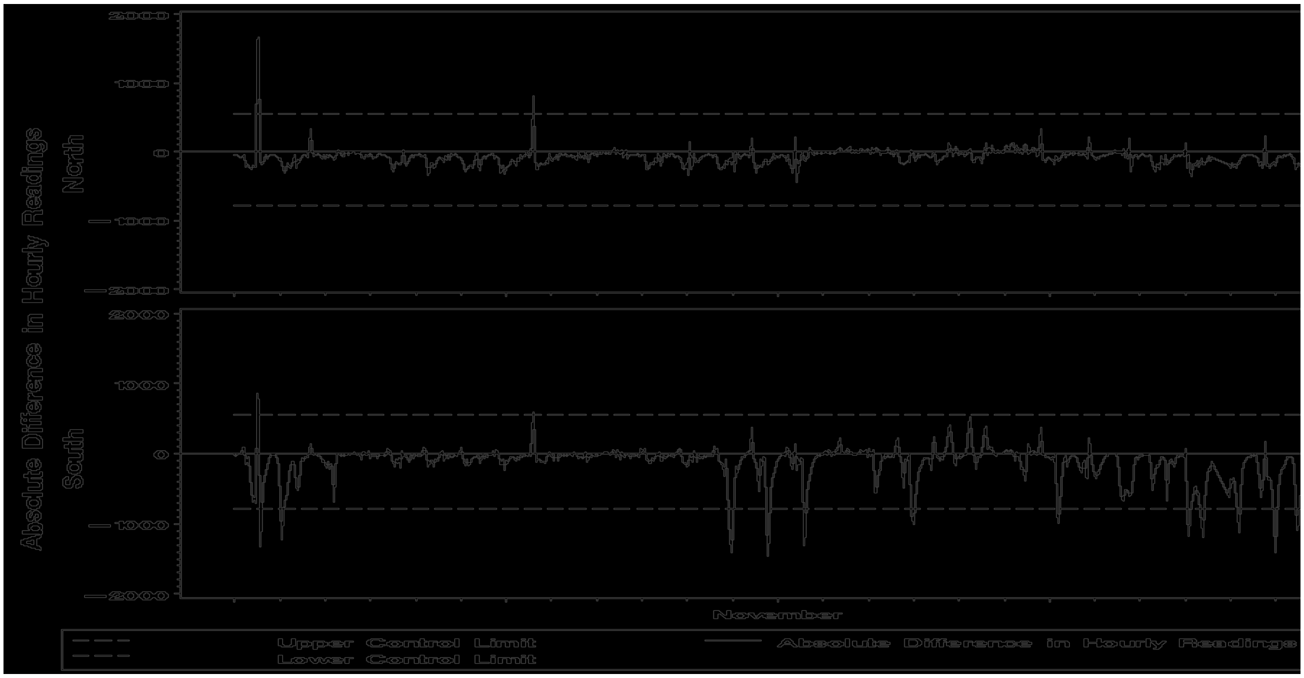

Figure 5-1a. Absolute Differences between Hourly ISDMI Sensor #2230 and ATR Readings from Philadelphia, Including Control Limits

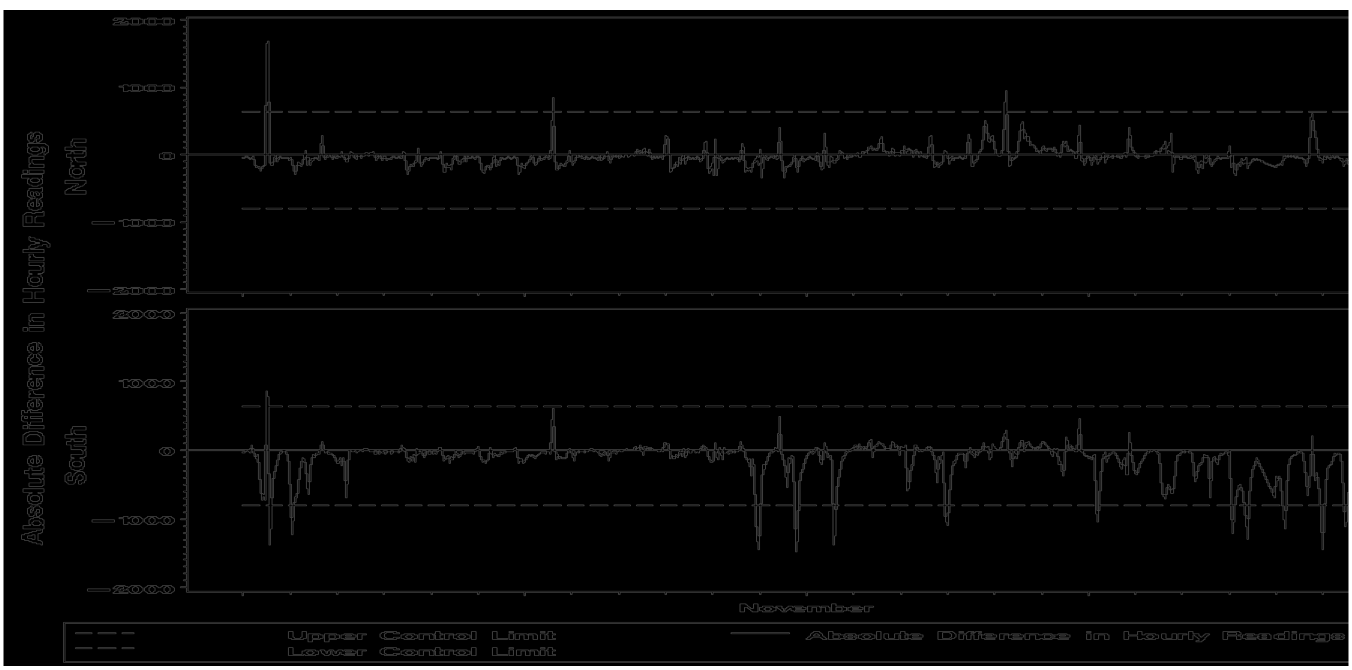

Figure 5-1b. Absolute Differences between Hourly ISDMI Sensor #2482 and ATR Readings from Philadelphia, Including Control Limits

Ten values were removed for each sensor in each direction (total of 20 values for each sensor) on November 28th. This is because from midnight to 10:00 am on this date the ATR did not record data due to a counter problem. Figures 5-2a and 5-2b show that once the outliers and zero-readings are removed, the absolute differences appear to follow a more stable pattern. In all, 134 (9%) data points for sensor # 2230 and 156 (11%) of data points for sensor #2482 were removed. It is noted that 85% (sensor #2230) and 76% (sensor # 2482) of the calculated differences are negative. These numbers also indicate a statistically significant, systematic variation in the sensor readings. However, contrary to the results in Pittsburgh, the sensors in Philadelphia consistently *overestimate* the ATR counts.

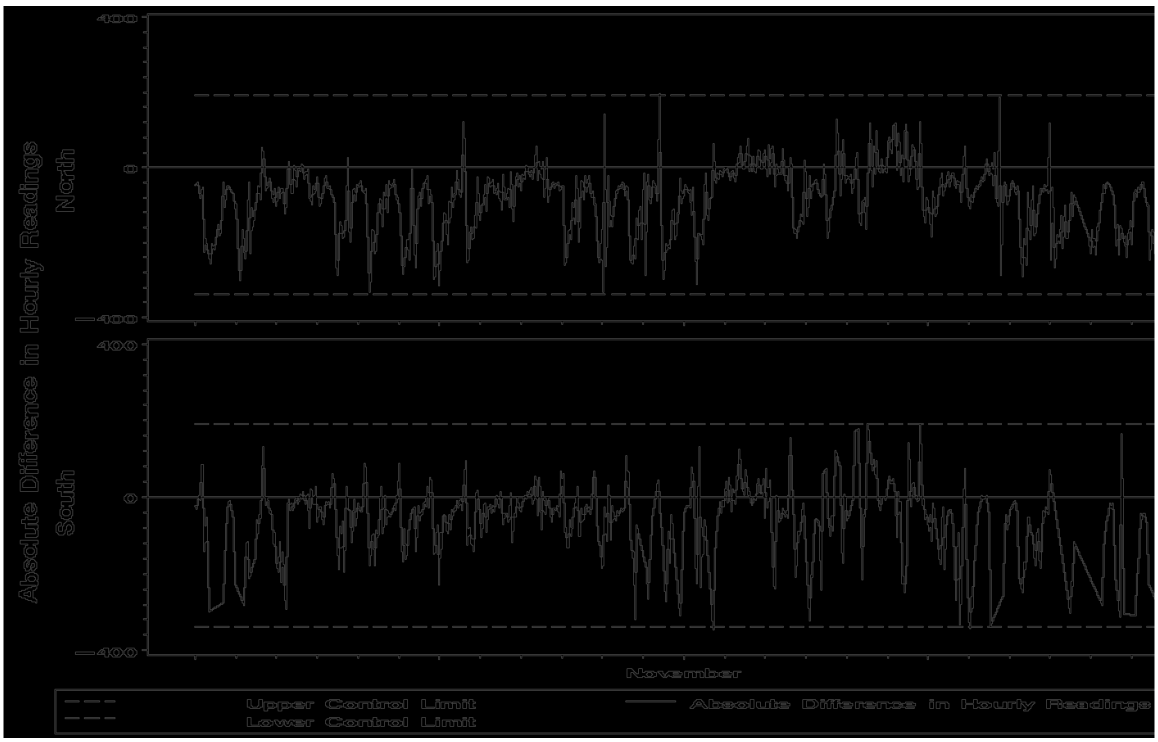

Figure 5-2a. Absolute Differences between Hourly ISDMI Sensor #2230 and ATR Readings from Philadelphia – Outliers and Zero-Readings Removed

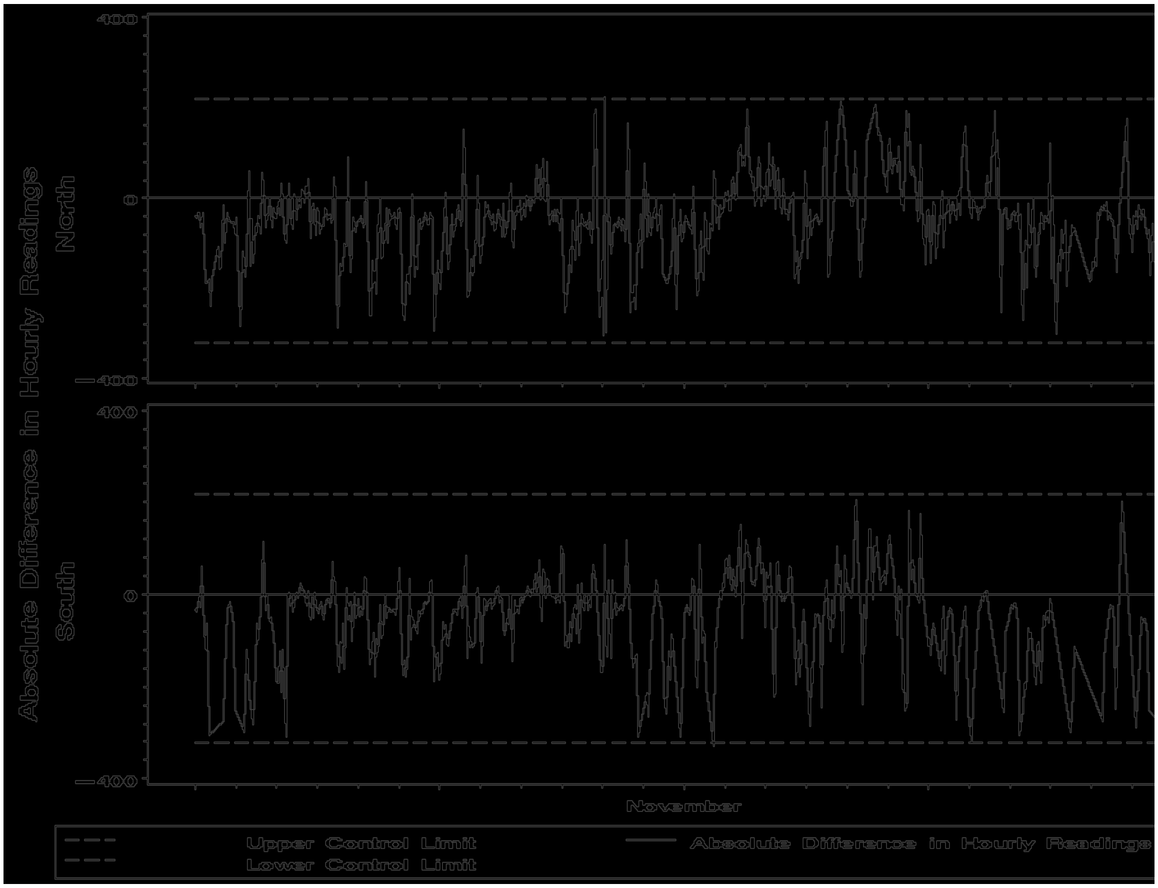

Figure 5-2b. Absolute Differences between Hourly ISDMI Sensor #2482 and ATR Readings from Philadelphia – Outliers and Zero-Readings Removed

The next step is to assess the precision of the sensor counts by examining the differences between the sensor recordings and ATR counts. Figures 5-3a and 5-3b display the absolute differences versus the ATR counts. Since the relationship between the sensor and ATR counts was the same for northbound and southbound lanes for each of the sensors, data from all lanes were combined for each sensor. Furthermore, given that the variability in the differences is constant and the relationship is consistent across all traffic volume levels, a simple linear regression model was fitted to each data set.

The resulting model predictions and their associated approximate 95% prediction bounds are shown in Figures 5-4a and 5-4b along with the model-input data. Prediction bounds are defined as the limits that, on average, will include 95% of predictions. The prediction bounds in Figure 5-4 represent the precision associated with the absolute difference at a given ATR count. For sensor #2230 (Figure 5-4a), the precision ranges from ± 169 to ± 170. For sensor #2482 (Figure 5-4b), the precision ranges from ± 175 to ± 176. These ranges indicate that the precision is fairly constant across all ATR traffic volumes.

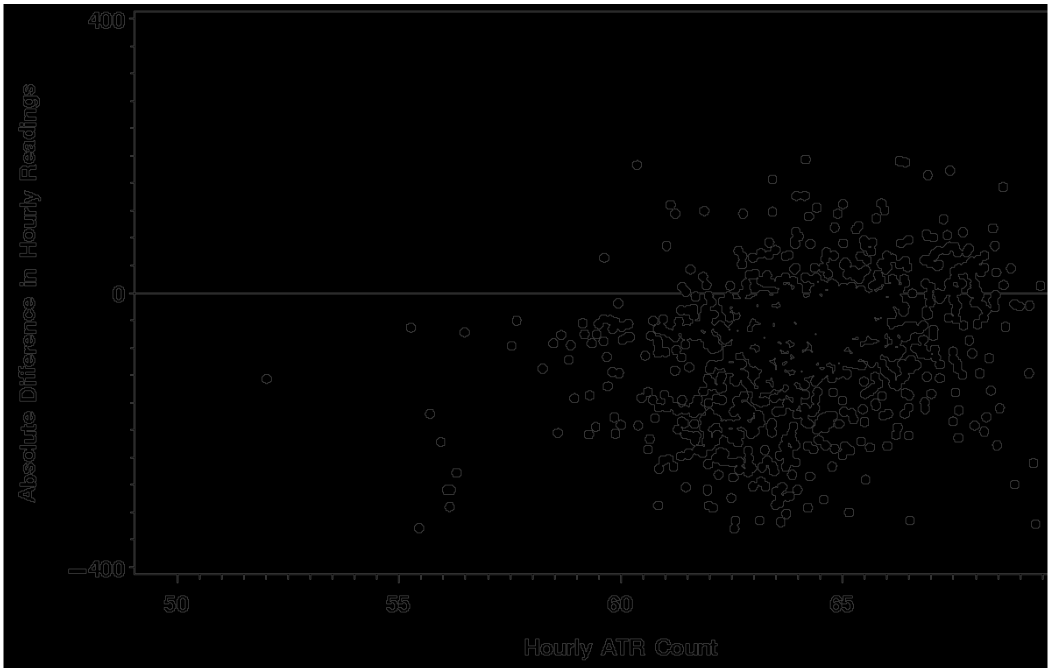

Figure 5-3a. Absolute Differences between Hourly ISDMI Sensor #2230 and ATR Readings vs. Hourly ATR Count in Philadelphia

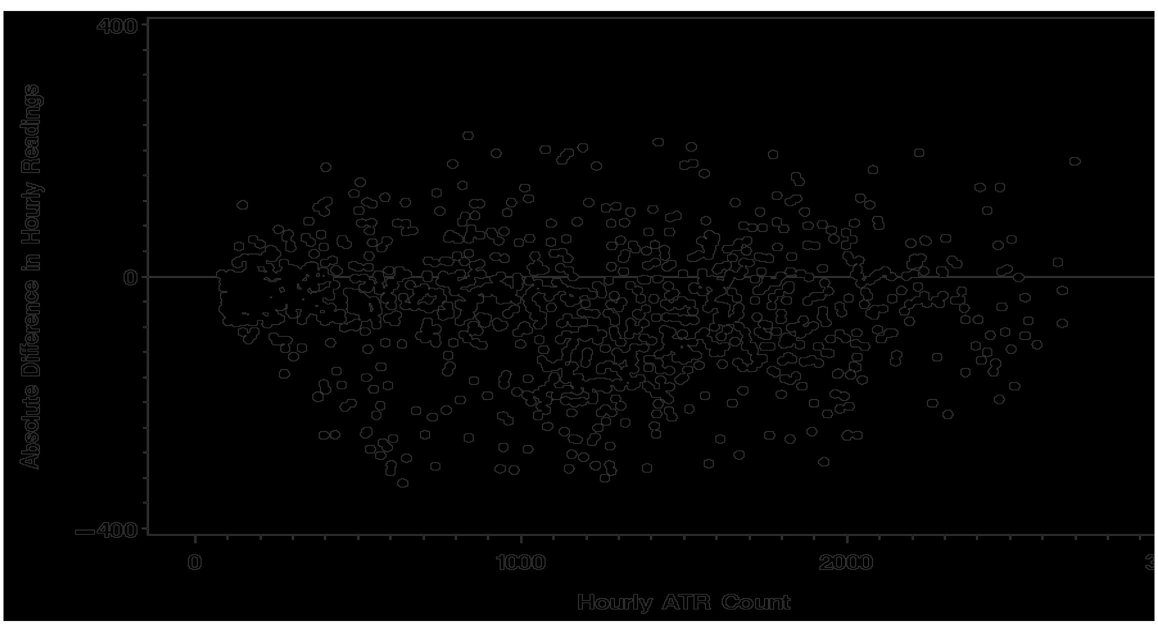

Figure 5-3b. Absolute Differences between Hourly ISDMI Sensor #2482 and ATR Readings vs. Hourly ATR Count in Philadelphia

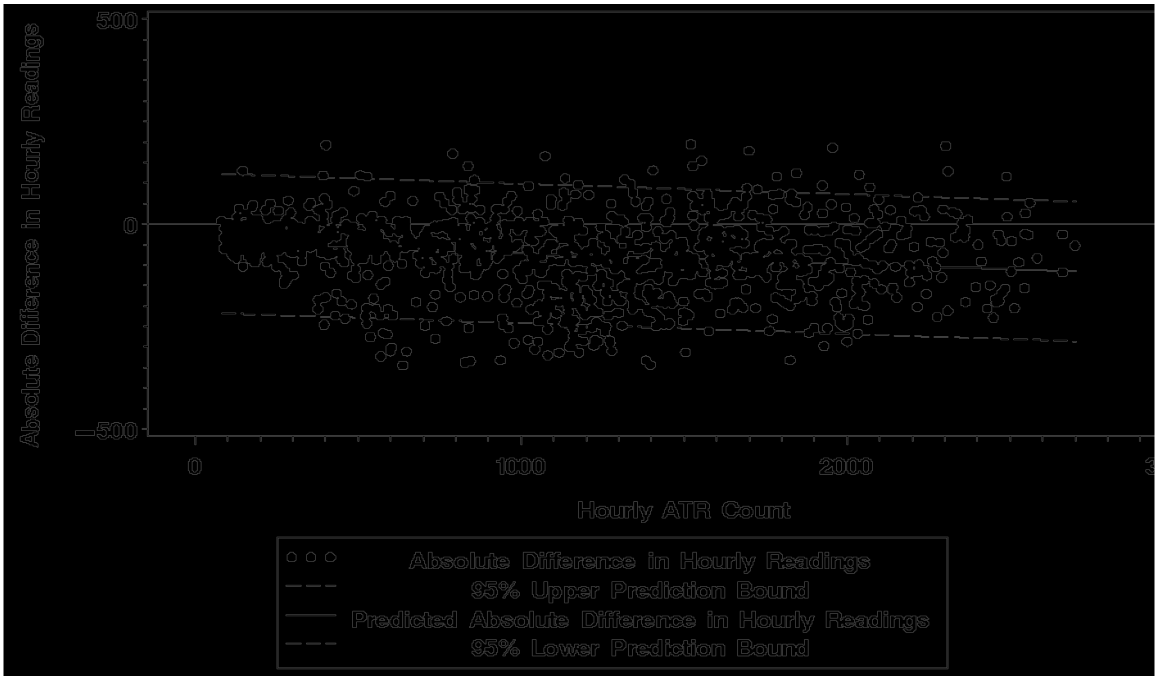

Figure 5-4a. Linear Regression Results of the Absolute Difference versus the ATR Readings – Approximate 95% Prediction Bounds Plotted (Sensor #2230)

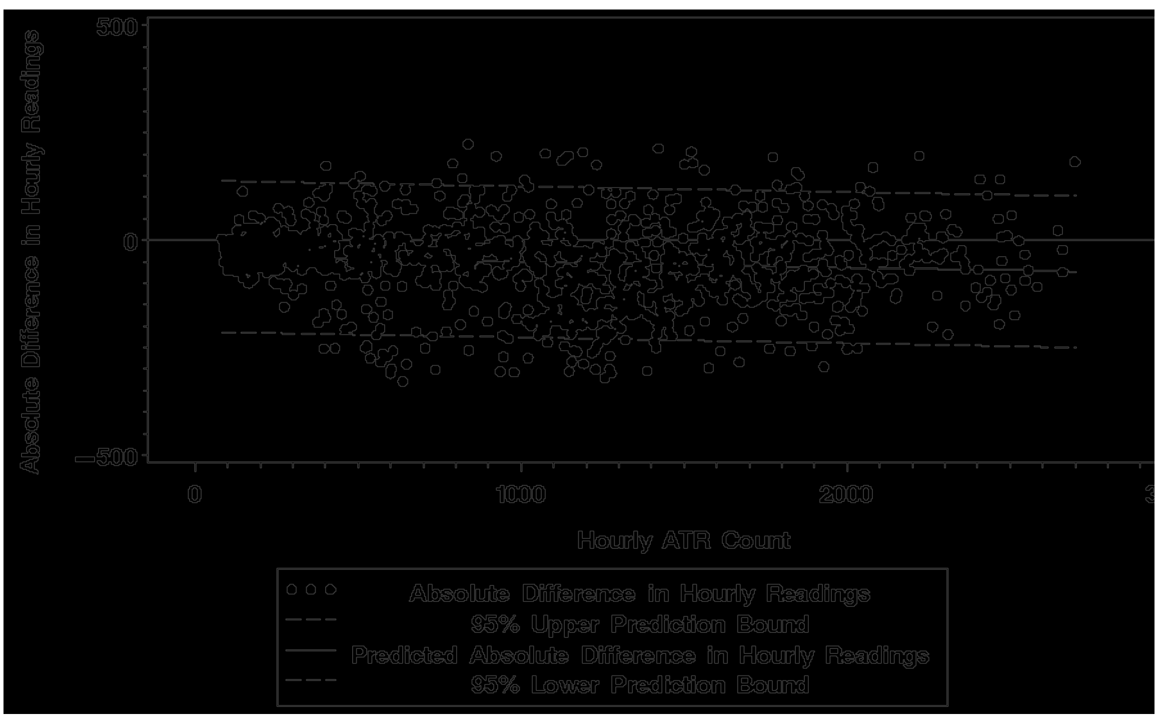

Figure 5-4b. Linear Regression Results of the Absolute Difference versus the ATR Readings – Approximate 95% Prediction Bounds Plotted (Sensor #2482)

Having adjusted the absolute differences for the variations in the traffic volume level, these differences can be expressed as relative differences, as shown in Figure 5-5. The relative differences are the absolute differences expressed as a percentage of the ATR count found in Figure 5-3. Figure 5-5 illustrates the relative differences versus increasing traffic counts on a finer scale, without those extreme points. For sensor #2230 (Figure 5-5a) the relative difference ranges from -266% to 149% at low ATR counts and from –11% to 2% for high ATR counts. For sensor #2482 (Figure 5-5b) the relative difference ranges from -261% to 168% for low ATR counts and from –9% to 4% for high ATR counts.

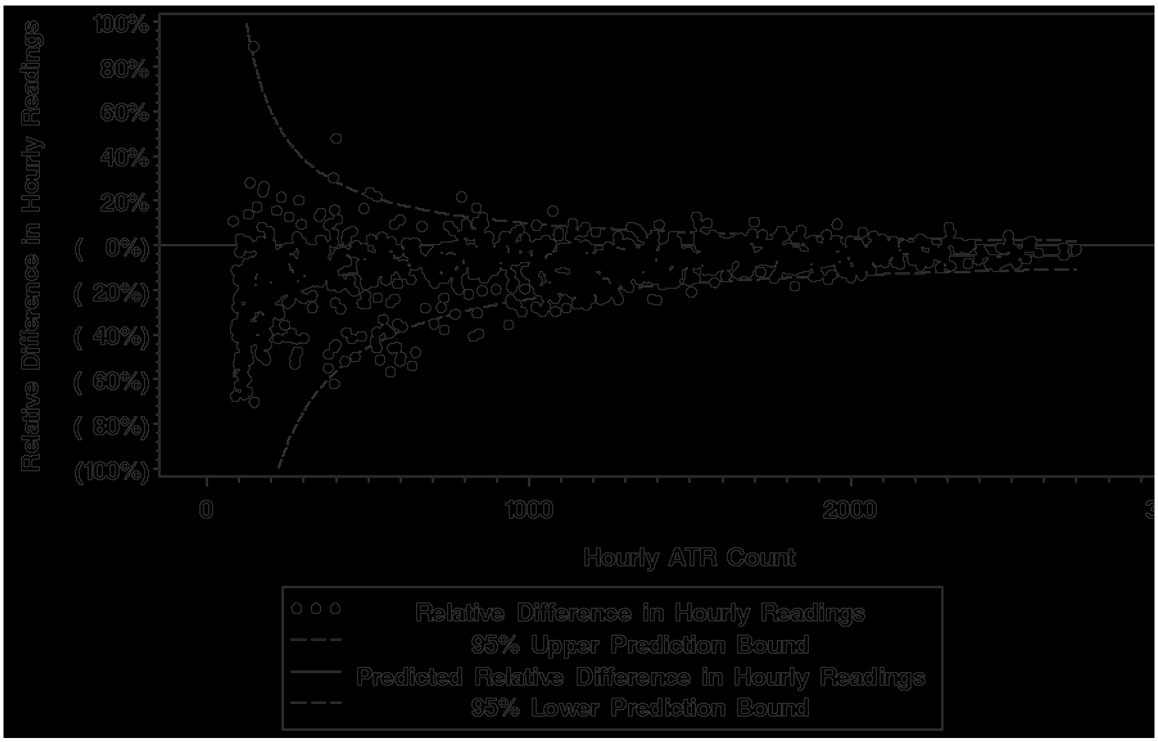

Figure 5-5a. Relative Differences between Hourly ISDMI Sensor #2230 and ATR Readings from Philadelphia versus Hourly ATR Count – Extreme Observations Removed from Graph

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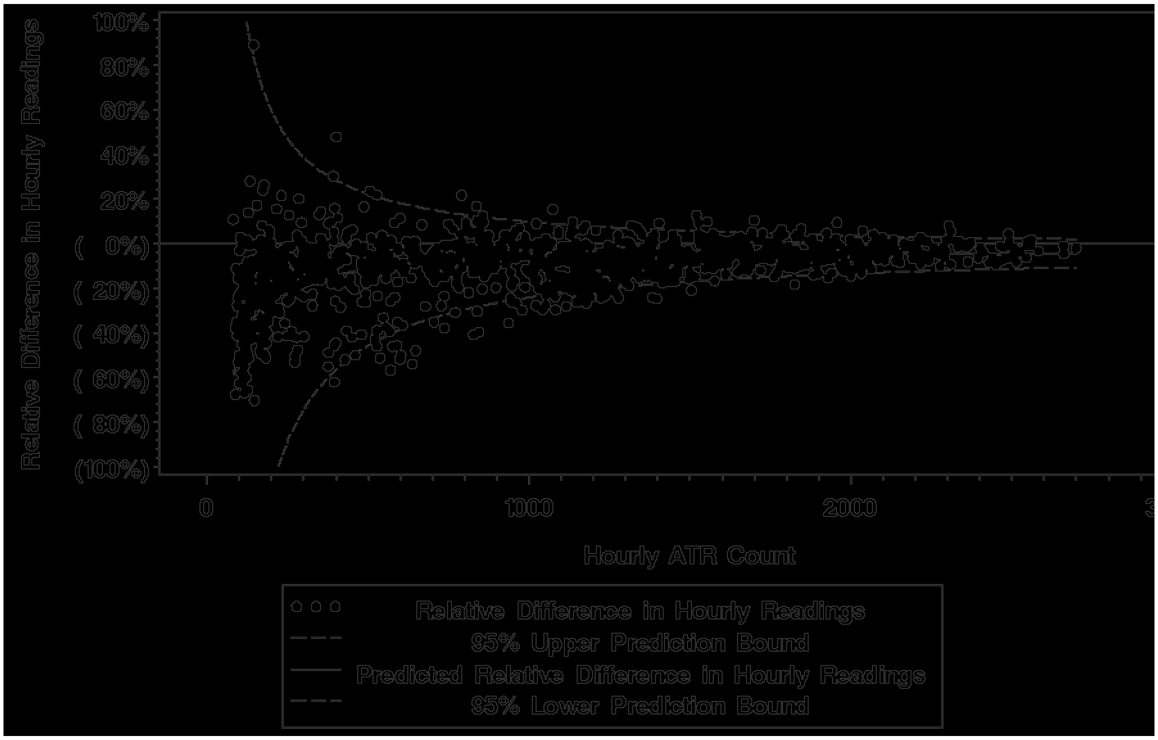

Figure 5-5b. Relative Differences between Hourly ISDMI Sensor #2482 and ATR Readings from Philadelphia versus Hourly ATR Count – Extreme Observations Removed from Graph

Table 5-1 shows the average precision bounds for both the absolute and relative differences at a 95% confidence level. The table shows the ranges and midpoint of the precision bounds relative to the ATR readings. The absolute differences between the ATR and sensor readings remain the same with increasing traffic volume. However, the relative differences decrease with increasing traffic volume recorded by the ATR (i.e., increased precision). It is interesting to note that the precisions of both sensors are identical. It can be said that the sensors recorded traffic volume data to the same level of accuracy when compared with the ATR records. It is recognized that the ATRs also have some level of error and the ATR values are used as the reference in this analysis given that the ATR represents the status quo or legacy system of traffic data collection.

Table 5-1. Summary of Precision Bounds for ISDMI Data Sensors #2230 and #2482

Philadelphia Sensor #2230		
Traffic Volume by ATR	**Precision at 95% Confidence**	
	Absolute Difference	**Relative Difference**
Minimum and Maximum Precision for Suggested Ranges		
0 – 500	± 169.8 to ± 169.9	± 34% to ± 207%
500 – 1500	± 169.8 to ± 169.8	± 11% to ± 33%
1500 – 2500	± 169.8 to ± 170	± 6% to ± 11%
>2500	± 170 to ± 170	± 6% to ± 6%
Midpoint of Minimum and Maximum Precision for Suggested Ranges		
0 – 500	± 169.9	± 136%
500 – 1500	± 169.8	± 22%
1500 – 2500	± 169.9	± 9%
>2500	± 170.0	± 6%
Philadelphia Sensor #2482		
Traffic Volume by ATR	**Precision at 95% Confidence**	
	Absolute Difference	**Relative Difference**
Minimum and Maximum Precision for Suggested Ranges		
0 - 500	± 174.5 to ± 174.6	± 35% to ± 212%
500 - 1500	± 174.5 to ± 174.5	± 11% to ± 34%
1500 - 2500	± 174.5 to ± 174.7	± 7% to ± 11%
>2500	± 174.7 to ± 174.7	± 6% to ± 6%
Midpoint of Minimum and Maximum Precision for Suggested Ranges		
0 - 500	± 174.6	± 124%
500 - 1500	± 174.5	± 23%
1500 - 2500	± 174.6	± 9%
>2500	±174.7	± 6%

5.3.1.2 *ISDMI Sensor vs. ATR Counts – Daily Counts*

The ISDMI sensor traffic volume data were also compared to ATR data on daily basis. Only 9 full days out of a possible 31 days were available for the daily analysis for sensor #2230 and only 8 full days were available for sensor #2482, when both northbound and southbound lanes were considered together. The absolute differences were calculated for the available daily values and are plotted against the increasing ATR counts as shown in Figures 5-6a and 5-6b. It is noted that all but one of the points fall well *below* the zero reference line for the two sensors. Figures 5-7a and 5-7b show the relative daily differences versus the daily ATR totals. The relative difference ranges from -9% to -2% for sensor #2230 and from -8% to 1% for sensor #2482. No further analyses were performed on the daily values since the results are similar to the hourly analyses.

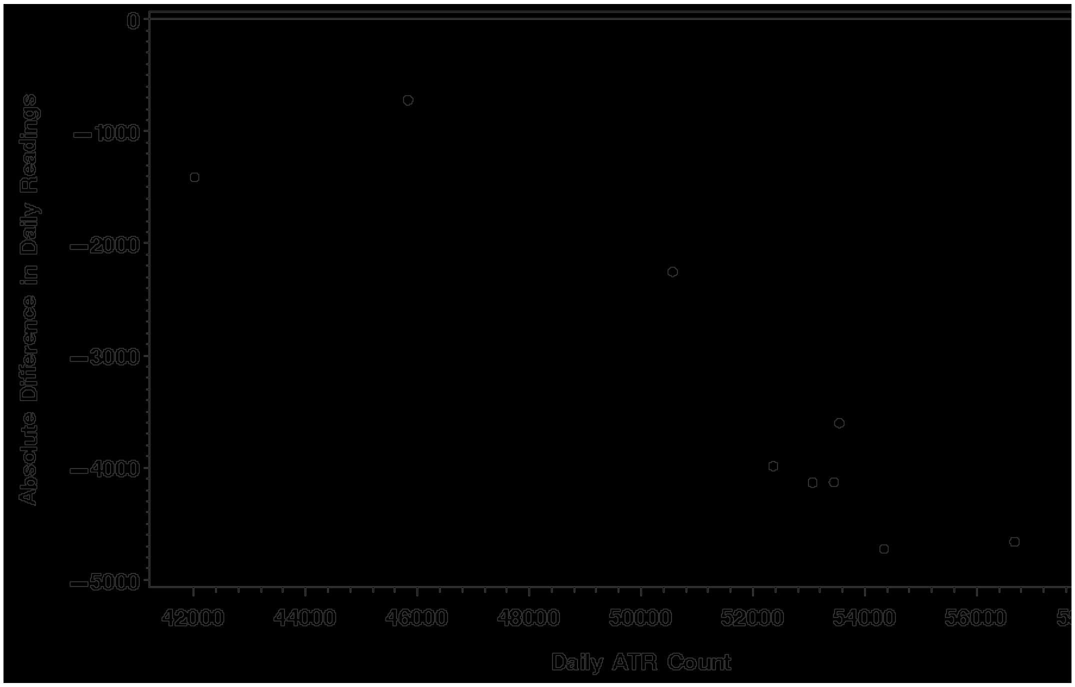

Figure 5-6a. Absolute Difference between Daily ISDMI Sensor #2230 and ATR Readings in Philadelphia vs. Daily ATR Count

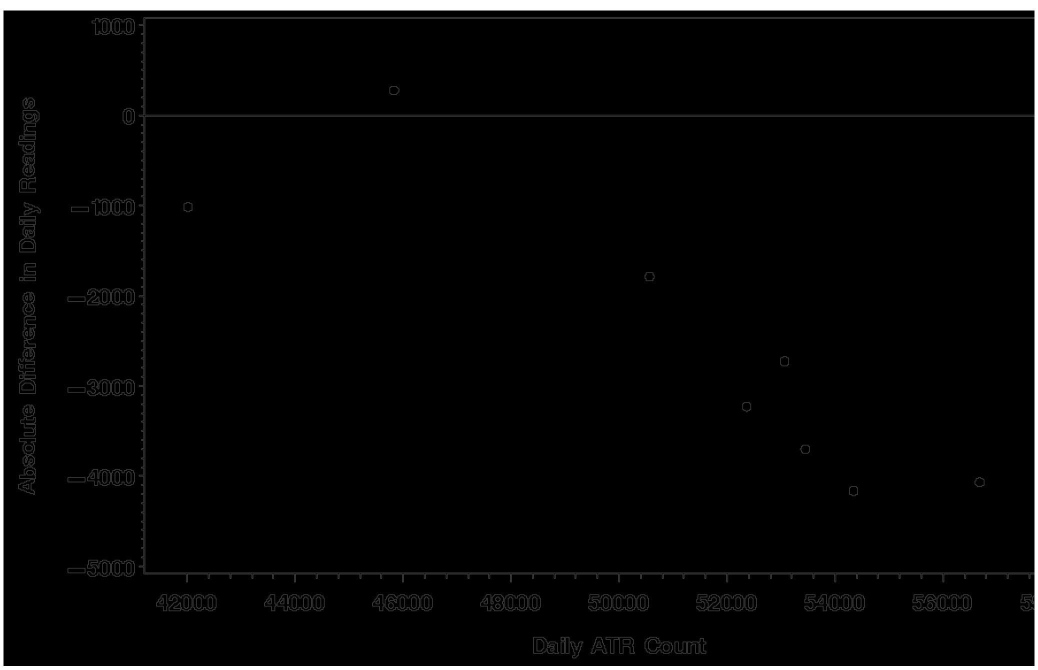

Figure 5-6b. Absolute Difference between Daily ISDMI Sensor #2482 and ATR Readings in Philadelphia vs. Daily ATR Count

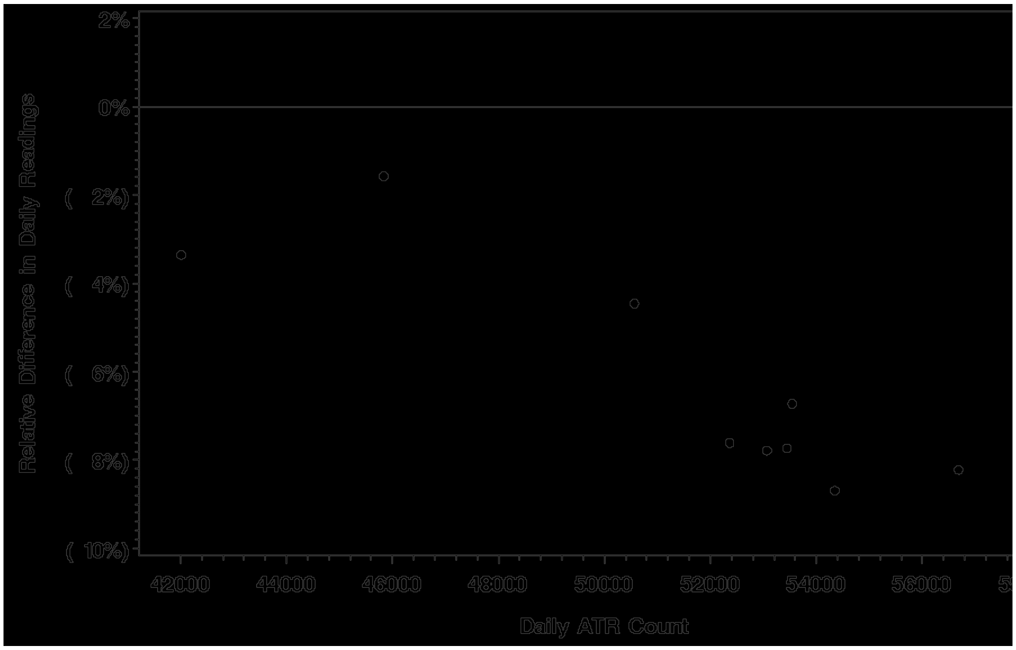

Figure 5-7a. Relative Difference between Daily ISDMI Sensor #2230 and ATR Readings in Philadelphia versus Daily ATR Count

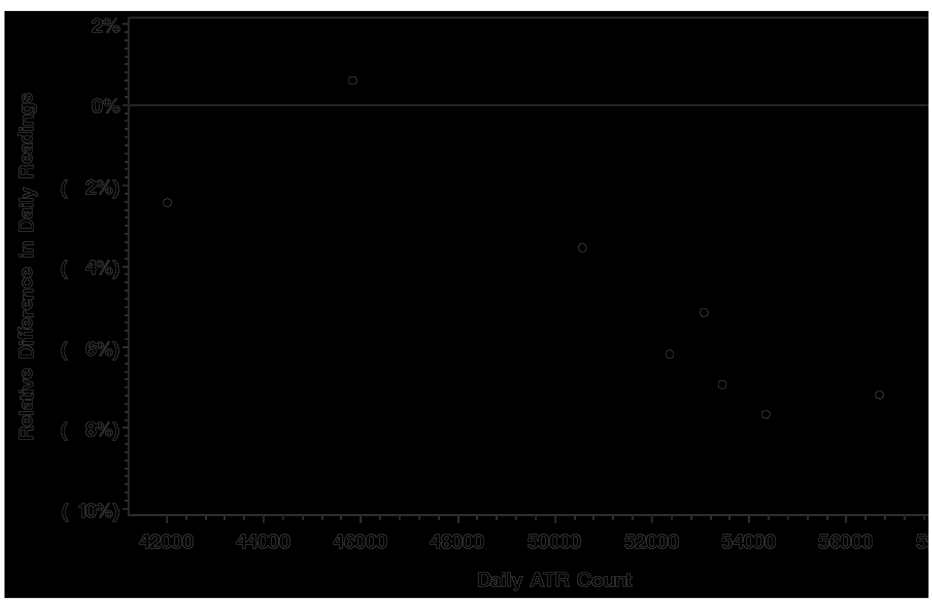

Figure 5-7b. Relative Difference between Daily ISDMI Sensor #2482 and ATR Readings in Philadelphia versus Daily ATR Count

5.3.2 Data Completeness

The data used for this analysis consists of volume, occupancy, and speed values reported at 5-minute intervals from 75 sensors November 1, 2001, through January 31, 2002. These sensors were selected at random from the 178 sensors in the Philadelphia area. The sample includes sensors from each corridor. The analyses reported here were performed on 5-minute data. However, additional data for all time intervals from one corridor (i.e., Rt. 202, 11 sensors on December 12, 2001) were used to characterize the validity of the larger-interval data.

5.3.2.1 Discussion of Results

Table 5-2 presents descriptive statistics in terms of the minimum, maximum, average, standard deviation, and median for the traffic volume, speed, and occupancy values recorded by the ISDMI sensors. The results are aggregated by corridor and also by month of the year. The overall minimum volume was 0 vehicles, and the overall maximum was 999 vehicles.

Table 5-2. Summary Statistics for the Reported Volume, Occupancy, and Speed

Summary Level	Statistic	Volume	Occupancy (%)	Speed (mph)
Overall	Minimum	0	0	1
	Maximum	999	99	92
	Average	162.95	4.41	57.31
	Standard Deviation	122.01	6.41	10.17
	Median	139	3	59
November 2001	Minimum	0	0	1
	Maximum	999	99	92
	Average	169.29	4.48	57.33
	Standard Deviation	126.97	6.32	9.88
	Median	145	3	58
December 2001	Minimum	0	0	1
	Maximum	980	98	92
	Average	163.08	4.41	57.61
	Standard Deviation	119.63	6.59	10.16
	Median	141	2	59
January 2002	Minimum	0	0	1
	Maximum	803	97	92
	Average	156.7	4.33	56.99
	Standard Deviation	119.14	6.32	10.43
	Median	132	2	58
I-476	Minimum	0	0	3
	Maximum	999	85	91
	Average	163.58	4.37	59.14
	Standard Deviation	112.4	4.48	9.58
	Median	160	3	60

Table 5-2. Summary Statistics for the Reported Volume, Occupancy, and Speed (Continued)

Summary Level	Statistic	Volume	Occupancy (%)	Speed (mph)
I-676	Minimum	2	0	6
	Maximum	975	58	78
	Average	220.63	6.01	53.75
	Standard Deviation	123.68	9.23	11.37
	Median	228	3	56
I-76	Minimum	0	0	2
	Maximum	985	65	89
	Average	176.95	5.82	55.19
	Standard Deviation	122.85	7.01	10.74
	Median	159	3	56
I-95	Minimum	0	0	2
	Maximum	980	80	92
	Average	189.9	3.42	60.83
	Standard Deviation	132.77	4.51	8.61
	Median	169	2	62
Rt. 1	Minimum	3	0	3
	Maximum	928	89	78
	Average	197.55	11.65	51.99
	Standard Deviation	102.9	13.92	11.68
	Median	208	7	55
Rt. 202	Minimum	0	0	1
	Maximum	828	97	89
	Average	121.31	4.43	55.86
	Standard Deviation	92.49	7.54	9.61
	Median	109	2	58
Rt. 291	Minimum	0	0	5
	Maximum	471	44	68
	Average	79.56	1.69	41.43
	Standard Deviation	49.84	2.19	5.36
	Median	76	1	42
Rt. 309	Minimum	0	0	1
	Maximum	842	59	78
	Average	85.82	4.37	52.06
	Standard Deviation	67.42	8.02	9.18
	Median	76	2	53
Rt. 422	Minimum	0	0	1
	Maximum	997	99	88
	Average	81.52	5.07	51.56
	Standard Deviation	73.49	9.8	9.45
	Median	65	2	53
Rt. 63	Minimum	0	0	3
	Maximum	407	65	82
	Average	88.01	2.12	55.41
	Standard Deviation	56.19	2.3	4.68
	Median	87	2	55

The overall minimum speed reported was 1 mph. This same minimum speed was reported in each of the three months of data analyzed and along 3 of the 10 corridors. The maximum speed reported among the 26 corridors ranges from 68 mph to 91 mph and the median speed is 59 mph, ranging from 42 mph to 62 mph among the corridors. The overall median occupancy value was 3%. It was observed that the sensors never reported a full occupancy reading in the analysis, although the maximum occupancy reported was 99%.

Table 5-3 presents the statistics on the completeness of archived data recorded by the ISDMI sensors. The number and percent of the traffic volume, speed, and occupancy values that are either negative, zero, or missing are presented. It is noted that less than 2% of all the potential 5-minute intervals contain missing values for each of the three variables. In other words, the overall percent completeness for traffic volume, speed, and occupancy is 98% each. The corridor with the highest percentage of missing values is Rt. 309, with more than 6% missing from each of the three values. The lowest percentage of missing values is found on Rt. 1, with just less than 1%.

Table 5-3. Summary Statistics for the Reported Volume, Occupancy, and Speed

	Statistic	Volume	Occupancy	Speed
Overall	Number Missing	50,454.00	50,454.00	54,770.00
	Percent Missing	1.92%	1.92%	2.09%
	Number Zero	1,084.00	312,508.00	0
	Percent Zero	0.04%	12.15%	0.00%
	Number Negative	0	0	0
	Percent Negative	0.00%	0.00%	0.00%
November 2001	Number Missing	19,036.00	19,036.00	19,840.00
	Percent Missing	2.23%	2.23%	2.32%
	Number Zero	357	90,628.00	0
	Percent Zero	0.04%	10.84%	0.00%
	Number Negative	0	0	0
	Percent Negative	0.00%	0.00%	0.00%
December 2001	Number Missing	13,560.00	13,560.00	15,272.00
	Percent Missing	1.53%	1.53%	1.73%
	Number Zero	348	104,075.00	0
	Percent Zero	0.04%	11.96%	0.00%
	Number Negative	0	0	0
	Percent Negative	0.00%	0.00%	0.00%
January 2002	Number Missing	17,858.00	17,858.00	19,658.00
	Percent Missing	2.02%	2.02%	2.22%
	Number Zero	379	117,805.00	0
	Percent Zero	0.04%	13.60%	0.00%
	Number Negative	0	0	0
	Percent Negative	0.00%	0.00%	0.00%

Table 5-3. Summary Statistics for the Reported Volume, Occupancy, and Speed (Continued)

	Statistic	Volume	Occupancy	Speed
I-476	Number Missing	5,210.00	5,210.00	7,168.00
	Percent Missing	1.23%	1.23%	1.69%
	Number Zero	185	46,397.00	0
	Percent Zero	0.04%	11.08%	0.00%
	Number Negative	0	0	0
	Percent Negative	0.00%	0.00%	0.00%
I-676	Number Missing	858	858	859
	Percent Missing	1.62%	1.62%	1.62%
	Number Zero	104	3,898.00	0
	Percent Zero	0.02%	7.48%	0.00%
	Number Negative	0	0	0
	Percent Negative	0.00%	0.00%	0.00%
I-76	Number Missing	12,097.00	12,097.00	12,187.00
	Percent Missing	2.40%	2.40%	2.42%
	Number Zero	136	37,499.00	0
	Percent Zero	0.01%	7.63%	0.00%
	Number Negative	0	0	0
	Percent Negative	0.00%	0.00%	0.00%
I-95	Number Missing	14,246.00	14,246.00	15,775.00
	Percent Missing	1.45%	1.45%	1.61%
	Number Zero	87	102,801.00	0
	Percent Zero	0.04%	10.64%	0.00%
	Number Negative	0	0	0
	Percent Negative	0.00%	0.00%	0.00%
Rt. 1	Number Missing	484	484	484
	Percent Missing	0.91%	0.91%	0.91%
	Number Zero	18	1,499.00	0
	Percent Zero	0.03%	2.85%	0.00%
	Number Negative	0	0	0
	Percent Negative	0.00%	0.00%	0.00%
Rt. 202	Number Missing	4,493.00	4,493.00	4,688.00
	Percent Missing	1.88%	1.88%	1.97%
	Number Zero	168	45,494.00	0
	Percent Zero	0.11%	19.44%	0.00%
	Number Negative	0	0	0
	Percent Negative	0.00%	0.00%	0.00%
Rt. 291	Number Missing	920	920	952
	Percent Missing	1.74%	1.74%	1.80%
	Number Zero	362	14,295.00	0
	Percent Zero	0.35%	27.45%	0.00%
	Number Negative	0	0	0
	Percent Negative	0.00%	0.00%	0.00%

Table 5-3. Summary Statistics for the Reported Volume, Occupancy, and Speed (Continued)

	Statistic	Volume	Occupancy	Speed
Rt. 309	Number Missing	9,856.00	9,856.00	9,969.00
	Percent Missing	6.20%	6.20%	6.27%
	Number Zero	24	29,410.00	0
	Percent Zero	0.05%	19.72%	0.00%
	Number Negative	0	0	0
	Percent Negative	0.00%	0.00%	0.00%
Rt. 422	Number Missing	1,740.00	1,740.00	2,114.00
	Percent Missing	1.64%	1.64%	1.99%
	Number Zero	0	19,406.00	0
	Percent Zero	0.00%	18.62%	0.00%
	Number Negative	0	0	0
	Percent Negative	0.00%	0.00%	0.00%
Rt. 63	Number Missing	550	550	574
	Percent Missing	1.04%	1.04%	1.08%
	Number Zero	0	11,809.00	0
	Percent Zero	0.00%	22.52%	0.00%
	Number Negative	0	0	0
	Percent Negative	0.00%	0.00%	0.00%

Figure 5-8 shows the variation of percent of data missing by month and Figure 5-9 shows the variation by corridor. It is noted that the percentage missing is fairly constant between November 2001 and January 2002. The percentage missing data in December 2001 is, however, less than the other two months.

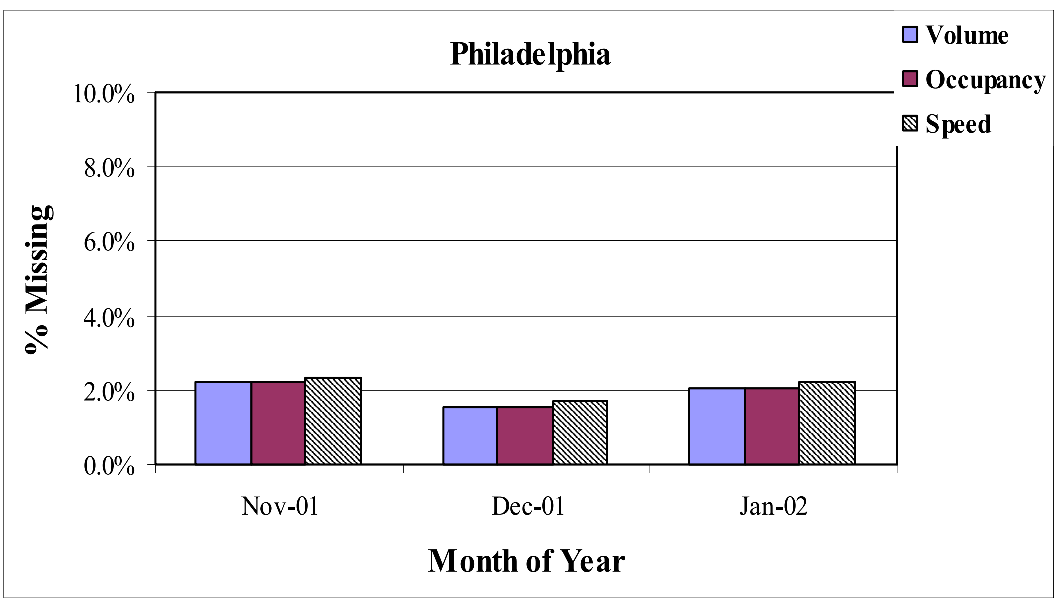

Figure 5-8. Percentage of Data Missing by Month

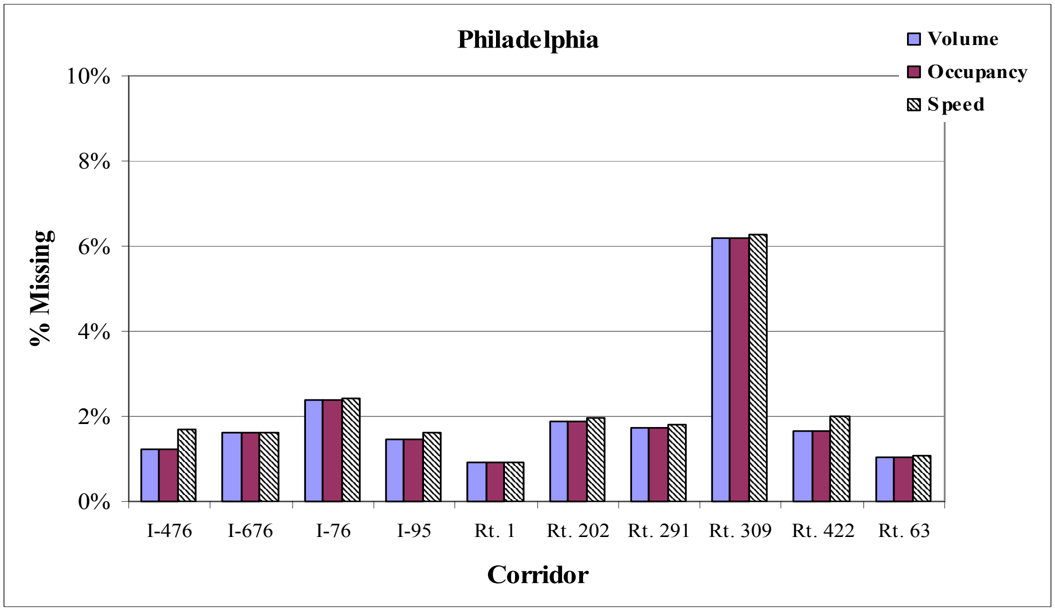

Figure 5-9. Percentage of Data Missing by Corridor

Table 5-4 summarizes the amount of simultaneous missing values for pairs of the variables, as well as all three variables. Table 5-4 indicates that no two data values are simultaneously missing without the third value also being missing. The data appear to be consistent in the occurrence of missing values, in that all three values are missing for the same time period.

Finally, data aggregated from smaller time intervals were compared to larger time interval data downloaded directly from the ISDMI archived database. Table 5-5 presents the results of the comparison. The results indicate that simply summing or averaging the values taken from the 5-minute data can create the larger interval data values. As noted above, this can cause a problem for users of the larger interval data, since it will underestimate the actual volume, occupancy, and speed if there is a significant amount of missing data. The purpose of this part of the analysis was to determine how “complete” the larger interval data values are, by determining how the values are created. For example, if the 1-hour interval data are created by summing the 5-minute data and there are several missing data values for the 5-minute data in any given hour, the 1-hour data could be underestimating or overestimating reality.

It was noted that the sensors did not record any negative traffic volume values. However, zero occupancy values and low occupancy readings were observed. Following the analysis it was discovered that the ISDMI sensors truncate the occupancy values. Therefore, some of the zero-occupancy values may not truly represent zero occupancy. For example, 0.9% would be recorded as 0%.

Table 5-4. Number and Percent of the Volume, Occupancy, and Speed Values That Are Missing in Conjunction with One or More Other Values

Summary Level	Number Missing (Percent Missing)			
	Only Volume and Occupancy Missing	Only Speed and Occupancy Missing	Only Speed and Volume Missing	Volume, Occupancy, and Speed
Overall	0 (0.00%)	0 (0.00%)	0 (0.00%)	50,454.00 (1.92%)
November 2001	0 (0.00%)	0 (0.00%)	0 (0.00%)	19,036.00 (2.23%)
December 2001	0 (0.00%)	0 (0.00%)	0 (0.00%)	13,560.00 (1.53%)
January 2002	0 (0.00%)	0 (0.00%)	0 (0.00%)	17,858.00 (2.02%)
I-476	0 (0.00%)	0 (0.00%)	0 (0.00%)	5,210.00 (1.23%)
I-676	0 (0.00%)	0 (0.00%)	0 (0.00%)	858.00 (1.62%)
I-76	0 (0.00%)	0 (0.00%)	0 (0.00%)	12,097.00 (2.40%)
I-95	0 (0.00%)	0 (0.00%)	0 (0.00%)	14,246.00 (1.45%)
Rt. 1	0 (0.00%)	0 (0.00%)	0 (0.00%)	484.00 (0.91%)
Rt. 202	0 (0.00%)	0 (0.00%)	0 (0.00%)	4,493.00 (1.88%)
Rt. 291	0 (0.00%)	0 (0.00%)	0 (0.00%)	920.00 (1.74%)
Rt. 309	0 (0.00%)	0 (0.00%)	0 (0.00%)	9,856.00 (6.20%)
Rt. 422	0 (0.00%)	0 (0.00%)	0 (0.00%)	1,740.00 (1.64%)
Rt. 63	0 (0.00%)	0 (0.00%)	0 (0.00%)	550.00 (1.04%)

Table 5-5. Number and Percent of Differences Between the Aggregated Data and the Downloaded Data

Aggregated Data	Downloaded Data	Number of Time Intervals (per Sensor[1])	Volume Different by 10 Vehicles[2]	Speed Different by 5 mph	Occupancy Different by 5%
5 Minutes	15 Minutes	1824 (91)	0 (0.00%)	8 (0%)	0 (0.00%)
	1 Hour	480 (24)	0 (0.00%)	0 (0.00%)	0 (0.00%)
	24 Hours	20 (1)	0 (0.00%)	0 (0.00%)	0 (0.00%)
15 Minutes	1 Hour	456 (23)	0 (0.00%)	0 (0.00%)	0 (0.00%)
	24 Hours	20 (1)	0 (0.00%)	0 (0.00%)	0 (0.00%)
1 Hour	24 Hours	20 (1)	0 (0.00%)	0 (0.00%)	0 (0.00%)

1 Number of time intervals per sensor - 11 sensors, totaling 20 directions of travel.
2 All of the compared volume values were exactly equal.

5.4 Customer Satisfaction

This section presents the results of the customer satisfaction study in Philadelphia. The findings are categorized by the three groups of customers: the public (including the general public and current subscribers to the Mobility Technologies website), stakeholders, and media houses that provide traveler information via radio and TV. Customer satisfaction was analyzed in the areas of awareness, access, acceptance, use, and value.

5.4.1 General Public

ISDMI information is being disseminated to the Philadelphia public through a variety of media sources, including the Internet, television, and radio. This section presents the results of the customer satisfaction analysis based on data gathered from the general public in Philadelphia.

Since the ISDMI information is a relatively new product, it was not possible to obtain one sample of respondents that could assess all levels of the customer satisfaction model. Therefore, two separate samples were employed: one to address the awareness of, access to, and acceptance of the ISDMI information and the other to address the use and value of that information. The *potential* users, i.e., the general public, were surveyed for awareness, access, and acceptance, while the *actual* users were surveyed for use and value.

Telephone surveys were completed with 250 potential users of the Traffic.com website in the Philadelphia area. The surveys were conducted via Computer Assisted Telephone Interviews (CATI) from April 1 through April 5, 2002. From April 2 through April 19, 2002, users of the Traffic.com website were surveyed via a web-based questionnaire. An e-mail message with a link to the survey was sent directly to 152 Traffic.com registered users from the Philadelphia area. A maximum of two follow-up e-mails were sent to potential respondents, asking them to complete the survey if they had not done so already.

The telephone survey response rate was approximately 14%, and the Internet survey completion rate was 42% (i.e., 64 completes out of 152 solicitations). The response rate for the telephone survey was calculated according to the guidelines procedures established by CASRO. The completion rate for the Internet survey is simply the ratio of the number of completes to the number of solicitations.

5.4.1.1 Analysis

The two types of interviews were conducted in order to address each of the five issues of the customer satisfaction model. Descriptive statistics such as frequencies and percentages were used to characterize the survey responses. Separate analyses were conducted for the telephone and Internet surveys since the respondents represented different sectors of the population (i.e., potential users vs. actual users). In addition, analysis weights were applied to the telephone survey responses to ensure that the results from the sample are representative of the target population. The weighting process included adjustments for non-response, multiple telephone lines, multiple people in a household, post-stratification to the age and gender distribution of the target population, and trimming of any extreme weights.

5.4.1.2 ***Discussion of Results***

This section discusses the findings related to the five major components of the customer satisfaction model: awareness, access, acceptance, use, and value. The results of both surveys indicate that the telephone survey respondents are quite different demographically from the Internet survey respondents. The telephone survey respondents include a higher percentage of older women, while the Internet respondents tended to be younger males. Table 5-6 provides the unweighted frequencies and percentages for selected descriptive variables for respondents of both surveys.

Table 5-6. Unweighted Frequencies and Percentages for Demographic Variables from Both the Telephone and Internet Surveys

Demographic Variable	Number (Percentage)	
	Telephone Survey	Internet Survey
Age		
Refused	1 (0.4 %)	0 (0.0 %)
18 - 24 years old	20 (8.0 %)	4 (6.3 %)
25 - 34 years old	37 (14.8 %)	21 (32.8 %)
35 - 44 years old	56 (22.4 %)	28 (43.8 %)
45 - 54 years old	53 (21.2 %)	7 (10.9 %)
55 - 64 years old	35 (14.0 %)	3 (4.7 %)
Over 65 years old	48 (19.2 %)	1 (1.6 %)
Gender		
Refused	0 (0.0 %)	0 (0.0 %)
Male	94 (37.6 %)	55 (85.9 %)
Female	156 (62.4 %)	9 (14.1 %)
Education		
Refused	1 (0.4 %)	0 (0.0 %)
Less than High School	11 (4.4 %)	0 (0.0 %)
High School Graduate/GED	79 (31.6 %)	2 (3.1 %)
Technical School/Professional Business School	13 (5.2 %)	3 (4.7 %)
Some College	21 (8.4 %)	7 (10.9 %)
Community College Graduate	19 (7.6 %)	3 (4.7 %)
College Graduate	71 (28.4 %)	30 (46.9 %)
Post-Graduate Degree	35 (14 %)	19 (29.7 %)
Frequency of Internet Use		
No Access	64 (25.6 %)	N/A
Everyday	88 (35.2 %)	56 (87.5 %)
Occasionally	69 (27.6 %)	7 (10.9 %)
Rarely	18 (7.2 %)	1 (1.7 %)
Never	11 (4.4 %)	N/A

Table 5-6. Unweighted Frequencies and Percentages for Demographic Variables from Both the Telephone and Internet Surveys (Continued)

Demographic Variable	Number (Percentage)	
	Telephone Survey	Internet Survey
# Days per week travel during weekday morning rush hr[1]		
None	73 (29.2 %)	4 (6.3 %)
Once	12 (4.8 %)	4 (6.3 %)
2-3 Days	20 (8.0 %)	10 (15.6 %)
4-5 Days	145 (58 %)	46 (71.9 %)
Length of one-way morning trip[1]		
Do Not Commute	73 (29.2 %)	4 (6.3 %)
Less than 5 Minutes	6 (2.4 %)	3 (4.7 %)
6 - 10 Minutes	32 (12.8 %)	2 (3.1 %)
11 - 30 Minutes	86 (34.4 %)	21 (32.8 %)
31 Minutes to 1 Hour	38 (15.2 %)	25 (39.1 %)
Over 1 Hour	15 (6 %)	9 (14.1 %)
# Days per week travel during weekday evening rush hr		
Refused	1 (0.4 %)	N/A
None	80 (32 %)	
1 Day	12 (4.8 %)	
2 Days	20 (8 %)	
3 Days	17 (6.8 %)	
4 Days	11 (4.4 %)	
5 Days	109 (43.6 %)	
Length of one-way evening trip		
Do Not Commute	81 (32.4 %)	N/A
Refused	0 (0.0 %)	
Less than 5 Minutes	7 (2.8 %)	
6 - 10 Minutes	17 (6.8 %)	
11 - 30 Minutes	86 (34.4 %)	
31 Minutes to 1 Hour	46 (18.4 %)	
Over 1 Hour	13 (5.2 %)	

Note: No distinction was made between morning and evening peak hours in the Internet survey. The question was worded differently in the two surveys.
N/A – Not Applicable

Awareness: At the time of the CATI survey, 23% of the Philadelphia area residents had heard of Traffic.com. The Internet survey indicates that Traffic.com information users heard about Traffic.com website most often by word of mouth (38%). This suggests that people who use Traffic.com website are satisfied enough with the information to suggest it to their friends.

Just over 50% of the telephone survey sample is comprised of daily commuters. Of all commuters, the majority (i.e., about 67%) has commute times of 30 minutes or less. About 20% have commute times of 10 minutes or less, compared to 57% (34 out of 60) of the Internet survey commuters who indicated having a commute time of more than 30 minutes. It is therefore not surprising that 23% of the general public had heard of the Traffic.com website because most of the telephone survey respondents are not looking for relief from traffic congestion.

In addition to the awareness of the website itself, users may or may not be aware of several of its helpful features. Of the 64 people who responded to the Internet survey, 69% knew that Traffic.com website provides information on point-to-point travel times. A larger portion of the users was aware of the information on route-specific travel speeds and maps, 70% and 81%, respectively. The telephone survey results could not adequately assess the user awareness of specific website features since only 15 of the 250 respondents (6.0%) visited the site.

Access: The respondents to the Internet survey obviously have access to the Traffic.com information because they are registered users of the site. Access for potential users can only be measured by how many "customers" in the population have access to the Internet. Roughly 77% of the households in the Philadelphia metropolitan area have access to the Internet, either at home, at work, or someplace else. This figure does not indicate how much of the population has visited the Traffic.com website. It simply indicates that 77% of the population could access the website if they wanted to.

Acceptance: Acceptance is measured by the number of customers that state they *would* use information from Traffic.com website. In relation to the Traffic.com website, the registered users (i.e., the Internet survey respondents) are assumed to have already accepted the information. Forty-nine percent (49%) of the Philadelphia population that have not used the Traffic.com website expect to do so in the future. Of those who would *not* use it in the future, 29% do not need traffic information. About 15% of the population would not use it because they get their traffic information from other sources. About 97% of the Internet survey respondents planned to continue using Traffic.com information in the future.

Use*:* Use is measured by the number of customers who actually *do* use Traffic.com website and its various features. The Traffic.com website can be used to gather information on the traffic for specific routes, as well as to check for accidents, current travel speeds, and current travel times. It also provides tools to aid in these searches, such as the point-to-point travel times, route-specific travel speed, and map features.

Only 15 of the 250 people (6%) surveyed via telephone had ever used Traffic.com information. This number is too small to draw any strong conclusions. However, since the Internet survey respondents were all registered users of the Traffic.com website, 100% of the respondents have used the site. The results for the two survey efforts cannot be combined due to the weighting of the telephone survey responses. Therefore, the usefulness of the Traffic.com information will be characterized primarily by the Internet survey results.

Figure 5-10 shows the percentage of users from each of the surveys in relation to *how* they used the site. The Internet survey respondents used Traffic.com website much more often than the telephone respondents for various reasons. Eighty-three percent (83%) of the Internet survey respondents checked for traffic on specific routes, 31% checked the current travel speeds, 77% checked for accidents, and 52% checked current travel times. Forty-four percent (44%) of the telephone respondent users in the Philadelphia checked for traffic on specific routes, 2% checked for accidents and 9% checked for current travel times. In general, more of the Traffic.com website users access the information in the evening than in the morning or afternoon. Also, most users access Traffic.com information from work.

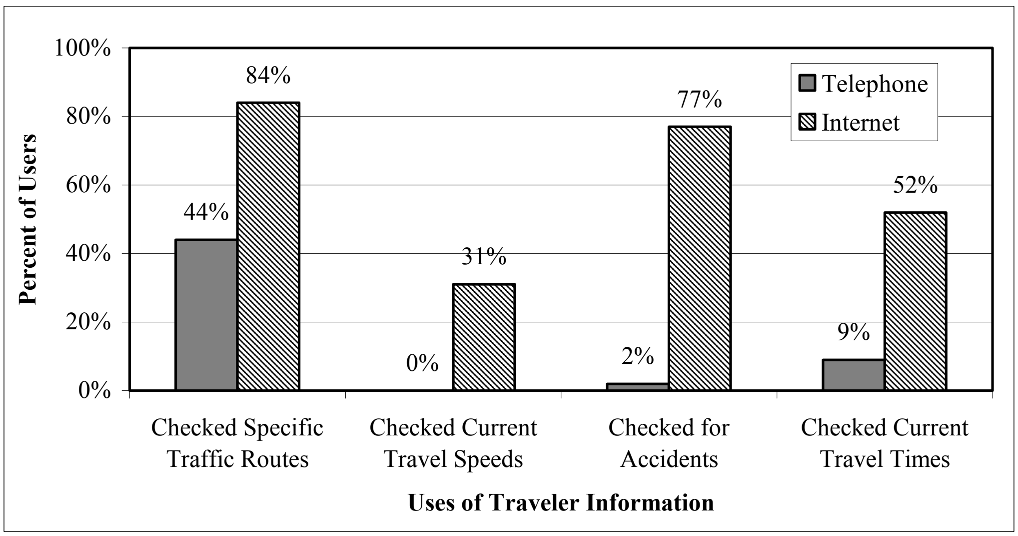

Figure 5-10. Percentage of Users from the Telephone and Internet Surveys That Used Traffic.com for the Listed Reasons

Value: The final phase of the customer satisfaction model is value of the traveler information. Many questions in the two surveys were directed at the value the respondent placed on certain aspects of the Traffic.com information, including their willingness to pay for the service. Figure 5-11 displays the percentage of users from the telephone and Internet survey that changed their original travel route, time of travel, or mode of transportation because of the information received from Traffic.com website. From the Internet survey, 86% of users changed their travel route, 66% changed their time of travel, and 8% changed their mode of transportation. From the telephone survey, about 83% of the general public users changed their original travel route, 34 % changed their original time of travel and 2% changed their original mode of transportation. These percentages could be an indication that the users are confident in the quality of the information. It is, however, important to note that due to the relatively small number of users identified in the telephone survey in Philadelphia, most of the information that can be used to describe the value customers place on the Traffic.com website comes from the Internet survey.

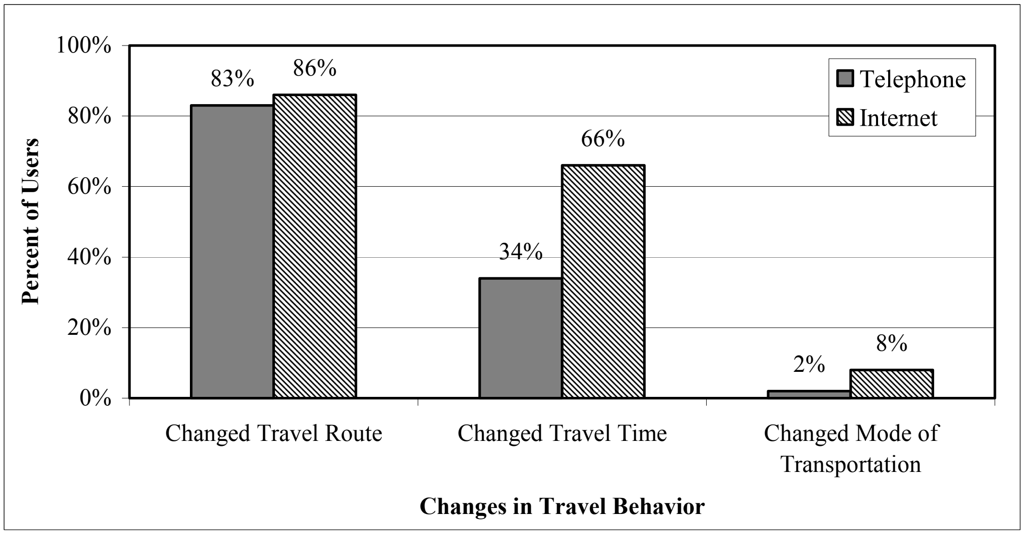

Figure 5-11. Percentage of Users from the Telephone and Internet Surveys That Changed Their Travel Behavior Based on Traffic.com Information

Fifty-eight percent (58%) of the 64 Internet survey respondents agree that the Traffic.com information is sufficient for their needs. Of the 11 who said it did not meet their needs, 6 offered suggestions for improvement. The top three suggestions related to changing or increasing the services provided, such as access from PDAs or text messaging alerts, as well as incorporating weather information along traffic routes. Two other comments related to increasing the number of routes covered.

The Internet survey results also indicate that 47% of the commuters feel that Traffic.com information helped to decrease their commute time. About 43% of the commuters feel that their commute time has remained the same. On the other hand, 97% of the point-to-point travel-time-users, 94% of the route-specific travel-speed-users and 96% of the map-users indicated that each specific feature was helpful in some way. All of these results suggest that the users value the Traffic.com information they receive. Twenty-seven percent (27% i.e., 17 out of 64) of the Internet users would be willing to pay for the services provided.

***System Performance**:* The customer satisfaction study also addresses the system performance in terms of how well the ISDMI systems perform the intended use. The Internet survey results indicate that the majority of the users believe the system performs well. Seventy percent (70%) think the website is easy to navigate through; 75% believe the information is easily understood; 68% feel the information is reliable; and 75% indicated that all or most of the routes they wanted to check for traffic were included in the system.

5.4.1.3 *Commentary*

The results of the telephone survey indicate that at the time of the survey, the majority of the general public in the Philadelphia area was unaware of the Traffic.com website. The Internet survey suggests that people who use the site have been telling others about the website. Over time this will likely result in a steady increase in the number of new users.

The acceptance of the Traffic.com information is not yet widespread in the Philadelphia area. Even though 45% of the population that has not used ISDMI plans to do so in the future, about 29% of the general public would not find the information necessary, applicable, or available to them. As for the website itself, the results seem to indicate that the information is helpful; however, use of it does not always translate into reduced travel times. About 45% of the registered users surveyed indicated that their travel time decreased, while about 6% indicated that use of the Traffic.com information actually increased their travel time.

5.4.2 Stakeholders

Only one of the stakeholders in Philadelphia, PennDOT District 6-0 TMC, reported accessing and using the ISDMI data at the time of the post-deployment interviews in April 2002. This is because the other stakeholders had not had prolonged exposure to the data at that time and it should be expected that their perceived levels of satisfaction with the ISDMI systems might change with time. The probable reasons why all stakeholders are currently not accessing or using the information from the ISDMI systems at the time of evaluation data collection could include: (i) lack of confidence in the quality of the data, (ii) stakeholders not fully prepared for the data generated from the ISDMI systems, (iii) availability of similar data from alternative sources such as legacy systems; (iv) ISDMI system not integrated with stakeholder legacy system.

The model used for assessing the level of satisfaction is the same as the one used for the general public. The issue of access is not relevant to evaluating stakeholder satisfaction. This is because all stakeholders are given free access to the databases and, unlike the general public, stakeholders are able to access both real-time and archived databases. In addition to the Internet interface, stakeholders also have PC-based interface software designed purposely to allow stakeholders access to the archived database and to generate customized reports for their specific applications. The satisfaction levels expressed by the officials of TMC are summarized below.

***Use*:** TMC staff use the ISDMI archived data on a limited basis to compare data from other sources such as cameras and detectors. The system is not yet integrated with their legacy system, which probably limits use. TMC continues to rely on its legacy systems and other sources of traffic data acquisition. Furthermore, incident detection and management procedures for the TMC have not changed as a result of the ISDMI system implementation.

Acceptance and Value: TMC staff indicated that they find the Internet interface easy to access and user-friendly. It is easier to use than the PC-based interface software. TMC staff indicated that the interface allows them to access information. TMC staff, however, expressed concern about the reliability and accuracy of the systems in incident location detection. As such, the staff of TMC are of the opinion that the system is not very useful for incident management purposes. It was noted that the concrete barriers separating traffic lanes reduce the accuracy of incident detection. Therefore, in order to improve incident detection accuracy it was suggested that the sensors should be provided for each direction of travel.

TMC staff also noted that the system would be adequate for ATIS needs, which is not the function of the agency. Travel times and speeds provided on TV and the Internet are the added value of the system for travelers, not for the TMC. No noticeable changes in congestion have been observed since the implementation of the ISDMI systems. The staff of TMC indicated that the impact of the system could not be quantified in terms of travel times, because there are several other variables in the highway system the affect travel time.

System performance: With regard to the quality of the data from ISDMI systems, it was noted that a minimal level of error has been encountered to-date. Since August 2001, there has only been one case where the detector reported erroneous results, and the error was corrected within minutes of reporting it to Mobility Technologies. In that case, the detector was reporting an incident being present, while it had already been cleared.

5.4.3 Media Houses

Information on customer satisfaction was obtained from three media houses operating in the Philadelphia area. These are Clear Channel Communications operating three stations (DAS-FM, AM, and WLCE), WIOQ-FM radio station, and WJJZ Smooth Jazz radio station. These media houses obtain traffic information from Mobility Technologies for a fee and provide traveler information to motorists especially during the morning and evening peak periods.

Access: All three media houses access real-time traffic data directly online in their studios through Traffic Pulse producer (Mobility Technologies) application via the Internet. The traffic data includes delays. On average the media houses access real-time traffic information via the ISDMI systems 16 times a day, 5 days a week during the morning peak and evening peak hours. One station indicated that 9 traffic reports are received during the morning peak period and 6 reports during the evening peak period. The media houses indicated that they do not experience any difficulties accessing data. However, one radio station noted that sometimes traffic delay information disappears from the screen leaving only travel times, which is not good for when broadcasting, live on the air.

***Use**:* The traffic information is used purely for broadcast purposes to inform listeners about traffic delays in the City of Philadelphia and its suburbs in the Delaware Valley. The media houses do not archive the traffic information after broadcast. On the question of whether the media houses receive feedback from the public on the traffic advisory information that they broadcast, the media houses indicate that sometimes listeners call to say that they find the travel time information very useful or to provide information on delays and incidents that are not available in the ISDMI systems.

Acceptance and Value: The quality of data is characterized as above average and getting better with the addition of travel times feature. The data satisfy their needs in terms of the format of data delivery, accuracy, timeliness, completeness, and reliability. One media house, however, noted that the format could be better but did not provide any suggestions. The media houses noted that the ISDMI systems offer a more convenient and easier way to obtain traffic information via the Internet compared to faxes, which is the legacy form of data access.

Aspects of the traffic information system that were found to be more useful included information on the causes reasons for long delays (e.g., crashes, construction, fire). This piece of information is considered useful because it would help travelers make decisions about alternate routes. One media house noted that long-term construction detours are less useful to the everyday rush hour listener. The other two media houses noted that information on less critical items is less useful.

All three media houses expressed satisfaction with the traffic information and indicated that they would recommend this source of traffic information to other potential customers. This is because it is a good, reliable source of traffic information. In terms of potential improvements, the media houses recommended that the information on the screen should be condensed so as to reduce the amount of scrolling. Furthermore, it is suggested that the items be listed in order of importance top down. One media house commented that Mobility Technologies continues to improve the product since its inception and recommended that the improvement effort continue. One media house suggests that all major highways be equipped with sensors to provide a wider coverage of the highways.

5.5 Congestion

In evaluating the potential impacts of the ISDMI systems on congestion in the Philadelphia area, two historically congested sections were identified. These are I-95 south of Exit 23 (Girard Avenue) (outbound or northbound) during the evening peak hour 3 to 6 pm, and I-95 Betsy Ross Bridge on-ramp (inbound or southbound) during the morning peak hour 6 to 9 am. Mobility Technologies' sensors #2130 and #2131 serve the northbound and southbound directions, respectively, of the Girard Avenue location, and sensors #2134 and #2135 serve the northbound and southbound directions, respectively, of the Betsy Ross Bridge site.

The congestion analyses were conducted on data from only one source, the ISDMI archived database. The archived data were downloaded from the ISDMI archived database for the morning and evening peak periods on Tuesday through Thursday for one week per month in September, October, November, and December of 2001, and January of 2002. It was assumed that traffic conditions are fairly stable between Tuesday and Thursday of any given week. The September 2001 data served as the baseline and the January 2002 data represent the post-deployment situation. Average speed and volume from the archived data were compared between September 2001 and January 2002 at the two locations to examine the potential impacts of ISDMI systems on traffic congestion.

In interpreting the results of the congestion analysis, it is important to note that changes in travel speed could be the result of several factors including location, time of day, direction of travel, weather, volume of traffic, occurrence of incident, availability of alternative routes, and also prior knowledge of traffic conditions at the location. It is therefore difficult to attribute any changes in travel speed and travel time directly to the effect of the availability of traveler information on congestion at any given location. For the purposes of this analysis, it was hypothesized that the availability of traveler information to road users would affect congestion, assuming all other factors remaining unchanged. The traveler information includes traffic condition information available to motorists via Internet, VMS, and HAR.

Archived data on travel speed and traffic volume recorded by the sensors at the two locations were downloaded and analyzed. Traffic data were generated at 5-minute intervals. Data for the dates in September 2001 were compared with data for January 2002. Data for some intermediate months (October, November, and December 2001) were also analyzed to examine the trend of traffic conditions at these locations. It is assumed that the quality and reliability of the archived traffic data are consistent in time and space.

With the 5-minute interval traffic data reports, 36 data points for each 3-hour peak period were analyzed for each month. The results are summarized in Table 5-7, Figure 5-12, and Figure 5-13. Table 5-7 shows the average speed and traffic volumes plus or minus 1 standard deviation, and the overall change between September 2001 and January 2002 expressed as a percentage of the September 2001 value. Negative values indicate decreases and positive values indicate increases above the September 2001 values, respectively. Figure 5-12 presents the average peak hour speeds by month for both directions of travel for the two locations. Figure 5-13 presents the average peak hour traffic volumes by month for both directions of travel for the two locations.

Figure 5-12. Average Peak Hour Speeds – (Archived Data)

Table 5-7. Summary Statistics of Speed and Volume – Archived Data

Average Speed (mph)				
Girard Avenue				
	Congested Direction		Non-congested Direction	
Sensor	2131	2130	2130	2131
Month	AM (SB)	PM (NB)	AM (NB)	PM (SB)
September	58.0 +/- 3.3	32.5 +/- 8.4	57.8 +/- 2.8	59.8 +/- 1.5
October	61.4 +/- 2.9	31.4 +/- 6.8	60.0 +/- 1.9	61.2 +/- 1.7
November	62.8 +/- 3.9	29.8 +/- 6.7	55.3 +/- 6.7	59.3 +/- 2.6
December	63.5 +/- 2.7	28.8 +/- 4.5	57.8 +/- 2.0	65.3 +/- 3.1
January	61.4 +/- 2.1	31.5 +/- 9.4	58.3 +/-1.9	61.4 +/- 2.4
Overall Change	5.9%	-3.1%	0.9%	2.7%
Betsy Ross Bridge				
	Congested Direction		Non-congested Direction	
Sensor	2135	2134	2134	2135
Month	AM (SB)	PM (NB)	AM (NB)	PM (SB)
September	14.9 +/- 2.1	55.5 +/- 1.4	55.7 +/- 1.5	47.4 +/- 17.6
October	30.4 +/- 3.8	54.2 +/- 2.2	56.7 +/- 1.4	51.9 +/- 14.8
November	16.9 +/- 2.7	49.2 +/- 7.9	56.4 +/- 1.7	36.6 +/- 19.4
December	14.9 +/- 3.1	52.2 +/- 3.7	54.6 +/- 1.7	31.2 +/- 16.3
January	16.4 +/- 2.8	47.2 +/- 5.6	51.8 +/- 1.9	36.4 +/- 16.7
Overall Change	10.1%	-15.0%	-7.0%	-23.2%
Traffic Volume				
Girard Avenue				
	Congested Direction		Non-congested Direction	
Sensor	2131	2130	2130	2131
Month	AM (SB)	PM (NB)	AM (NB)	PM (SB)
September	558 +/- 34	421 +/- 30	396 +/- 31	494 +/- 48
October	513 +/- 46	427 +/- 26	396 +/- 33	494 +/- 40
November	521 +/- 86	425 +/- 64	408 +/- 69	485 +/- 83
December	429 +/- 60	431 +/- 45	405 +/- 50	425 +/- 38
January	473 +/- 56	407 +/- 36	402 +/- 53	434 +/- 35
Overall Change	-15.2%	-3.3%	1.5%	-12.1%
Betsy Ross Bridge				
	Congested Direction		Non-congested Direction	
Sensor	2135	2134	2134	2135
Month	AM (SB)	PM (NB)	AM (NB)	PM (SB)
September	366 +/- 22	480 +/- 47	378 +/- 30	367 +/- 35
October	357 +/- 42	500 +/- 48	375 +/- 35	363 +/- 33
November	379 +/- 63	480 +/- 81	401 +/- 72	361 +/- 61
December	361 +/- 43	490 +/- 41	413 +/- 58	367 +/- 33
January	374 +/- 38	457 +/- 40	387 +/- 50	358 +/- 30
Overall Change	2.2%	-4.8%	2.4%	-2.5%

Notes
1. Overall change is the change between September 2001 and January 2002, expressed as a percentage of the September 2001 value.
2. Negative change indicates a decrease relative to September 2001; positive indicates an increase.
3. Values in the above table represent the mean value +/- one standard deviation.

Figure 5-13. Average Peak Hour Volume – (Archived Data)

It is noted that average speeds during the evening peak period in the congested direction of travel at the Girard Avenue location has actually decreased slightly by 3% between September 2001 and January 2002. The morning peak period in the congested direction did show an improvement in average speed (6% increase). The average speeds in the non-congested directions remained about the same during the morning peak period, and during the evening peak period, only a small improvement was seen (about 3% increase in speed). It is also noted in Figure 5-12 that average peak period speeds at this location did not fluctuate significantly from September 2001 through January of 2002. Similarly, the average volume stayed relatively constant during this period in the northbound direction during both the morning and evening peak periods (Figure 5-13). However, in the southbound direction, the average traffic volume at this location decreased by 15% in the morning peak period (identified as the congested direction), and by 12% in the evening peak period (identified as the non-congested direction). Thus large decreases in volume did not result in proportional increases in speed at this location.

The Betsy Ross Bridge location, on the other hand, showed rather significant changes in average peak hour speed between September 2001 and January 2002. It was noticed that the average speed during the morning peak period increased by 10% in the congested direction of travel but actually decreased by 7% in the non-congested direction of travel. The average traffic volumes for both directions at this location during this peak period showed an insignificant change (about 2%). Larger decreases in average speed were noted for the evening peak period – a 15% decrease in the congested direction and a 23% decrease in the non-congested direction of travel.

Only small decreases in volume were experienced for both the congested and non-congested directions during this evening time period (about 5% and 3%, respectively). Examination of Figure 5-12 reveals that the decrease in evening peak period average speed in the non-congested direction was rather erratic from September 2001 through January 2002, contrary to the relatively smooth decrease in average speed for the congested direction. The pattern was reversed for the morning peak period; the congested direction showed greater fluctuation in average speeds than the fairly constant nature of the non-congested direction. The change in traffic volume during all of the periods studied is less noticeable, with the average volumes remaining relatively constant throughout the surveyed months (Figure 5-13).

The inconsistent changes in both traffic speed and traffic volume during the peak periods at these locations hinder the generation of a definite conclusion regarding the effects of the improved traveler information to motorists. It should be noted that a major construction project was underway in the vicinity of these locations on I-95, which most likely had an impact on the results observed in this analysis. Additional factors affecting motorist behavior, such as mentioned earlier, including weather and availability of alternate routes, may be overshadowing any positive effects of the availability of real-time traveler information and its influence on trip making decisions and congestion. The only noticeable improvements in congestion include the 5% and 10% increases in average speed for the congested direction in the morning peak period at the Girard Avenue and Betsy Ross bridge locations, respectively. Additional improvements in congestion include the 15% decrease in traffic volume for the congested direction in the morning peak period and the 12% decrease in traffic volume in the non-congested direction in the evening peak period, both at Girard Avenue. These improvements seem to support the hypothesis that the availability of real-time traveler information may in fact influence trip making decisions and therefore congestion.

Results of the customer satisfaction study indicate that 44% of the traveling public does check real-time traffic information in making travel decisions. Also, about 83% of motorists interviewed reported changing their route and 34% changed their original time of travel based on traffic information accessed on the Internet. While it is not possible to relate these changes directly to the use of highway sections served by the sensors examined, the results seem to suggest that availability and access to real-time traffic information influences trip-making decisions and consequently congestion.

5.6 Cost Analysis

As noted in Chapter 4 of this report, the focus of the cost analysis is to determine the cost savings to the various stakeholders in terms of data collection, processing, storage, and retrieval. These cost savings exclude system deployment costs. The cost analysis estimates the cost savings to stakeholders assuming that they rely entirely on the ISDMI systems as the only source of traffic data. However, the stakeholders in Philadelphia did not provide detailed cost information that would permit a comprehensive analysis of the potential cost savings to each agency. The following sections summarize some cost items associated with traffic data gathering, processing, and dissemination by the stakeholders.

5.6.1 PennDOT District 6 - Traffic Management Center

Video is currently the agency's primary means of gathering incident-related information. Currently there are 46 cameras and a total of 90 cameras are expected to be installed by the end of 2002. TMC transmits traveler information to the public via 10 permanent VMS boards and 13 portables. The district plans to install 24 detectors on I-95 (RTMS, similar to the ones used by Mobility Technologies). The primary purpose is incident detection; however, the detectors will also be used to collect speed, flow, occupancy, and vehicle classification information by lane.

TMC also obtains incident information from private traffic information providers such as Express Traffic, Metro Traffic, and Smart Traveler. Additional information is sometimes obtained through the I-95 corridor coalition (Maine to Virginia), when the borders with other states are affected (NJ and Delaware). Information is also obtained from TRANSCOM (NJ). TMC paid $90,000 per month to Smart Traveler for traffic information, which included the cost of the development and distribution of traveler information through telephone and internet systems – the contract ended February 2002.

The estimated cost of the equipment, operations, and maintenance were not available to the evaluation team to allow a detailed estimation of cost savings. Should the TMC access and use data from the ISDMI systems to supplement information from the cameras, the minimum potential cost savings would be $90,000 per month or $1,080,000 annually, being the cost of data from secondary sources such as Smart Traveler.

5.6.2 Delaware Valley Regional Planning Commission

DVRPC owns and maintains its own counting equipment for traffic data collection. It was estimated that the annual cost of traffic data collection, processing, analysis, and reporting is approximately $600,000 including salaries and equipment purchasing. At the time of evaluation data collection in April 2002, DVRPC was not using data from the ISDMI systems. DVRPC plans to access and use data from the ISDMI systems. Until then, it is not possible to estimate the potential cost savings to the agency that might result form the use of data from the ISDMI systems. However, should DVRPC rely entirely on ISDMI systems for its traffic data needs, then the agency could save up to $600,000 annually.

5.6.3 City of Philadelphia, Streets Department

The City of Philadelphia's estimated annual cost for data collection is $90,000 in Federal funds. It is possible the City could save this amount if it is determined that the nature and quality of data from the ISDMI systems sufficiently meets their needs.

5.7 Safety

As noted in Section 3.4.5 of this report, information on safety impacts is anecdotal and qualitative. However, the stakeholders in Philadelphia were not using data from the ISDMI systems at the time of the evaluation data collection in April 2002. Consequently, they were not able to provide any information that can used to speculate on the potential impacts on safety. In any case, it is anticipated that safety benefits similar to those identified in Pittsburgh would be realized in Philadelphia when the stakeholders, particularly the TMC, begin using real-time traffic information from the ISDMI systems on a continuous basis. Furthermore, given that the ISDMI systems have a wider coverage of the highway network than the legacy systems (e.g., cameras) the TMC will be able to monitor traffic over a wider area than with the cameras only.

5.8 Institutional Issues

This section discusses institutional issues associated with the deployment of the ISDMI systems in both Pittsburgh and Philadelphia. Information on institutional issues was also collected through interviews with stakeholders and officials of Mobility Technologies. The following are summaries of the institutional issues associated with the deployment of the ISDMI systems as identified by the stakeholders.

- No major institutional issues have been identified with the deployment and usage of the systems in the Pittsburgh and Philadelphia areas. The ISDMI project is unique in terms of the public/private partnership in its design and implementation. As such, certain institutional issues are not likely to surface at this time but may become evident in the future. These issues may include data quality and the recourse available to the public in the event of erroneous or incomplete data, and public rights to the data (though not an issue to date). In turn, competitors may be discouraged from trying to provide identical data.

- The nature of this public/private partnership in which the private enterprise designs, builds, maintains, operates, and manages the systems offers clear benefits to public agencies. The most significant of these is that there are no questions about competing budgets or political issues.

- Operational changes in BPR in terms of traffic data analysis and projection are expected to occur with availability of data from ISDMI systems. The technical approach for doing so, the level of detail, and accuracy will change because data from ISDMI systems are more comprehensive in terms of spatial and temporal coverage.

- With regard to data collection activities, SPC and DVRPC, the agencies that collect traffic data and share them with other agencies in Pittsburgh and Philadelphia respectively, do not see any conflicts with the data offered by the new systems versus their legacy systems. Instead the new source of data is seen as supplementing congestion study data and other traffic data collection activities.

- With the implementation of ISDMI systems, data collection responsibilities may change. Currently, the MPOs in Pittsburgh and Philadelphia collect traffic data for the DOT. This change may result in more efficient use of resources.

- Data that were hitherto unavailable to stakeholders will now be available. Therefore, analyses, and decisions based on the outputs of those analyses, would be based on larger data sets – hence resulting in more confidence in decisions based on such data.

- The deployment of the system is likely to improve coordination among agencies. For example, DVRPC will be able to pull ISDMI data into the Philadelphia Regional Integrated Multi-modal Information Sharing (PRIMIS) program. Thus, the deployment of ISDMI systems is expected to indirectly facilitate interagency communication. In Philadelphia, DVRPC developed a regional ITS architecture that takes into account ISDMI. Direct coordination with PennDOT in locating placement of sensors will ensure consistency with other projects.

- The following are some "lessons learned" that are related to institutional issues associated with the implementation of ISDMI and similar systems.

  a) Some stakeholders feel that the duration of the agreement between the public and private agencies and the occupancy of the Right-of-Way should be specified. Occupancy of the ROW is indefinite in the current agreement.
  b) The specified use of funds allocated for the project should be defined – i.e., state money allocated to equipment rather than time and effort costs. The system assets should be tied to the state moneys.
  c) Highway Occupancy Permits should be used to track the placement of detectors. It was noted that Philadelphia's process was more stringent than Pittsburgh's.

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CHAPTER 6: DISCUSSIONS AND CONCLUDING REMARKS

6.1 Introduction

This chapter presents a general discussion of the findings in Pittsburgh and Philadelphia. The purpose is to highlight the major findings, differences, and similarities, and identify lessons learned in the ISDMI systems deployment. Where possible, the general discussions compare findings with results from other similar studies. This chapter also presents some concluding remarks from the evaluation effort.

The following are some key differences between the two cities in terms of the ISDMI systems deployment and evaluation that need to be highlighted.

- Deployment was completed in Pittsburgh before Philadelphia.
- Pittsburgh data for completeness analysis covered all 111 sensors. The data covered periods before and after systems acceptance testing in Pittsburgh in May 2001.
- Data for quality analysis in Philadelphia were collected after systems acceptance testing. Data from a sample of sensors were used in the data quality analysis in Philadelphia.
- Forty (40) of the sensors were in operation in Philadelphia long before the full deployment. These sensors were installed for the Republican Party convention in 2000. Consequently, residents of Philadelphia were aware of the ISDMI systems before full deployment and acceptance testing.

6.2 Discussion of Findings

The following sections discuss the findings for the two cities.

6.2.1 Technical Effectiveness

The technical effectiveness study assesses the systems' ability to capture, process, store, and report traffic data accurately, completely, and of acceptable quality for the various applications. Both quantitative and qualitative assessments were performed.

6.2.1.1 Archived Data Accuracy

ISDMI Sensors vs. ATR Counts: The data accuracy analysis used traffic volume counts from ATRs and manual counts as the reference values, against which sensor data were compared. It is recognized that ATRs have some inherent random and systematic error. However, the ATR and manual counts represent the status quo or legacy systems for traffic volume data collection. Therefore, data from any ITS or other advanced source should be better than or comparable in quality to the status quo in order to be attractive or acceptable.

Only traffic volume data were used in the data accuracy analysis, even though the sensors capture speed and occupancy data in addition to the traffic volume data. This is because there was no reference speed or occupancy data from the ATRs to be used in the data quality analysis. It was therefore assumed that the quality of traffic volume data reflects the quality of other traffic data captured by the sensors.

In Pittsburgh, the analysis shows that the ISDMI sensors recorded lower traffic counts than the ATR counts in approximately 81% of the readings and that the difference between the sensor and ATR counts increase with increasing traffic volume. At the 95% confidence level, precision of the sensor counts ranges from ± 74% for ATR traffic volumes less than 500 vehicles per hour to ± 7% for ATR traffic volumes greater than 2,500 vehicles per hour. In Philadelphia on the other hand, the analysis shows that the ISDMI sensors recorded higher traffic counts than the ATR counts in approximately 81% of the readings and that the absolute differences between the ATR and sensor counts remain fairly constant (±175) for all levels of traffic volume. At the 95% confidence level, precision of the sensor counts range from ± 124% for ATR traffic volumes less than 500 vehicles per hour to ± 6% for ATR traffic volumes greater than 2,500 vehicles per hour. Studies elsewhere (Turner et al., 2000) observed that differences between ATR and ITS data typically fall within 10% of one another. These studies also noted large differences in traffic volumes, ranging from 18 to 39%, in directly comparing ATR to detectors at certain locations. Therefore, it could be said that the precision of ISDMI sensors are comparable to results obtained elsewhere.

There is no clear explanation for the differences in accuracy of traffic volume data between Pittsburgh and Philadelphia. Although Pittsburgh analysis included data collected before the systems had undergone acceptance testing, the results indicate that the quality of data before and after the acceptance testing are comparable. The differences could be attributed to several factors. A possible reason is that, the sensors were deployed in Pittsburgh before Philadelphia. Therefore, experiences with the sensors and lessons learned in Pittsburgh might have been taken into account in the Philadelphia deployment.

ISDMI Sensor vs. Manual Counts: Sensor records of traffic volume were also compared with manual counts conducted at 10 different test locations in Pittsburgh. Manual traffic count data were not available for Philadelphia. It was found that the ISDMI sensors recorded lower traffic volume counts than the manual counts in 18 of 25 measurements (72%). Also, the difference between ISDMI sensor records and manual counts ranges between -16% and +20% relative to the manual counts.

6.2.1.2 Archived Data Completeness

The purpose of the data completeness analysis is to examine the ability of the ISDMI sensors to capture, process, and store traffic data completely. The data used to characterize the completeness of the archived data collected by the ISDMI sensors consists of volume, occupancy, and speed values reported at 5-minute intervals.

As noted earlier, a much larger data size was used for the completeness analysis in Pittsburgh than in Philadelphia. For the Pittsburgh, it was noted that data completeness improved from January through June 2001 but decreased between June and September 2001. The overall average percentage complete for all three variables is around 70 percent. It is noted that just under a third of all the potential 5-minute intervals contain missing values for each of the three quantities (29% for volume, 27% for occupancy, and 31% for speed). Volume and speed data were simultaneously missing approximately 3% of the time, with all three values were missing about 27% of the time. In general, the speed values appear to be missing slightly more often than the volume or occupancy values.

The data for Philadelphia were found to be 98% complete. Obviously, the sensors in Philadelphia are capturing, processing, and storing a higher percentage of expected amount of data than in Pittsburgh. It is important to note that despite the differences in data completeness between the two cities, the results compare favorably with other archived ITS data. For example, a study in Texas (Turner et al., 2000) observed that the amount of missing data typically ranges from 5 to 25%. A more recent study (Lomax et al., 2001) showed that completeness ranged from 38 to 93 percent for 10 different cities in the U.S. A value of 70% complete for Pittsburgh would be on par with several other cities. A value of 98% complete for Philadelphia is much better than the current maintenance levels of most data archives. Realistically, 100% completeness is not expected and there is no established acceptable threshold value to distinguish between good and poor quality archived traffic data. In the absence of such a threshold, the only reference for gauging the quality of archived ITS data would be evidence from similar studies or systems.

In interpreting the results of the data quality analysis, it is recognized that any new technology is bound to have initial start-up problems, such as equipment malfunctioning and calibration. With time these problems are addressed, and the quality of data generated improves. It was therefore not surprising that the quality of data from Philadelphia appears to be better than Pittsburgh's.

6.2.1.3 Real-Time Data

Only qualitative assessments of the systems and real-time data were made based on discussions with the users of real-time data in Pittsburgh. The stakeholders in Philadelphia were not accessing data from the ISDMI systems at the time of evaluation data collection and therefore were unable to provide information on the quality of real-time data. Officials of the TMC in Pittsburgh noted that the ISDMI systems are performing their intended functions of providing timely traffic information to traffic operators to help manage traffic in the Pittsburgh area, and providing traveler information to the general public.

6.2.2 Customer Satisfaction

Customer satisfaction studies were conducted to measure the opinions of the public (including the general public and current subscribers to the Mobility Technologies website), stakeholders, and media houses offering traveler information to travelers. Random telephone surveys of the general public were conducted to evaluate awareness, access, and acceptance and an Internet survey of actual users (subscribers to the Mobility Technologies website) were conducted with a focus on use and value associated with the ISDMI system. Note that in the customer satisfaction survey questions, Traffic.com or TrafficPulse was used to reference the actual website of ISDMI information. Two media houses in Pittsburgh and three in Philadelphia were surveyed. Specific findings from each of the three groups of customers are presented below

6.2.2.1 General Public

Awareness: According to the telephone survey, 28% of Pittsburgh residents and 23% of Philadelphia residents had heard of Traffic.com. The Internet survey indicates that Traffic.com website users heard about most often from a television or radio advertisement (32%) in Pittsburgh, and mostly by word of mouth in Philadelphia (35%).

Out of the people who responded to the Internet survey, 58% in Pittsburgh and 69% in Philadelphia knew that Traffic.com provides information on point-to-point travel times. More users were aware of the information on route-specific travel speeds and maps, 78% and 81% respectively in Pittsburgh, 70% and 81% respectively in Philadelphia.

Access: About 65% of the households in the Pittsburgh area and 77% in the Philadelphia area have access to the Internet. Access to the Internet is used as a proxy for access to Traffic.com information. Thus, 65% to 77% of the population in these two cities could access the website if they desire.

Acceptance: Almost all Internet survey respondents (95% in Pittsburgh and 97% in Philadelphia) plan to continue using Traffic.com traffic information in the future. This is a clear indication that current users find the information useful and will continue to use it.

Use: About 16% of the users in the Pittsburgh population compared to 44% in the Philadelphia population checked for traffic on specific routes and 6% (Pittsburgh) versus 9% (Philadelphia) check for current travel times. About 84% of Internet respondent users in both cities indicated that they check for traffic on specific routes.

Value: According to the Internet survey results, 68% of users in Pittsburgh and 86% in Philadelphia changed their original travel route, while 47% (Pittsburgh) and 66% (Philadelphia) changed their original time of travel. The effect on the choice of transportation mode is less noticeable, i.e., 6% in Pittsburgh and 2% in Philadelphia changed their original mode of transportation.

About 75% of commuters from the Internet survey in Pittsburgh and 43% in Philadelphia feel that their commute time has remained about the same. However, 18% (Pittsburgh) and 47% (Philadelphia) of the commuters feel that Traffic.com information helped to decrease their commute time.

The results seem to indicate that the real-time traffic information provided by the Traffic.com information is helpful to motorists in making their trip planning decisions. At the time of the survey, fewer than 10% of the users in Pittsburgh and 27% in Philadelphia indicated their willingness to pay for the services provided.

The Internet survey results indicate that the majority of the users believe the system performs well. Seventy percent (70%) think the website is easy to navigate through; 75% believe the information is easily understood; 60% and 68% in Pittsburgh and Philadelphia respectively feel the information is reliable; and 72% and 75% in Pittsburgh and Philadelphia respectively indicated that all or most of the routes they wanted to check for traffic were included in the system.

The customer satisfaction studies indicate that members of the general public who are aware of the Traffic.com website use and value the information provided in making their travel decisions. The results indicate that the levels of satisfaction expressed by users in both cities are similar. More than half of the users indicate that the information meets their needs. Although the numbers of respondents in the surveys are small, the results clearly indicate that the information from the Traffic.com website impacts travelers' choices of travel routes more than the time of travel. It is noted that the system is relatively new, and usage should increase with time.

Results of customer satisfaction studies of traveler information projects elsewhere suggest that percentages of users of ISDMI systems in Pittsburgh and Philadelphia are quite high relative to other cities. For example, in Boston in 1994 a random survey revealed that 47% of the respondents were aware of SmarTraveler, but only 9% used the services. In Washington D.C., about 11% of the respondents were aware of SmarTraveler in the Partners in Motion program, but only 10% of them used the telephone information system (Schintler, 1998). Another study in Greater Cincinnati and Northern Kentucky (Aultman-Hall, 1999) observed 55% awareness and 12% use of Advanced Regional Traffic Interactive Management and Information Systems (ARTIMIS). The results indicate that awareness and use of the ISDMI system are consistent with those reported in other studies. This could be attributed to both successful radio and TV campaigns and users' satisfaction with the information.

6.2.2.2 Stakeholders

At the time of customer satisfaction data collection, only two of the five stakeholders in Pittsburgh, PennDOT District 11 TMC and BPR, were actually accessing and/or using the ISDMI data. In Philadelphia, only the TMC was accessing the ISDMI data on a limited basis at the time of data collection in April 2002. Some possible reasons why all stakeholders were not accessing or using the information from the ISDMI systems at the time of evaluation data collection could include: (i) lack of knowledge of data quality (ii) stakeholders' lack of preparation for the data generated from the ISDMI systems, (iii) availability of similar data from alternative sources such as legacy systems; (iv) the fact that the ISDMI system is not currently integrated with stakeholder legacy systems. Due to the limited use of the data, a comprehensive assessment of the stakeholder satisfaction with data generated by the ISDMI systems was not possible.

Expressions of satisfaction presented in this report reflect those of a few stakeholders, and these expressions may not necessarily be true reflections of all the stakeholders in the two cities. This is because each stakeholder uses real-time or archived traffic data for different applications. It is interesting to note that the TMC staff in Pittsburgh and Philadelphia have divergent impressions about the data from the ISDMI systems. For example, the TMC staff in Pittsburgh noted that (i) the ISDMI systems improve coverage of highway systems and therefore improve traffic surveillance and incident management (emergency response), and that (ii) the system of data collection is convenient and useful because it is non-intrusive and continuous. The TMC staff in Philadelphia, on the other hand, expressed concerns about the reliability and accuracy of data generated by the ISDMI systems for incident detection. In Philadelphia, they feel that information generated from the ISDMI systems is not useful for incident management purposes.

Stakeholders who currently access data from the ISDMI systems all agree that the Internet interface is user-friendly and facilitates access to the data. Also, they find the Internet interface more useful than the PC-based interface software provided by Mobility Technologies.

6.2.2.3 Media Houses

Two media houses in Pittsburgh and three in Philadelphia were surveyed. On the average, the media houses access real-time traffic information via ISDMI systems 3 to 4 times during each peak period every day. The media houses expressed satisfaction with the quality of the data in terms of the format of data delivery, accuracy, timeliness, completeness, and reliability. It is noted that the new systems offer a more convenient and easier way to obtain traffic information via the Internet compared to faxes, the legacy form of data access.

All media houses expressed satisfaction with the traffic information and indicated that they would recommend this source of traffic information to other potential customers. This is because this service has totally changed the way the media houses deliver traffic information to listeners and it is believed that it saves the traveling public time on the road.

6.2.3 Congestion

The primary objective of the congestion study is to examine the potential impacts of the availability of traffic information from the ISDMI systems on traffic congestion. It is recognized that there is no direct linkage between changes in traffic speed and volume and the availability of traveler information to travelers. The results of the congestion analysis only provide indications of possible effects of the availability of traveler information on congestion.

In Pittsburgh, traffic speed and volume characteristics at two historically congested locations were compared between two points in time. Data from the ISDMI archived database and video recordings of traffic movements were used. A similar analysis was conducted in Philadelphia, but no video data were used.

Significant improvements in average speeds during the evening peak period were noticed at one location in Pittsburgh. There was a corresponding decrease in traffic volume at this location during the evening peak period. The average speed and traffic volume during the morning peak period remained about the same. At the second location, however, average speeds stayed practically the same during morning and evening peak periods and in both directions of travel. In Philadelphia, the results indicate that average morning peak period speed increased but the conditions at the second location remained relatively constant. These results do not permit conclusive attribution of any changes in speed or volume at these locations to the availability of traveler information to travelers.

TMC personnel in Pittsburgh observed that changes in traffic congestion in the Pittsburgh area in general were marginal. It was noted that congestion seemed to have improved on corridors without camera coverage. This is probably the result of providing motorists with traffic information through VMS and HAR on those corridors and through commercials and radio information provided by Mobility Technologies. The end result is better information to a greater number of motorists, particularly during the peak periods or in the event of an incident. Thus, availability of timely traffic information improves the traffic management operations of TMC and assists motorists in trip- making decisions. The officials of Philadelphia's TMC also observed that no noticeable changes in congestion had taken effect since the implementation of the ISDMI systems.

6.2.4 Cost Analysis

The focus of this cost analysis is to determine the cost savings available to the various stakeholders in terms of data collection, processing, storage, and retrieval for legacy versus ISDMI systems. This cost analysis was limited to estimating the cost savings to the stakeholders, assuming that they rely entirely on data provided by the ISDMI systems. Given the uniqueness of each stakeholder in terms of its data needs, legacy data sources, and plans for the near future, no attempt was made to compare cost savings to stakeholders in two cities.

The cost savings to stakeholders are essentially the non-recurrent costs of deploying new data collection systems and the recurring costs of operating and maintaining the existing legacy and new systems. Even for stakeholders such as the TMC, who consider data from the ISDMI systems as supplemental to their legacy sources, it is clear that each stakeholder will potentially realize some cost savings if it relies entirely upon the ISDMI systems for its traffic data needs.

6.2.5 Safety

Information on safety impacts is anecdotal and qualitative. The TMC personnel in Pittsburgh noted that the major safety benefit offered by the ISDMI systems is that access to real-time traffic information from the systems resulted in a reduction in the number of secondary incidents. This is also due to the fact that the ISDMI systems have a wider coverage of the highway network, allowing the TMC to monitor traffic over a wider area than with cameras only. The information alerts motorists of incidents ahead and allows them to react accordingly before getting closer to the incident location. It also allows motorists to make decisions regarding alternative routes, thus avoiding congestion and delays caused by incidents. Overall, the TMC personnel claim to be able to perform the incident management functions better with the availability of the ISDMI systems.

Even though the TMC personnel in Philadelphia did not provide any specific information on safety impacts, the observations in Pittsburgh regarding wider coverage and reduced secondary incidents are expected to be applicable to Philadelphia as well.

6.3 Concluding Remarks

The primary purpose of the evaluation is to demonstrate the technical and institutional feasibility, cost savings, and customer satisfaction with the traffic data generated by the ISDMI systems. Five major goal areas were evaluated: systems performance, mobility, productivity and efficiency, safety, and institutional issues. In evaluating these goal areas, six studies were conducted: technical effectiveness, customer satisfaction, congestion, cost, safety, and institutional issues. The evaluation attempts to address a number of questions related to the goal areas. The following concluding remarks summarize the findings.

6.3.1 Technical Effectiveness Study

The systems are operating as expected in collecting, processing, and storing traffic data non-intrusively and on a continuous basis. While the quality of archived data, measured in terms of accuracy and completeness, is comparable to results from studies elsewhere, there is room for improvement. The results indicate that sensors and communication systems are capable of capturing, processing, and transmitting real-time traffic data in required format to users. The systems are capable of generating customized reports from archived databases.

The majority of the general public users believe the system performs well. All stakeholders agree that the Internet interface is user friendly and facilitates access to the data. In fact, they find the Internet interface more useful than PC-based interface software.

6.3.2 Customer Satisfaction

The general public and media houses accept the data generated by the ISDMI systems. Over 95% of the general public users indicated their willingness to continue using the information and all media houses expressed satisfaction with the traffic information and indicated that they would recommend this source of traffic information to other potential customers. These users find overall performance of the systems to be acceptable and the information useful for their needs. On the other hand, stakeholders are slow to begin using the data from the ISDMI systems, and so it is impossible to offer any meaningful concluding remarks regarding stakeholder satisfaction with the data from the ISDMI systems. The few stakeholders that are currently accessing the data express satisfaction with the data.

6.3.3 Congestion

Due to the several factors affecting traffic flow, the direct impact of the ISDMI systems on congestion could not be conclusively and quantitatively established. Moreover, the time between deployment and evaluation was not long enough to capture any noticeable effects of the ISDMI systems on congestion. However, it is probable that the availability of accurate and complete real-time traffic information, providing wide coverage for the traffic managers and travelers, improves route choice decisions and consequently impacts congestion.

6.3.4 Cost Study

Certain characteristics of the ISDMI systems offer potential cost savings to the stakeholders who collect, process, store, and use traffic data, especially archived data. These characteristics include: (i) wider coverage area compared to loop detectors and cameras, (ii) non-intrusive and continuous data collection; (iii) ready availability of archived data; (iv) no data latency (i.e., no waiting period between data collection and reporting); and (v) less duplication of data collection efforts. Therefore, reliance on data from the ISDMI systems would result in cost savings to stakeholders who collect and process traffic data (both archived and real-time). These cost savings are essentially the non-recurrent costs of deploying new data collection systems and the recurring costs of operating and maintaining the existing legacy and new systems.

6.3.5 Safety Study

Safety impacts are difficult to measure. The availability of real-time traffic information to the TMC and travelers helps reduce the number of secondary incidents. There were mixed observations regarding the usefulness of real-time data from the ISDMI systems for incident management.

6.3.6 Institutional Issues

No major institutional issues have been identified with the deployment and usage of the systems in the Pittsburgh and Philadelphia areas. Certain institutional issues are not likely to surface at this time but may become evident in the future. These issues may include data quality and the recourse available to the public in the event of erroneous or incomplete data, and public rights to the data (though not an issue to date). Also, with the implementation of ISDMI systems, data collection responsibilities may change, which may result in more efficient use of resources. Finally, data that were hitherto unavailable to stakeholders will now be available and therefore, analysis and decisions based on the outputs of those analyses would be based on larger data sets data – hence resulting in more confidence in decisions based on such data.

6.4 Recommendations for Future Evaluations

The following are some potential questions that future evaluations of deployments should address. The evaluation effort should explore emerging uses of the data. These questions are essentially institutional issues and customer satisfaction type questions.

- What are the potential non-traditional uses of this new information?
- Does this information conflict with or supplement traditional traffic data – how does it integrate with legacy system(s)?
- What are the advantages and limitations of reliability-based performance measures for traffic management and operations activities?
- What are the implications of reliability-based performance measures for efficiency and productivity in traffic operations and planning activities?

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Appendix A: Survey Instruments

Baseline Interview Questions

(Used for both Pittsburgh and Philadelphia, PA)

INTEGRATED SURVEILLANCE AND DATA MANAGEMENT INFRASTRUCTURE (ISDMI) PROGRAM

BASELINE STUDY – INTERVIEW GUIDE

PURPOSE OF STUDY AND INTERVIEW OBJECTIVES

The primary objective of the Integrated Surveillance and Data Management Infrastructure (ISDMI) program is to build an infrastructure to measure various transportation system metrics to aid in planning, analysis, and operation of the transportation systems. This project is designed, developed, implemented, operated, and maintained by a privately owned company, Traffic.com.

The purpose of the interview is to gather sufficient baseline data that would allow an evaluation of the deployment of ISDMI in Pennsylvania. The interview guide is designed with the primary objective to obtain sufficient information on:

- the various kinds of traffic data and their uses by various organizations.
- activities related to traffic data collection, processing, archiving, and retrieval.
- costs and resources associated with traffic data collection, processing, archiving, retrieval, and usage.

The interview guide is divided into sections to help focus on the different aspects of traffic data collection and usage and how they relate to the objectives of the ISDMI project. The guide attempts to identify pertinent data elements that needs to be captured in order to conduct a meaningful evaluation.

BACKGROUND

The purpose of this section is to gather background information on the types of traffic data used by the organization.

1. Name of agency

2. What is your agency's major road traffic related activity?

3. Describe the types of traffic data used by your organization. What kinds of activities/analysis do you use these traffic data for?

4. Describe your sources of traffic data. Does your agency collect all its needed traffic data?

5. How often do you collect traffic data?

6. Describe the system(s) or method(s) that your organization uses to collect traffic data (data collection method or techniques).

7. What other agencies does your agency interact with in terms of traffic data sharing? Do you rely on data collected by other organizations?

8. Describe your agency's most significant coordination issues in working with other agencies in collecting and sharing traffic data.

9. How much does it cost your organization to collect traffic data?
   – The number of people, on average, required to collect or process (or handle) traffic data
   – Time spent collecting or accessing and processing (or handling) data (e.g., labor hours/monthly/yearly)
   – The average salary levels of the individuals collecting, processing (or handling), and archiving traffic data
   – Other costs associated with traffic data collection, processing, (or handling, archiving, and retrieval.

10. Does your agency primarily use real time or archived traffic data for its operations?

TRAFFIC DATA USAGE

This section focuses on the sources and usage of real time and archived traffic data.

Real Time Data

11. Describe the activities of your organization that require real time traffic data (the primary uses of real time data).

12. Describe the kinds of real time traffic data required for your day-to-day operations.

13. Describe how your organization accesses real time data (i.e., methods)

14. Describe how you transmit/obtain traffic data to/from other organizations (if any)

15. How long does it take to access real time data (if collected by another agency)

16. How much ($) does your agency pay for real time data (if collected by another agency)?

17. Describe how your organization processes (or handles) or stores (archives) traffic data.

18. Describe the method(s) used to get traveler information from your organization to the travelers.

19. Describe your incident detection / management procedures (where applicable).

20. Describe how incident detection information is transmitted to incident management center(s).

21. Describe any safety related uses of real time traffic data by your organization

22. Describe traffic (congestion) management procedures and the kinds of traffic data used.

23. Describe (identify) 1 or 2 typical congestion problem areas within the city of Pittsburgh / Philadelphia covered by your traffic management systems?

24. Provide congestion studies conducted in the last 2 years at congestion problem areas that will be covered by Traffic.com's data collection devices.

25. Describe any other issues related to source and usage of archived data.

ARCHIVED DATA

26. What kinds of archived data do you require for your day-to-day activities?

27. Describe the primary uses of archived data

28. What are your sources of archived traffic data?

29. Do you receive archived traffic data in ready-to-use formats or reprocessing is required?.

30. Describe your data processing (or handling) and archiving processes (if required).

31. Describe any problems associated with accessing archived data from other agencies.

32. Describe potential areas of improvement in accessing and using archived traffic data.

33. Describe any safety related uses of archived data by your organization.

34. Describe congestion management studies conducted in the last 2 years (if available).

35. Identify 3-5 data collection sites for which congestion data is available and which will be covered by Traffic.com's data collection devices.

36. Provide congestion data for these sites identified in 35.

37. Describe any other issues related to the source, processing (handling), and usage of archived data

DATA QUALITY AND PROBLEMS

This section focuses on data quality relating to collection, processing, handling, storage, and retrieval activities.

38. Describe the kinds and magnitude of errors or problems you often encounter with traffic data
    - collection
    - processing/handling
    - archiving/storing
    - retrieving/reporting

    How often do these errors occur?

    Provide any documentation of these errors, if available

39. Describe the effects of these data errors on your operations (usage).

40. Describe the limitations and deficiencies of the current methods or approaches (in terms of cost, reliability of devices and systems, storage capacity, processing difficulties etc) for traffic data
    - collection
    - processing / handling
    - archiving / storing
    - retrieving / reporting

41. Describe any other data quality issues.

Post-Deployment Interview Questions

(Used for both Pittsburgh and Philadelphia, PA)

INTEGRATED SURVEILLANCE AND DATA MANAGEMENT INFRASTRUCTURE (ISDMI) PROGRAM

POST-DEPLOYMENT STUDY SURVEY

INTERVIEW OBJECTIVES

The purpose of the post deployment key informant interview is to gather sufficient data that would allow an assessment of the changes resulting from the deployment of Mobility Technologies' systems in the Pittsburgh and Philadelphia regions.

The interview guide is divided into sections to help focus on the different aspects of traffic data collection and usage and how they relate to the objectives of the ISDMI project.

Customer Satisfaction

This section focuses on customer satisfaction with the Mobility Technologies systems.

1. How often do you access traffic information

2. Is the data easy to access? - Is the query interface easy to understand for all kinds of data queries?

3. Does the query interface allow you access and retrieve data for all your needs?

4. Comment on the user-friendliness of the interfaces (Internet versus PC-based interface software)

5. What problems do you encounter in retrieving historical data? (How easy it is to navigate the system and generate customized reports)

6. Were you able to use the data formats provided by the data archive?

7. Does the data satisfy all your needs?

8. How is Mobility Technologies data integrated with your legacy system?

9. What improvements (if any) would recommend?

10. Do you have confidence in the data generated by the systems (real-time and archived data)?

11. Do you find the quality of data (accuracy, reliability, completeness) acceptable for your applications? If NO, why?

12. What is the added value of the products offered by the system?

13. What aspects of the systems are considered more useful or beneficial than other aspects?

14. Are you satisfied with the overall performance of the systems?, If No, why? - What are the limitations of the systems?

15. With specific reference to your applications, what aspects of the system need improvement?

Traffic Data Usage

This section focuses on the sources and usage of real time and archived traffic data.

Real Time Data

16. How has the data you acquire changed since the deployment of Mobility Technologies ?

17. How have the methods that your organization use to access real time data changed since the deployment of Mobility Technologies (e.g., legacy system, Mobility Technologies , of both)?

18. How long does it take to access real time data from Mobility Technologies 's systems?

19. How much ($) does your agency pay for real time data collected by Mobility Technologies ?

20. How have your method(s) used to get traveler information from your organization to the travelers changed since having access to Mobility Technologies data?

21. How have your incident detection / management procedures changed since having access to Mobility Technologies data?

22. Describe any noticeable changes in congestion within the city of Pittsburgh at the following locations that you identified in the previous survey:

- Site #1: I-279 Rosslyn Farm (*Mobility Technologies* sensor # 11)
- Site #2: I-376 Beechwood Boulevard (*Mobility Technologies* sensor # 36)

23. What other impacts has the implementation of Mobility Technologies system had on your procedures and operations?

24. What do you feel are some of the benefits of integrating Mobility Technologies into your current traffic data system?

25. What do you feel are some of the drawbacks of integrating Mobility Technologies into your current traffic data system?

Archived Data

26. How have your sources or uses of archived data changed since Mobility Technologies data became available?

27. How have your data processing (or handling) and archiving processes changed since the implementation of Mobility Technologies ?.

28. With the legacy system, how long does it take to make traffic data available to users – (from collection through processing to delivery (production of traffic data book))?

Data Quality And Problems

This section focuses on data quality relating to collection, processing, handling, storage, and retrieval activities.

29. Describe the kinds and magnitude of any new errors or problems you have encountered with traffic data from Mobility Technologies 's systems:
    - collection
    - processing/handling
    - archiving/ storing
    - retrieving /reporting

    How often do these errors occur?

    Provide any documentation of these errors, if available

30. Describe the effects of these data errors on your operations (usage).

31. What are the advantages of legacy data collection, processing and storage methods?

32. What are the limitations of legacy data collection methods (e.g. coverage of all highway links, duration of data collection etc)?

33. What are the advantages of accessing traffic data from Mobility Technologies 's systems (i.e., NTDC)?

34. What are the problems and limitations of accessing and retrieving archived traffic data from NTDC?

35. Describe other limitations and deficiencies of the legacy and Mobility Technologies 's methods in terms of cost, reliability of devices, systems and data, storage capacity, processing difficulties etc for traffic data:
    - collection
    - processing / handling
    - archiving / storing
    - retrieving / reporting

36. Describe new aspects or further developments of the data quality issues previously reported, and describe new ones that have presented themselves.

37. Describe potential areas of improvement in accessing and using archived Traffic data.

INSTITUTIONAL ISSUES

38. Which agency (e.g. Penn DOT) is responsible for coordinating the deployment of ISDMI?

39. What other (local or state) agencies are affected by ISDMI deployment?

40. What institutional issues (e.g., competing budgets, priorities etc) have arisen during the deployment of ISDMI?

41. What state laws (e.g., data privacy etc) affect the use of the products from ISDMI systems?

42. What agency policies or procedures are likely to change or be modified over time due to ISDMI implementation (e.g., frequency of data downloads, data sharing)?

43. What are some institutional or non-technical/non-cost <u>impediments</u> to ISDMI (e.g., data privacy, data security)?

44. What are some institutional or non-technical/non-cost issues that <u>support</u> ISDMI (e.g., political pressure, TEA-21 legislation, ITOP funding)

45. How is ISDMI project coordinated with other ITS projects?

46. How is the organizational structure likely to be affected by ISDMI implementation (e.g., coordination/consolidation of activities between agencies or departments)?

47. How will ISDMI relate to other agency information systems? For example, will ISDMI traffic data be integrated into your agency's traffic information system, or will it essentially be another database that potentially conflicts with traffic data in another traffic database?

48. Please describe "lessons learned" to be shared with other states deploying ISDMI or related technologies.

Cost Data

This section will gather cost information related to collecting, processing, and archiving traffic data.

49. What is the cost of traffic data collection equipment (including equipment installation and calibration, and software)?
50. What is the cost of maintaining and operating the data collection equipment (hardware and

software)?

51. What is the cost to your organization to collect and process traffic data in terms of:

- number of people, on average, required to collect and process (or handle) traffic data
- average time spent collecting or accessing and processing (or handling) data (e.g., labor hours/monthly/yearly)
- average salary levels of the individuals collecting, processing (or handling), and archiving traffic data
- other costs associated with traffic data collection, processing, (or handling, archiving, and retrieval.

52. What is the cost of maintaining and operating the data processing systems or equipment (include hardware and software)?

53. What is the cost of production of traffic data book? How often are these books produced?

54. What other costs are associated with traffic data collection, processing and storage (legacy and Mobility Technologies)?

Pittsburgh Telephone Questions

Section I: Screening and Introduction

INTRO. Hello, this is ________________ of MORPACE International, a research firm located in Michigan. I'm calling on behalf of the U.S. Department of Transportation. We are conducting a research study about the awareness and use of a traffic information service and to assess other transportation related issues. The results of this research could help to reduce the traffic congestion in your area. This is not a sales call and no sales calls will result from the interview. Your answers will be kept completely confidential. For quality control purposes, this call may be monitored.

SCREEN. Are you a member of this household and at least 18 years old?

1 Yes
2 No **(ASK TO SPEAK TO SOMEONE WHO IS, IF NOT AVAILABLE, SCHEDULE A CALLBACK)**
9 *Refused* **(THANK AND TERMINATE)**

PHONE. Is this phone number used for . . .?

1 Home use only
2 Business use only, or **(THANK AND TERMINATE)**
3 Home and business use
98 Don't Know **(THANK AND TERMINATE)**
99 Refused **(THANK AND TERMINATE)**

Section II: Rush hour travel

Q1. How many days per week do you typically make a regular trip traveling during weekday MORNING rush hours (Note: Morning rush hours are from 6:00 a.m. to 9:00 a.m.)? *(ALLOW 1-5 FOR ANSWER)*

97 None (go to Q3)
98 Don't Know (go to Q3)
99 Refused (go to Q3)

Q2. ***Approximately, how long is this one-way trip? Would you say it is…?*** *(READ LIST)*

1 Less than 5 minutes
2 6 – 10 minutes
3 11 – 30 minutes
4 31 minutes to 1 hour, or
5 Over 1 hour
98 Don't Know
99 Refused

Q3. ***How many days per week do you typically make a regular trip traveling during weekday EVENING rush hours? (Note: Evening rush hours are from 4:00 p.m. to 6:00 p.m.)*** *(ALLOW 1-5 FOR ANSWER)*

97 None (go to Q5)
98 Don't Know (go to Q5)
99 Refused (go to Q5)

Q4. ***Approximately, how long is this one-way trip? Would you say it is…?*** *(READ LIST)*

1 Less than 5 minutes
2 6 – 10 minutes
3 11 – 30 minutes
4 31 minutes to 1 hour, or
5 Over 1 hour
98 Don't Know
99 Refused

Section III: Internet usage and media sources

Q5. ***Do you have access to the Internet at home, at work, or both?***

1 At home
2 At work
3 Both home and work
4 Neither *(go to Q7)*
98 Don't Know (go to Q7)
99 Refused (go to Q7)

Q6. How often do you obtain information from the Internet? Would you say it is . . .?
(READ LIST)

1 Everyday
2 Occasionally
3 Rarely, or
4 Never
98 Don't Know
99 Refused

Q7. From what types of media sources do you typically obtain traffic information?
(DO NOT READ, MULTIPLE RESPONSE)

1 Television
2 Radio
3 Newspaper
4 Internet
96 Other (SPECIFY) ______________________________
97 None
98 Don't Know
99 Refused

Section IV: Awareness

Q8. Have you ever heard of the website, Traffic.com?

1 Yes
2 No *(go to* **EXPLAIN***)*
98 *Don't Know (go to* **EXPLAIN***)*
99 *Refused (go to* **EXPLAIN***)*

Q9. Have you ever visited the Traffic.com website?

1 Yes *(go to Q13)*
2 No
98 Don't Know
99 Refused

EXPLAIN. Well, Traffic.com is an Internet-based service that provides up-to-the-minute traffic and accident conditions on local roadways and provides real-time driving times and speeds on all major roadways.

Section V: Acceptance

Q10. Do you think that this is something you might use in the future?

1 Yes
2 No *(go to Q12)*
98 *Don't Know (go to Q12)*
99 *Refused (go to Q12)*

Q11. How often do you think you would use it? Do you think you would use it . . .? *(READ LIST)*

1 More than once a day *(go to Q25)*
2 Once a day *(go to Q25)*
3 Multiple times a week *(go to Q25)*
4 Weekly *(go to Q25)*
5 Monthly *(go to Q25)*
98 *Don't Know (go to Q25)*
99 *Refused (go to Q25)*

Q12. Why would you NOT use Traffic.com? *(DO NOT READ, MULTIPLE RESPONSE)*

1 No computer *(go to Q25)*
2 No Internet access *(go to Q25)*
3 Do not have a car *(go to Q25)*
4 Do not commute/drive during rush hour *(go to Q25)*
5 No wireless device (cellular phone, pager, etc.) **(NOTE: This does not pertain to the Internet)** *(go to Q25)*
6 Do not need/use traffic information *(go to Q25)*
7 Obtain traffic information elsewhere/Radio/TV *(go to Q25)*
96 Other (SPECIFY) ___________________________ *(go to Q25)*
98 *Don't Know (go to Q25)*
99 *Refused (go to Q25)*

Section VI: Use

Q13. For what reasons do you use Traffic.com?
(MULTIPLE MENTION, DO NOT READ LIST)

1 Check traffic on a specific route
2 Check for accidents
3 Check for current travel speeds
4 Check current travel time
5 To see what the website is about
97 Other (SPECIFY) ______________________
98 *Don't Know*
99 *Refused*

Q14. How often do you use Traffic.com? Do you use it . . .? *(READ LIST)*

1 More than once a day
2 Once a day
3 Multiple times a week
4 Weekly
5 Monthly, or
6 Once or twice
98 *Don't Know*
99 *Refused*

Q15. Would you say the information you obtain from Traffic.com is . . . *(READ LIST)*

1 Very Reliable *(go to Q18)*
2 Somewhat Reliable
3 Somewhat Unreliable, or
4 Very Unreliable
98 *Don't Know*
99 *Refused*

Q16. Has the reported information ever been incorrect?

1 Yes
2 No *(go to Q18)*
98 *Don't Know* (go to Q18)
99 *Refused* (go to Q18)

Q17. How often, would you say, is the information you receive from Traffic.com incorrect? Would you say it is Always, Sometimes, or Rarely incorrect?

1 Always
2 Sometimes
3 Rarely
98 Don't Know
99 Refused

IF Q1 OR Q3 =1—5, ASK Q18, OTHERWISE GOTO Q19

Q18. What impact do you think Traffic.com has had on your regular weekday rush hour travel time? Would you say your travel time has . . .? *(READ LIST)*

1 Increased
2 Decreased, or
3 Stayed about the same
98 Don't Know
99 Refused

Q19. Has Traffic.com helped you avoid major traffic delays?

1 Yes
2 No
98 Don't Know
99 Refused

Q20. Have you ever changed your original travel ROUTE based on information you received from Traffic.com?

1 Yes
2 No
98 Don't Know
99 Refused

Q21. Have you ever changed your original travel TIME based on information you received from Traffic.com?

1 Yes
2 No
98 Don't Know
99 Refused

Q22. Have you ever changed your original MODE of transportation based on information you received from Traffic.com? (Note: By mode I mean automobile, public transportation, etc.)

1 Yes
2 No
98 Don't Know
99 Refused

Q23. Does Traffic.com provide you with all the traffic information you need?

1 Yes *(go to Q25)*
2 No
98 Don't Know
99 Refused

Q24. What other kind of information would you like to see available on the Traffic.com website? *(OPEN END)*

____

98 Don't Know
99 Refused

Section VII: Additional Phone Line Information

Next, I have just a few questions regarding additional phone lines in your home.

Q25. Do you have any other telephone lines in your house that someone would answer? (This does not include dedicated computer, fax lines, or cellular phones.

1 Yes
2 No *(go to Q28)*
98 Don't Know (go to Q28)
99 Refused (go to Q28)

Q26. How many other telephone lines are there? *(ALLOW 1-9 FOR ANSWER)*

____

98 Don't Know
99 Refused

Q27. What is the primary use of this (these) additional telephone line(s)?
(DO NOT READ)

1 Home use only
2 Business use only
3 Home and business use
97 Other (SPECIFY)____________________
98 Don't Know
99 Refused

<u>*Section VIII: Demographics*</u>

Finally, I have a few more questions to be used for demographic purposes only.

Q28. Which of the following best represents your age group? *(READ LIST)*

1 18 – 20 years old
2 21 – 30 years old
3 31 – 40 years old
4 41 – 50 years old
5 51 – 60 years old
6 Over 60 years old
98 Don't Know
99 Refused

Q29. Including yourself, how many people age 18 years or older live in your household?
(ALLOW 1-9 FOR ANSWER)

____

98 Don't Know
99 Refused

Q30. What is the highest level of education you have completed? *(DO NOT READ)*

1 Less than High School
2 High School Graduate/GED
3 Technical school/professional business school
4 Some college
5 Community college graduate (Associate Degree, 2 year Degree)
6 College graduate (4 year Degree)
7 Post-graduate degree (Masters, Ph.D., Lawyer, Medical Doctor)
98 Don't Know
99 Refused

Q31. Record gender *(BY OBSERVATION)*

1 Male
2 Female

CONC. This concludes our survey. On behalf of the Department of Transportation, thank you for participating. Your opinions are valued.

Pittsburgh Internet Questions

The U.S. Department of Transportation is conducting a research study in your area to learn more about customer satisfaction and system performance from users of the Traffic.com website.

1. Are you at least 18 years old?

1 Yes
2 No (*cannot complete the survey*)

Please answer the following general questions about your travel.

2. How often do you use public transportation?

1 Everyday
2 2-3 days per week
3 Once a week
4 Never

3. How often do you travel during rush hour?

1 Everyday
2 2-3 days per week
3 Once a week
4 Never (*go to question 6*)

4. How long is your typical commute, one-way?

1 Less than 5 minutes
2 5 – 10 minutes
3 10 – 30 minutes
4 30 minutes to an hour
5 Greater than one hour

5. What impact do you think Traffic.com has had on your commute time? Has it . . .

1 Increased?
2 Decreased?
3 Stayed about the same?

6. How did you hear about Traffic.com?

1 From another Internet website
2 Someone told you about it
3 A billboard advertisement
4 Searching for traffic information on the web
5 From a TV or radio ad
6 From a newspaper or magazine ad
7 Other (specify) ___________________________

7. HOW OFTEN do you use information from Traffic.com?

1 More than once a day
2 Everyday
3 2-3 days per week
4 Once a week

8. WHY do you use Traffic.com? (Check all that apply.)

1 To check traffic on a specific route
2 To check for accidents
3 To check current travel speeds
4 To check current travel time
5 Other (specify) _____________________

9. WHEN do you use Traffic.com? (Check all that apply.)

1 Morning
2 Afternoon
3 Evening

10. From WHERE do you use Traffic.com? (Check all that apply.)

1 Home
2 Work
3 Other (specify) ________________________

11. Do you plan to use Traffic.com in the future?

1 Yes
2 No

12. Would you be willing to pay a nominal fee for the information provided by Traffic.com?

1 Yes
2 No

13. From what other sources do you get traffic information? (Check all that apply.)

1 Television
2 Radio
3 Newspaper
4 Other (specify) ______________________________

14. How often do you obtain information from the Internet?

1 Everyday
2 Occasionally
3 Rarely
4 Never

For the questions 15 - 19, please indicate how strongly you agree or disagree with the following statements.

15. The information presented on the Traffic.com website is easily understood.

1 Strongly Agree
2 Agree
3 Neutral
4 Disagree
5 Strongly Disagree

16. The Traffic.com website is easy to navigate through.

1 Strongly Agree
2 Agree
3 Neutral
4 Disagree
5 Strongly Disagree

17. The data provided by the Traffic.com website is accurate.

1 Strongly Agree
2 Agree
3 Neutral
4 Disagree
5 Strongly Disagree

18. The data provided by the Traffic.com website is reliable.

1 Strongly Agree
2 Agree
3 Neutral
4 Disagree (*go to question 18a*)
5 Strongly Disagree (*go to question 18a*)

18a. Has the reported information ever been incorrect?

1 Never
2 Rarely
3 Occasionally
4 Usually
5 Always

19. The information provided on the Traffic.com website is sufficient for your needs.

1 Strongly Agree
2 Agree
3 Neutral
4 Disagree (*go to question 19a*)
5 Strongly Disagree (*go to question 19a*)

19a. What other information would you like to see?

____

____

20. Have you ever used the "using Traffic.com" help link?

1 Yes
2 No (*go to question 22*)

21. Would you say the "using Traffic.com" link is . . .

1 Very Helpful?
2 Somewhat Helpful?
3 Not at All Helpful?

22. Are all of the routes you want to check traffic for provided at Traffic.com?

1 All of them
2 Most of them
3 Some of them
4 None of them

23. What other routes would you like to see added to Traffic.com?

____

____

24. Do you know that Traffic.com provides information on point-to-point travel times?

1 Yes
2 No (*go to question 27*)

25. Have you ever used the information on point-to-point travel times?

1 Yes
2 No (*go to question 27*)

26. Would you say the information on point-to-point travel times is . . .

1 Very Helpful?
2 Somewhat Helpful?
3 Not at All Helpful?

27. Do you know that Traffic.com provides information on route-specific travel speeds?

1 Yes
2 No (*go to question 30*)

28. Have you ever used the information on route-specific travel speeds?

1 Yes
2 No (*go to question 30*)

29. Would you say the information on route-specific travel speeds is . . .

1 Very Helpful?
2 Somewhat Helpful?
3 Not at All Helpful?

30. Do you know that Traffic.com provides graphical traffic information on maps?

1 Yes
2 No (*go to question 33*)

31. Have you ever used the map information?

1 Yes
2 No (*go to question 33*)

32. Would you say the map information is . . .

1 Very Helpful?
2 Somewhat Helpful?
3 Not at All Helpful?

33. Have you ever changed your original travel route based on information you received from Traffic.com?

1 Yes
2 No

34. Have you ever changed your original travel time based on information you received from Traffic.com?

1 Yes
2 No

35. Have you ever changed your original mode of transportation based on information you received from Traffic.com?

1 Yes
2 No

36. What is your zip code?

____

37. How old are you?

1 18 – 20 years old
2 21 – 30 years old
3 31 – 40 years old
4 41 – 50 years old
5 51 – 60 years old
6 Over 60 years old

38. Are you male or female?

1 Male
2 Female

39. What is the highest level of education you have completed?

1 Less than High School
2 High School Graduate/GED
3 Technical school/professional business school
4 Some college
5 Community college graduate (AA: Associate of Arts Degree)
6 College graduate (BA or BS: Bachelor of Arts or Sciences Degree)
7 Post-graduate degree (Masters, Ph.D., Lawyer, Medical Doctor)

Philadelphia Telephone Questions

Section I: Screening and Introduction

INTRO. Hello, this is ________________ of MORPACE International, a research firm located in Michigan. I'm calling on behalf of the U.S. Department of Transportation. We are conducting a research study about the awareness and use of a traffic information service and to assess other transportation related issues. The results of this research could help to reduce the traffic congestion in your area. This is not a sales call and no sales calls will result from the interview. Your answers will be kept completely confidential. For quality control purposes, this call may be monitored.

SCREEN. ***Are you a member of this household and at least 18 years old?***

1 Yes
2 No **(ASK TO SPEAK TO SOMEONE WHO IS, IF NOT AVAILABLE, SCHEDULE A CALLBACK)**
9 Refused **(THANK AND TERMINATE)**

PHONE. Is this phone number used for . . .?

1 Home use only
2 Business use only **(THANK AND TERMINATE)**
3 Home and business use
100 *Don't Know* **(THANK AND TERMINATE)**
101 *Refused* **(THANK AND TERMINATE)**

Q1. ***Record gender*** *(BY OBSERVATION)*

1 Male
2 Female

Q2. Which of the following best represents your age group? *(READ LIST)*

1 18 – 24 years old
2 25 – 34 years old
3 35 – 44 years old
4 45 – 54 years old
5 55 – 64 years old
6 65 years and older
98 *Don't Know*
99 *Refused*

Section II: Rush hour travel

Q3. How many days per week do you typically make a regular trip traveling during weekday MORNING rush hours (Note: Morning rush hours are from 6:00 a.m. to 9:00 a.m.)? *(ALLOW 1-5 FOR ANSWER)*

____

97 None (go to Q5)
98 Don't Know (go to Q5)
99 Refused (go to Q5)

Q4. Approximately, how long is this one-way trip? Would you say it is…? *(READ LIST)*

1 Less than 5 minutes
2 6 – 10 minutes
3 11 – 30 minutes
4 31 minutes to 1 hour
5 Over 1 hour
98 Don't Know
99 Refused

Q5. How many days per week do you typically make a regular trip traveling during weekday EVENING rush hours? (Note: Evening rush hours are from 4:00 p.m. to 6:00 p.m.) *(ALLOW 1-5 FOR ANSWER)*

____

97 None (go to Q7)
98 Don't Know (go to Q7)
99 Refused (go to Q7)

Q6. Approximately, how long is this one-way trip? Would you say it is…? *(READ LIST)*

1 Less than 5 minutes
2 6 – 10 minutes
3 11 – 30 minutes
4 31 minutes to 1 hour
5 Over 1 hour
98 Don't Know
99 Refused

Section III: Internet usage and media sources

Q7. Do you have access to the Internet at home, at work, or both?

1 At home
2 At work
3 Both home and work
4 Neither *(go to Q9)*
98 Don't Know (go to Q9)
99 Refused (go to Q9)

Q8. How often do you obtain information from the Internet? Would you say it is . . .? *(READ LIST)*

1 Everyday
2 Occasionally
3 Rarely
4 Never
98 Don't Know
99 Refused

Q9. From what types of media sources do you typically obtain traffic information? *(DO NOT READ, MULTIPLE RESPONSE)*

1 Television
2 Radio
3 Newspaper
4 Internet
5 Other (SPECIFY) ______________________________
97 None
98 Don't Know
99 Refused

Section IV: Awareness

Q10. Have you ever heard of the website, Traffic.com?

1 Yes
2 No *(go to Q11a)*
98 Don't Know (go to Q11a)
99 Refused (go to Q11a)

Q11. Have you ever visited the Traffic.com website?

1 Yes *(go to Q15)*
2 No
100 Don't Know
101 Refused

Q11a. Have you ever heard of the Traffic Pulse brand on television?

1 Yes
2 No *(go to* **EXPLAIN1***)*
98 Don't Know (go to **EXPLAIN1***)*
99 Refused (go to **EXPLAIN1***)*

Q11b. Have you ever visited the Traffic Pulse webpage on NBC-10's website?

1 Yes *(go to Q15)*
2 No
102 Don't Know
103 Refused

EXPLAIN1. Well, Traffic Pulse is NBC-10's traffic provider for their local news broadcasts. Through road-side sensors, it provides up-to-the-minute traffic and accident conditions on local roadways and provides real-time driving times and speeds on all major roadways. This information is available on the NBC-10 website as well as their local news broadcasts.

For [Traffic Pulse/Traffic.com]
If Q9=1, insert [Traffic.com]
If Q9a=1, insert [Traffic Pulse]
If Q9<>=1 AND Q9a<>=1, insert [Traffic.com]

Section V: Acceptance

Q12. Do you think that [Traffic Pulse/Traffic.com] is something you might use in the future?

1 Yes
2 No *(go to Q14)*
100 Don't Know (go to Q14)
101 Refused (go to Q14)

Q13. How often do you think you would use it? Do you think you would use it . . .? *(READ LIST)*

1 More than once a day *(go to Q27)*
2 Once a day *(go to Q27)*
3 Multiple times a week *(go to Q27)*
4 Weekly *(go to Q27)*
5 Monthly *(go to Q27)*
98 Don't Know (go to Q27)
99 Refused (go to Q27)

Q14. Why would you NOT use [Traffic Pulse/Traffic.com]? *(DO NOT READ, MULTIPLE RESPONSE)*

1 No computer *(go to Q27)*
2 No Internet access *(go to Q27)*
3 Do not have a car *(go to Q27)*
4 Do not commute/drive during rush hour *(go to Q27)*
5 No wireless device (cellular phone, pager, etc.) **(NOTE: This does not pertain to the Internet)** *(go to Q27)*
6 Do not need/use traffic information *(go to Q27)*
7 Obtain traffic information elsewhere/Radio/TV *(go to Q27)*
a. Other (SPECIFY) ____________________________ *(go to Q27)*
100 Don't Know (go to Q27)
101 Refused (go to Q27)

Section VI: Use

Q15. For what reasons do you use [Traffic Pulse/Traffic.com]?
(MULTIPLE MENTION, DO NOT READ LIST)

1 Check traffic on a specific route
2 Check for accidents
3 Check for current travel speeds
4 Check current travel time
5 To see what the website is about
6 Other (SPECIFY) ______________________
98 Don't Know
99 Refused

Q16. How often do you use [Traffic Pulse/Traffic.com]? Do you use it . . .? *(READ LIST)*

1 More than once a day
2 Once a day
3 Multiple times a week
4 Weekly
5 Monthly
6 Once or twice
98 Don't Know
99 Refused

Q17. Would you say the traffic information you obtain from [Traffic Pulse/Traffic.com] is . .
(READ LIST)

1 Very Reliable *(go to Q20)*
2 Somewhat Reliable
3 Somewhat Unreliable
4 Very Unreliable
98 Don't Know
99 Refused

Q18. Has the reported traffic information ever been incorrect?

1 Yes
2 No *(go to Q20)*
98 Don't Know (go to Q20)
99 Refused (go to Q20)

Q19. How often, would you say, is the traffic information you receive from [Traffic Pulse/Traffic.com] incorrect? Would you say it is Always, Sometimes, or Rarely incorrect?

1 Always
2 Sometimes
3 Rarely
98 Don't Know
99 Refused

IF Q3 OR Q5 =1—5, ASK Q20, OTHERWISE GOTO Q21

Q20. What impact do you think the traffic information from [TrafficPulse/Traffic.com] has had on your regular weekday rush hour travel time? Would you say your travel time has . . .? *(READ LIST)*

1 Increased
2 Decreased
3 Stayed about the same
98 Don't Know
99 Refused

Q21. Has [Traffic Pulse/Traffic.com] helped you avoid major traffic delays?

1 Yes
2 No
98 Don't Know
99 Refused

Q22. Have you ever changed your original travel ROUTE based on information you received from [Traffic Pulse/Traffic.com]?

1 Yes
2 No *(go to Q23)*
98 Don't Know
99 Refused

Q22a. How often have you changed your original travel ROUTE based on information from [Traffic Pulse/Traffic.com]? Would you say. . .(READ LIST)

1. More than once a day
2. Once a day
3. Multiple times a week
4. Weekly
5. Monthly
6. Once or twice

98 Don't Know
99 Refused

Q23. Have you ever changed your original TIME of travel based on information you received from [Traffic Pulse/Traffic.com]?

1 Yes
2 No *(go to Q23)*
98 Don't Know
99 Refused

Q23a. How often have you changed your original travel TIME based on information from [Traffic Pulse/Traffic.com]? Would you say. . .(READ LIST)

1 More than once a day
2 Once a day
3 Multiple times a week
4 Weekly
5 Monthly
6 Once or twice
98 Don't Know
99 Refused

Q24. Have you ever changed your original MODE of transportation based on information you received from [Traffic Pulse/Traffic.com]? (Note: By mode I mean automobile, public transportation, etc.)

1 Yes
2 No *(go to Q25)*
98 Don't Know
99 Refused

Q24a. ***How often have you changed original MODE of travel based on information from [Traffic Pulse/Traffic.com]? Would you say. . .(READ LIST)***

1 More than once a day
2 Once a day
3 Multiple times a week
4 Weekly
5 Monthly
6 Once or twice
98 Don't Know
99 Refused

Q25. ***Does [Traffic Pulse/Traffic.com] provide you with all the traffic information you need?***

1 Yes *(go to Q27)*
2 No
98 Don't Know
99 Refused

Q26. ***What other kind of information would you like to see available on the [Traffic Pulse/Traffic.com] website?*** *(OPEN END)*

____

97 None/Nothing
98 Don't Know
99 Refused

Section VII: Additional Phone Line Information

Next, I have just a few questions regarding additional phone lines in your home.

Q27. ***Do you have any other telephone lines in your house that someone would answer? (This does not include dedicated computer, fax lines, or cellular phones.***

1 Yes
2 No *(go to Q31)*
98 Don't Know (go to Q31)
99 Refused (go to Q31)

Q28. How many other telephone lines are there? *(ALLOW 1-9 FOR ANSWER)*

_____

98 Don't Know
99 Refused

Q29. What is the primary use of this (these) additional telephone line(s)?
(DO NOT READ)

1 Home use only
2 Business use only
3 Home and business use
4 Computer/Internet use
97 Other (SPECIFY)____________________
98 Don't Know
99 Refused

Section VIII: Demographics

Finally, I have a few more questions to be used for demographic purposes only.

Q30. Including yourself, how many people age 18 years or older live in your household? *(ALLOW 1-9 FOR ANSWER)*

______

98 Don't Know
99 Refused

Q31. What is the highest level of education you have completed? *(DO NOT READ)*

1 Less than High School
2 High School Graduate/GED
3 Technical school/professional business school
4 Some college
5 Community college graduate (Associate Degree, 2 year Degree)
6 College graduate (4 year Degree)
7 Post-graduate degree (Masters, Ph.D., Lawyer, Medical Doctor)
98 Don't Know
99 Refused

CONC. This concludes our survey. On behalf of the Department of Transportation, thank you for participating. Your opinions are valued.

Philadelphia Internet Questions

The U.S. Department of Transportation is conducting a research study in your area to learn more about customer satisfaction and system performance from users of the Traffic.com website, also known as Traffic Pulse.

1. Are you at least 18 years old?

1 Yes
2 No (*cannot complete the survey*)

Please answer the following general questions about your travel.

2. How often do you use public transportation?

1 Everyday
2 2-3 days per week
3 Once a week
4 Never

3. How often do you travel during rush hour?

1 Everyday
2 2-3 days per week
3 Once a week
4 Never (*go to question 6*)

4. How long is your typical commute, one-way?

1 Less than 5 minutes
2 5 – 10 minutes
3 10 – 30 minutes
4 30 minutes to an hour
5 Greater than one hour

5. What impact do you think Traffic.com/Traffic Pulse has had on your commute time? Has it . . .

1 Increased?
2 Decreased?
3 Stayed about the same?

6. How did you hear about Traffic.com/Traffic Pulse?

1 From another Internet website
2 Someone told you about it
3 A billboard advertisement
4 Searching for traffic information on the web
5 From a TV or radio ad
6 From a newspaper or magazine ad
7 Other (specify) ___________________________

7. HOW OFTEN do you use information from Traffic.com/Traffic Pulse?

1 More than once a day
2 Everyday
3 2-3 days per week
4 Once a week

8. WHY do you use Traffic.com/Traffic Pulse? (Check all that apply.)

1 To check traffic on a specific route
2 To check for accidents
3 To check current travel speeds
4 To check current travel time
5 Other (specify) _____________________

9. WHEN do you use Traffic.com/Traffic Pulse? (Check all that apply.)

1 Morning
2 Afternoon
3 Evening

10. From WHERE do you use Traffic.com/Traffic Pulse? (Check all that apply.)

1 Home
2 Work
3 Other (specify) ________________________

11. From what other sources do you get traffic information? (Check all that apply.)

1 Television
2 Radio
3 Newspaper
4 Other (specify) ______________________________

12. How often do you obtain information from the Internet?

1 Everyday
2 Occasionally
3 Rarely
4 Never

For the questions 13 - 17, please indicate how strongly you agree or disagree with the following statements.

13. The information presented on the Traffic.com/Traffic Pulse website is easily understood.

1 Strongly Agree
2 Agree
3 Neutral
4 Disagree
5 Strongly Disagree

14. The Traffic.com/Traffic Pulse website is easy to navigate through.

1 Strongly Agree
2 Agree
3 Neutral
4 Disagree
5 Strongly Disagree

15. The traffic information provided by the Traffic.com/Traffic Pulse website is accurate.

1 Strongly Agree
2 Agree
3 Neutral
4 Disagree
5 Strongly Disagree

16. The traffic information provided by the Traffic.com/Traffic Pulse website is reliable.

1 Strongly Agree
2 Agree
3 Neutral
4 Disagree (*go to question 16a*)
5 Strongly Disagree (*go to question 16a*)

16a. Has the reported traffic information ever been incorrect?

1 Never
2 Rarely
3 Occasionally
4 Usually
5 Always

17. The traffic information provided on the Traffic.com/Traffic Pulse website is sufficient for your needs.

1 Strongly Agree
2 Agree
3 Neutral
4 Disagree (*go to question 17a*)
5 Strongly Disagree (*go to question 17a*)

17a. What other information would you like to see?

____

____

18. Are all of the routes you want to check traffic for provided at Traffic.com/Traffic Pulse?

1 All of them
2 Most of them
3 Some of them
4 None of them

19. What other routes would you like to see added to Traffic.com/Traffic Pulse?

____

____

20. Do you know that Traffic.com/Traffic Pulse provides information on point-to-point travel times?

1 Yes
2 No (*go to question 23*)

21. Have you ever used the information on point-to-point travel times?

1 Yes
2 No (*go to question 23*)

22. Would you say the information on point-to-point travel times is . . .

1 Very Helpful?
2 Somewhat Helpful?
3 Not at All Helpful?

23. Do you know that Traffic.com/Traffic Pulse provides information on route-specific travel speeds?

1 Yes
2 No (*go to question 26*)

24. Have you ever used the information on route-specific travel speeds?

1 Yes
2 No (*go to question 26*)

25. Would you say the information on route-specific travel speeds is . . .

1 Very Helpful?
2 Somewhat Helpful?
3 Not at All Helpful?

26. Do you know that Traffic.com/Traffic Pulse provides graphical traffic information on maps?

1 Yes
2 No (*go to question 29*)

27. Have you ever used the map information?

1 Yes
2 No (*go to question 29*)

28. Would you say the map information is . . .

1 Very Helpful?
2 Somewhat Helpful?
3 Not at All Helpful?

29. Have you ever changed your original travel ROUTE based on information you received from Traffic.com/Traffic Pulse?

1 Yes
2 No (*go to question 30*)

29a. How often have you changed your original travel ROUTE based on information you received from Traffic.com/Traffic Pulse?

1 More than once a day
2 Once a day
3 Multiple times a week
4 Weekly
5 Monthly
6 Once or twice

30. Have you ever changed your original travel TIME based on information you received from Traffic.com/Traffic Pulse?

1 Yes
2 No (*go to question 31*)

30a. How often have you changed your original travel TIME based on information you received from Traffic.com/Traffic Pulse?

1 More than once a day
2 Once a day
3 Multiple times a week
4 Weekly
5 Monthly
6 Once or twice

31. Have you ever changed your original MODE of transportation based on information you received from Traffic.com/Traffic Pulse?

1 Yes
2 No (*go to question 32*)

31a. How often have you changed your original MODE of transportation based on information you received from Traffic.com/Traffic Pulse?

1 More than once a day
2 Once a day
3 Multiple times a week
4 Weekly
5 Monthly
6 Once or twice

32. Do you plan to use Traffic.com in the future?

1 Yes
2 No

33. Would you be willing to pay a nominal fee for the information provided by Traffic.com?

1 Yes
2 No

34. What is your zip code?

____

35. How old are you?

1 18 – 24 years old
2 25 – 34 years old
3 35 – 44 years old
4 45 – 54 years old
5 55 – 64 years old
6 65 years and older

36. Are you male or female?

1 Male
2 Female

37. What is the highest level of education you have completed?

1 Less than High School
2 High School Graduate/GED
3 Technical school/professional business school
4 Some college
5 Community college graduate (AA: Associate of Arts Degree)
6 College graduate (BA or BS: Bachelor of Arts or Sciences Degree)
7 Post-graduate degree (Masters, Ph.D., Lawyer, Medical Doctor)