Deploying Portable Advanced Traveler Information Systems: Redding Deployment Evaluation

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DISCLAIMER

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1. INTRODUCTION

Advanced Traveler Information Systems (ATIS) have been employed over the past two decades to provide travelers with real-time traffic information. Most of the efforts have focused on using a fixed system, which provides timely traffic information at locations with regularly occurring congestion. Traffic delay and congestion conditions can be caused by nonrecurring congestion. Motorists whose routes are disrupted by special events, natural disasters, or construction projects may be better served with a portable ATIS that can be rapidly deployed.

Portable ATIS can provide real-time traffic information--including advanced travel times, delay times, and reduced average speeds--to motorists by updating portable changeable message signs (PCMS) with real-time messages. In some circumstances, portable ATIS can be connected to a regional or city traffic management center (TMC) to ensure accurate messages are being portrayed and to provide information to the TMC.

Drivers alerted to traffic flow changes may select an alternative route, be less anxious because of advanced knowledge, and/or drive more cautiously. Currently, there is a lack of implementation of portable ATIS because there have been only a limited number of demonstrations of its capabilities.

Caltrans initiated a research project to further investigate portable ATIS. The project has reviewed existing best practices, interviewed practitioners, and identified and reviewed off-the-shelf technology. A draft literature review and a draft guidelines document have been developed. This document summarizes the efforts and results of a portable ATIS demonstration project in Redding, California.

The demonstration project or showcase is described in more detail in Section 2, covering the data collection systems, and the host construction project. For the demonstration, four different portable ATISs were deployed on a construction project in Redding, CA for a two week period. Section 3 covers the data analysis and results from the demonstration considering three aspects of the portable ATIS tested, accuracy, reliability, and usability. Accuracy was evaluated by comparing travel time and speed measured across the different systems and with a measured baseline. Reliability was assessed by monitoring and summarizing the failures and maintenance the systems needed during the demonstration. System usability was addressed in terms of ease of setup and calibration.

2. DEMONSTRATION/SHOWCASE

In order for a functional portable ATIS to operate, a data collection system needs to be present to collect real-time traffic data. Several different data collection systems were investigated and are described in more detail in Section 2.1. The showcase location and related construction project are described in more detail in Section 2.2.

2.1. Portable ATISs Evaluated

Four portable ATISs were deployed to capture the traffic data throughout the two-week demonstration period: Blufax, iCone, License Plate Reader and Adaptir. The Adaptir system, described later, was the only live system that, through a wireless connection, updated a password-protected website that could be accessed by a laptop computer in the TMC. A TMC representative monitored the laptop for speeds dropping under the desired threshold. For the current experiment, when an average traffic speed over a five-minute period dropped under 35 miles per hour, the TMC representative would post a message on the PCMS. Unless the average travel speeds dropped below the speed threshold for more than five minutes, no messages were posted. The other three data collection systems could measure travel time or speed, but in their off-the-shelf forms were not an integrated system that could report real-time status to the TMC. These three systems, although not connected to the TMC, were evaluated for their accuracy in measuring travel times, and their reliability (or durability) in a roadside setting. Each data collection system had different traffic information outputs:

- Blufax: Travel times every 15 minutes
- iCone: Average spot speed every 5 minutes
- License Plate Reader: Individual travel times
- Adaptir: Average spot speed every 5 minutes

Systems that measure average speed (iCone and Adaptir) can be used to estimate travel time, assuming the speed is relatively constant between detector stations. If considerable congestion occurred such that speeds varied (or traffic even stopped) between detectors, the travel times may not be as accurate.

The four Blufax units used in the project were leased from Traffax Inc. The Blufax units use a Bluetooth detection system to capture and record Mac IDs from Bluetooth devices in passing vehicles. Detectors can be placed at two or more locations to match up unique Mac IDs and detection times to determine the travel times of the vehicles with the Bluetooth device. The units are battery powered and all data is stored on removable storage cards. The battery life was observed to be approximately eight days and could be recharged in approximately four hours. The units were turned off and removed from their site locations while recharging. For installation, the Blufax units were simply locked to trailers (see Figure 1). Raw Blufax data was recorded with lists of all recorded Mac IDs and detection times. Blustats analysis software was used to post-process the raw Blufax data and generate travel times between locations.

Figure 1: Blufax Unit

Three iCone units, owned by Caltrans, were set up to web interface the status of the iCone units to the iCone Traffic website. Five-minute tabulations of both average speeds and counts were downloadable from the website. iCones use Doppler radar to measure vehicle speed and satellite communication to upload traffic counts and vehicle speeds to a centralized server. The entire units are encased in a traffic control barrel (see Figure 2). The units were charged overnight off site after approximately a week of continuous collection. For installation, the iCone units are placed close to the highway facing oncoming traffic at about a 45-degree angle. The line-of-sight from the iCone unit to the traffic needs to be clear in order for the iCone to accurately record the traffic data.

Figure 2: iCone Unit

PIPS License Plate Reader (LPR) cameras were provided by the California Center for Innovative Transportation (CCIT). The LPR software uses video images to identify license plate numbers. Similar to Blufax, a unique vehicle can be identified at two locations in order to determine the travel time between the locations. For this demonstration, license plate numbers and times were recorded and matched up for post processing. These three units were mounted onto portable trailers with the cameras adjusted to point to the closest oncoming lane of traffic. The communication boxes were also stored on the portable trailers. Using the off-line setting, license plate signatures and corresponding recorded times were downloadable from each trailer. Recharging trailers were brought in to recharge the batteries while the system continued to run. Figure 3 is a picture of an on-site LPR unit.

Figure 3: LPR Camera

The Adaptir system included one Remote Traffic Microwave Sensor (RTMS) and two SI-3 radar sensors. The RTMS sensor is mounted onto a portable trailer and is raised approximately 17 feet above the roadway. It records both average speeds and lane-specific counts every five minutes. The SI-3 radar sensors are mounted on the trailer and pointed towards the oncoming traffic. These sensors record average speeds for every five-second interval. All the sensors were powered by the batteries on the portable trailer and were recharged by a generator. Figure 4 shows an on-site RTMS sensor mounted on top of the pole. The LPR camera and Blufax unit can also be seen in the same picture. Figure 5 is a picture of an on-site SI-3 radar sensor.

Figure 4: Adaptir RTMS Sensor

Figure 5: Adaptir SI-3 Radar Sensor

2.2. Description of Demonstration Project

The "Dana to Downtown Project" was chosen as the host construction project for the two-week showcase. The project is located on State Route 44 (SR44) and Interstate 5 in Redding, California, located in Shasta County, which is part of Caltrans District 2. The City of Redding is an urbanized area with approximately 109,000 residents. The purpose of the reconstruction project is to reduce congestion in the greater Redding area, help improve highway traffic safety, and enhance the access across the Sacramento River into downtown Redding. The project will entail the construction of an access ramp from Dana Drive to westbound SR44, widening the Sacramento River Bridge from a four-lane to a six-lane facility, and adding off-ramp lanes in the surrounding area. The ground-breaking ceremonies took place on April 22, 2008. Project completion is expected within three years.

During construction, delays are expected to increase as major arterials and intersections will be closed and restricted. The construction project had long been a top priority of the county's planning committee. Figure 6 shows the highlighted areas of the "Dana to Downtown Project" under construction.

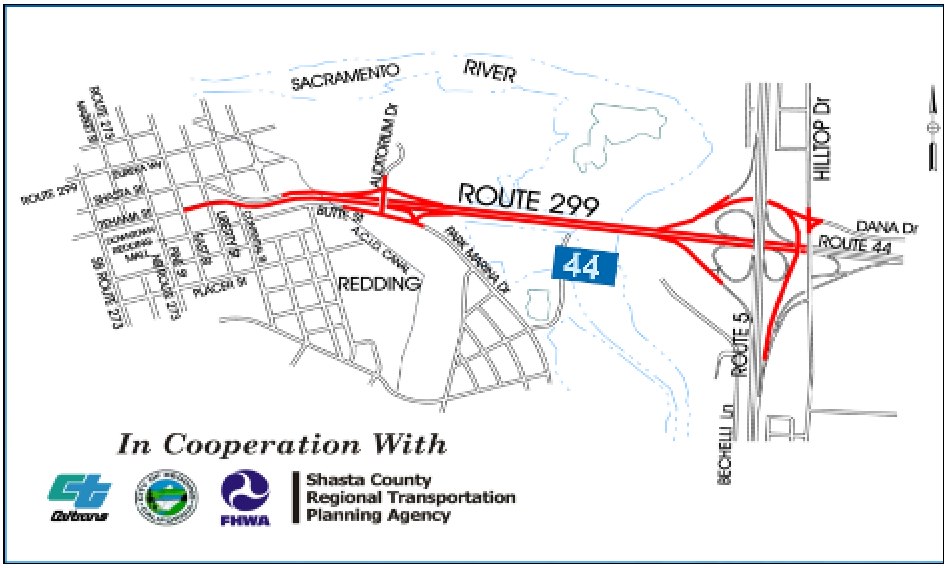

Figure 6: Dana to Downtown Construction Site (Source: Caltrans)

The installation locations of the systems were determined by the on-site system manager with input from Caltrans staff, the construction manager, and members of the research team. These locations allowed for the analysis of travel times through several routes. The locations were also selected to provide adequate protection from public or construction disturbances. Figure 7 shows the location of the data collection systems and the identification numbers for these systems.

Figure 7: Redding Site Layout

The evaluation focused on westbound traffic across the bridge ending at location 5. Locations 1 through 4 represent the upstream stations for the different routes from which a vehicle can approach the previously described construction site. Location 4 is a single-lane section, and the other locations are two-lane sections. Table 1 describes the route distances and average travel times.

Table 1: Route Data

Route	Travel Distance (Miles)	Average Travel Time (GPS)
No. 1-5	0.90	0:01:48
No. 2-5	1.50	0:02:02
No. 3-5	0.60	0:00:43
No. 4-5	0.55	0:00:46

An on-site system manager was hired from the Scientex Corporation to setup, monitor, repair, and tear down the data collection systems during the two-week showcase. Scientex utilized the private company of Traffic Solutions to install the systems as Traffic Solutions had trailers and was already managing the traffic control for the construction project. In addition to these daily tasks, the manager was in charge of recharging all the data collection systems and downloading/delivering the summarized traffic data at the conclusion of the showcase.

When recharging the portable trailers that power the LPR and Adaptir systems, the on-site manager coordinated with Traffic Solutions to deliver and remove recharging units to the trailer sites. Traffic Solutions also assisted in delivery of the three iCone units to the Caltrans District 2 equipment garage for recharging. The system manager personally collected and charged the Blufax units.

3. DATA ANALYSIS AND RESULTS

The purpose of the portable ATIS is to reduce driver frustration, enhance driver safety and improve traffic operations. The portable ATIS system was evaluated by analyzing the accuracy of the measured traffic data, the reliability of the systems, the convenience or usability of the systems and motorist reaction.

System accuracy (Section 3.1) is directly related to the portable ATIS's ability to estimate delay and/or average travel speed. Using stopwatches and validating with GPS data, travel times were measured manually and credited as accurate real-time data. Each system was compared to this baseline data to test the accuracy. Additionally, travel times and speeds were compared between the portable ATIS systems. The reliability (Section 3.2) of the systems is described based on how each system worked in the field (e.g., failures, maintenance needs, and operational needs). The convenience and usability (Section 3.3) of the portable ATIS was measured based on setup times, ease of system use, and usefulness. Setup times were observed by a student researcher at the beginning of the showcase. Usefulness was also evaluated by Caltrans staff and the on-site system manager during interviews. Measurement of motorist reaction (Section 3.4) was attempted through a motorist survey.

3.1. Accuracy

Several travel routes were used to evaluate the accuracy of travel times as measured by the various systems. As shown in Figure 7, the routes all end at location 5 and are referred to by their starting location (1 through 4) or by the starting and ending location (e.g., route 2-5). Average speeds collected by the Adaptir and iCone systems are spot speeds investigated at locations 3, 4, and 5.

To provide a baseline travel time, a student researcher drove three selected routes (note, route 4-5 is a subset of both route 1-5 and route 2-5) multiple times per day and recorded stopwatch times at landmarks and equipment trailers along the route. The stopwatch times were validated with a portable GPS device to ensure accuracy. Stopwatch times with GPS validation are hereafter referred to as “GPS data” to help readability.

The systems that collect travel times (Blufax and LPR) were compared to the GPS baseline data. These comparisons are limited to the number of recorded GPS travel times, representing a subsample of the data collected automatically by the systems. The larger samples of the system-measured travel times were compared to each other and the system-measured spot speeds were compared to each other. The systems that collect spot speeds (Adaptir and iCone) were also compared to the GPS baseline data. However, the GPS data provided an average travel speed instead of a spot speed, and thus were not a true baseline. The comparison of system-measured spot speeds between the two systems proved to be more telling, so the GPS-based comparison is not included in this report.

A common way of evaluating the accuracy of detection devices is to report the average error, or the average absolute error. Large positive and large negative errors can cancel each other out showing a system with large errors to have a small average error. Average absolute error provides a better picture, but may not be appropriate for portable ATIS. For example, consider a system that is perfectly accurate 80 percent of the time and shows a 15 mph error 20 percent of the time. The average absolute error is 3 mph. That may seem good but the large errors would lead to false alarms or clearly erroneous readings 20 percent of the time (more than twice per hour when considering five-minute averages). A more appropriate approach may be to show a cumulative frequency of absolute error. A particular threshold of appropriate error can be applied to the cumulative frequency to determine the percentage of time the system is within this appropriate level of error. Based on discussions with Caltrans staff, errors of less than 10 mph may be acceptable. Appropriate travel time errors were more difficult to define. For this project 10 seconds was chosen, arbitrarily, as a threshold.

3.1.1. GPS Travel Time Comparisons

The LPR camera at location 3 was never functioning properly in the course of this investigation, so the analysis of travel times between the LPR and GPS methodologies was considered over route 4-5. Multiple LPR route times, beginning within five minutes of the GPS starting times, were used to determine differences in travel times. Therefore, more than one LPR route time could be compared to the same GPS route time. The sample analyzed included 49 LPR travel times and 36 GPS travel times. In an actual portable ATIS deployment, the LPR output would likely be averaged over five minutes (instead of for individual vehicles), which may normalize individual errors resulting in a more accurate estimate. Figure 8 shows the percentage of data points equal to or less than an absolute difference in LPR travel time and the baseline GPS travel time. The maximum error is nearly 16 seconds, which is a large percentage considering the average travel time is 46 seconds along this route. On a more positive note, 98 percent of the readings had less than ten second error.

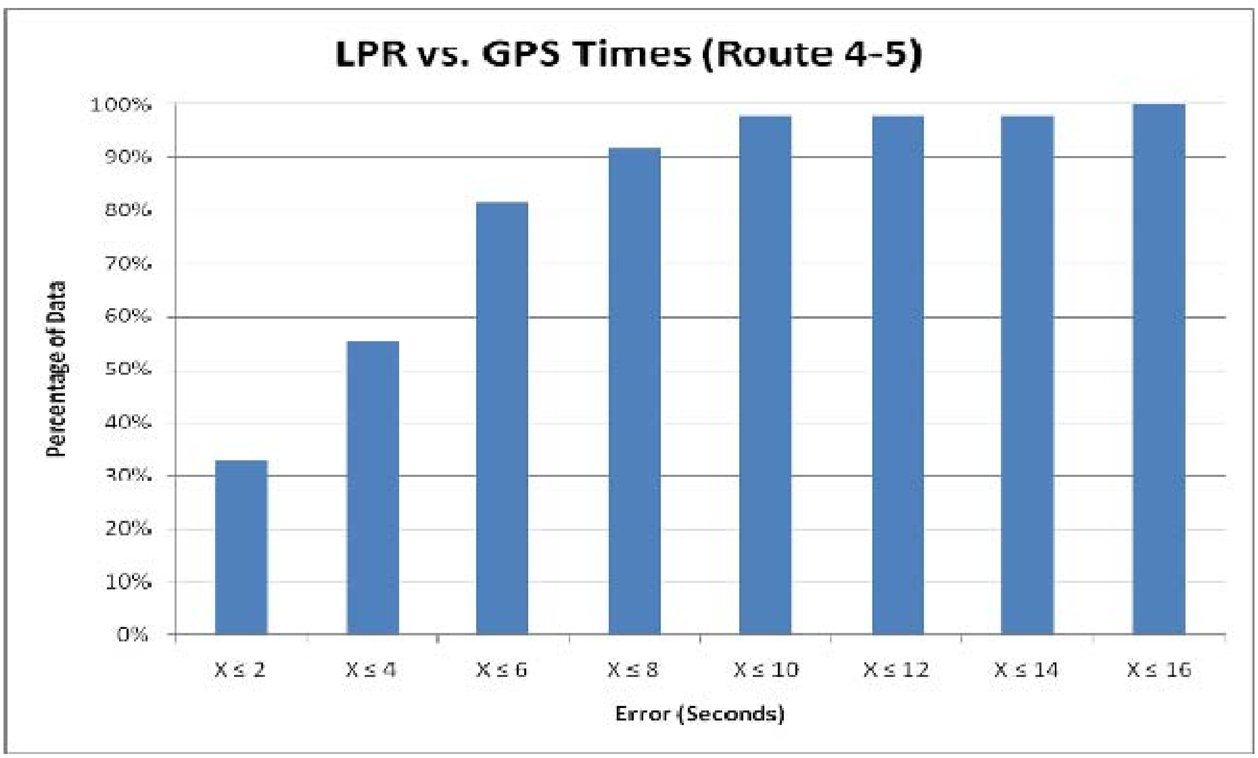

Figure 8: Travel Time Comparison--LPR vs. GPS (Route 4-5)

The analysis of travel times between Blufax system and the GPS baseline was considered over three routes starting from locations 1, 2, and 3 (all ending at location 5). The Blufax software was limited to outputting 15-minute average route travel times. The 15-minute intervals that included a GPS start time were used to determine the absolute error in travel times. Figure 9 shows the percentage of data points equal to or less than a difference in travel time, or error, measured in seconds for route 1-5 based on a sample size of 11. The travel time averaged 108 seconds along this route. The error was less than 10 seconds only 45.5 percent of the time.

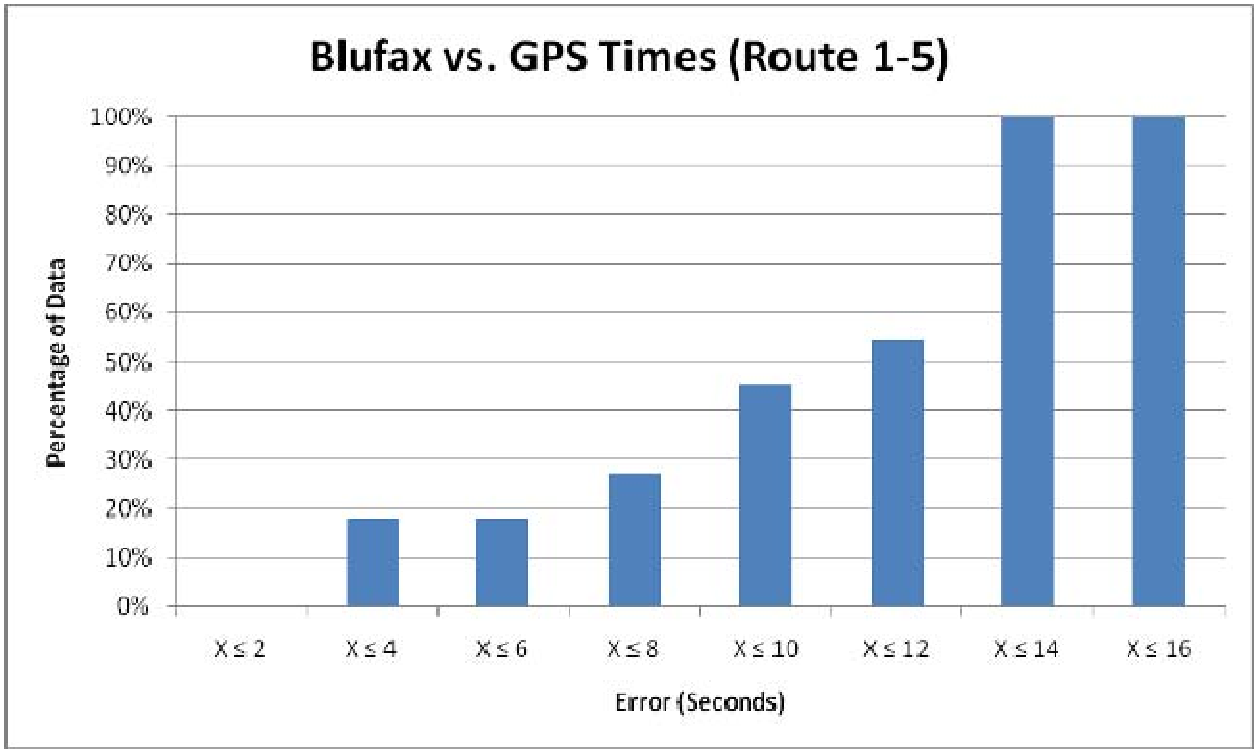

Figure 9: Travel Time Comparison--Blufax vs. GPS (Route 1-5)

Further investigation of the data revealed that the Blufax units on route 1-5 consistently underestimated travel times by an average of nine seconds. This error could be due to a difference in speeds. The Blufax unit at location 1 (see Figure 7) catches southbound traffic on Interstate 5, usually traveling near the posted speed limit of 70 miles per hour. The Blufax unit at location 5 catches westbound Highway 44 traffic, usually traveling less than the posted speed limit of 45 miles per hour. The Blufax units have a detection radius of 300 feet. With the great variance in speed limits for vehicles passing the Blufax units, the exact detection points could vary from hundreds of feet before the units to hundreds of feet after. An average difference in travel times of nine seconds was subtracted from each data point, and a new figure was generated. Figure 10 shows the percentage of data points equal to or less than a difference in travel time or error measured in seconds for the route from location 1 to location 5 after adjustments were made for the nine-second shift. This yields much more reasonable results with error within 10 seconds 100 percent of the time.

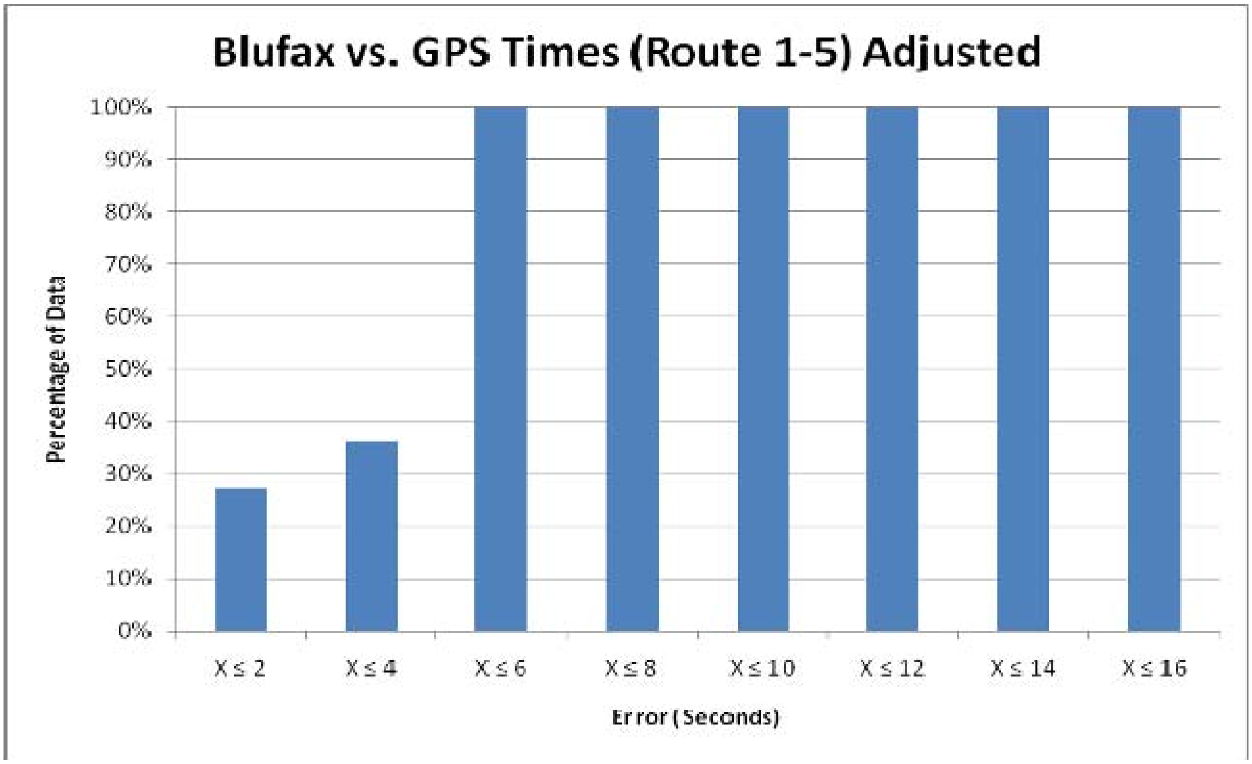

Figure 10: Travel Time Comparison--Blufax vs. GPS (Route 1-5) Adjusted

Figure 11 shows the error in Blufax travel times for route 2-5, and Figure 12 shows route 3-5. These two routes did not show the same systematic error seen in route 1-5, so no adjustment was made. Data for route 2-5 had a sample size of 55 and an average travel time of 122 seconds. Data for route 3-5 had a sample size of 88 and an average travel time of 43 seconds. For both of these routes, the maximum error was less than 8 seconds.

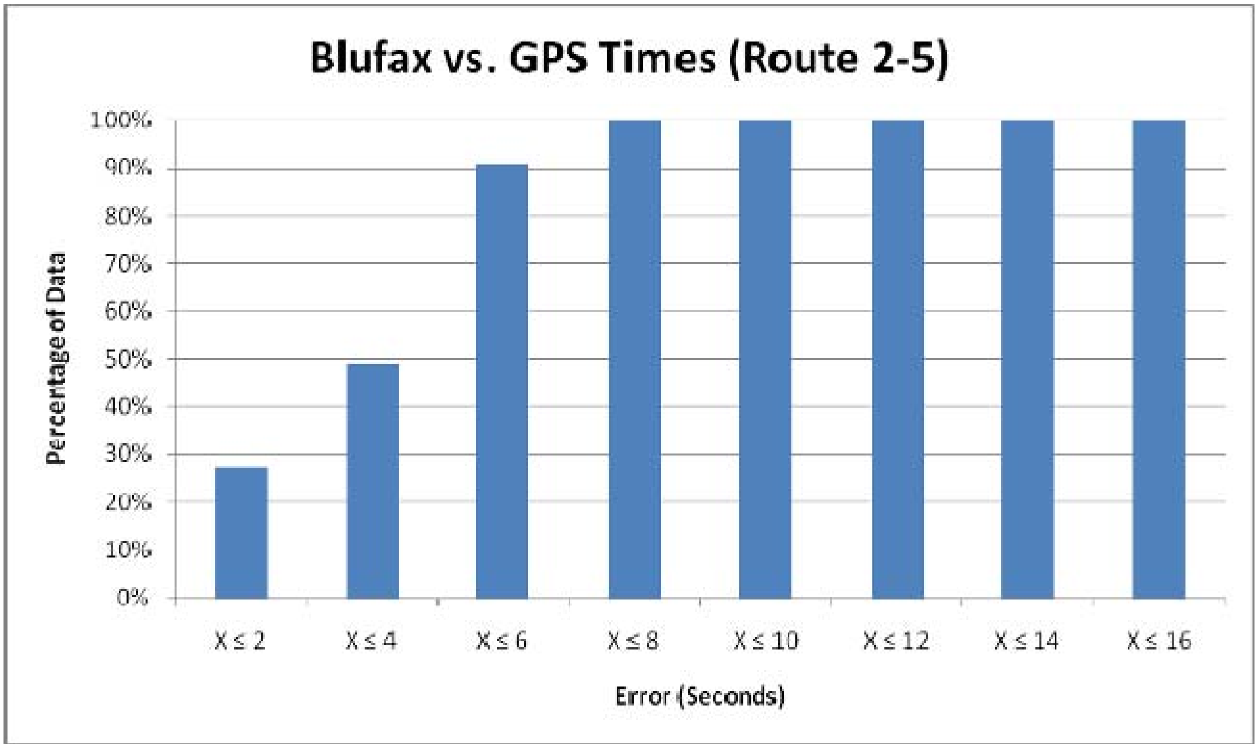

Figure 11: Travel Time Comparison--Blufax vs. GPS (Route 2-5)

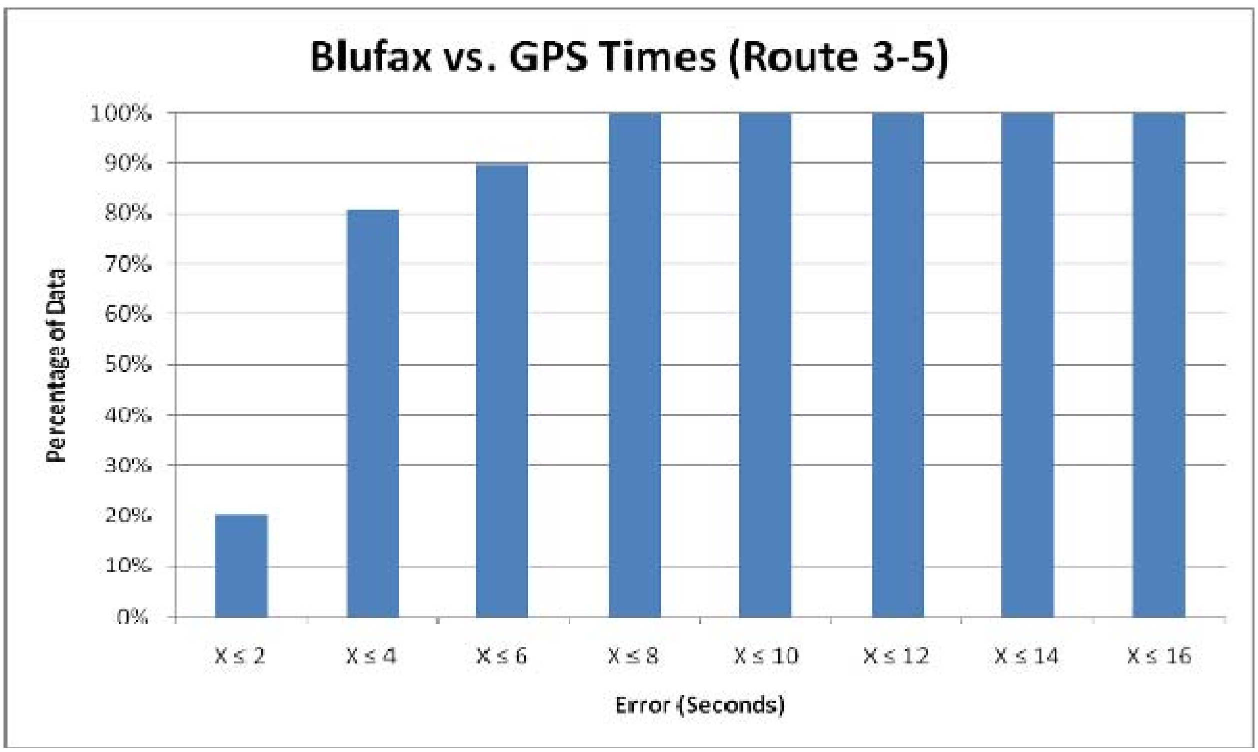

Figure 12: Travel Time Comparison--Blufax vs. GPS (Route 3-5)

After route 1-5 was adjusted, the Blufax system had a maximum error of less than 8 seconds for all three sites combined (i.e., 100 percent of the time the error is less than 10 seconds). The problems with route 1-5 indicate the need for validating the system after setup to eliminate systematic errors. The maximum error in travel time for the LPR system was less than 16 seconds. The LPR system had an error of less than 10 seconds 98 percent of the time.

3.1.2. Blufax vs. LPR Travel Time Comparison

The analysis of travel times between Blufax and LPR was considered over the route from location 4 to location 5. Since a Blufax unit was not installed at location 4, Blufax travel times were used from location 2 to location 5 as this route contains as a subset route 4-5. The GPS travel times from location 2 to location 4 ranged from 67 seconds to 78 seconds, with an average of 76 seconds. This average time was subtracted from all the Blufax times to generate travel from location 4 to 5. Every LPR travel time for the entire showcase was used with the corresponding Blufax 15-minute average route times to determine differences in travel times, resulting in a sample size of 882. Figure 13 shows the percentage of data points equal to or less than a difference in travel time or error measured in seconds. With only 78 percent of the differences being lower than 10 seconds, these results are not as promising as the previous comparison to the GPS baseline. Less weight should be given to these results because the adjustment to the Blufax route 2-5 travel times accounts for some of the difference seen.

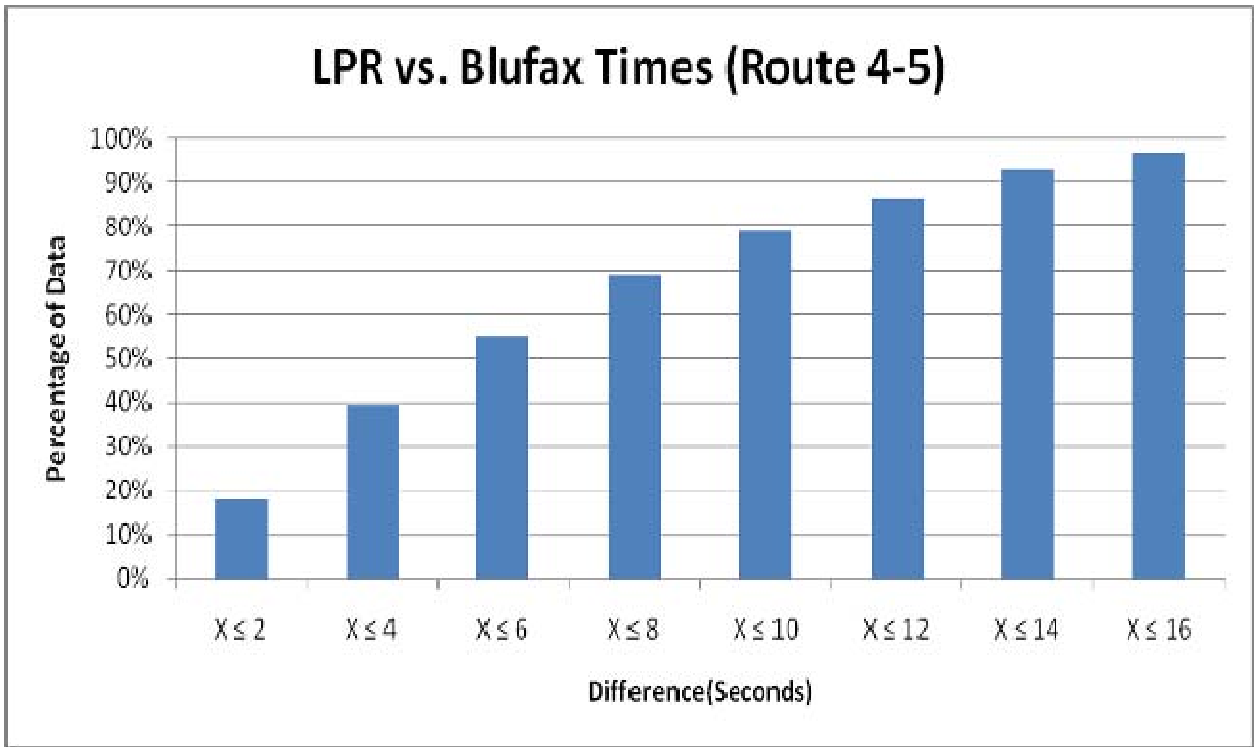

Figure 13: Travel Time Comparison--LPR vs. Blufax (No. 4-5)

3.1.3. iCone vs. Adaptir Speed Comparison

The analysis of vehicle speed between iCone units and the Adaptir system was considered at locations 3, 4, and 5. Five-minute average speeds for both systems during the entire showcase were used to determine the difference in recorded speeds. Figure 14 shows the percentage of data points equal to or less than a difference in speed or error measured in miles per hour at location 3. Figure 15 describes the same comparison at location 4, and Figure 16 for location 5.

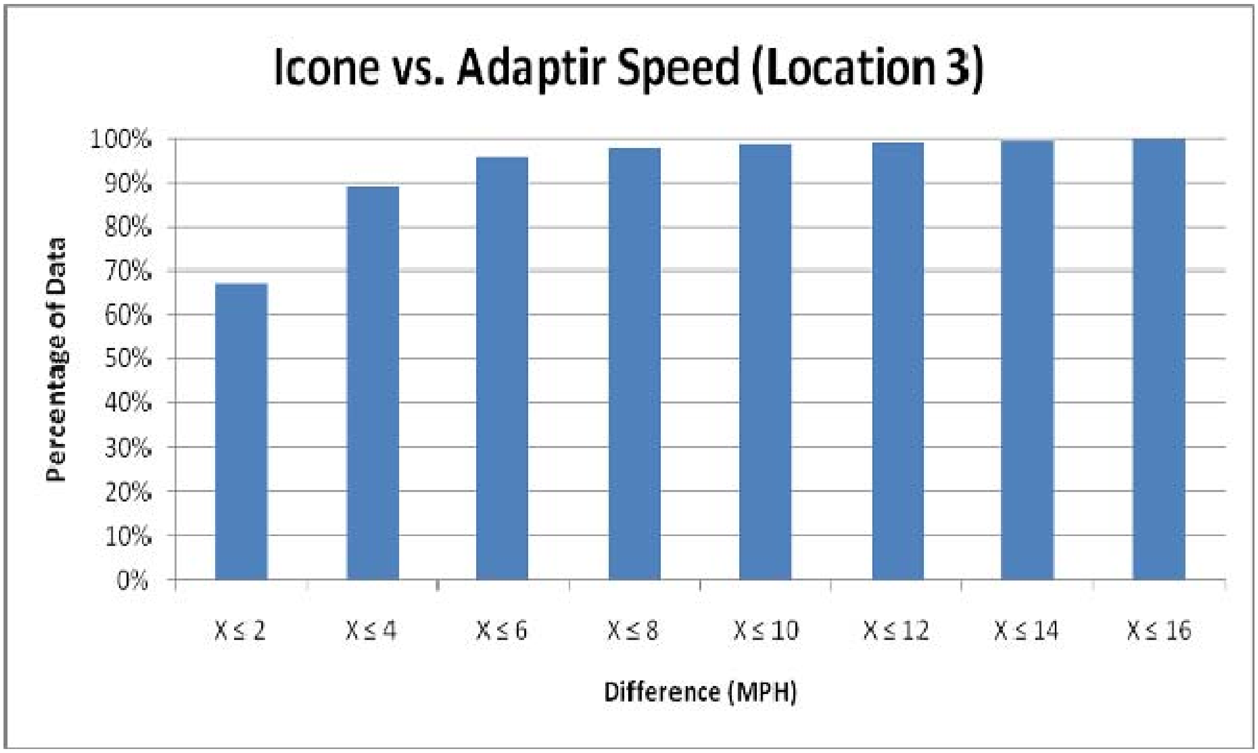

Figure 14: Speed Comparison--iCone vs. Adaptir (No. 3)

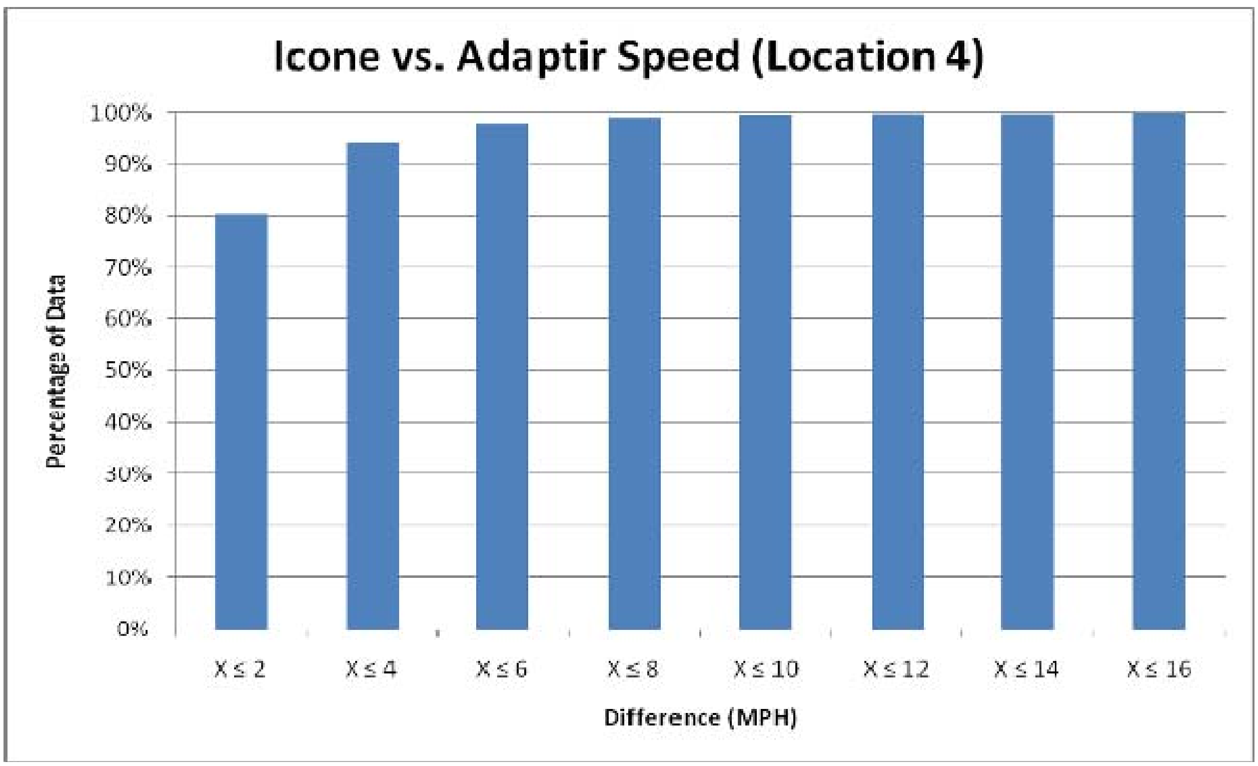

Figure 15: Speed Comparison--iCone vs. Adaptir (No. 4)

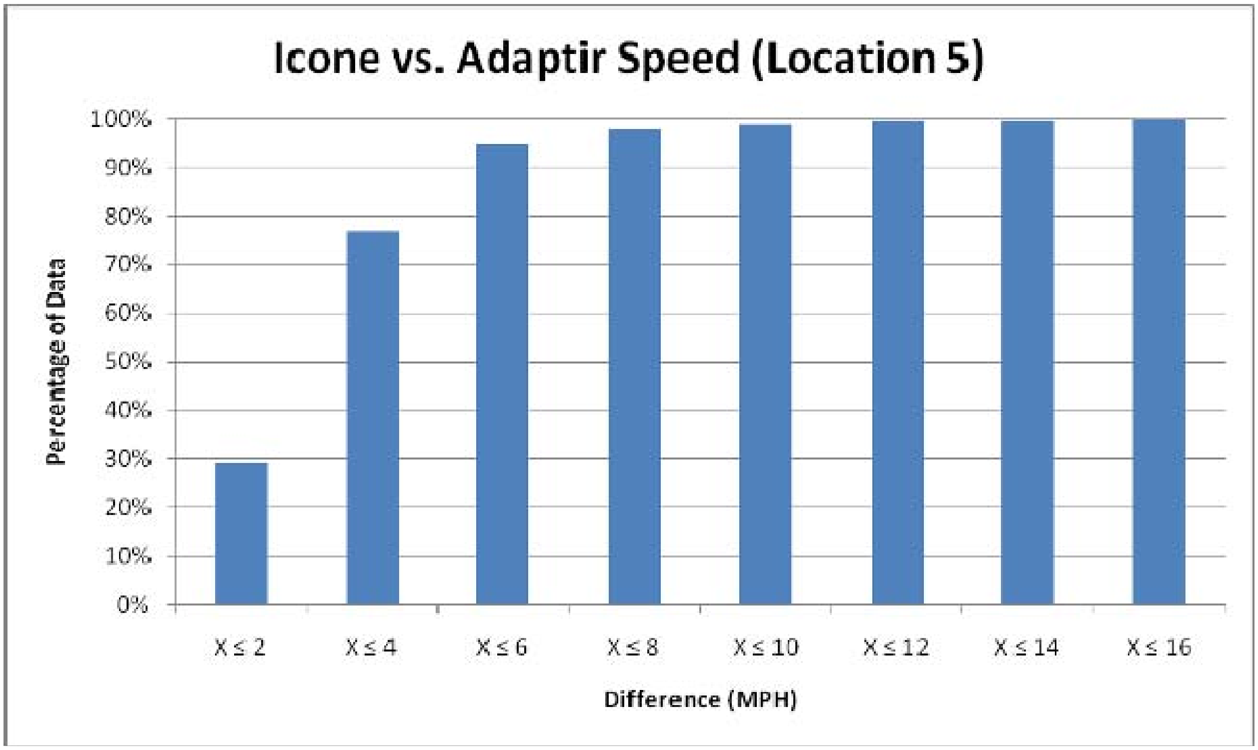

Figure 16: Speed Comparison--iCone vs. Adaptir (No. 5)

These figures are all similar in character, with differences in speeds measured by the two systems being less than 10 mph at least 99 percent of the time for all locations.

3.1.4. Accuracy Summary

When comparing to GPS data, the travel times were within 10 seconds 98 percent of the time for the LPR system and 100 percent of the time for the Blufax, if Route 1 to 5 is adjusted. The iCone and Adaptir systems measured speeds within 10 mph of each other 99 percent of the time.

3.2. Reliability

The first step in analyzing the reliability of the systems is to describe how each of the data collection systems worked in the field. This section provides a summary for each system of the types of failures that occurred during the demonstration and what types of maintenance was required. The goal of portable ATIS is a system that can be setup and left alone for several months with very little maintenance effort. The short time-frame of the demonstration, along with having a system manager on site, continuously monitoring the systems, is not a true test of the needed reliability. However, this demonstration provided some insight into the current reliability of the systems.

The Blufax units had very few problems for the duration of the showcase. The battery life of the Blufax units in the off-line setting was said to be 10-14 days by the manufacturer; however, it was observed that the units lasted between eight and nine days before they had to be recharged. The off-line setup made it difficult to observe a power failure, since the remaining charge available in the batteries was not known until the units were removed and downloaded.

The iCone units also had very few problems. The only problem observed during the showcase was on July 1st at approximately 1:00 p.m.: one iCone unit was mistaken for a regular construction cone, and it was turned off and moved by a construction worker. The problem was fixed by the on-site system manager approximately 21 hours later. This problem could have been recognized and fixed sooner by closer evaluation of the online status of the iCone unit.

The LPR system had several problems during the showcase. The first problem involved the camera at site 3. During installation, the camera would not work. After a couple hours of switching cables and cameras around, it was determined the cable used at location 3 was faulty and, therefore, no LPR data was collected at location 3 for the entirety of the showcase. The camera at location 2 had adjustment issues (i.e., was not properly positioned to capture license plate information) near the beginning of the showcase, which resulted in nearly seven hours of no data being collected. The battery trailer used at this location also caused numerous power failures for the LPR unit resulting in periods of no data. The LPR camera at location 5 also had problems. This unit seemed to react to the high temperatures and the LPR communication box shut off in the afternoons of five consecutive days. The high temperature for these days averaged over 100 degrees Fahrenheit and the system would shut down during the hottest part of the day (12pm to 1pm). In general, the LPR cameras caused the on-site system manager the most frustration and needed the most maintenance of all the systems.

The Adaptir system (including RTMS and radars units) had no problems during the showcase. There were no gaps in data for the two-week observation period.

3.2.1. Capture Rates

One problem that arose during the demonstration with the Blufax and LPR systems was the lack of data points collected during periods of low traffic flows. With low traffic flows there were periods of time when these systems were not able to report travel times because there were not enough cars passing that offered the characteristics necessary to be captured by the systems (cars with Bluetooth, for instance). Blufax typically had seventeen 15-minute periods per day with no travel times with one consecutive time period of over five hours without a recorded travel time. LPR, when the system was functioning, went as long as 130 minutes without recording an individual travel time.

The Blufax system's capture rate was also restricted by the number of vehicles with a Bluetooth signal present. The Blufax units have a detection zone of approximately 300 feet and could therefore record multiple lanes of traffic. On the other hand, the LPR system's capture rate was restricted to vehicles with California registered license plates, and could only record the closest lane of traffic. Because the LPR system only captured vehicle license plates in the outside lane, the capture rate for the inside lane for two-lane sections was zero. Upon review of the data, iCone appeared to miss many of the vehicles in the inside lane as well.

Capture rates for the four data collection systems were calculated for a 22-hour time period when all systems were functioning from July 2nd at 2 p.m. until July 3rd at 12 p.m. The RTMS unit at location 3 was assumed to have the true traffic count values at that location, a section with two-lanes in one direction. The iCone and Blufax data were compared to this RTMS to determine an estimated capture rate for a two-lane location. Because LPR only captures one lane, its capture rate in a two-lane setting depends on how the traffic is split between the two lanes. The iCone unit at location 4 was assumed to have the true traffic count values for a single-lane location.

Since Blufax is lane independent, capture rates for one lane should be the same as capture rates for two lanes. Table 2 shows the capture rates of total vehicles at a single location for the four data collection systems. For the travel time systems (Blufax and LPR), the same vehicle must be captured at two locations to obtain a valid travel time. The rate of a valid travel time from vehicles being captured and matched between two locations is also shown in Table 2. Traffax Inc. staff suggested a higher capture rate for the Blufax system could be achieved by raising the units higher (e.g., mounting on a pole as opposed to the bottom of a trailer).

Table 2: Capture Rates

Capture Rates of Total Vehicles			
System	**Location**	**Capture Rate 1 Location**	**Match Rate 2 Locations**
Adaptir RTMS (2 lanes)	3	*100%	
iCone (2 lanes)	3	55%	
Blufax (2 lanes)	3	20%	8%
iCone (1 lane)	4	*100%	
LPR (1 lane)	4	18%	2.1%

*assumed value

Notice that for the Blufax system, the total capture rate is based on both the proportion of vehicles with a Mac ID and the ability of the system to capture individual Mac IDs. If the proportion of vehicles with a Mac ID increases, the Blufax capture rate will also increase. Based on the values in Table 2, an estimating method (detailed in Appendix B) indicates that as many as 50 percent of the vehicles in the traffic stream had an enabled Bluetooth device and the Blufax system had a 40 percent chance of capturing each Mac ID. The estimating procedure is preliminary and based on several assumptions. The estimate of 50 percent of vehicles with an enabled Bluetooth device intuitively seems high. But based on the capture rate at one location we know that at least 20 percent of the vehicles for this demonstration had a Bluetooth device.

3.3. Usability

The convenience and usability of the portable ATIS was measured based on setup times, ease of system use, and usefulness. Setup times were observed by a student researcher at the beginning of the showcase. The goal of this project was to have a fully functional system deployed within four hours. This includes site specific system modifications, placement, calibration, etc. This goal was based on the assumption that a system was fully functional and "off-the-shelf." Only the Adaptir system was fully functional; the other three systems operated off-line. Adaptir is an open ended system that can be utilized for a number of uses and required some tailoring for this specific application. Additionally, software had to be modified for the specific demonstration location. These activities were completed by the vendor and the level of effort was not monitored. Research staff were only able to monitor the actual field setup times (discussed further below). Note, that these setup times do not include some of the site-specific calibration completed by vendors, nor does it include configuration of communication equipment for the off-line systems.

The Blufax system came preassembled and had the least hassle. No maintenance was needed after the initial switch of the power button. Setup time was simply the travel time to the site locations plus about 5-10 minutes to lock the system to a secure object and turning on the unit.

The iCone units also came preassembled and offered little trouble. The iCone units weigh 60 pounds each and needed to be loaded onto a truck to be transported to the site locations by at least two people. Once at the site location, the iCone units were turned to face the oncoming traffic at approximately a 45-degree angle and the power switch was turned on.

The LPR cameras took the most time for setup. The cameras needed to be mounted on the trailers so that they were able to easily pick up on license plates in the near lane, the software needed to be calibrated, and the wiring had to be connected to the power source/communication system. This was all done prior to leaving the shop; however, it could have been done in the field and would take an additional 20 minutes. Each trailer took approximately 30 minutes for setup and calibration. An extra two hours was spent troubleshooting the problems with the LPR camera at location 3 before it was determined the cable was faulty.

The speed radars for the Adaptir system were set up and ready on the first day of the showcase. The timeframe for mounting and connecting the system was approximately 30 minutes per location. The antenna had to be relocated to a higher vantage point on the trailer to ensure the best communication line of sight. This was done prior to the first two trailers leaving the shop and took about 15 minutes. The RTMS radar also had to be relocated to a specific angle and was therefore remounted, which delayed the deployment of that trailer for another day.

Because several systems were attached to individual trailers, total setup time for a location ranged between 10 and 30 minutes, depending on drop-off location accessibility and the preassemble status. The trucks could only hitch up two trailers at a time, so multiple trailers would mean multiple trips or multiple drivers. The positioning of the trailers proved to be the most time consuming due to accessibility. The actual powering-up took less than five minutes, waiting for the indicator lights to verify the system was working and collecting data. Systems without need for the trailers (Blufax, iCone) would have an estimated setup time of less than five minutes, as their systems are essentially self-contained.

In several conversations with the on-site system manager, he stressed the LPR system needed the most maintenance of the four systems. Hours of setup time would have been saved if all the equipment was checked out first to ensure all the cables and cameras were working properly before they were brought to the project site. In addition, the manufacturer of the LPR system has six separate configurations for data collection, and they were not set up for an offline collection. He noted that the other three data collection systems worked well and required little maintenance or troubleshooting time.

In several conversations with a Caltrans District 2 representative, he noted that the Blufax system seemed like the most realistic and reliable system for use in a rural area like District 2. His one concern was regarding the detection rate and how it would be affected by the limited cell coverage in the district. He also noted that an external power source would need to be used to limit the recharging of the units.

3.4. Motorist Reaction

A motorist survey was conducted to collect information regarding the impacts of portable ATIS on drivers. The survey asked about changes in frustration, driving behavior, and routing. Some demographic data was also collected in the survey. The motorists would only receive information from the system if there was significant delay; if the speed reported by Adaptir over a five-minute period dropped under 35 miles per hour, the TMC representative would post a message on the PCMS. This condition was never met. Because messages were never posted, no response to the system could be measured.

The survey did have a few responders. All the respondents traveled through the construction area and were knowledgeable about the construction before their trip. There was a 50/50 split of respondents who said the construction delay caused them frustration vs. those who said it did not cause any frustration. Since the congestion threshold was not met, the changeable message signs were never updated and the remainder of the survey data was insignificant.

4. CONCLUSIONS

Portable ATIS has the potential to provide real-time traffic information—including advanced travel times, delay times, and reduced average speeds—to motorists by updating PCMS with real-time messages. Advanced knowledge of changing traffic flows, provided by portable ATIS, can help alert drivers to use alternative routes, cause them to drive with caution, and help them make better travel decisions based on real-time data. However, there is currently a low level of implementation of portable ATIS, due in part to the limited number of demonstration projects.

Caltrans initiated this research project to further investigate portable ATIS. The project has reviewed existing best practices, interviewed practitioners, and identified and reviewed off-the-shelf technology, as summarized in the Literature Review and Concept of Operations reports. This report summarizes the demonstration effort in which four portable ATIS systems (Blufax, iCone, License Plate Reader and Adaptir) were deployed for a two-week period in Redding, California. Table 3 summarizes the results of the demonstration.

Table 3: Summary of Results

System	Measures	Accuracy*	Reliability**	Usability***	Integrated System
Blufax	Travel time	100% < 10 sec	B, C	Easy	No
iCone	Speed	99% < 10 mph	M, B	Easy	Partial
LPR	Travel time	98% < 10 sec	M, B, O, C	Hard	No
Adaptir	Speed	99% < 10 mph	M, B	Medium	Yes

* Accuracy presented as the percentage of time the maximum error is less than a specified threshold.

** Reliability challenges included: M – a unit was accidentally moved by construction workers, B – the units required a recharge of the battery, O – the unit shut down apparently due to overheating, C – during periods of low traffic the system was unable to report travel time due to low capture rate.

*** Note the usability categorization is based on the authors' opinions and may be subjective. For more detail on specific usability issues, refer to the body of this report.

Two of the systems measure spot speeds (the speed of vehicles passing a fixed point) and two measure travel times (based on identification of particular vehicles traveling the measured route). Travel times could be estimated based spot speeds but the accuracy of these estimates would depend on the variability of speeds between detectors.

In general, all the systems were found to record fairly accurate traffic characteristics. The systems were almost always accurate within 10 miles per hour for spot speeds or within 10 seconds for travel time. The exception to this was the travel time on Route 1-5 as measured by the Blufax system, though its errors could have been fixed testing for a biased error after the system is deployed and adjusting system to account for this error.

In order for a system to be portable it's necessary that it be able to run on battery power. The batteries on all the systems tested required recharging at least once during the demonstration project. This problem could be addressed by using solar panels or more batteries. Some of the systems were moved by construction staff, as they were mistaken for traffic control devices. The LPR system had the most issues of reliability with several instances of the units shutting down, presumably due to overheating. Both of the travel time systems had challenges estimating travel times during periods of low traffic, as they only captured travel times for a portion of the passing vehicles (2 percent for LPR and 8 percent for Blufax).

The ease of installation and usability could be improved for some of the systems. The Blufax and iCone systems are simply set in place and switched on. The LPR system requires alignment of the cameras and calibration of the software. The Adaptir system requires alignment of the radar units and the RTMS unit.

Of the four systems, Adaptir is the only one integrated with communications and software to allow for real-time updates to the traffic management center. The Adaptir system also could have been configured to update the PCMS directly. The iCone system does have a communication component to allow for storage of the recorded traffic data on a central server, but it would take some work to provide real-time warnings to the traffic management center or to automatically update PCMS. The LPR and Blufax systems, as provided, were not integrated into a deployable system and were evaluated with post-processing of the data collected. However, these two systems could be integrated into a similar deployable configuration.

Further demonstration of portable ATIS systems should be done to better evaluate their effectiveness over a longer testing time period and possible a longer demonstration site (say 10-20 miles long). Testing at a site with no cellular phone service would be useful for verifying the usefulness in a rural setting. Future demonstrations should also be conducted using systems that have integrated control and communication capabilities that allow for automatic PCMS updating. This testing should be done at sites that have a high likelihood of experiencing delay so motorist response to the system can be evaluated.

5. APPENDIX A: VENDOR CONTACTS

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6. APPENDIX B: CAPTURE RATE ESTIMATION FOR BLUFAX

As discussed in Section 3.2.1, the total capture rate for the Blufax system is based on both the proportion of vehicles with a Mac ID and the ability of the system to capture individual Mac IDs. If the proportion of vehicles with a Mac ID increases, the Blufax capture rate will also increase. The following is a preliminary method for estimating the capture rate for the Blufax system as a proportion of vehicles with Mac IDs on the road instead of as a proportion of total traffic. The research team was unable to estimate the number of Mac IDs in the traffic stream, but the value could be estimated by the equations derived below.

First, consider the capture rate (20 percent in Table 2). That is, for what proportion of vehicles will a Mac ID be obtained at a single station? This is the probability of capture:

(1) $$P(capture) = \frac{no\_Mac\_ID\_recorded}{no\_vehicles}$$

With a second Blufax station downstream, a match rate can be determined (eight percent in Table 2). The probability of capturing the same Mac ID at both stations for a given vehicle (that may or may not have an enabled Bluetooth) is defined as:

(2) $$P(match) = \frac{no\_Mac\_ID\_recorded\_at\_both\_locations}{no\_vehicles}$$

Equations 1 and 2 are useful, but two other values are of interest to consider alternative scenarios of traffic levels and proportions of vehicles with a Bluetooth. The first is the proportion of Bluetooth-enabled vehicles on the roadway:

(3) $$P(Bluetooth) = \frac{no\_Bluetooth}{no\_vehicles}$$

If the probabilities in Equations 1 and 2 are equal, then the Blufax system is capturing all Bluetooth Mac IDs. The data found these to be unequal, and thus the Blufax system is not capturing all enabled Bluetooth devices. In other words some Mac IDs are captured at one station, but not the other. In this case the proportion of Bluetooth devices in the traffic stream (Equation 3) cannot be measured directly. The second value of interest is the proportion of enabled Bluetooth-equipped vehicles that a Blufax unit detects. In other words, what is the probability that a single Blufax unit will capture a Mac ID given that an enabled Bluetooth unit is passing by:

(4) $$P(capture|Bluetooth) = \frac{no\_Mac\_ID\_recorded}{no\_Bluetooth}$$

The values of Equations 1 and 2 can be measured directly from the data. Although Equations 3 and 4 cannot be measured directly from the data, it can be solved by considering several probabilities. The probability that a Blufax unit captures a Mac ID is equal to the probability that a Bluetooth is present multiplied by the probability that the device will capture a Mac ID given that a Bluetooth is present.

(5) $$P(capture) = P(Bluetooth) * P(capture|Bluetooth)$$

The match rate can be thought of as the probability that a Bluetooth is present (at both locations) times the probability that a match is made given a Bluetooth is present.

(6) $P(match) = P(Bluetooth) * P(match|Bluetooth)$

If a Bluetooth is present, the probability of a match is equal to the probability that both units will capture the Bluetooth.

(7) $P(match|Bluetooth) = P(capture|Bluetooth)^2$

The previous equations can be used to solve for the desired values (Equations 3 and 4) in terms of the measured values (Equations 1 and 2):

(8) $P(Bluetooth) = \frac{P(capture)^2}{P(match)}$

(9) $P(capture|Bluetooth) = \frac{P(capture)}{P(Bluetooth)}$

From Table 2, the probability of capture; P(capture) is 0.20. During this same time period, P(match) is measured by Blufax capturing travel times on route 3-5 (i.e., captured the same vehicle at locations 3 and 5) at 8.0 percent of the total traffic flow. This suggests, based on Equations 8 and 9, that 50 percent of the vehicles on the road had a valid Mac ID and that the Blufax system has a 40 percent chance of capturing each Mac ID.