Technical Memorandum No. 1

Innovative Traffic Data Collection:

An Analysis of Potential Uses in Florida

Prepared for:

Florida Department of Transportation
ITS Office (MS 90)
605 Suwannee St., Burns Bldg.
Tallahassee, Florida 32399-0450

Prepared by:

PBS&J
1901 Commonwealth Lane, West Bldg.
Tallahassee, Florida 32303

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Executive Summary of Innovative Traffic Data Collection: An Analysis of Potential Uses in Florida

The Florida Intrastate Highway System (FIHS) is the most important strategic road system in the state. Carrying nearly one-third of the state's vehicular traffic on just three percent of its road mileage, the roughly 3,792-miles of limited-access roads, controlled access roads, and major arterials are the backbone of Florida transportation. As the Florida Department of Transportation (FDOT) moves to enhance its ability to manage and operate the FIHS, the need for accurate, timely, and reliable real-time traffic sensor data increases.

This document provides an analysis of a number of innovative methods for collecting traffic sensor data and their potential applications in Florida. The main focus of this analysis falls on the applications of these data collection methods on the FIHS. Each of the methods considered is consistent with the S*tatewide Intelligent Transportation System Architecture (SITSA)* and the emerging corridor architectures because each can be characterized as consistent with the Network Surveillance or Probe Surveillance Market Packages.

For the purpose of this study, innovative data collection methods are defined as those that facilitate the direct measurement of segment, or "link," travel times or average speeds along a roadway. This is in contrast to "point" sensors such as loop detectors, video image detectors (VID), and infrared and acoustic detectors that characterize traffic flow at a specific location along a roadway. While in some cases innovative methods could replace traditional methods of data collection, it is more likely that innovative data collection will be used to supplement data from traditional sources, thereby providing a better overall picture of traffic conditions. This analysis is not intended as an "either/or" assessment of traditional data collection versus innovative data collection. Rather, it is intended to characterize the relative attractiveness of these methods for use in Florida and provide recommendations for further activities as may be appropriate.

This analysis focuses on the following innovative data collection methods:

- In-Vehicle transponders;
- License plate readers (LPR);
- Cellular probes;
- Transit automatic vehicle location (AVL);
- Private fleet AVL and management; and
- Telematics.

This document contains a section that provides information on background and usage extent, particularly the market status in Florida, for each of the methods listed above. Information includes vendors and users, general business models and cost information where meaningful, trends, summaries of industry interviews, an assessment of implementation issues, and recommendations to FDOT regarding further examination of the methods for use in Florida.

- In-Vehicle Transponders – Several public entities across the country are currently using vehicle identification, transponder-based technology to determine travel times and speeds on their roads. Additional hardware and software are required to turn an existing electronic toll collection (ETC) system into one capable of collecting accurate travel time data. In other words, additional antennas and readers may have to be located between toll collection areas to provide supplemental data, and processing equipment and software may have to be set up at a centralized processing facility. However, with such modifications, ETC systems have the potential to become an abundant source of travel time and speed data.

  While invasion of privacy could be an issue, existing systems have successfully overcome this potential problem by scrambling the transponder number and/or deleting user identification information once a travel time has been calculated.

  With 650,000 to 700,000 ***SunPass***® and E-PASS transponders operating statewide, Florida is a logical candidate for this data collection method. The Orlando-Orange County Expressway Authority (OOCEA) is currently pilot testing a system-wide, transponder-based data collection system on its 90-mile network, all of which is part of the FIHS. Additionally, FDOT's Intelligent Transportation Systems (ITS) Office is developing a field test to assess market penetration of transponders at six locations across the state.

  We recommend that FDOT strongly consider deploying a transponder-based travel time data collection system along the FIHS in areas where sufficient transponder penetration is found in the field test.

  Florida also utilizes in-vehicle transponders for electronic screening of commercial vehicles at twelve sites on I-95, I-75, and I-4, part of a national system known as Pre-Pass. With over 186,000 commercial vehicles participating in the system nationwide, there were nearly 200,000 "reads" in Florida during October 2001 – an average of over 6,400 per day. While this number could grow over time, it is a very small percentage of the total toll transactions in Florida. As a result, we recommend the continued monitoring of Pre-Pass usage in Florida, but for the time being no additional efforts to utilize these transponders for traffic flow data collection should be considered.

- LPR's – Applied extensively in the United Kingdom and undergoing testing in Oregon, the use of LPR's to determine travel times is a data collection method that should be given careful consideration in Florida. This method uses optical character recognition (OCR) technology to identify license plate numbers and convert them to electronic identifiers. This method has essentially the same functionality as transponders-based systems, but does not require the transponder. As a result, it has the potential to operate successfully even in areas where transponder penetration is low, as could very well be the case in northern Florida.

Again, invasion of privacy is an issue that could impact implementation of this data collection method. However, it can be addressed by eliminating the first and last character from the electronic identifier of the plate, thereby preventing exact correlation between the identifier and the actual plate.

Based on an interview with the Oregon Department of Transportation's ITS manager, it has been determined that their current data collection pilot project, which utilizes six LPR sites, is yielding excellent results, and will likely be expanded in the near future, particularly for the collection of data in rural areas.

We recommend that FDOT conduct a test of the LPR method in northern Florida, with the test emphasizing:

- Whether such a system has the capacity to read the many different types of license plates used in Florida; and

- Whether single lane deployments, which cost less than deploying a reader in each lane, will yield accurate data. The estimated cost for such a test is roughly $250,000.

- Cellular Probes – In the United States, deployment of technologies for wireless handset locations have been driven by regulatory mandates related to Enhanced 911 (E-911). On June 12, 1996, the Federal Communications Commission (FCC) established a timetable within which mobile phone companies were required to be able to locate wireless callers' physical locations when the caller dials 911.

  Several vendors developing location solutions to satisfy the FCC's E-911 mandate have also indicated that, aside from providing latitude and longitude information for individual phones, their technologies can also provide velocity and direction information for significant numbers of phones traveling on local roads and, therefore, real-time traffic information. Consequently, once wireless carriers have deployed an E-911 location system for use, it might also be utilized as a platform for the provision of other location-based applications, including the provision of traffic information to government agencies and private entities.

  This document provides a thorough review of E-911 issues, technologies, and deployment statuses. Our analysis indicates that FDOT should proceed cautiously in further investigation of cellular probes for the following key reasons:

- Slow Occurrence of E-911 Implementation – On October 1, 2001, the deadline for technology selection and implementation passed with each wireless carrier seeking at least a partial waiver on full implementation of the FCC ruling. Though all carriers are moving to deploy E-911, the rate of progress is varied and unpredictable. According to the Florida State Technology Office, the coordinator for E-911 in Florida, it still might take years to complete deployment of full E-911 capabilities across the state.

- Technological Uncertainty – Since all carriers have not selected or fully tested the technologies they will use to meet the FCC's E-911 mandate, it is not yet clear whether any or all of the carriers' systems will lend themselves to use in monitoring traffic conditions.

- Business and Implementation Issues – In our opinion, it will be cost-prohibitive and otherwise very difficult to implement cellular probe systems without the cooperation of one or more of the wireless carriers. In interviews, only one carrier indicated an existing interest in using their system to monitor traffic. Furthermore, use of cellular probe systems has incited the largest outcry of all methods investigated in terms of potential privacy invasion. Finally, it is unclear what the impact will be of the increasing number of legislative initiatives limiting cellular phone use while driving.

Due to the great degree of uncertainty concerning cellular phone tracking methods, we recommend that FDOT not engage in any specific projects or initiatives at this time. However, FDOT should continue to monitor the evolution of E-911 and consider conducting such activities in the future, as appropriate.

- Transit AVL – Since there are many transit fleets currently operating in Florida, a potentially cost-effective method for assessing traffic conditions would be to use buses equipped with AVL [i.e., global positioning system (GPS) devices] as probe vehicles. However, no such systems are currently in operation anywhere in the country. Our research identified a test of this concept in Orange County, California, where 15 AVL-equipped buses were to be used as probe vehicles by the Orange County Transportation Authority (OCTA). However, OCTA's analysis found little correlation between speed estimates determined by the transit probe algorithm and recorded automobile speeds. Problems with the analysis of project data concerned the fact that the algorithm failed to distinguish between actual congestion and normal stopping delays, especially when buses ran ahead of schedule.

  We recommend that FDOT simply monitor any agencies that may choose to further investigate this area in order to observe whether new applications are developed that can overcome the inherent complexity of using transit vehicles as probes.

- Private Fleet AVL – Given the widespread deployment of fleet management systems such as Qualcomm's OmniTRACS (currently installed on approximately 300,000 long-haul tractors in North America), we believe that it might be possible to employ vehicular location and speed data from these systems to develop aggregate representations of traffic conditions on roads nationwide. Aside from benefits to drivers in general, the development of accurate, real-time traffic information on inter-city highways would likely provide significantly greater benefits to the operators of commercial vehicles themselves.

  Qualcomm, by far the largest supplier of long-haul fleet tracking services, is not currently interested in utilizing their data for traffic monitoring purposes for two key reasons:

  - According to Qualcomm's contracts with their customers, all data collected for fleet management purposes belong to the customer, rather than Qualcomm.

  - Their core business competency is fleet management, not traffic data collection. Consequently, for such an application to be attractive to Qualcomm, it would have to be an obvious revenue generator, something that traffic data collection has not yet demonstrated.

  Even so, Qualcomm indicated that they would be open to further discussions on the subject if it were something that the motor carrier industry wished to pursue. Moreover, we believe it might be useful to contact some of Qualcomm's larger costumers in order to determine whether one or more of them would be willing to participate in a pilot test utilizing their vehicles as probes. Based on these ideas, FDOT should consider pursuing of one or both of the following courses of action:

  - Report on the issue to the ITS America Commercial Vehicle Operations (CVO) Committee, the United States Department of Transportation's (USDOT) ITS Joint Program Office (JPO), and/or the American Trucking Association (ATA) to determine whether there is interest in pursuing the issue with Qualcomm.

  - Contact the Florida Trucking Association to see whether one or more carriers would be interested in conducting a pilot test using data on the movement of their vehicles received from Qualcomm or another fleet management service provider.

- Telematics – Every automobile manufacturer in North America is developing systems and applications that will allow them to interact with their vehicles via wireless communications for purposes related to safety, security, convenience, and vehicle maintenance. These systems, collectively known as "telematics" systems, may also facilitate the use of vehicles as traffic probes, with the telematics systems acting much like transit or private fleet AVL systems.

As penetration of telematics devices in automobiles and other vehicles increases during the next decade, real opportunities will arise for telematics service providers to collect and aggregate traffic data based on the movement of their subscriber base. However, it is highly probable that for the time being traffic data collected from in-vehicle telematics devices will simply be used to supplement traffic data purchased from aggregators/disseminators of traffic content, such as Westwood One and Mobility Technologies. In the interim, FDOT should make an effort to continue monitoring developments in the telematics field.

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List of Acronyms

ADS... Archived Data Service
AFLT... Advanced Forward Link Trilateration
AGPS .... Network Assisted Global Positioning System
ALI.. Automatic Location Identification
AMPS.. Advanced Mobile Phone Service
ANI .... Automatic Number Identification
AOA.. Angle of Arrival
APTS... Advanced Public Transportation System
ARG .... Autonomous Route Guidance
ATA .... American Trucking Association
ATIS... Advanced Traveler Information System
ATMS .... Advanced Traffic Management System
AVI .... Automatic Vehicle Identification
AVL .... Automatic Vehicle Location
AWS.. AT&T Wireless
BANM... Bell Atlantic NYNEX Mobile
BTS .... Base Transceiver Stations
CAD .... Computer-Aided Dispatch
CAPITAL...................................... Cellular APplied to ITS Tracking and Location
CCTV.. Closed-Circuit Television
CDMA.. Code Division Multiple Access
CPS .... Cambridge Positioning Systems
CVO .... Commercial Vehicle Operations
DASH.. Daytona Area Smart Highways
DMS... Dynamic Message Sign
DOT .... Department of Transportation
DSRC .... Dedicated Short-Range Communications
E-911.. Enhanced 911
EFLT .... Enhanced Forward Link Trilateration
E-OTD.. Enhanced Observed Time Difference
ETC .... Electronic Toll Collection
FCC .... Federal Communications Commission
FDOT .... Florida Department of Transportation
FHWA... Federal Highway Administration
FIHS.. Florida Intrastate Highway System
FSI... Farradyne Systems, Inc.
GIS .... Geographic Information System
GPS .... Global Positioning System
GSM... Global System for Mobile Communication
HAR .... Highway Advisory Radio

HELP....Heavy Vehicle Electronic License Plate, Inc.
HOV....High Occupancy Vehicle
IMS....Incident Management System
ISP....Information Service Provider
ITS....Intelligent Transportation System
JPO....Joint Program Office
LMU....Location Measurement Unit
LOS....Level of Service
LPM....Location Pattern Matching
LPR....License Plate Reader
MIST....Management Information System for Transportation
MPM....Mobility Performance Measures
MNLS....Mobile Assisted Network Location System
MPH....Miles Per Hour
MPO....Metropolitan Planning Organization
MSHA....Maryland State Highway Administration
NET....National Engineering Technology Corp.
NSS....Network Software Solution
OCR....Optical Character Recognition
OCTA....Orange County Transportation Authority
OEM....Original Equipment Manufacturers
OOCEA....Orlando-Orange County Expressway Authority
PATH....Partners for Advanced Traffic and Highways
PCS....Personal Communications System
PSAP....Public Safety Answering Point
PTFM....Passive Target Flow Measurement
RF....Radio Frequency
SITSA....Statewide Intelligent Transportation System Architecture
SMIS....Surveillance Motorist Information System
SMR....Specialized Mobile Radio
SWRI....Southwest Research Institute
TDMA....Time Division Multiple Access
TDOA....Time Difference of Arrival
TMC....Traffic Management Center
TRANSMIT....TRANSCOM's System for Managing Incidents and Traffic
TTMS....Telemetered Traffic Monitoring System
USCC....US Cellular Corporation
USDOT....United States Department of Transportation
VID....Video Image Detector
VMS....Variable Message Sign
VMT....Vehicle-Miles Traveled

1. Introduction

The FIHS, a priority system of about 3,792 miles of freeways, toll roads, and intercity arterials, experienced a 40 percent increase in peak period congestion between 1990 and 1999. During this period, FDOT invested more than $3.1 billion toward the construction of an additional 10.3 percent of lane miles. Moreover, it is projected that by the year 2020, the FIHS will require the capacity to accommodate over 21 million residents and 80 million visitors per year. Vehicle-miles traveled (VMT) by personal automobile and commercial vehicles are expected to increase by approximately 60 percent, while mileage associated with transit trips is projected to rise by another 40 percent. Due to this unprecedented demand for access to the FIHS, traditional infrastructure management programs focusing on roadway expansion will be insufficient to keep congestion within tolerable levels. In its place, FDOT and other state departments of transportation (DOT) will be forced to pursue alternative techniques for managing and operating our existing infrastructures. Included in these alternative techniques are:

- Advanced traveler information systems (ATIS), to better inform the driving public of changing roadway, weather, and traffic conditions;
- Advanced traffic management systems (ATMS), to ensure coordinated operations and active facilities management during peek periods of demand and to support evacuation coordination during emergencies; and
- Archived data services (ADS), to support operations, performance evaluation, and transportation planning.

However, for these traffic management applications to have a noteworthy impact, they will require access to traffic data that is superior to what is currently available with respect to both quality and geographic coverage. Consequently, the purpose of this paper is to evaluate an assortment of innovative traffic data collection technologies, based on their potential benefits, within a Florida-specific context.

1.1 Traditional Focus on Sensor-Oriented Traffic Data Collection

Traffic data collection is an activity that has traditionally been performed by public agencies charged with managing traffic flow, responding to incidents, carrying out planning activities, and maintaining the surface of the roadway. The traditional techniques deployed include inductive loop detectors, closed-circuit television cameras (CCTV), and other surveillance devices in an effort to monitor conditions on roads within their jurisdictions. Unfortunately, the high cost of deploying and maintaining this surveillance equipment has precluded most agencies from collecting real-time data on roads other than portions of freeway and important arterials, thereby limiting its usefulness for operations and management purposes.

However, recent advances in technology facilitate the tracking of wireless devices (i.e., cell phones, telematics devices in vehicles, fleet management devices on trucks, etc.) by information service providers (ISP) and managers. Recently, public and private sector interest has increased in leveraging these technologies to create "probe vehicles," or vehicles that are operating under normal flow conditions, to gather traffic data and avoid the need for large amounts of fixed surveillance equipment.

1.1.1 Relationship of Data Collection to Florida's ITS Architecture

In developing an ITS architecture for use with the FIHS, a large number of market packages were identified which provide a deployment-oriented perspective concerning the manner in which the architecture will address the Florida's transportation needs. More specifically, these market packages identify the pieces of the physical architecture required to implement a particular transportation service. Numerous market packages are directly linked to data collection, either as a resource or due to their reliance on the data provided.

1.1.1.1 Data Collection Oriented Market Packages

The two following market packages provide over-arching depictions of traffic data collection methodologies. See Appendix A for more information.

- Network Surveillance Market Package (ATMS01) – This market package includes traffic detectors, other surveillance equipment and the supporting field equipment, and wireline communications to transmit the collected data back to the Traffic Management Subsystem. The data generated by this market package enables traffic managers to monitor traffic and road conditions, identify and verify incidents, detect faults in indicator operations, and collect census data for traffic strategy development and long-range planning.

- Probe Surveillance Market Package (ATMS02) – This market package provides an alternative approach for surveillance of the roadway network. Two general implementation paths are supported by this market package: 1) wide-area wireless communications between the vehicle and ISP are used to communicate current vehicle location and status; and 2) dedicated short-range communications (DSRC) between the vehicle and roadside are used to provide equivalent information back to the Traffic Management Subsystem. This market package enables traffic managers to monitor road conditions, identify incidents, analyze and reduce the collected data, and make it available to users and private information providers.

- Other market packages associated with probe surveillance include the:

  - Transit Vehicle Tracking Market Package (APTS1);
  - ETC Market Package (ATMS10);

- Virtual Traffic Management Center (TMC) and Smart Probe Data Market Package (ATMS12);
- Fleet Administration Market Package (CVO01); and
- Electronic Clearance Market Package (CVO03).

1.1.1.2 Market Packages that Rely on Data Collection

Most of the remaining market packages' success relies on intelligence or data about traffic operating conditions or transit operating characteristics. The market packages in Table 1.1 on the following page are supported by data collection systems.

Table 1.1 – Market Packages Supported by Data Collection Systems

Advanced Public Transportation Systems (APTS)	
APTS2	Transit Fixed-Route Operations
APTS3	Demand Response Time Operations
APTS5	Transit Security
APTS7	Multi-modal Coordination
APTS8	Transit Traveler Information
Advanced Traveler Information Systems (ATIS)	
ATIS1	Broadcast Traveler Information
ATIS2	Interactive Traveler Information
ATIS4	Dynamic Route Guidance
ATIS5	ISP-Based Route Guidance
ATIS6	Integrated Transportation Management/Route Guidance
ATIS9	In-Vehicle Signing
Advanced Traffic Management Systems (ATMS)	
ATMS03	Surface Street Control
ATMS04	Freeway Control
ATMS05	High Occupancy Vehicle (HOV) Lane Management
ATMS06	Traffic Information Dissemination
ATMS07	Regional Traffic Control
ATMS08	Incident Management System (IMS)
ATMS09	Traffic Forecast and Demand Management
ATMS10	Electronic Fare Collection *(for congestion pricing purposes)*
ATMS12	Virtual TMC and Smart Probe Data
ATMS20	Speed Management
Commercial Vehicle Operations (CVO)	
CVO01	Fleet Administration
Emergency Management (EM)	
EM2	Emergency Routing
EM4	Evacuation Management
Archived Data and Management (AD)	
AD1	ITS Data Mart
AD2	ITS Data Warehouse
AD3	ITS Virtual Data Warehouse

1.2 Existing Traffic Data Collection Programs in Florida

1.2.1 Real-Time Monitoring (Collection) and Usage of Traffic Data in Urban Areas

In addition to the information about FDOT district agency operations provided below, it should also be noted that Districts 2, 5, 6, and 8 currently operate TMC's, Districts 4 and 7 currently have programmed TMC's, and Districts 1 and 3 are in the planning stages for deploying their own TMC's.

- District 1 does not currently operate or maintain any ITS systems; however, they are in the process of implementing an IMS along I-75.

- District 2 has begun a comprehensive program to implement an incident management program along I-10, I-95, I-295, and SR 9A. This system already operates along I-10 from I-295 to I-95.

- District 3 has a small scale IMS along the I-10 Escambia Bay Bridge and dynamic message signs (DMS) on I-10. Moreover, they have completed an ITS Interstate Plan and the ITS program will soon include freeway management systems for Pensacola, Tallahassee, and the rural areas in between.

- Districts 4, 5, and 6 have already implemented ATIS, ATMS, and incident management programs along the I-95 and I-4 corridors. Incidence response patrols currently operate along urban area interstates, with plans for expansion statewide.

- Districts 4, 6, and 8 (the Turnpike) have recently entered into a regional agreement for the integration of ITS systems and the sharing of data for ATIS services. District 4 has implemented a DMS system for I-95 and I-595 and is planning to expand the system along I-95 in Palm Beach County. Additional plans include a video monitoring system and variable speed zone monitoring systems along I-95 in both Broward and Palm Beach counties and along I-75.

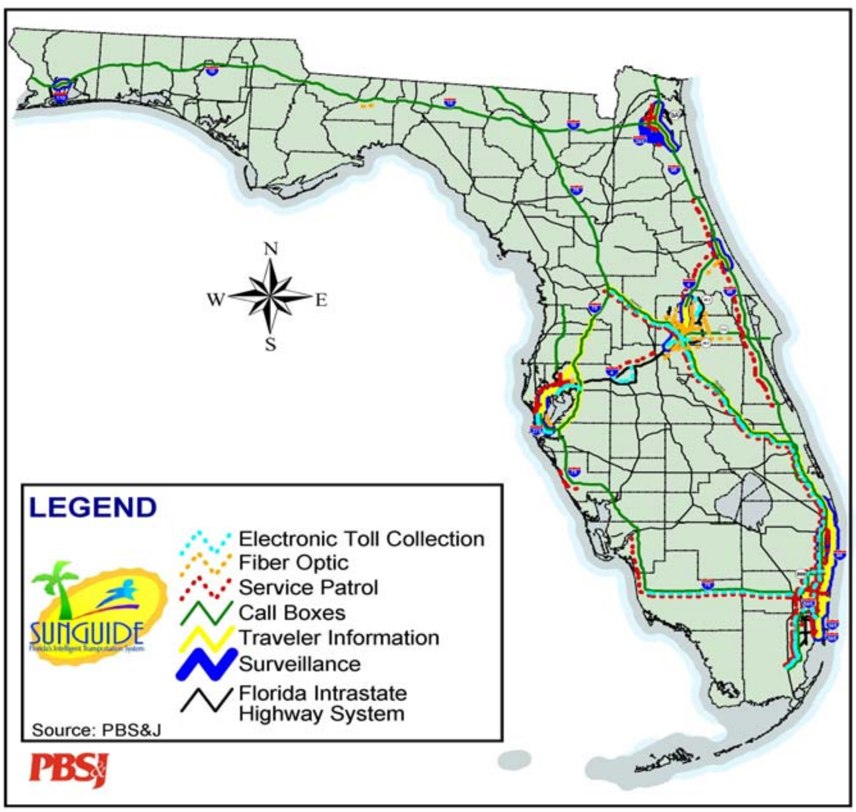
- District 5 plans to expand both the existing I-4 Surveillance Motorist Information System (SMIS) and the Daytona Area Smart Highways (DASH) system. These IMS' will eventually cover the entire length of I-4, I-95, and I-75 in District 5. FDOT is also working with Volusia County and the local transit agency, VOTRAN, to integrate the ITS systems for the purpose of sharing incident data, traveler information, and other transportation-oriented information.

- District 6 currently maintains the Golden Glades Interchange IMS, the Intelligent Corridor System ATMS, and the Sunguide ATIS. Additional plans for ITS services in the District include ITS Information Systems on I-75, I-395, and I-195.

- District 7 has implemented a traveler information system along I-275 for special events at Tropicana Field in addition to a bridge advisory and monitoring system along the Sunshine Skyway Bridge. The district has recently completed an ITS Master Plan for the Interstate System and has planned a Traveler Information System and Highway Advisory Radio (HAR) System along most of I-275 and I-75 (in addition to enhancements to the Sunshine Skyway Bridge Advisory and Monitoring System).

- The Turnpike currently maintains and operates electronic toll systems on all its facilities and operates a HAR system on the mainline. ITS improvement plans include expansion of the HAR and the implementation of a DMS system, an incident detection surveillance system and a traffic monitoring video system on the mainline, and the installation of fiber optics.

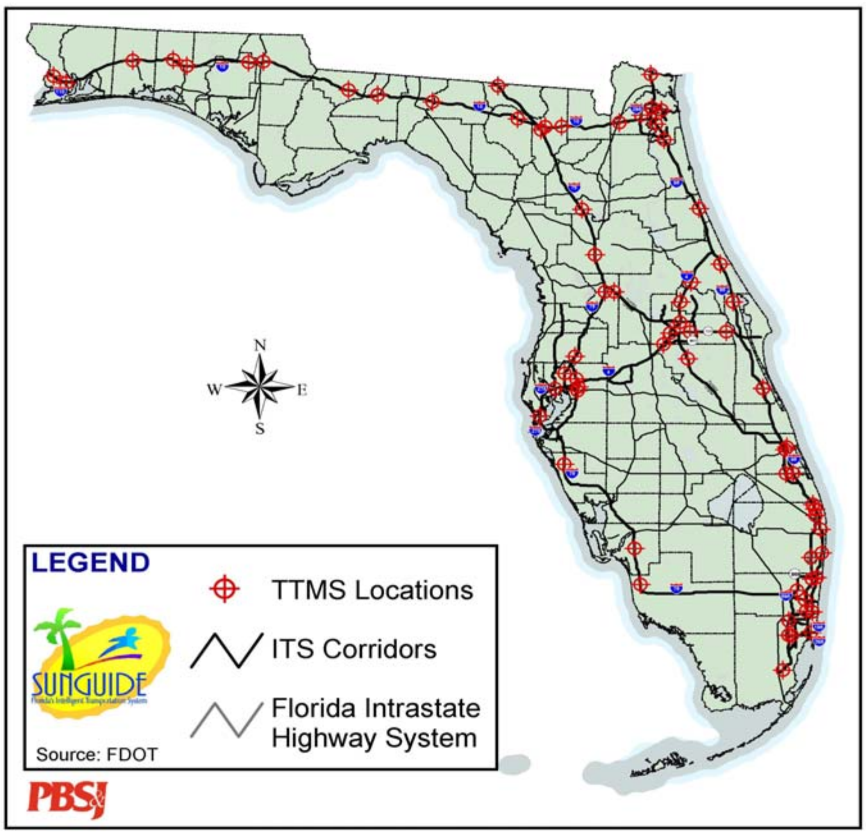
Figure 1.1 – Existing ITS



1.2.2 Deployment of Telemetered Traffic Monitoring Systems (TTMS) to Support the Florida Mobility Performance Measures (MPM) Program

Since 1996, FDOT has worked to implement a series of mobility performance measures (MPM) for evaluating and reporting highway and transit system effectiveness. To support the MPM program, FDOT collects traffic data on a continuous basis through its TTMS. TTMS's are automatic traffic recorders permanently sited throughout the state. Their purpose is to record the distribution and variation of traffic flow. Florida's continuous count program is currently comprised of over 200 sites. FDOT also coordinates with local jurisdictions to obtain additional data from their permanent count stations, expanding the FDOT database to over 300 sites. FDOT's goal is to integrate the TTMS data collection system with existing and planned ITS deployments to maximize the cost-efficiency of communication networks and data archiving services.

Figure 1.2 – Telemetered Traffic Monitoring Sites (TTMS)



1.3 The Need for Substantial Expansion of Traffic Data Collection Capacity

As described in Section 1.1.1 concerning the relationship of traffic data collection to Florida's ITS architecture, market packages are organized around the need for ITS systems to satisfy certain user needs. Although ITS monitoring infrastructures currently have the capacity to provide some of the data necessary to meet these needs, gaps exist with regard to both geographic coverage and data quality. These gaps must be addressed if FDOT is to successfully manage the state highway system and FIHS over the long-term. Moreover, as the range and scope of the MPM expands, additional ITS data resources will be required to provide the full range of data needed.

1.4 Innovative Approaches to Traffic Data Collection

Advances in wireless and sensor technology and the potential to leverage this technology to provide commercial services to drivers have resulted in increased private sector interest in the development of probe-oriented traffic data collection solutions. The emerging technologies that will be reviewed in this paper include:

- ETC and pre-clearance (for CVO purposes) systems that monitor the movement of wireless transponders along segments of road;

- Vehicle tracking solutions utilizing optical LPR's to monitor vehicles along segments of road;

- Data collection solutions making use of car-based cell phones as probes;

- Vehicle location solutions used by transit systems to improve the management and operation of bus fleets;

- Vehicle location and communication solutions used by Qualcomm and other service providers to facilitate nationwide fleet management for long-haul trucking companies; and

- Telematics devices installed in vehicles by automobile manufacturers and/or third party service providers to supply after-care services to drivers.

1.5 Potential Opportunities Provided by Innovative Data Collection Solutions

Based on what has been learned about probe-oriented traffic data collection solutions, it appears that tremendous opportunities potentially exist for these technologies to cost effectively complement, and in some cases replace, traditional traffic data collection resources. This is due to the reality that whereas traditional data collection efforts require the installation and maintenance of large amounts of expensive and difficult to maintain fixed infrastructures, probe vehicle systems are designed to require significantly less infrastructure, while at the same time providing improved data.

1.6 Recommendations for Future Directions of FDOT Programs in this Area

The primary goal of this study is to provide FDOT decision-makers with the information necessary to make informed decisions concerning the testing and deployment of innovative data collection technologies within the state, specifically focusing on the needs of the FIHS.

1.6.1 Description of the FIHS

Established in 1990 by the Florida Legislature, the FIHS is the priority system of streets and highways designed to provide high-speed and high-volume traffic movements across the state of Florida. Although the FIHS comprises only three percent of Florida's roadways, it carries 32 percent of all traffic and 78 percent of truck traffic.

The following five FIHS corridors represent the backbone of the state highway system, linking all modes of travel within the state:

- I-95 Corridor;
- I-75 Corridor;
- I-4 Corridor;
- I-10 Corridor; and
- Florida's Turnpike.

1.6.2 Focus of the Study on the FIHS

Due to the importance of the FIHS to the state's economy, any analyses carried out within this paper will reflect the data needs described in the *ITS Master Plans* and *ITS Program Plan* already under development for the five principal FIHS transportation corridors. By pursuing this course of action, it is believed that any recommendations stemming from this study will be more readily folded into existing plans for the statewide deployment of an integrated, interoperable ITS.

2. Traffic Flow Data Collection Techniques

2.1 Introduction to Differences between Various Types of Traffic Monitoring Systems

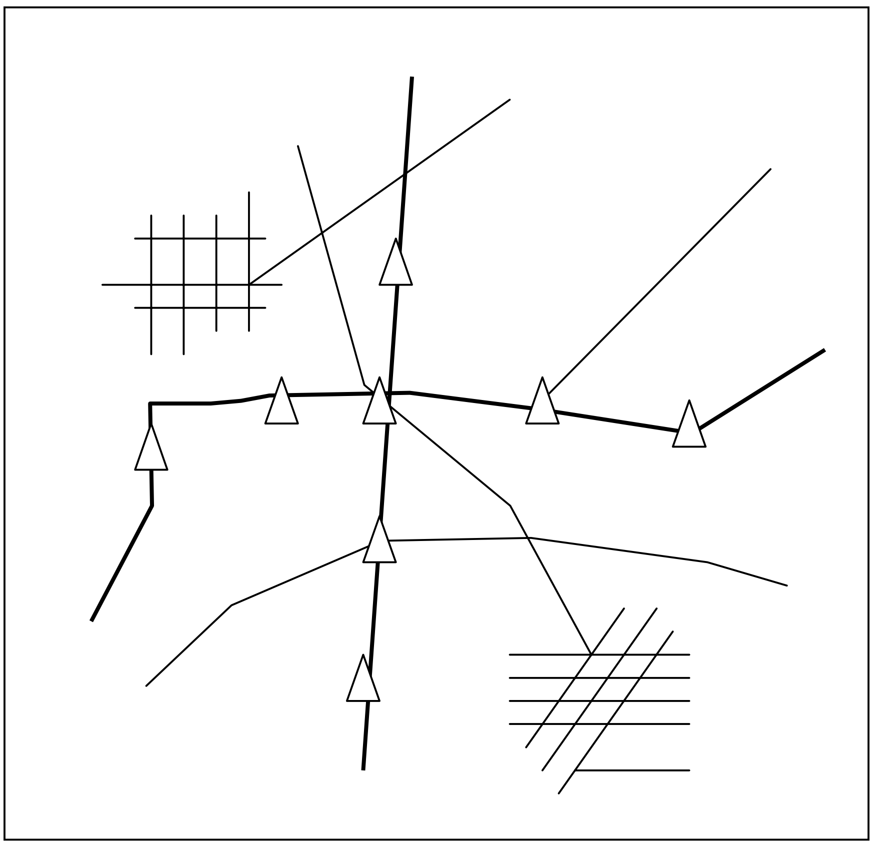
Table 2.1 – Differences between Various Types of Traffic Monitoring Systems

	Loop Detectors	**VID**	**Tracking of ETC Transponders**	**LPR's**	**Tracking of Cell Phones**
Operator	Public or Private Sector	Public or Private Sector	Public or Private Sector	Public or Private Sector	Public or Private Sector
Nature of the Data Collected	Point-Sensor Oriented	Point-Sensor Oriented	Link Oriented	Link Oriented	Network Oriented Probe Vehicle Data
Functionality of Data Collected	Volume, Vehicle Class, Point Speed (when pairs of detectors are used), and Estimated Travel time, and Incident Detection	Speed of Vehicles within Range of Camera and Estimated Travel Time, Volume, Vehicle Class, and Incident Detection	Average Speed and Travel Time between various Antennae, Estimated Volumes, and Incident Detection	Average Speed and Travel Time Between Various Readers, Estimated Volumes, and Incident Detection	Location of Individual Phones for E-911/etc., Link Speed and Travel Time, Estimated Volumes, and Incident Detection
Type of Infrastructure Used	Sensors Embedded in the Road	Cameras used to monitor traffic conditions	Antennas Track ETC tags as they pass underneath	Optical plate readers track license plates as they pass by	GPS chipset embedded in cell phone/cellular tracking infrastructure
Maturity of the System	Very Mature	Very Mature	Mature	Mature	Still under development for wireless 911 purposes, application to traffic data collection still unknown
How System Collects Information on Vehicles - Flow of Data	Detectors store data or send it via modem to ATMS center	Processor in camera housing analyzes traffic conditions and transmits image and data to ATMS center	Antennae send data to roadside readers which transmit the data via modem to ATMS center	Optical readers send image of plate to roadside processor which transmits the data via modem to ATMS center	Tracking technology locates phone/transmits its location via cell phone signal

	Loop Detectors	VID	Tracking of ETC Transponders	LPR's	Tracking of Cell Phones
Range of Detection Area	Area immediately above the sensor	Area within visual range of the camera	Area within range of each ETC antenna	Area within the range of vision of each reader	Areas in which GPS set can locate itself or range of cellular infrastructure**
Provision of Real-Time Data for ATIS	Sometimes, but not normally	Yes	Yes	Yes	Yes

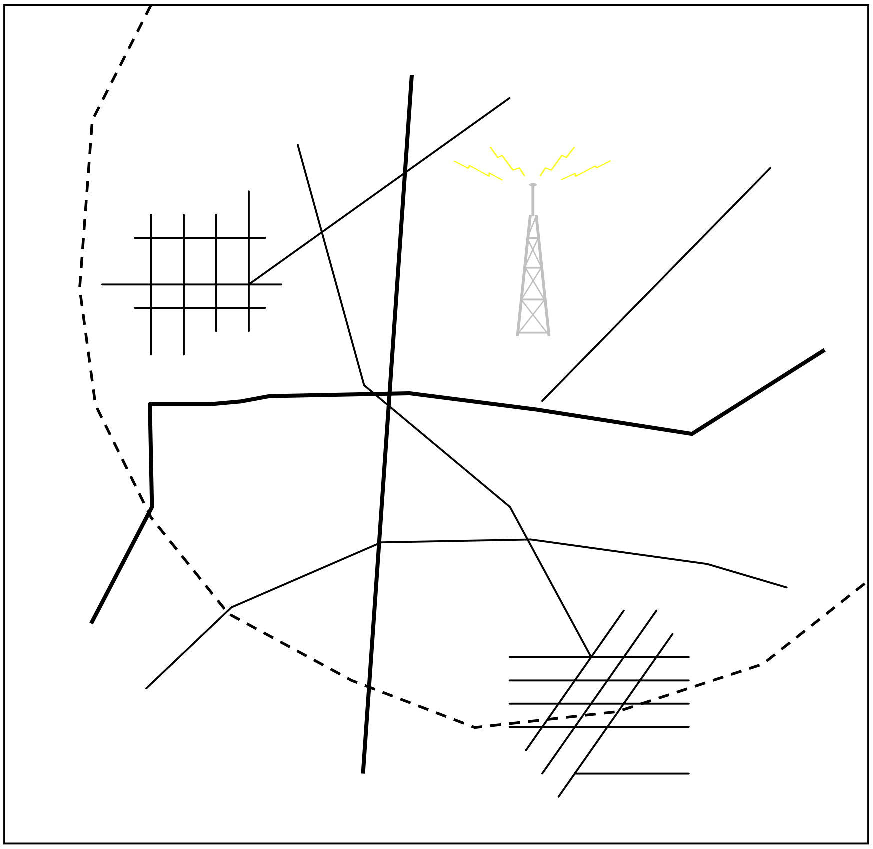
** The area that can be covered by each cell tower varies depending on local geography and the number of cell phones in the area. For example, while the range might be five miles in North Dakota, it is likely to be about .one-half to one mile in New York City.

Figure 2.1 – Deployment of Point-Sensor Infrastructure



Δ = Sensor (Loop Detector, CCTV Camera, ETC Reader)

Figure 2.2 – Deployment of Probe Vehicle Infrastructure



The Dotted Line indicates the area under surveillance of a tracking system making use of a nearby cell tower either as a base on which to locate its tracking equipment or as a conduit for transmitting location data from wireless devices to an operations center.

As Figures 2.1 and 2.2 demonstrate, significant differences exist in the manner through which each type of system collects traffic data. In Figure 2.1**,** we see that sensors must be positioned every so often in order to maintain surveillance on a given road. Consequently, adding even one road to the list of those under surveillance requires the procurement, installation, and maintenance of a number of sensors. In contrast, Figure 2.2 demonstrates how probe vehicle-based solutions have the ability to monitor entire sections of a network of roads from a single centralized location (i.e., a nearby cell tower). As all vehicles and roads within broadcast range of the tracking infrastructure are potentially under surveillance from that single location, the decision to add roads to the list of those under surveillance involves only marginal additional costs, primarily related to processing the data at the traffic operations center or ISP. As a result, this technology avoids many of the linear investments associated with more traditional traffic collection infrastructure investments.

2.2 Traditional Data Collection – Point Sensing

Point-sensor oriented traffic data collection systems monitor traffic conditions at individual points along a roadway. These systems are capable of generating information concerning instantaneous (point) speed at instrumented points along a road. This point speed is then processed to determine average speed and estimated travel time between detection points. However, given that point detectors are often spaced at intervals one-half mile or greater in length and are unable to assess conditions in between (i.e., sense congestion or incidents), there can be significant errors in the travel time and average speed estimates such systems produce.

2.2.1 Technologies that Facilitate Point Sensing

Historically, the inductive loop detector has been the primary technology used for roadway surveillance. A loop detector consists of an insulated electrical wire placed below the surface of the road. Driving an electric current through the loop generates an electromagnetic field. Metal objects (i.e., cars) passing over the loop absorb a portion of this energy, resulting in a decrease in the inductance and resonant frequency of the field. When these aspects of the field take on certain pre-determined characteristics, the detector records the passing of a vehicle.

Although the most widely used type of traffic sensor, loop detectors have been criticized for having short life spans, providing unreliable data, and requiring lane closures during installation, maintenance, and replacement. Other problems with loop detectors are related to malfunctions that result in inaccurate data being produced. The causes of such problems can range from stuck sensors to cross-talk (when two sensors in close proximity interfere with one another). Although some public agencies have developed detection systems that transmit loop detector information to the traffic operations center in real-time, most merely download data from their detectors every few weeks in order to analyze volume and vehicular classification data for road maintenance and planning purposes.

In addition to loop detectors, other types of point-sensors include VID cameras, and infrared, microwave, and acoustic-based sensor systems.

Other types of data generated by point-sensors include:

- Traffic Flow Rate – By counting the number of axles passing overhead, loop detectors are able to calculate the number of vehicles per day (or other interval of time). This enables interested parties to obtain an estimate of vehicles per hour at a specified point.

- Vehicle Classification – Pairs of loop detectors are able to provide estimates of vehicle length based on the distance between axles. This facilitates classification of those vehicles.

Although loop detectors and other point-oriented sensors have in the past provided the bulk of traffic data for operations, incident management, and planning purposes, they are not the focus of this study.

2.2.2 Use of Point-Sensors in Florida

Continuous data collection is available from point-sensors across the state. Due to the manner in which they operate, they are actually better at providing lane specific information (i.e., point speed, traffic flow rate, and vehicle classification) than network solutions.

2.3 Link Sensing

Link sensing applications utilize vehicle identification technologies to track vehicles as they pass specified points within a network of roadways. Field controllers transmit location, time, and vehicle identification information to a central processor. By knowing the length of the link traveled and the beginning and end times at which travel on that link took place, travel time for that link can be determined. Special software is used to analyze the data and remove anomalies.

Link sensing data collection applications typically have the capacity to provide:

- Real-time travel times and average speed between the sections of roadway under surveillance; and
- Incident detection capabilities.

2.3.1 Technologies that facilitate link-based traffic data collection include:

- In-vehicle transponders (ETC, CVO pre-clearance, etc.); and
- LPR's.

2.4 Probe Vehicles

Interest in the development of probe vehicle-based data collection systems stems from their hypothetical ability to track the location and speed of multiple target vehicles by monitoring wireless devices carried onboard. Probe vehicle systems are typically composed of:

- The vehicles themselves;
- A technology for determining vehicle location; and
- A communication system between the vehicle and a management center.

Whereas traditional data collection technologies require the installation and maintenance of large amounts of expensive and difficult-to-maintain, fixed roadside infrastructures, probe vehicle-based data collection systems are designed to require significantly less infrastructure, with none located at the roadside, while also having the ability to provide traffic data on a specific point, a link between two points, or a network of roads.

By and large, technologies that facilitate the implementation of the vehicles-as-traffic-probes concept theoretically have the capacity to provide:

- Real-time travel times and vehicular speeds;
- Incident detection capability; and
- Other travel behavior information.

2.4.1 The following devices/services may facilitate probe vehicle-based data collection systems:

- Cellular phones;
- Public/private fleet management services;
- Telematics devices; and
- Transit vehicle location systems.

2.5 Differences between Link Sensing and Probe Vehicle Concepts

It is important to note that link-sensing applications are fundamentally different from probe vehicle applications. For example, although the tracking of ETC transponders enables public agencies to track individual vehicles, thereby facilitating the collection of higher quality traffic data than has generally been available in the past, ETC transponders are limited in that they only have the ability to transmit data over very short ranges. As a result, collection of data concerning a given section of road requires the installation and maintenance of roadside infrastructure, resulting in many of the same cost problems associated with the usage of more traditional detection equipment (i.e., loop detectors.). A similar situation exists in the case of LPR’s.

3. Analysis of Innovative Data Collection Solutions

This section of the study is focused on providing the reader with background information on the innovative traffic data collection solutions listed in Section 1.4 – Innovative Approaches to Traffic Data Collection, as well as our analysis of the practicality of implementing each within the context of Florida and the FIHS.

In contrast with the point-oriented nature of data provided by traditional traffic data collection technologies (described in Section 2.2 – Traditional Data Collection – Point Sensing), the innovative data collection solutions described in this section have been developed with the goal of gathering real-time traffic data pertaining to entire roadway links (i.e., areas between mainline toll plazas on a highway) or even sections of a network of roads. (See Section 2.3 – Link Sensing, and Section 2.4 – Probe Vehicles.)

3.1 Link or Section Sensing

3.1.1 In-Vehicle Transponders

3.1.1.1 Background

Transponder-based electronic vehicle identification technologies are currently in use by public agencies across the United States for an assortment of purposes, including ETC, CVO electronic clearance (inspection), etc. Although an increasing number of public agencies have begun using such equipment for traffic surveillance and incident detection purposes, its primary applications remain ETC and CVO electronic clearance. The four primary components of electronic toll, transponder-based systems are:

- Vehicles equipped with ETC transponders;
- Roadside antennae that detect the presence of passing transponders;
- Readers which bundle data from each antenna; and
- A central management facility to collect and analyze the data from the readers.

ETC transponders are each encoded with a unique identification number. Detection antennas are located either on the roadside, on structures such as bridges, or as a part of a tollbooth. Data about each transponder is collected by a roadside reader (via DSRC communications technology) and assigned a time/date stamp and antenna identification stamp. This data is then bundled with other probe data and transmitted to a central facility where it is processed and stored. In this manner, it is possible to track individual probe vehicles along the road network, calculating travel times and average speeds by comparing the differences between time stamps from successive antennas. The main constraints on data collection for ETC-based systems are related to the sample size of probe vehicles on the road at any one time, the coverage area of infrastructures, and the ability of local communications infrastructures to carry transponder data from the field to a centralized processing facility.

Several public entities across the country are currently using vehicle identification, transponder-based technology to determine travel times and speeds on their roads. Additional hardware and software are almost certainly required to turn an existing ETC into one capable of collecting accurate travel time data. In other words, additional antennas and readers might have to be located between toll collection areas to provide supplemental data, and processing equipment and software may have to be set up at a centralized processing facility). However, with such modifications, ETC systems have the potential to become an abundant source of travel time and speed data.

According to TRANSCOM's System for Managing Incidents and Traffic (TRANSMIT) – an ETC-based traffic data collection system operating in New York and New Jersey that is carried out by the Institute for Transportation at the New Jersey Institute of Technology) – ETC-based probe technologies are capable of the following:

- Vehicle Identification, Location, and Classification – Because each ETC transponder's identification number is unique, information can be recorded about where each transponder has traveled, when it traveled, and the type of vehicle it is in.

- Path/Link Travel Time – Because the system can identify individual transponders, the travel times (and therefore the average speeds) between two antennae can be assessed by comparing the time stamps for when a given transponder passed between an upstream and downstream antenna. By assessing the travel times of multiple transponder-enabled vehicles, average link travel time speed can be estimated.

- Incident Detection – By comparing historical travel times to real-time estimates of link travel time, possible incidents can be detected and investigated. According to a report produced by Booz-Allen & Hamilton for the USDOT, during TRANSMIT's test phase, over half of its incident detections occurred at least eleven minutes prior to those incidents being detected by conventional traffic detectors.

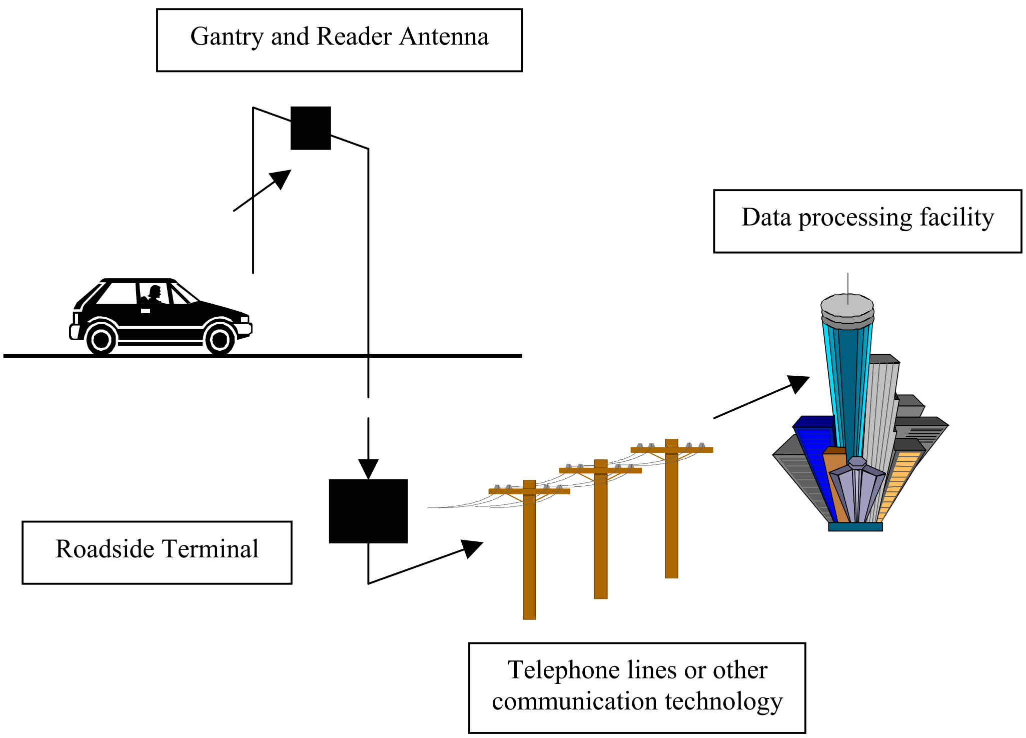
The advantages of using ETC probe vehicles for travel time collection include:

- Continuous Data Collection – ETC systems enable traffic data collection on a constant basis during each day of the year.

- Reduced Personnel Requirements – As the ETC data collection process is completely automated, personnel are only needed to maintain the system and process data.

- Increased Data Availability – As data can be collected on a continuous basis, and the potential exists to collect data from larger numbers of probe vehicles over the entire year and in all types of weather, vast amounts of traffic data will be available for planning purposes that have not been available via more conventional data collection equipment.

Figure 3.1 - Structure of a Toll Transponder-Based Traffic Data Collection System



Example of how the signal from an ETC Transponder can be beamed from a car or truck to the reader on a gantry, toll booth, or antenna linked to a CVO inspection station, processed by a roadside terminal and sent (via computer modem) over phone lines to a central facility for processing.

3.1.1.1.1 Field Data Collection Studies to be Conducted in Florida

PBS&J and FDOT are in the process of developing a plan to deploy a small number of portable roadside toll-transponder readers on three urban and three rural corridors. The purpose of this plan is to determine whether sufficient volumes of transponder-equipped vehicles operate within Florida, which could be used to facilitate deployment of a statewide transponder-based traffic data collection system.

Although CVO pre-clearance transponder systems are not currently compatible with toll collection systems and have penetration locally, a field study is currently being planned to evaluate whether sufficient coverage (in terms of the percentage of vehicles and the geographic spread) exists to deploy permanent readers for tracking CVO-oriented, pre-clearance transponders within the state.

3.1.1.2 Current Usage in Florida

This technology is currently used within Florida for both ETC and electronic screening applications (***SunPass***® and E-Pass systems).

PBS&J is currently working with OOCEA to conduct a pilot-test concerning the viability of using E-Pass transaction data as a source of real-time, link-oriented travel time and speed data.

3.1.1.3 Market Status

3.1.1.3.1 Vendors

Vendors providing transponder-based technologies include:

- Mark IV;
- TransCore/Amtech; and
- Sirit.

3.1.1.3.2 Users

Public sector users of this type of technology include toll collection authorities and agencies concerned with managing the movement of commercial vehicles, as well as those agencies that wish to make use of the data collected for traffic analysis purposes.

Information about other public entities that have implemented toll tag tracking systems to determine traffic conditions on their roadways can be found at the websites listed below. See Appendix B for more information.

- San Antonio – TransGuide (www.transguide.dot.state.tx.us);
- Houston (traffic.tamu.edu); and
- New York City Metro Area – Transmit (www.transmitsite.com).

3.1.1.3.3 Costs

The cost of deploying a transponder-based traffic data collection system is approximately $40,000 per site. For more information about system costs, see *Probe Data Collection Phase 1 – Concept Study: Final Report.*

3.1.1.3.4 Trends

There is an increasing trend toward the deployment of transponder-based ETC and CVO clearance technologies to assist in congestion management, revenue collection, and safety enforcement. Many public agencies are currently using data garnered from toll collection systems to assess traffic conditions on roads under their jurisdiction.

3.1.1.4 Industry Interview Summaries

No interviews were carried out with representatives of either toll collection authorities or the private vendors providing the technology used in such systems.

3.1.1.5 Implementation Issues

- Privacy – Fears surrounding potential abuses of location tracking applications have led public agencies to apply great care to the manner in which electronic toll transponders are tracked for traffic data collection purposes. For example, TRANSCOM, the traffic management organization which operates the ETC system in the New York area, has set up roadside transponder readers so that they scramble each tag's identification number in order to prevent data gathered from the tracking of unique tags from being linked back to the owner.

- Transponder Penetration – In some areas of Florida, ***SunPass***® and E-Pass transponders provide a significant opportunity for data collection studies. Between these two toll-oriented transponder systems, 650,000 to 700,000 transponders have been deployed across the state.

Within Florida, the only CVO electronic screening system currently in operation is the Heavy Vehicle Electronic License Plate, Inc.'s (HELP, Inc.) Pre-Pass System. Over 186,000 trucks are currently registered with the system nationwide. According to Jim Gentener of HELP, 199,132 Pre-Pass transponder reads were recorded during October 2001, an average of 6,423 per day, at the twelve sites in Florida on I-95, I-75, and I-4.

3.1.1.6 Recommendations for FDOT Action

Traffic data collection systems based on this type of technology have already been implemented on a large scale in several cities across the country. Although such a system would not provide the flexibility or scalability of a fully deployed wireless system, it does provide significant benefits over more traditional data collection infrastructures. Such a system also facilitates the collection of data in a more cost-effective manner than traditional systems, while overcoming institutional issues that may arise concerning reliance on traffic data from systems not owned and operated by the state itself. Still, it must be kept in mind that such systems are limited by the fact that they cannot provide data on roads on which no transponder readers have been deployed and that granularity of data is directly correlated with the distance between transponder readers. Moreover, such systems should only be considered in areas having sufficient penetration of transponders.

Despite these issues, FDOT should strongly consider deploying transponder-based travel time data collection systems along the FIHS in areas where field tests have determined sufficient transponder penetration exists. Although other concepts involving vehicles as probes may eventually surpass this technology, it currently has the greatest potential for providing travel time and average speed data in a cost-effective manner.

Additionally, FDOT might engage HELP, Inc., to analyze whether the flow of transponder-enabled CVO vehicles might provide supplemental traffic data in areas where ETC tags are not deployed in sufficient quantity to provide useful information.

3.1.2 License Plate Readers (LPR)

3.1.2.1 Background

License plate matching began being used during the early 1950's to support travel time studies, but during the intervening years has more commonly been used for the tracking or identification of vehicles in origin-destination surveys. Early methods relied on the ability of observers to note the license plate numbers of passing vehicles along with the corresponding time. License plates were manually matched later and travel times computed. Fortunately, recent advances have substantially improved the simplicity and precision of this data collection technique.

Trafficmaster, a United Kingdom firm specializing in the collection, aggregation, and dissemination of traffic data, uses license plate number recognition technology to "grab" the four center digits of passing vehicles' license plates. This process is referred to as passive target flow measurement (PTFM). The license plate number is read using OCR technology, after which the record is time-stamped with data about the location at which it was spotted. The Trafficmaster equipment turns this into a four-digit anonymous electronic identification number on site, with no license plate data being retained. This information is then time stamped, batched with other license plate reads, and transmitted to the traffic control center via a packet-switched radio (in the United Kingdom), or a dedicated telephone line. As the vehicle proceeds along the road, average travel time and traffic speeds are calculated based on the time at which each unique license plate is "seen" at each subsequent site. This information is then analyzed via a proprietary algorithm to make determinations about variations in traffic flow and, consequently, incidents of congestion. Although somewhat similar in nature to systems that monitor the movement of electronic toll transponders, LPR-based networks do not require transponder-equipped vehicles and are consequently much more easily implemented, especially in areas that do not have tolling systems on their road networks.

In the Trafficmaster example, the United Kingdom's Department of Transport has granted Trafficmaster a 25-year exclusive license to operate their equipment – either overhead or at the side of all United Kingdom motorways and trunk roads. (Each sensor is approximately four miles from the next nearest site).

In addition to using this traffic information to create a picture of current traffic conditions, Trafficmaster has indicated that future services may include route guidance, status of park-and-ride facilities, local parking availability, etc.

Some of the advantages of license plate matching include this system's ability to:

- Provide large sample sizes during almost any data collection period;
- Provide accurate estimates of link travel times via random sampling; and
- Provide travel time during short time intervals, facilitating the ability to develop speed profiles for sections of roadway being studied during different portions of the peak period.

3.1.2.2 Current Use in Florida

According to our research, no projects are currently being carried out in Florida using LPR's to collect data on traffic conditions.

3.1.2.3 Market status

3.1.2.3.1 Vendors

- PIPS (formerly Pearpoint);
- AutoVu;
- Hi-Tech Solutions;
- Zamir Recognition Systems;
- Electro-Optical Technologies; and
- SIEMENS Eagle Traffic Control

3.1.2.3.2 Users

In addition to Trafficmaster in the United Kingdom, the Oregon Department of Transportation is also carrying out a traffic data collection project using license plate scanning technology.

3.1.2.3.3 Costs

Jim Kennedy of PIPS, outlined the following cost structure for deployment of an LPR system:

- Plate Reader Stations – $10,000 per site, per lane covered. Therefore, for one lane in each direction at one site, deployment of the system will cost $20,000 or $40,000 to deploy the technology on two lanes in each direction. However, this does not include the cost of installing a telecommunications medium. *Note: Mr. Kennedy indicated that there are volume discounts for purchases of significant numbers of readers.*

- Central Data Analysis Station – Approximately $40,000 to install hardware and provide software to bundle and analyze data from the plate reader station. One such station has the ability to analyze data from approximately 50 plate reader stations (one plate reader station = one plate reader covering one lane of traffic at one site).

According to Galen McGill, Oregon Department of Transportation's ITS Manager for the Traffic Management Division, the cost of implementing the Oregon Department of Transportation's traffic data collection system can be broken down as follows:

- $64,275 – Software costs (with license for up to 20 sites);
- $97,644 – Hardware costs (includes six license plate cameras and image processing equipment);
- $89,592 – Installation (labor and equipment for installing equipment, including poles and power service); and
- $18,063 – Training (system operation and maintenance).

Total Cost of System Deployment - $269,574

3.1.2.3.4 Trends

Although some interest exists in the United States concerning usage of LPR's to facilitate a link-oriented traffic data collection, the bulk of such systems are currently implemented in Europe.

3.1.2.4 Industry Interview Summaries

According to Jim Kennedy of PIPS, the vendor who provides the license plate scanning technology used by Trafficmaster as well as technology being used in a project being carried out in Oregon, has technology with the ability to scan for a license plate 60 times per second. This means that even if a car approached a reader at 100 miles per hour (mph), the technology would still be able to scan that car's plate three times. Although the manner in which each site is set up varies according to that site's unique characteristics, Mr. Kennedy indicated that, in general, a site records the five clearest license plate reads from every 30 vehicles that pass by during each 15-second period of time. A portion of the decision concerning sample size taken is based on the cost of transmitting this data to a central data analysis station. These plate reads are then compared against plate reads taken further down the road in order to determine average speeds and travel times on that segment of road. Mr. Kennedy also stated that their system is not always deployed on all lanes of a given road, depending on an analysis of traffic patterns on that roadway.

Our interview with Galen McGill indicated that they deployed an experimental traffic data collection system using LPR's approximately one year ago. Although a formal evaluation of the system is to be carried out by the Western Transportation Institute, it has not yet begun. Even so, Mr. McGill indicated that except for a few glitches in the software package being used to analyze the data collected by the system, they have been pleased with the project's results and will likely expand the system in the near future. Mr. McGill emphasized that this system would likely be utilized to collect data from rural areas. Finally, he likened the data collected by this system to what would be available from systems that track the movement of toll transponders across a network of roads.

3.1.2.5 Implementation Issues

- Privacy – As with transponder-based systems, fears surrounding potential abuses of location tracking applications have led public agencies to apply great care to the manner in which vehicles are tracked for traffic data collection purposes. In order to overcome this problem, most data collection systems utilizing this technology exclude the first and last numbers of a license plate when the optical scan of the plate is converted to a digital format. As a result, it is impossible to later identify the vehicles that have been tracked.

- Sufficient Ability to Read Different Types of License Plates – Given that license plates in Florida are available to drivers in numerous formats, it must be determined whether LPR systems will have the ability to read a sufficient number of plates across a range of configurations.

3.1.2.6 Recommendations for FDOT Action

This technology is based on much the same concept as data collection systems that track ETC and CVO transponders, except for the fact that no driver recruitment is necessary. As a result, all vehicles on a given roadway can potentially be utilized as traffic probes. We believe that such a system would be especially useful in areas with little or no transponder penetration (i.e., rural parts of the state). Consequently, we recommend that FDOT consider initiating a field trial using this technology as soon as feasible. Although privacy issues do exist, it has already been proven that they can be overcome and peoples' identities protected.

3.2 Vehicles as Probes

3.2.1 Cellular Probes/E-911

3.2.1.1 Background

In the United States, deployment of technologies for wireless handset location has been driven by regulatory mandates related to E-911. On June 12, 1996, the FCC established a timetable within which mobile phone companies were required to be able to locate a wireless caller's physical location when the caller dials 911.

Several vendors developing location solutions to satisfy the FCC's E-911 mandate have also indicated that aside from providing latitude and longitude information for individual phones, their technologies can also provide velocity and direction for significant numbers of phones traveling on local roads and, therefore, real-time traffic information. Consequently, once wireless carriers have deployed an E-911 location system for use, it might also be utilized as a platform for the provision of other location-based applications, including the provision of traffic information to government agencies and private entities. Collection of data via the use of vehicles as probes has the potential to be an important tool for filling traffic "data gaps," as well as reducing dependency on expensive to construct and maintain roadside data collection infrastructures.

- FCC's Stages of E-911 Wireless Location Service Implementation – An understanding of the state of affairs surrounding E-911 is necessary to truly understand how the concept of vehicles as probes would operate. With that in mind, the following sections provide an outline of the timeframes and technologies underlying the FCC's E-911 mandate.
  - Phase 0 – Serves as the foundation for wireless 911 services. It called for wireless service providers to develop the ability to route 911 calls to the local public safety answering point (PSAP).

- Phase I – Requires that, along with routing wireless calls to the appropriate PSAP, wireless service providers also provide the PSAP with the phone number associated with each wireless 911 call, thereby allowing the operator to call back if a disconnection occurs. This service is referred to as automatic number identification (ANI). Deadline for implementation of Phase I was April 2000. Phase I implementation also requires that the wireless carrier have the capacity to provide information to the PSAP concerning the cell-site from which the call originated.

- Phase II – Requires carriers to deploy handset or network-based technology that will allow them to deliver more specific location information on wireless 911 callers to the PSAP. This service is referred to as automatic location identification (ALI). With the implementation of Phase II, PSAP's will be provided with a wireless 911 caller's phone number and location, the same information currently available to PSAP's during 911 calls from landline phones. According to the FCC, wireless service providers must begin selling ALI-capable phones by October 1, 2001.

The deadline of October 1, 2001, set for beginning the implementation of Phase II of the FCC's mandate (the section requiring high accuracy location capability), has passed with all major wireless carriers having filed petitions for partial waivers, either for their selected technologies' accuracy, implementation date, or both. Moreover, most PSAP's (i.e., those 911-linked call centers oriented toward the routing of emergency services) have yet to acquire the technology necessary to utilize the location data that would become available if the wireless carriers were Phase II compliant. In fact, many PSAP's, as much as 80 percent nationwide, have yet to invest in the technology that would make them Phase I compliant.

According to Bill Baker of the USDOT ITS JPO's Public Safety Program, the United States Secretary of Transportation has asked his office to assist in accelerating deployment of wireless E-911. Consequently, they are currently developing plans to:

- Assist PSAP's in the acquisition of appropriate technologies;

- Facilitate increased discussions between the stakeholders involved in E-911 deployment; and

- Work with stakeholders to examine the possibility of developing location solutions that have not been examined before.

According to Mr. Baker, benefits to DOT's that could accrue from this pursuit of this project include improved incident management and enhanced routing of emergency services. There have also been discussions concerning the possibility of creating partnerships between PSAP's and nearby TMC's to facilitate the increased exchange of information.

Other resources at the Federal Highway Administration (FHWA) indicate that there has been some interest in the technologies involved in the collection of location data for E-911. Although they believe that traffic data applications will not themselves drive the market for location data, they do believe that the potential exists for such applications to evolve on the secondary tier of location services. Although they have decided to take a wait-and-see approach over the next year while some maturation takes place in the technology surrounding E-911, they have not ruled out the possibility of conducting future tests of one or more location solutions for the purpose of collecting traffic data.

- Solutions being Developed to Meet the FCC's E-911 Wireless Phone Location Mandate – The various solutions being developed to meet the FCC's E-911 location requirements can be grouped into two primary categories:

  - Network-Based Solutions – These systems rely on the existing wireless network to support the geolocation process; and

  - Handset-Based Systems – These systems require that wireless customers acquire new GPS-enabled handsets.

  The primary location solutions currently being developed for use by the wireless telecommunications industry are:[1]

  - Enhanced Observed Time Difference (E-OTD);
  - Time Difference of Arrival (TDOA);
  - Angle of Arrival (AOA);
  - Location Pattern Matching (LPM); and
  - Network-Assisted GPS (AGPS).

  The TDOA, AOA, and LPM methods are considered network-based solutions, while the AGPS method is handset based. The E-OTD method is considered to be a hybrid of network and handset technologies. See Appendix C for more information about these technologies).

[1] Due to differences in the air interfaces used by various cell phone companies, different location determination techniques are more effective with some systems than others. The E-OTD solution is best suited for GSM-based networks. E-OTD is already part of the GSM standard, utilizing many of the built-in timing measurements that the handsets normally perform. A relatively simple software modification to the handset is all that is needed to accommodate the reporting of timing differences in order to assist in the location determination process. The TDOA and AOA location solutions will work with the AMPS, TDMA, and CDMA air interfaces with no modifications to existing handsets. Consequently, the existing subscriber base of legacy handsets will benefit from location determination technology with no direct impact to the customer. In contrast, the AGPS method of location determination would require that subscribers acquire new GPS-equipped handsets.

3.2.1.2 Current Use of E-911 Solutions in Florida

According to Winston Pierce, Florida's State Technology Office (Wireless Board), 911 services in Florida are organized on a countywide basis. Consequently, requests for implementation of wireless 911 services have been highly segmented. Of the 67 counties in Florida, somewhere between 15-20 have yet to request implementation of Phase I of the FCC's mandate, while only 5-10 have requested that carriers implement Phase II. As a result of this situation (both on the part of the carriers and PSAP's), Mr. Pierce estimated that it might take years for full deployment of Phase II to occur.

Lee County has integrated geographic information system (GIS) and computer-aided dispatch (CAD) technology into their 911 PSAP system in order to provide detailed location information (with over 97.5 percent accuracy) about landline callers. Wireless calls are currently routed to the county sheriff's office. This PSAP is able to view a 911 caller's number, but not their location. At present, the Lee County Division of Public Safety is currently working with a private consultant to develop a "GeoServer," that will enable them to make use of the latitude/longitude data that will become available after the implementation of Phase II of the FCC's E911 mandate. Matt Rechkemmer, Director of Public Safety, estimated that it would cost about $400,000 to fully develop and implement the technology needed by the PSAP to utilize Phase II data, as well as $500,000 annually to keep the system staffed and fully up-to-date. According to Mr. Rechkemmer, the only wireless carrier to sign a contract to provide Phase II E-911 service in Florida is Cingular Wireless, who signed a contract with Orange County.

In addition to the segmentation of 911 services within the state, there is also wide variability in the implementation of wireless 911-related services by the various carriers operating in Florida as shown below:

- AT&T – no Phase I implementation in Florida (no invoices submitted to the state for reimbursement);
- Alltel – implemented Phase I in three counties;
- Cingular – implemented Phase I in nine counties;
- Sprint – implemented Phase I in threecounties;
- Verizon – implemented Phase I in 14 counties;
- Voicestream – implemented Phase I in five counties;
- Nextel – no Phase I implementation in Florida (no invoices submitted to the state for reimbursement); and
- US Cellular – no Phase I implementation in Florida (no invoices submitted to the state for reimbursement, but may have deployed Phase I service in the Tallahassee area).

Until reasonable deployment of Phase II E-911 service have taken place, it will not be feasible for any wireless carrier or technology vendor to provide other location-oriented services, including the provision of real-time traffic data. That said, several technology vendors, TruePosition, Cell-Loc, and US Wireless, as well as one wireless carrier – Sprint – have indicated that they would be interested in exploring the possibility of testing such an application in conjunction with FDOT.

3.2.1.3 Market Status

3.2.1.3.1 Vendors

Table 3.1 – Technology Vendor's Location Solutions

	US Wireless	True-Position	Cell-Loc	SnapTrack	CPS	Grayson Wireless	IntelliOne
Location Solution	LPM	TDOA/ AOA	TDOA	AGPS Handset	E-OTD	TDOA	Unknown
Category of Solution	Network	Network	Network	Handset	Hybrid	Network	Network
Wireless Carriers Contracted With	None	Cingular and possibly AT&T Wireless' TDMA networks	None	Spring and possibly Verizon and Nextel	Strong possibility for Voicestream, and AT&T and Cingular's GSM networks	Possible AT&T Wireless' TDMA Network	None
Interest in Traffic Data Collection using their E-911 Network	Yes	Yes	Yes	Not currently, Sprint (carrier) is	Not directly, but possibly through third parties	No	Yes

- TruePosition (TDOA/AOA hybrid) – Rather than tracking the small number of phones making active calls at any one time, TruePosition plans to deploy a technology to assess velocity and location for the much larger sample of phones turned on within a local cellular network. Information will be gathered during the fraction of a second when the phone contacts the network to provide registration information. Doing so might enable them to get location, direction, and velocity information on several hundred phones within a cell site at any one time. During our conversation, Matthew Ward, TruePosition's Manager of Strategic Product Planning, indicated that they would be interested in discussing possible pilot projects with FDOT. TruePosition is a subsidiary of the Liberty Media Corporation.

- Cell-Loc (TDOA) – According to Andrew Hillson, Cell-Loc's Director of Technology, the company has the capacity to gather data on the movement of mobile phones simply by co-locating their equipment on cellular towers and "listening" to signals from nearby phones [those with advanced mobile phone service (AMPS) and code division multiple access (CDMA) interfaces. Consequently, they do not necessarily need to have a relationship with local wireless carriers to collect this data. According to Mr. Hillson, Cell-Loc's solution enables them to anonymously gather data from multiple phones being used to make calls within a cellular network (for 20-30 seconds each), thereby enabling them to calculate both location (and direction) and velocity information. In addition to the anonymous tracking of many vehicles, Cell-Loc's traffic data collection concept also calls for the continuous tracking of phones that are registered with Cell-Loc specifically for this purpose, thereby providing a stream of data from a set of identifiable vehicles. During our conversation, Mr. Hillson indicated that Cell-Loc would be very interested in working with FDOT to deploy a pilot data collection project in Florida.

- SnapTrack (AGPS) – According to John Cunningham of SnapTrack, they have signed a contract to provide Phase II E-911 service to Sprint PCS and may soon sign one with Verizon as well. He further stated that their handsets are designed to provide latitude and longitude for the caller, as well as altitude, velocity, and bearing (direction). With regard to the collection of traffic data using their system, Mr. Cunningham stated that they had the ability to collect such data either by programming handsets to occasionally submit data or querying them from time to time to gather that information (all based on permission first being given by their customers to do so). SnapTrack is a subsidiary of Qualcomm.

- US Wireless (LPM) – According to Richard Mudge, President of the Compass Services division of US Wireless, the company initially focused a great deal of its efforts on the application of its solution toward meeting the FCC's Phase II E-911 mandate. However, as no wireless carrier selected their solution for this purpose. US Wireless has re-directed its efforts to the application of their location solution to transportation-related applications. Whereas the US Wireless system was initially oriented solely toward the tracking of analog (AMPS) phones, it has now been expanded to enable the tracking of both AMPS and time division multiple access (TDMA), or digital, phones, thereby increasing the pool of trackable phones. During our conversation, Dr. Mudge noted that US Wireless would be very interested in working with FDOT to deploy a test system.

  Unlike some other technology vendors whose solution requires that the company overlay their infrastructure on the existing cellular infrastructure, US Wireless' equipment can track cell phones independent of wireless carrier participation. Moreover, as their solution simply attempts to "listen" to and analyze the nature of the radio signals being transmitted by cellular phones during live calls (over approximately a 30-second period), and has no access to records concerning ownership of a given phone, many potential privacy-related issues may be avoided. At present, it is estimated that the US Wireless system can track approximately 24 calls per minute within the range of each "listening" device.

US Wireless filed for Chapter 11 protection at the end of August 2001. As a result, some questions exist concerning the company's ability to remain in existence over the long-term. At the same time, Dr. Mudge maintains that US Wireless has a current contract to deploy their solution in one metropolitan area, with several other metropolitan areas in the process of drafting contracts with the company.

- Cambridge Positioning Systems [CPS] (E-OTD) – At present, CPS is the primary location solution vendor for GSM-oriented wireless carriers in the United States.

- IntelliOne – Although IntelliOne's business plans include the provision of traffic data to public agencies, they are not a provider of location solutions like those vendors listed above. Rather than having developed technology to be overlaid on existing infrastructures or within handsets, IntelliOne plans to gather switching data directly from the wireless carriers' networks, subsequently running this data through specially developed algorithms to make determinations on travel times and speeds on nearby roads. Similar to TruePosition and Cell-Loc, IntelliOne plans to utilize their solution to gather velocity and location from a much larger sample of the phones that are simply turned on with a local cellular network. Rather than gathering location and speed information from the relatively small number of "live" callers who are on the phone at any one time (over a longer period of time, i.e., anywhere from a few seconds on up), the information will be gathered during the fraction of a second when the phone contacts the network to provide registration information.

  IntelliOne's lack of their own infrastructures for data collection results in a situation where they will be completely reliant on wireless carriers to provide them with access to the necessary data. Aside from deals signed for testing purposes, they currently have no long-term contracts with any wireless carriers to collect this data). Should these carriers choose to stop providing this data to IntelliOne, they will be presented with a significant problem concerning how to continue providing service to their customers.

3.2.1.3.2 Users of E911 Location Solutions

Table 3.2 – Summary of Choices Made by Major Wireless Carriers Operating in Florida for Meeting the FCC Phase II E-911 Location Mandate

	FCC Requirement	Voicestream	Nextel	Cingular (a)	Cingular (b)	AT&T Wireless (a)	AT&T Wireless (b)	Verizon	Sprint	Alltel	US Cellular (a)	US Cellular (b)
Air Interface	---	GSM	IDEN (GSM-based)	GSM	TDMA/ AMPS	GSM	TDMA	CDMA	CDMA	CDMA	CDMA	TDMA
Solution Type	---	E-OTD	AGPS	E-OTD	TDOA/ AOA	E-OTD	TDOA/ AOA	AGPS/ AFLT	AGPS/ AFLT	AGPS	AGPS	AGPS
Interest in Traffic Data Collection using their E-911 Network	---	Not willing to talk about location services	Focused on imple-mentation of E-911 Phase II	Not at the present	Not at the present	Not willing to talk about location services	Unlikely	Possibly, but not in the near-term	**Yes**	No response	No response	No response
Location Solution Vendor	---	CPS	SnapTrack – Motorola ??	CPS	True-Position	CPS	True Position or Grayson Wireless	SnapTrack or Lucent	SnapTrack and/or Qualcomm	???	SnapTrack, Lucent, or Nortel	???
Scheduled Start Date	10/1/01	10/01/01	10/01/02	10/01/01	2000 cell sites by 12/31/02	40% network by 12/01	12/31/01	12/31/01	10/01/01	07/01/02	12/31/01	???

3.2.1.3.3 Business Models

Technology vendors providing a location solution include:

- TruePosition – According to Matthew Ward, TruePosition's Manager of Strategic Product Planning, the company hopes to deploy their cell phone location solution with support from wireless carriers seeking to meet the FCC's location mandate. Although no tests have yet been carried out, they anticipate being able to gain access to this data for use in other applications (i.e., the analysis of traffic conditions). However, it was noted that the main barriers to the realization of such an application are 1) the need for a wireless carrier to first have them deploy their location solution in the area where they want to provide such a service, and 2) the cooperation of the carrier – allowing TruePosition to make use of the tracking data being collected for wireless 911 purposes

- Cell-Loc – In addition to the tracking of cell phones to assist wireless carriers in meeting the FCC's E-911 mandates, Cell-Loc is also seeking to deploy proprietary "beacons" of their own design that can be utilized for other purposes such as fleet and asset tracking. Due to the existence of this second area of interest, Cell-Loc hopes that once sufficient penetration of these beacons exists, they will be able to utilize aggregate information about their movement to supplement traffic data collected from the tracking of cell phones.

- SnapTrack – Although the collection of traffic data was an application they have considered pursuing, the carriers they are involved with have not yet expressed a deep interest in that area. Consequently, their business model focuses primarily on the provision of an E-911 solution to wireless carriers.

- US Wireless – US Wireless plans to contract with state DOT's to build out their data collection networks, subsequently providing those DOT's (and other interested parties) with minute-by-minute updates concerning traffic conditions on specified roads. Once their network is deployed, US Wireless might also consider implementing fleet and asset management solutions.

- CPS – According to Roy Palmer, Vice President of Applications for CPS, their business model calls for the company to focus exclusively on the provision of location data for use by wireless carriers in meeting the FCC's E-911 mandate. When asked specifically about the application of the location solution to the collection of traffic data, Mr. Palmer stated that they had no plan to develop commercial applications based on location information such as TruePosition plans to do. However, CPS does plan to assist the carriers they work with in working with third parties to develop applications based on the location data that their solution provides. In fact, they have created a division within the company, called Coverge, whose purpose is to do just this. At present, Coverge is working with third party content providers on CPS test networks in Cambridge, Massachusetts, and Washington, D.C., to examine potential commercial applications (some of the parties that have approached them to utilize this network to test their applications have been interested in developing traffic-related applications).

- Grayson Wireless – Grayson Wireless' representative stated that they see themselves as a provider of technology to wireless carriers and that any data collected using their solution will be owned exclusively by those carriers. Consequently, their business model currently calls for them to provide a technological solution for the FCC's E-911 mandates and nothing further. George Marble, Vice President of Marketing, stated that if anyone were interested in collecting location data for commercial purposes, they would have to speak directly with the carrier.

- IntelliOne - IntelliOne plans to use their location solution to provide two traffic-related applications: TrafficAid, which will collect roadway information and provide motorists with alternate driving routes, and 511Ti, which will automate the collection and delivery of highway and transit data, enabling transportation agencies to meet 511 traveler information guidelines.

- Wireless Carriers – Although wireless carriers have been considering the deployment of commercial services based on the E-911 solutions that must be deployed to meet the FCC's Phase II mandate, only Sprint has indicated any interest in discussing the possibility of developing a traffic data collection application.

3.2.1.3.4 Costs

At present, only US Wireless has been able to provide information concerning the cost of deploying and operating their system. According to the information they provided, the cost of implementing their solution will be approximately $60,000 for each cell site covered. A significant portion of this cost was associated with the need to get zoning approval to deploy their equipment on cell towers and other structures, as well as the cost of leasing that space. The allocation of these costs will depend on the nature of each partnership established between US Wireless and interested public sector entities.

No other information is currently available concerning the cost of using E-911 based cell phone tracking solutions to collect traffic data. Funding for E-911 Phase I and Phase II deployment in Florida is provided via a $.50 monthly wireless 911 surcharge on mobile phone users' bills. This funding is reserved for usage as follows:

- Two percent reserved for use by PSAP upgrades related to wireless E-911;

- Forty-four percent reserved for use by county governments to pay for wireless 911 related debt; and

- Fifty-four percent reserved to reimburse carriers for costs related to implementing Phases I and II of the FCC's wireless E-911 mandate.

3.2.1.3.5 Trends

Due to the FCC's E-911 mandate and private sector interest in commercial services associated with consumer location, deployment of trackable phones will almost certainly increase until 100 percent penetration is achieved. The FCC has set December 31, 2005, as the deadline for this to occur.

3.2.1.4 Industry Interview Summaries

The following are summaries of conversations with major wireless carriers operating in Florida concerning the deployment of E-911 and the application of location solutions to traffic data collection.

- Sprint PCS – Deployment of location services for E-911 will begin during early 2002, likely followed soon after by the implementation of enhanced, location-oriented directory assistance. During discussions with Sprint's Senior Product Manager for Location Based Services, we were told that they would be very interested in carrying out a cell phones, probes-based traffic study with FDOT. Sprint plans to collect position data on its customers in two ways: 1) aggregate, time stamped data providing position and velocity via multiple fixes on the people calling 911 and using other location services, and 2) the tracking of customers who have agreed to act as probes so that Sprint can collect data on identifiable vehicles. Sprint believes that such a system would allow them to build maps of historical traffic data as well as provide maps of current traffic conditions. Sprint also sees this as an opportunity for them to become more involved in 511 issues, initiating relationships with state DOT's to enable callers to 511 to be transferred to their call centers in order to receive "enhanced" location-based services.

  Sprint believes that there will be definite interest in traffic-related information. They see the market being composed of at least two groups: 1) those that are willing to pay a relatively low rate in order to receive general information, and 2) those that are willing to pay higher costs for more accurate, customized information (primarily businesses and high-end consumers).

  Sprint actually began selling AGPS enabled handsets in Rhode Island on October 1, 2001, and plans to begin providing Phase II E-911 capability throughout that state before the end of this year.

- Verizon – According to Verizon's representative, they are currently considering the market potential for hundreds of different commercial applications that could be based on the location solution they have chosen to implement to meet the FCC's mandate. He stated that they would not rule out the possibility of collecting traffic data, but whether Verizon would have an interest in pursuing this application would depend upon whether a profitable market existed for the product. However, at the moment, there are no plans for even a pilot project.

- Voicestream – They have identified PSAP's for initial rollout of Phase II E-911 and other location applications during 2002, but were unwilling to talk about any aspect of implementation either for E-911 or any other subsequent location-based service.

- Nextel – According to Nextel's representative, questions remain concerning when other location-based services will roll out subsequent to implementation of E-911. Although they see a range of business opportunities stemming from the use of their location solution, their main concern presently revolves around making sure their solution works for E-911 purposes. Moreover, they questioned whether their selected E-911 solution, which uses AGPS handsets, would enable them to collect appropriate traffic data (i.e., velocity). Consequently, they currently have nothing to say about the potential for using their E-911 location solution for the collection of traffic data.

- AT&T Wireless – AT&T's representative told us that they do not believe that the FCC will allow the location networks being developed to meet the FCC's Phase II mandate to be used as a base for the provision of unrelated commercial services. Moreover, as they plan to phase out their TDMA network overtime, replacing it with a GSM overlay, they plan to focus their commercial services on their existing GSM network. Finally, they indicated that as their deployment of E-911 is still pretty far out, they are not yet ready to discuss the implementation of other location-based services, including the collection of traffic data.

- Cingular (formerly BellSouth Mobility) – According to Cingular's representative, they have no current plans for any usage of their location solution beyond the deployment of Phase II for E-911.

- Alltel – This vendor did not respond to inquiries.

- US Cellular – This vendor did not respond to inquiries.

3.2.1.5 Implementation Issues

- Applicability of E-911 Technology for Traffic Monitoring – At this time, only US Wireless has worked with independent third parties to evaluate their solution's viability for traffic data collection. The Universities of Maryland and Virginia, with support from their respective state DOT's are currently investigating the potential of US Wireless' solution to provide data for traffic management applications. A test carried out in June 2001, which pertained to the tracking of analog phones in the vicinity of the Washington, D.C., beltway, utilized an early version of US Wireless' solution, yielded small volumes of trackable vehicles and exhibited modeling difficulties. However, since that time, US Wireless has re-worked its tracking software, as well as further refined its system in order to track TDMA phones as well, thereby increasing the potentially trackable population of phones. According to Dr. Brian Smith, University of Virginia, although final results of tests on the new system will not be available until the end of the year, early results indicate that the data collected by the system appears to be of a higher quality with regard to volumes tracked, location accuracy, and vehicle speeds than that collected before. Still, Dr. Smith noted that this does not necessarily imply that the system will be practically implementable.

- Privacy – The greatest challenge to collecting data via the tracking of probe vehicles may not be technical, but may instead lie in convincing the public that such a technology will not violate their privacy. According to a recent article in the *Washington Post*, "These 'intelligent transportation systems,' as they've been named may help solve traffic problems and be a boon to marketers, but they also raise the fear of a new threat to privacy: the idea that drivers could soon be leaving electronic footsteps whenever they leave home."[2] According to this same article, a 1996 survey by Priscilla Regan, George Mason University, found that Americans overwhelmingly preferred that high-tech transportation systems collect only anonymous information, such as overall traffic counts.

  On July 11,2001, Senator John Edwards (D-NC) introduced to the Senate S.1167, otherwise known as the "Location Privacy Protection Act of 2001." This legislation mandates that the FCC initiate a rule-making proceeding within 180 days to review the possibility of restricting location-based services providers' ability to collect, use, retain, or distribute the location data of their customers without prior notification and consent. Under the bill, companies that provide wireless services would have to notify consumers when collecting information about their location. Companies could not disclose or sell this information without first obtaining consumer consent. Businesses that gather location data would have to let individuals know what information has been assembled, provide a way to correct errors, and safeguard the data against

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[2] Sipress, A., "Big Brother Could Soon Ride Along in the Back Seat."

unauthorized access. According to Senator Edwards, “people should to have control over their own private information…and it needs to be meaningful control.” Data requested by court order, aggregate data, and data used for emergency services would be exempted from the notification and consent requirement.

In order to address privacy-related fears, representatives of companies interested in traffic data collection via cellular geo-location, GPS chipsets in phones, etc., have stressed that their solutions would not enable them to monitor phone calls or identify individual users except when a caller initiates a call to 911, but simply track the location and velocity of phones anonymously in order to collect data on local traffic conditions.

One option under consideration is the use of features that would enable users to turn off the tracking functionality of their phones. Consequently, identification information would only be accessible with the user's consent. Additionally, wireless carriers and their location vendors are considering the option of having their customers “opt-in” to the location-tracking systems. By doing so, only those customers interested in receiving location-specific information could be used as data probes.

- Driver Distraction – The growth in cellular phone usage over the last decade has been accompanied by growing concerns about hazards resulting from cell-phone usage by drivers. A National Highway Traffic Safety Administration report entitled "An Investigation of the Safety Implications of Wireless Communications in Vehicles," concluded that cellular phone use by drivers does, at least in isolated cases, increase the risk of a crash. This report further indicated that increased phone usage will likely result in an increase in crashes, unless changes take place in mobile phone technology and/or its use that will mitigate this trend.

  These safety concerns are reflected in the growing numbers of legislative initiatives that have sprung up across the United States related to the use of wireless devices by drivers. For example, a recent article in the New York Post reported that "Using a hand-held cellular phone while driving is about to be outlawed in New York City." This ordinance has subsequently been enacted. The same article stated that "the whole point is to make it safer for the driver and obviously safer for the pedestrian.”

  Aside from the ordinance passed in New York City, the New York State Legislature recently passed an initiative, scheduled to take effect on November 1, 2001, banning the use of handheld cell phones while driving. The law does permit use of cell phones if the driver is using a hands-free kit.

  Within the state of Florida, an ordinance passed in late September and scheduled to take effect during October 2002 bans Miami residents from using hand-held phones while driving. As with the New York legislation, this ordinance exempts the use of cell phones used in conjunction with hands-free accessories.

All told, more than 40 states, counties, and cities are currently considering legislation to ban the use of handheld phones by drivers. On a national level, separate bills have been introduced in the United States Senate (Sen. Jon Corzine, D-NJ) and the House of Representatives (Rep. Gary Ackerman, D-NY) to ban the use of hand-held phones while driving. Internationally, at least 23 nations, including Great Britain, Japan, Italy, and Israel, have already instituted bans on cell phone use while driving.

Overall, although no definitive conclusions have yet been reached concerning the impact of mobile phone use on driver concentration, the legislative trend is clearly slanted toward implementation of further legal restrictions on drivers' use of cell phones not having hands-free capability.

3.2.1.6 Recommendations for FDOT Action

Serious questions persist concerning the ability of cell phone location solutions to collect accurate E-911 related information and, consequently, traffic data. Some technology-related issues include:

- Systems' Ability to Snap Location Fixes to Correct Roadways – Problems with location hardware and/or software can limit the application of the solution to data collection on certain types of roadways (i.e., highways versus arterials versus urban roads). Examination of test data from technology vendors and wireless carriers demonstrates wide discrepancies in location effectiveness. Tests carried out by the Partners for Advanced Traffic and Highways (PATH) (University of California – Berkeley) indicate that location solutions with a 20-meter accuracy can produce acceptable traffic data for 99.2 percent of road segments and 98.9 percent of freeway segments. At 190-meter accuracy, unambiguous traffic data can be generated for 45 percent of freeway segments and 76 percent of major streets. These tests were carried out in Alameda and Contra Counties in the San Francisco Bay area. The results of this test also indicate that tracking a single probe for longer periods can help to improve positional accuracy and ability to provide travel times. Data collection systems must also be able to discard phones that are not in vehicles.

- The need for critical mass of location network build out/handset deployment for the traffic data application to be widely implementable.

- The need for measures to be taken to ensure that phones tracked by these systems remain anonymous. Cell phone probe systems may face problems due to possible implementation of legislation such as the Federal Location Privacy Act, as well as the increasing trend towards state and local legislation banning use of cell phones without hand-free appliances in cars.

- Results of tests carried out by PATH suggest that tracking 4-5 percent of vehicles can provide a good estimate of travel time based on simulated results. Given this requirement, a deeper examination of the volume of phones that various location solutions can track at any one time is required. This could have an especially hard impact on systems that track only phones making active calls.

- Handset versus Network – Handset (i.e., GPS-based) location solutions are expected to be more accurate than network-based solutions, but controversy exists regarding which will provide the foundation for a more effective traffic solution.

- Size of Wireless Networks Implementing Each Solution – Different location solutions are effective on different wireless phone air interfaces (i.e., AMPS, CDMA, TDMA, GSM, iDEN). Selecting a solution that works on a sparsely deployed interface (i.e., iDEN or TDMA, which will be phased out over time in favor of GSM) may result in an inability to meet threshold penetration criteria.

Despite these issues, certain highly favorable characteristics of the "phones as probes" concept lead us to believe that it could mark a watershed with regard to data collection techniques if the above issues can be overcome. These characteristics include:

- Scalability and Flexibility of System – Such a system has the potential to provide coverage on all major routes, from highways to arterials and urban roads, without the need to deploy major amounts of new infrastructure and telecomm capability. Also, it would have the ability to quickly begin collecting data on non-recurring congestion taking place in areas with no sensors.

- Granularity of Data – Such a system has the potential to provide data on any part of a road, not just points at which sensor infrastructures are deployed.

- Cost-Effectiveness of System – Due to its scalability and the ability to share data with other entities (i.e., the private sector), deployment of such a system should have both lower capital and maintenance costs than would be incurred to deploy a network of point-oriented sensors covering an equivalent amount of roadway. The nature of the wireless technology on which the system operates also overcomes the telecommunication costs associated with current point-oriented sensor technologies.

Aside from technology-related issues, there are three institutional issues related to the deployment of cell-phones as probes that should also be considered. They are:

- Need to Achieve Deployment of Phones/Networks – Except for one or two cases, the carriers and technology vendors attempting to implement a location solution will need to either deploy their infrastructure or achieve a great enough penetration of locatable cell phones to provide E-911 service and subsequently unambiguous traffic data. Deployment will likely take some time and will undoubtedly be slowed by the fact that the FCC has approved almost all of the waivers applied for by wireless carriers concerning the implementation of Phase II of the -911 mandate, and the fact that most PSAP's are not yet ready to make use of Phase II data even if provided by the carriers.

- Carrier View of Commercially-Oriented, Location-Based Services – In our conversations with most carriers, it was apparent that they are not ready to move forward with location services until E-911 deployment is in full swing. Moreover, we were left with the impression that many carriers and their vendors may not be particularly interested in traffic data collection applications.

- Cost of Service – Major questions remain concerning the types of relationships that might be established with wireless carriers and their vendors, and the cost of acquiring high quality traffic data from them.

Given that so many questions persist regarding the implementation of the "cell phones as probes" concept, particularly concerning the maturity of the technology, we find it unlikely that any traffic data collection systems will be deployed during the near-term. However, our research indicates that one wireless carrier and a number of technology vendors are interested in conversing with FDOT regarding initiation of a pilot project utilizing cell phones for probes. Consequently, we recommend that the FDOT ITS Office pursue further discussions with these entities concerning the potential to collect ATIS and other traffic-related data using their proprietary technologies. This would enable state officials to remain informed about advancements in the various solutions, as well as provide the opportunity to pursue joint implementation of pilot projects, should interest in such an opportunity develop. However, even if FDOT should choose to pursue a pilot project with one of these businesses, it should be remembered that the solutions being used in this first generation of systems could be supplanted with significantly more advanced location solutions within the next few years, potentially rendering systems founded on current technology obsolete.

3.2.2 Transit AVL

3.2.2.1 Background

Service reliability problems are a major concern shared by transit system users and operators. Unreliable service leads to additional vehicle requirements and higher operating costs. Passengers suffer increased waiting times and higher travel time uncertainty, leading to a general dissatisfaction with service and the possibility of seeking other means of transport. Because of the significance of this problem, in recent years, considerable research attention has been focused on developing ways to improve service reliability.

One mechanism that has been utilized by public transit systems in an attempt to improve service is AVL. AVL systems are computer-based vehicle tracking systems that use electronic tags and a positioning system, generally GPS-based, to monitor vehicle location in real-time. After the vehicle's location is determined by the AVL system, it is transmitted at regular intervals to a central transit dispatch center. Data analysis and relay methods vary, depending on the transit system's needs and the technologies it has procured. Data transmitted from transit vehicles are assimilated by CAD software that enables bus status, condition, position, schedule adherence, operator, and incident information to be displayed on computer screens at dispatcher workstations. CAD software also manages communications, assists the dispatcher in making operational decisions, and archives data for a variety of other transit agency needs.

At present, there are at least 61 transit agencies with operational AVL systems and another 100 agencies in either the planning or implementation phase.

- Potential benefits to transit fleet management from AVL systems include:

    - Improved dispatching and operating efficiency;
    - Increased transit safety and security;
    - Faster response to service disruption;
    - Provision of more extensive planning information than has traditionally been available;
    - Provision of demand responsive services; and
    - AVL systems can be used as a tool to evaluate level of service (LOS).

- Potential benefits of the use of buses as probe vehicles to collect information on travel times along bus routes:

    For traffic managers, the use of buses as probe vehicles could provide supplemental data concerning vehicular speed and travel times on roads currently under surveillance via fixed infrastructures (i.e., loop detectors, CCTV's, etc.), as well as data on roads on which no infrastructure is currently in place. This technology has the potential to assist TMC staff in determining what conditions are like in the gaps between surveillance infrastructure locations, which would be especially helpful in responding to incidents that might not otherwise be detected for several minutes. Moreover, data from buses traveling on routes on which there is currently no surveillance infrastructure (primarily arterials and secondary roads) will provide traffic management officials with at least minimal information about conditions on these roads.

Our research led us to a project carried out by the National Engineering Technology (NET) Corporation surrounding the provision of an ATIS that integrates transit and traffic management capabilities. In this project, GPS-based AVL technology was employed to remotely track the position of 15 OCTA (California) buses in real-time. The application of GPS technology allowed these buses to be used as traffic probes, primarily for detect congestion on arterials and freeways. This information was provided to TMC's at Caltrans and to the City of Anaheim and the City of Santa Ana. This information was also to be shared with another OCTA project, called TravelTIP in order to provide congestion information and accurate data on bus locations to the public through sources such as dial-up telephone services, the Internet, and the radio.

3.2.2.2 Current Use in Florida

According to a soon-to-be released report from the USDOT's Volpe Center and Oakridge National Labs, the results of a survey of 800 transit agencies operating in the United States indicates that the Florida-based agencies listed in the following table[3] are currently using AVL solutions to collect data about their transit systems.

Table 3.3 – AVL Use in Florida

Agency	City	State	Transit Vehicles Used as Probes – 2000	Transit Vehicles to be Used as Probes – 2005
Miami-Dade Transit Authority	Miami	Florida	A, F	A, F
Jacksonville Transportation Authority	Jacksonville	Florida	A, F	A, F
A = Arterials; F = Freeways				

However, as is indicated in Section 3.1.2.4 – Industry Interview Summaries, no transit providers within the state of Florida are currently using vehicle location technology aboard their buses to collect data on traffic conditions.

[3] From a yet to be published paper from the USDOT's Volpe Center (Robert Casey) and Oakridge National Labs (Steven Gordon).

3.2.2.3 Market Status

3.2.2.3.1 Vendors

Vendors providing AVL systems for use by transit agencies include:

- Orbital Transportation Management Systems;
- 3M;
- Siemens; and
- Navigation Data Systems.

3.2.2.3.2 Users

Users of data generated by transit AVL systems will generally be limited to transit authorities and traffic management agencies interested in compiling the data for planning and/or operations purposes.

3.2.2.3.3 Costs

- According to the final report of the NET/OCTA pilot project, the budget for the project using their buses as probes totaled $1.8 million dollars, most of which came from federal and state grants.

- From a study conducted by the USDOT as part of the "Benefits Assessment of APTS," bus fleets for six transit systems were examined in order to elicit cost data concerning AVL implementation. These systems were the:

  - Milwaukee County Transit System (Milwaukee, Wisconsin);
  - Ann Arbor Transportation Authority (Ann Arbor, Michigan);
  - King County Department of Transportation (King County, Washington);
  - Metro Transit Division (Seattle, Washington);
  - Tri-County Metropolitan Transportation District (Portland, Oregon); and
  - Montgomery County Transportation Authority (Rockville, Maryland).

  The results of this study determined that the cost of an integrated AVL system is dependent on the size of the system, its level of sophistication, and the components to be included. Systems included in the cost study carried out as part of the "Benefits Assessment of APTS" ranged from those with relatively basic features (i.e., GPS, CAD, silent alarms, remote diagnostics, etc.) to very comprehensive systems, which included automatic passenger counters, surveillance cameras, and extensive automated passenger information.

Overall, the study indicates that the cost per AVL-equipped bus across the six study sites ranged from $6,800 to $30,500. Of the sites, four were grouped between $11,100 and $16,900 per bus. The average per-bus cost for all six systems was just over $15,500.

- According to the TCRP Synthesis *AVL Systems for Bus Transit*, "An AVL system is a significant investment." Survey results indicate that, on average, systems cost about $13,700 per vehicle. (As was previously stated, smaller agencies tend to pay more per vehicle because they must spread the cost of the infrastructure and control software over fewer buses.) Based on the figures provided by this paper, the minimum cost for even a small AVL system (32 buses) that requires a communications system is about $350,000. These costs will vary depending on the features installed and the sophistication of the control software. Other costs are distributed among training and maintenance activities."[4]

3.2.2.3.5 Trends

Although there have been significant increases in the use of AVL technology to facilitate improved fleet management, better informed transit planning, and more accurate traveler information, we are not aware of any public agencies in the United States currently making use of such a system for traffic data collection purposes.

3.2.2.4 Industry Interview Summaries

- Our interview with the Miami-Date Transit Authority indicated that AVL systems have been deployed on 585 buses with the data collected from the system being used exclusively for schedule adherence purposes. Although the system does provide the transit authority with data concerning average speed of the vehicle and travel time between two points, this data is not currently being shared with local traffic agencies, nor developed into an aggregate representation of traffic conditions on the roads on which transit authority vehicles are traveling.

- Our interview with the Jacksonville Transit Authority yielded much the same result as the one with the Miami-Dade Transit Authority. Although the system is used for schedule adherence and records information on bus movements on approximately 85 vehicles for comparison against historical travel times, the transit authority does not collect or use this information in real-time or share this travel time data with either the local TMC or metropolitan planning organization (MPO).

[4] TCRP Synthesis 24, "AVL Systems for Bus Transit," pg. 37-38.

3.2.2.5 Implementation Issues

Results of the OCTA transit probe project indicated that numerous problems must be overcome to successfully utilize a transit AVL system to collect traffic information. These issues include:

- Reliability of Data – The transit probe project experienced many reliability problems. Due to inoperable/failed units, lack of coverage on routes, and system generation of many duplicate records, thereby confounding data analysis, the project was viewed as having failed to meet reliability expectations for full deployment.

- Effectiveness of Interfaces between the Probe System and Users – Once it became apparent that the project would only be deployed on a small scale, plans to create interfaces with nearby TMC's were abandoned. Consequently, the project never provided a source of data on local street congestion for Caltrans, or the Anaheim and Santa Ana TMC's. Aside from a single traveler information kiosk installed at the tail-end of the project, which received high ratings in a test evaluation, no other public interfaces were established.

- Usefulness for Congestion Management – OCTA's analysis found little correlation between speed estimates determined by the transit probe algorithm and recorded automobile speeds. Problems with the analysis of project data concerned the fact that the algorithm failed to distinguish between actual congestion and normal stopping delays, especially when buses run ahead of schedule. OCTA's analysis of the data indicated that rather than attempting to measure congestion on entire roadway segments, a more useful approach would likely be to measure congestion around major intersections where delay is likely to occur. It was believed that the most sensible approach would be to utilize a "congestion alarm," that would be set off when a transit vehicle was delayed by more than one cycle at an intersection, indicating over-saturation and delay beyond normal.

- Institutional Performance – Initial partner participation in the project was very high. In the second phase, after award of the contract, outside participation dropped to almost nothing. However, as the congestion measurement aspect of the project was never used except by system evaluators, there was never really any need for outside agencies to be involved. Evaluation of the project indicated that it would have been more effective had there been more participation from drivers, dispatchers, and maintenance staff in the design and operation of the system.

3.2.2.6 Recommendations for FDOT Action

Results of the OCTA pilot project indicate that significant problems, both institutional and in the development of algorithms to analyze data from the transit probes, will have to be overcome in order to make use of a transit vehicle-oriented traffic data collection system. Moreover, it may well be that transit vehicles themselves do not represent a significant enough portion of the traffic stream to have the ability to consistently characterize traffic flows. Even so, data from such vehicles might be able to provide useful supplemental data, especially during peak periods when the number of buses on the road is the greatest. Nevertheless, we do not necessarily find this to be the most appealing of the traffic data collection systems reviewed in this document. Consequently, we recommend that FDOT simply monitor any agencies that may choose to further investigate this area in order to observe whether new applications are developed.

3.2.3 Private Fleet AVL

3.2.3.1 Background

Fleet management systems are commercial-oriented telematics devices that utilize two-way mobile satellite communications and vehicle-tracking systems to enhance the customer's communication with and control of their equipment (typically inter-city oriented commercial vehicles).

Applications such as Qualcomm’s OmniTRACS system facilitate the routing of data from the customer’s fleet management center to Qualcomm’s network management center (via landline), then to the vehicle via communications satellite. The vehicle also uses the communications satellite to send messages back to the network management center, where the message, as well as the vehicle's location (determined via a GPS unit or Qualcomm proprietary location technology), diagnostic information, etc., are routed back to the customer.

Given the existence of fleet management systems like OmniTRACS, what relationships might be established for the purpose of using their vehicular location and speed data to develop aggregate representations of traffic conditions on roads nationwide? Aside from benefits to drivers in general, the development of accurate, real-time traffic information on inter-city highways would likely provide significantly greater benefits to the operators of commercial vehicles themselves.

3.2.3.2 Current Use in Florida

As fleet tracking is a privately operated, confidential service, we currently have no specific information about the average number of vehicles monitored in Florida at any given time. However, we hope that future discussions with providers of fleet management services will begin to yield more specific information about the capability of their systems to provide traffic-related information.

3.2.3.3 Market Status

3.2.3.3.1 Vendors

Approximately 80 percent of the long haul fleets in the United States and Canada (about 300,000 vehicles) use OmniTRACS and other Qualcomm fleet management systems to communicate with drivers, monitor vehicle locations, and provide customer service.

3.2.3.3.2 Users

Commercial fleet management systems are most typically used by the dispatching systems of long-haul, commercial truck fleets.

3.2.3.3.3 Business Models

Fleet management service providers' business models focus on the provision of information concerning the movement and condition of a commercial fleet's vehicles in a secure manner, inaccessible to all but the fleet's operations center.

3.2.3.3.4 Costs

No information is currently available on the cost of using fleet management systems to collect traffic data.

3.2.3.3.5 Trends

As stated above, Qualcomm is by far the industry leader in commercial fleet management services. No major shifts in the industry have been perceived that would alter this situation.

3.2.3.4 Industry Interview summaries

According to a representative of Qualcomm's Wireless Business Solutions Division, they have previously been approached by third parties regarding the possibility of developing a traffic data monitoring system based on the analysis of data collected from the vehicles managed by Qualcomm's fleet management network. According to the representative, Qualcomm has turned down these offers for two reasons:

- According to Qualcomm's contracts with their customers, all data collected for fleet management purposes belongs to the customers rather than Qualcomm.
- Their core business competency is fleet management, not traffic data collection. Consequently, for such an application to be attractive to Qualcomm, it would have to

be an obvious revenue generator (something that traffic data collection has not yet demonstrated).

3.2.3.5 Implementation Issues

- Privacy – Data collected from a significant percentage of vehicles tracked for fleet management purposes could potentially be a useful source of data for inter-city highway ATIS and ATMS information. Unfortunately, due to Qualcomm's focus on the confidentiality of client information, they would not be interested in attempting to develop a traffic data collection application unless their customers indicated it was something that they both wanted and would be willing to pay for.

- Carrier Cooperation – Due to Qualcomm's reservations about providing access to their database, it might be useful to contact Qualcomm's larger customers directly, in an effort to determine whether they would be interested in working to develop a traffic analysis system based on the data they receive from Qualcomm concerning their vehicles. Such data could be utilized both for public and private CVO-oriented operations and consequently have significant commercial value to the owner of the data - outside of providing them with the ability to re-route their vehicles based on real-time traffic conditions.

3.2.3.6 Recommendations for FDOT Action

Given what we have learned about the nature of the fleet management industry, FDOT might consider pursuing one of the following courses of action:

- Report on the issue to the ITS America CVO Committee, ITS JPO, and/or ATA to determine whether there is interest in pursuing the issue with Qualcomm.

- Contact the Florida Trucking Association to see whether one or more carriers would be interested in conducting a pilot test using data on the movement of their vehicles received from Qualcomm or another fleet management service provider.

3.2.4 Telematics

3.2.4.1 Background

Since the early 1980's, the word "telematics" has historically meant the blending of computers and telecommunications (i.e., the Internet). However, over the past few years, the definition of "telematics" has shifted to mean "automotive telematics" – that is, the use of computers and telecommunications to enhance the functionality of motor vehicles. For example, wireless data applications in cars, trucks, and buses. According to the *Tech Encyclopedia*, the term has evolved to refer to automobile systems that combine GPS and other types of satellite tracking and wireless communications for automatic roadside assistance, remote diagnostics, etc. The following table illustrates the different components and players involved in the provision of telematics services.

Table 3.4 – Entities Involved in the Provision of Telematics Services

Player	Function
Original Equipment Manufacturers (OEM)	Produce the vehicles and equipment that enable provision of telematics services.
Service Providers	Carry out call center and service functions. Some OEM's (i.e., OnStar (General Motors) are also service providers.
Content Providers	Provide data and programs through the service provider.
Telecommunications Providers	Provide the networks required to conduct transmissions between the vehicle and service provider.

Telematics systems provide a range of applications, two of which are mayday services and vehicle navigation.

- Mayday Services – Mayday systems represent the next generation of in-vehicle safety technology. For example, mayday systems automatically notify a private call center, such as OnStar or ATX Technologies, when a vehicle's airbag has been deployed. This is known as automatic collision notification. In non-impact emergencies, pressing an emergency button in the car results in an immediate connection with the call center. After conferring with the passengers, call center operators can then notify the proper 911 PSAP about the incident, the apparent condition of the passengers, and the exact location of the crash as identified by a GPS antenna attached to the vehicle. Other mayday systems include 24-hour roadside assistance, remote door unlocking, theft tracking, and commercial-oriented concierge services.

  OnStar was among the first providers of telematics services, beginning with three Cadillac models in 1996. More importantly, OnStar is currently the leader in mayday services, with over 1.7 million subscribers at present.

- Navigation Systems – Older navigation systems, which are referred to as autonomous route guidance (ARG) systems, operated on computing power and navigational databases located in the car itself. Next generation, ISP-based telematics systems will provide "off-board" navigation assistance. This means that the database and the majority of computing capacity are located outside the vehicle at a service center.

Since most of the information is off-board, the consumer is able to gain access to accurate, real-time traffic information.

What is important to note about both of the above systems is that they rely upon:

- The ability of the vehicle to locate itself via a GPS device or other technology; and
- The presence of equipment to establish a telecommunications link between the vehicle and a centralized service center.

It is the existence of these types of equipment in the vehicle that facilitates implementation of the vehicles as probes using telematics devices.

One of the problems of related usage of cellular phones as traffic data probes concerns the confusion that will almost certainly stem from difficulty differentiating between cell phones traveling in vehicles on the road and cell phones being carried by people along the roadside, in parked cars, in people homes, etc. To avoid this problem, some people have suggested that rather than using cell phones as probes, data collection networks should be developed around wireless telematics devices integrated into vehicles' hardware.

3.2.4.2 Current Use in Florida

Telematics providers are currently working to deploy their systems on a nationwide basis. We currently have no information about the penetration of such devices in Florida-based vehicles.

3.2.4.3 Market Status

3.2.4.3.1 Vendors Attempting to Use Telematics Devices to Collect Traffic Data

- One firm interested in using telematics devices to generate vehicle-based probe data is Wingcast, a Ford-Qualcomm joint venture. Wingcast recently formed a strategic alliance with the Oracle Corporation to develop next-generation wireless telematics services. One of these services is focused on the implementation of advanced in-vehicle navigation systems that will receive information about local traffic conditions from the Wingcast System at the same time that the vehicle itself acts as a probe to help generate information about those local conditions.

- A second firm pursuing the use of telematics devices to collect traffic data is Infomove. During the summer of 2001, Infomove received a patent on its technology (a combination of software and hardware) to provide a system for the instantaneous monitoring of traffic congestion via the collection of location and speed information from motor vehicles equipped with Infomove telematics devices (locatable using GPS technology). This information is meant to enable drivers to receive estimated time of arrival and alternative route information based on current and predictive traffic flow information.

One possible impact of the patent granted to Infomove for its traffic data collection application surrounds the possibility that other companies pursuing traffic data collection applications, even those utilizing cell phones as probes (whether network or handset based) rather than GPS units, might find themselves facing charges of infringement on Infomove's patent. Consequently, the granting of Infomove's patent may, depending on how the patent is interpreted, have long-term impacts on the maturation of a competitive market surrounding the collection of traffic data from wireless probe vehicles.

- Other providers of telematics services include:

    - OnStar – General Motors;
    - ATX Technologies;
    - Acunia;
    - Motorola; and
    - Many, many other companies.

3.2.4.3.2 Users

At present, users of telematics services are generally limited to consumers from upper income brackets with significant interest in additional safety and security measures for themselves and their families.

3.2.4.3.3 Business Models

Although some telematics providers, such as Wingcast, appear eager to make use of their customer base to collect traffic-oriented data, others, including OnStar, remain unconvinced that the launch of applications requiring that they infringe upon their customers' privacy makes good business sense. Consequently, like Infomove, they would prefer to seek out third party traffic data content providers (i.e., Tele Atlas Worldwide and Westwood One Inc.'s Metro Networks) rather than collect the information themselves.

3.2.4.3.4 Costs

No information is currently available on the cost of using networks of telematics devices to collect traffic data.

3.2.4.3.5 Trends

According to a new study published by Telematics Research Group, automotive telematics is currently in its infancy stage and will soon begin to experience a major cycle of expansion. This report estimates that while only five percent of new automobiles sold today are telematics-enabled, by 2006, 33 percent of new automobiles sold will have installed telematics, resulting in a base of nearly 21 million telematics-enabled vehicles.

3.2.4.4 Industry Interview Summaries

A conversation with Tom Ross, Infomove's Chief Operating Officer, indicated that while the application of Infomove's software/hardware solution is projected to generate average speed information on a given roadway, the deployment of a critical mass of telematics devices has not yet taken place.

Moreover, despite the fact that Infomove has received a patent for the collection of traffic data from a network of telematics-equipped vehicles, they would prefer to partner with other content providers (i.e., Mobility Technologies, who would provide Infomove with traffic data content which they could provide to their customers along with other location-based services.). Consequently, although Infomove might have an interest in pursuing traffic-related applications in the future, Infomove's decision-makers currently view traffic applications as a sub-component of the broader set of commercial telematics applications they are currently trying to develop.

3.2.4.5 Implementation Issues

- Privacy – Telematics service providers are among the ITS-oriented entities that could be directly impacted by the scope of federal privacy legislation such as the "Location Privacy Act." Moreover, these entities must be sensitive to the concerns of their customer base related to location privacy. As a result, any telematics provider interested in the collection of traffic data based on the movements of their customer base will have to be very careful in the manner in which such an application is implemented.

3.2.4.6 Recommendations for FDOT Action

As penetration of telematics devices in automobiles and other vehicles increases during the next decade, real opportunities will arise for telematics service providers to collect and aggregate traffic data based on the movement of their subscriber base. However, it is highly probable that for the time being data traffic data collected from in-vehicle telematics devices will simply be used to supplement traffic data purchased from aggregators/disseminators of traffic content such as Westwood One and Mobility Technologies. In the interim, FDOT should make an effort to become more aware of the growth of this data collection application by establishing relationships with service providers such as Wingcast and OnStar.

4. Summary and Recommendations

The following tables summarize the technologies investigated in this paper and their usefulness.

Table 4.1 – Detailed Evaluation of Technologies Discussed in this Study

	ETC and CVO Transponder Monitoring	LPR's	Cell Phones	Transit AVL	Fleet Tracking Systems Data Analysis	Tracking of Telematics Devices
Nature of Data Collected	Time/Location stamps as transponders pass readers	Time/Location stamps as cars pass readers	Data about location, direction, and velocity of phones	Data about location, speed, and direction of bus	Data about location, direction, and velocity (?) of vehicles	Data about location, direction, and velocity of vehicles
Functionality of Data	Link travel times and average speeds.	Link travel times and average speeds.	Theoretically, travel time, instantaneous velocity and/or average speed.	Theoretically, travel time, and instantaneous velocity and average speed.	Theoretically, travel time, and instantaneous velocity and average speed.	Theoretically, travel time, and instantaneous velocity and average speed.
Adaptability of System	Only able to determine conditions where infrastructure exists	Only able to determine conditions where infrastructure exists	Theoretically able to collect data on traffic conditions anywhere in system's range	Theoretically able to collect data anywhere along bus route	Theoretically able to collect data on traffic conditions anywhere in system's range	Theoretically able to collect data on traffic conditions anywhere in system's range
Infrastructure Relied Upon	Transponders on vehicles, readers on roadways, and communication equipment	Optical Readers above roadway and communication equipment	Data monitoring equipment overlaid on or collocated with cellular network	GPS devices and communication equipment on transit vehicles	Location devices and communication equipment on vehicles	GPS devices and communication equipment on vehicles
Other needs	Placement of readers in roadway right of way. Need critical mass of transponders	Placement of readers in roadway right of way	Need cooperation of carrier, technology vendor, and/or cell phone subscribers	Need sufficient number of vehicles equipped with GPS and communication equipment	Need cooperation of fleet management company and/or fleets themselves	Need cooperation of telematics providers and/or vehicle owners
System Ownership	Toll Authority	Involved Roadway Authority	Wireless Carrier or Technology Vendor	Transit System	Fleet Management Entity	Telematics Service Provider
Basis of Business Model	Primary – for toll and CVO applications. Secondary – traffic data collection.	Traffic Data Collection	Primary –- meet 911 mandates. Secondary – commercial applications?	Primary – collect data for fleet management. Secondary – traffic data collection.	Primary – Provision of fleet management services. Secondary – traffic data collection.	Primary –- provision of commercial services based on user location. Secondary – traffic data collection.

	ETC and CVO Transponder Monitoring	LPR's	Cell Phones	Transit AVL	Fleet Tracking Systems Data Analysis	Tracking of Telematics Devices
Scalability of System	Improve data collection via deployment of additional readers	Improve data collection via deployment of additional readers	System should be able to collect data on more roads with small additional investment	Improve data collection capacity by deploying more equipment on buses	Large network of vehicles and communication infrastructure already exists	Data collection improves as greater numbers of telematics systems are deployed
Technical Maturity/Feasibility	Technology currently used for toll collection and traffic data collection.	Technology currently used for traffic data collection	Still in early stages of E-911 technology deployment. No location services yet.	Technology currently used for fleet management, traffic data collection.	Large number of vehicles deployed.	Early stages of telematics deployment. No critical mass of devices yet.
Time Frame for Implementation	Available for use now	Available for use now	2-5 years	With additional testing, likely implementable in approximately 2 years	With agreement from companies like Qualcomm or their customers, could be available within 2 years	Need deployment of technology and testing. Likely 2-5 years
Institutional Constraints	Need agreements between interested agencies and toll authority. Potential impact from privacy legislation	Potential impact from privacy legislation	Need agreements with carriers or vendors. Potential impact from privacy and phone safety legislation	Need agreements between interested agencies and transit authority	Data "belongs" to customers. Need to convince fleet manager that traffic application has strong revenue potential	Need to contract with telematics service provider to receive data
Conceptual Costs for Data	For OOCEA, $560,000 to $4 million, depending on build out	Cost for test project in Oregon $269,574	Most likely purchase data from content provider –- ???	Deployment of OCTA system on 15 buses –- $1.8 million	Purchase data from content provider – ???	Purchase data from content provider – ???
Cost Effectiveness	Medium-High (depends on penetration of transponders)	Medium-High (due to point-nature of infrastructure)	Potentially High	Low-Medium (due to likely spottiness of coverage)	Potentially High (depends on number of vehicles tracked)	Potentially High (but depends on cost of information)
ATIS Needs Met	Travel Time, Speed, and Congestion/ Incident information(?)	Travel Time, Speed, and Congestion/ Incident information(?)	Travel Time, Speed, and Congestion/ Incident information(?)	Travel Time and speed (algorithm needs to take movement of buses into account)	Travel Time, Speed, and Congestion/ Incident information	Travel Time, Speed, and Congestion (?) and Incident (from mayday system) data
ATMS Needs Met	Data about non-recurring congestion in areas with sufficient ETC penetration	Potential to provide traffic data, especially in rural areas and areas with low ETC penetration	Potential to provide information about non-recurring congestion – especially in rural areas	Potential to provide data about non-recurring congestion	Potential to provide information about non-recurring congestion – especially in rural areas	Potential to provide information about non-recurring congestion – especially in rural areas

	ETC and CVO Transponder Monitoring	LPR's	Cell Phones	Transit AVL	Fleet Tracking Systems Data Analysis	Tracking of Telematics Devices
Planning Needs Met	Travel times and speeds, no volume or vehicle classification. Possible usefulness for O-D studies	Travel times and speeds, no volume or vehicle classification. Possible usefulness for O-D studies	Travel Times and speeds, no volume or vehicle classification data. Possibly usable for O-D studies	Travel times and speeds, no volume or vehicle classification.	Travel times and speeds, no volume or vehicle classification. Good for CVO-oriented O-D studies	Travel times and speeds, no volume or vehicle classification. Good for O-D studies

Table 4.2 – Usefulness of Different Data Collection Technologies for the Next Two Years

	Cell Phones	Transit AVL	ETC and CVO Transponder Monitoring	LPR's	Tracking of Telematics Devices	Fleet Tracking Systems Data Analysis
Short-Term Status (Next 2 Years)	Requires further testing and refinement of both hardware and software, as well as widespread deployment of location solution infrastructure. Not likely implementable, but pilot tests possible.	Potentially useful, but more testing needed with larger bus fleets. Real usefulness remains improvement of transit service reliability and traveler information	Most useful in the near-term.	Most useful in the near-term. Can be especially useful in locations with low-penetration of toll probes.	Requires further testing and refinement of both hardware and software, as well as increased penetration of telematics devices. Unlikely to be implemented, but pilot tests possible.	Requires partnering with fleet management provider or customers. If institutional issues are overcome, then pilot of existing systems could take place in short-tern.

Table 4.3 – Usefulness of Different Data Collection Technologies for the Next Two to Five Years

	Cell Phones	Transit AVL	ETC and CVO Transponder Monitoring	LPR's	Tracking of Telematics Devices	Fleet Tracking Systems Data Analysis
Long-Term Ranking (2-5 Years and Beyond)	If systems are successful, they could provide high quality data for ATIS and ATMS purposes. However, partnerships or contractual agreements would need to be established in order to facilitate acquisition of data for public use.	Could remain useful, especially to supplement existing data collection infrastructure, but much less important than data collected from large numbers of wireless devices.	Usefulness will likely continue, but highly accurate data from wireless devices would make transponder-based systems appear less cost-effective and inflexible	Much the same as with transponder monitoring, except in rural areas where low penetration of cellular technology might make data collection infeasible	Value could grow, especially if telematics devices begin to be installed in all cars. However, as with cell phones, some sort of contract would need to come into being for the public sector to gain access to the data.	Data could become resource for inter-city traveler information and ATMS.

4.1 Impact of FDOT Data Needs on Selection of Data Collection Solutions

FDOT staff should consider a few institutional issues prior to making any decisions concerning selection of "innovative" data collection solutions. These include:

- Will it be possible for public agencies to engage in the purchase of traffic data from the private companies operating the data collection systems described in this study? Traditionally, funding for traffic data collection has gone toward the procurement and maintenance of infrastructures owned by the public entities involved. Will sufficient support exist to overcome the institutional inertia that may arise related to a shift in the focus of procurement from an infrastructure to data orientation?

- Data collection solutions need to fit a purpose. What data requirements need to be met? How can the various technologies described in this paper help FDOT meet its ATIS, ATMS, and transportation planning needs?

4.2 Conclusions about Privacy

For any of the probe data collection systems described in this paper to be successful over the long term, safeguards must be put into place to ensure that the privacy of the individual drivers being sampled is protected. With this in mind, we recommend that any probe data collection programs implemented by FDOT adhere to ITS America's Fair Information and Privacy Principles. These principles were prepared in recognition of the importance of protecting individual privacy within the context of ITS and have been reviewed by the Legal Issues Committee of ITS America. They are intended to guide transportation professionals in making privacy-oriented decisions amid a backdrop of technological, social, and cultural change.

4.3 Recommendations

Based on our analysis of the current state of technology, PBS&J recommends that FDOT pursue the following integrated strategy pertaining to traffic data collection:

- FDOT should strongly consider deploying transponder-based travel time data collection systems along the FIHS in areas where field tests have determined sufficient transponder penetration exists. Although the concept of using other vehicles as probes may eventually surpass this technology, it currently has the greatest potential for providing travel time and average speed data in a cost effective manner.

  - o Cost to field test/deploy such a system – Approximately $40,000 per site. (The total cost depends on the level of deployment.)
  - o Time Frame – Next one to two years.

- FDOT should seriously consider the possibility of initiating a pilot project to use LPR's to collect travel time and average speed data. Although similar in nature to systems used to track toll transponders, plate-scanning systems require no driver recruitment and can be implemented in areas with low transponder penetrations, especially rural areas.

  - o Cost to field test/deploy – Approximately $250,000. (The total cost depends on the level of deployment).
  - o Time Frame – Next twelve months.

- FDOT should monitor developments in the field of probe vehicle data collection and, as appropriate, cultivate partnerships with those businesses attempting to deploy wide-area data collection systems (i.e., phones as probes, telematics devices, and fleet management). Although these technologies may not currently be feasible for traffic data collection, that may change in the near future. Moreover, the existence of relationships with these entities would facilitate FDOT's participation in pilot tests of these technologies when appropriate. Specifically, FDOT should consider pursuing one of the following courses of action:

  - o Report on the issue to the ITS America CVO Committee, the ITS JPO, and/or the ATA to determine whether there is interest in pursuing the issue with Qualcomm; and
  - o Contact the Florida Trucking Association to see whether one or more carriers would be interested in conducting a pilot test using data on the movement of their vehicles received from Qualcomm or another fleet management service provider.

Appendix A

Details on the Relationship between Traffic Data Collection and ITS Architecture Market Packages

The following is a detailed summary of the relationship between traffic data collection and ITS architecture market packages.[5]

- Network Surveillance Market Package (ATMS01) – This market package includes traffic detectors, other surveillance equipment, the supporting field equipment, and wireline communications to transmit the collected data back to the Traffic Management Subsystem. The derived data can be used locally, as when traffic detectors are connected directly to a signal control system, or remotely, as when a CCTV system sends data back to the Traffic Management Subsystem. The data generated by this market package enables traffic managers to monitor traffic and road conditions, identify and verify incidents, detect faults in indicator operations, and collect census data for traffic strategy development and long-range planning. The collected data can also be analyzed and made available to users and the ISP Subsystem.

- Probe Surveillance Market Package (ATMS02) – This market package provides an alternative approach for surveillance of the roadway network. Two general implementation paths are supported by this market package:

  - Wide-area wireless communications between the vehicle and ISP are used to communicate current vehicle location and status; and

  - DSRC between the vehicle and roadside are used to provide equivalent information back to the Traffic Management Subsystem.

  The first approach leverages wide-area communications equipment that may already be in the vehicle to support personal safety and advanced traveler information services. The second approach utilizes vehicle equipment that supports toll collection, in-vehicle signing, and other short-range communications applications identified within the architecture. The market package enables traffic managers to monitor road conditions, identify incidents, analyze and reduce the collected data, and make it available to users and private information providers. It requires one of the communications options identified above, roadside beacons and wireline communications for the short-range communications option, data reduction software, and it utilizes wireline links between the Traffic Management and ISP Subsystems to share the collected information. Both “opt out” and “opt in” strategies are available to ensure the user has the ability to turn off the probe functions to ensure individual privacy. Due to the large volume of data collected by probes, data reduction

[5] The market package descriptions contained in this Appendix are taken from PBS&J’s *Draft Technical Memorandum No. 2 – ITS Needs Model: ITS Corridor Master Plans for Florida’s Principal FIHS Corridors*.

techniques are required in this market package that include the ability to identify and filter out-of-bound or extreme data reports.

- ETC Market Package (ATMS10) – This market package provides toll operators with the ability to collect tolls electronically and detect and process violators. Variations in the fees that are collected enable implementation of demand management strategies. DSRC between the roadway equipment and the vehicle is required as well as wireline interfaces between the toll collection equipment and transportation authorities and the financial infrastructure that supports fee collection. Vehicle tags of toll violators are read and electronically posted to vehicle owners. Standards, inter-agency coordination, and financial clearinghouse capabilities enable regional and ultimately national interoperability for these services. The population of toll tags and roadside readers that these systems utilize can also be used to collect road use statistics for highway authorities. This data can be collected as a natural by-product of the toll collection process or collected by separate readers that are dedicated to probe data collection.

- Virtual TMC and Smart Probe Data Market Package (ATMS12) – This market package provides for special requirements of rural road systems. Instead of a central TMC, traffic management is distributed over a very wide area (i.e., a whole state or collection of states). Each locality has the capability of accessing available information for assessment of road conditions. The package uses vehicles as smart probes that are capable of measuring road conditions and providing this information to the roadway for relay to the Traffic Management Subsystem and potentially direct relay to following vehicles (i.e., the automated road signing equipment is capable of autonomous operation). In-vehicle signing is used to inform drivers of detected road conditions.

- Transit Vehicle Tracking Market Package (APTS01) – This market package provides for an AVL system to track the transit vehicle's real-time schedule adherence and update the transit system's schedule in real-time. Vehicle position may be determined either by the vehicle through GPS and relayed to the infrastructure or may be determined directly by the communications infrastructure. A two-way wireless communications link with the Transit Management Subsystem is used for relaying vehicle position and control measures. Fixed-route transit systems may also employ beacons along the route to enable position determination and facilitate communications with each vehicle at fixed intervals. The Transit Management Subsystem processes this information, updates the transit schedule, and makes real-time schedule information available to the ISP Subsystem via a wireline link.

- Fleet Administration Market Package (CVO01) – This market package keeps track of vehicle locations, itineraries, and fuel usage at the Fleet and Freight Management Subsystem using a cell-based or satellite data link and the pre-existing wireless infrastructure. The vehicle has a processor to interface to its sensor (i.e., fuel gauge) and to the cellular data link. The Fleet and Freight Management Subsystem can provide the vehicle with dispatch instructions and can process and respond to requests for assistance and general information from the vehicle via the cellular data link. The market package also provides the Fleet Manager with connectivity to inter-modal transportation providers using the existing wireline infrastructure.

- Electronic Clearance Market Package (CVO03) – This market package provides for automated clearance at roadside check facilities. The roadside check facility communicates with the Commercial Vehicle Administration Subsystem over wireline to retrieve infrastructure snapshots of critical carrier, vehicular, and driver data to be used to sort passing vehicles. This package allows a good driver/vehicle/carrier to pass roadside facilities at highway speeds using transponders and DSRC to the roadside. The roadside check facility may be equipped with AVI, weighing sensors, transponder read/write devices, and computer workstation processing hardware, software, and databases.

Appendix B

Additional Information Concerning the Deployment of Traffic Probe Systems Using ETC Technology

The following contains additional information concerning the deployment of traffic probe systems using ETC technology.[6]

- TransGuide System (San Antonio, Texas) – The TransGuide probe surveillance system became operational in 1997 as part of San Antonio's ITS Model Deployment Initiative. The system augmented the 26-mile Texas Department of Transportation's loop detector system in the downtown San Antonio area that formed the core of the legacy Traffic Management System. The roadside devices are located at 54 locations covering 98 centerline miles. The probe surveillance system is intended solely for traffic data gathering, as no toll roads exist in the region. A website uses probe data and provides a system-wide speed map and capabilities to determine the trip time between two interchanges on the network. Travel times are now being automatically displayed on variable message signs (VMS) throughout the region as well. TransGuide software is available to public agencies under a free license from the Texas Department of Transportation. TransGuide software has been developed by Southwest Research Institute (SWRI) and operates on Sun computers in a Unix operating environment. Amtech deployed and maintains the field equipment in the system.

  Applying for tags is free and voluntary. As the vehicles pass by the tag reader field sites, the roadside antennas recognize the tags and report the tag reads to the data processing system located at the TransGuide Operations Center. The tag reads are reported using conventional modems over analog dial-up telephone lines. When a tag read arrives at the Operations Center, the automatic vehicle identification (AVI) data processing system records the tag data in the hash table associated with the site. Tag data is composed of a unique identifier and a time stamp of the read. Later, the tag passes by a second site resulting in its data being recorded in a second hash table. Every time the system reads new tag data, it scans adjacent sites for matching tag data. Tag reads need not arrive in time-order. When a match is found, the travel time and speed over the link is calculated. The tag identification number is scrambled and the system is not used to give speeding tickets or to track vehicles or drivers. By the spring of 2000, over 500,000 tags had been distributed.

- TranStar System (Houston, Texas) – Operational since 1993, the Houston area was the first to deploy a probe surveillance system for travel time calculations. The system encompasses approximately 130 sites throughout Houston. A map display that uses the system outputs is currently posted on the TranStar website and several governmental offices in the city. The website experiences over 400,000 hits per month. The system was not designed for and is not very suited to portability. Their main objective is to operate, maintain, and enhance the system to take into account new technology as well as adding additional features for incident management. TTI developed and maintains the processing software. Amtech deployed and maintains the field equipment in Houston. The original

[6] The information contained in this Appendix is taken from PBS&J's *Draft Technical Memorandum No. 3.2 – ITS Corridor Concept Plans for Florida's Principal FIHS Corridors*.

pilot distributed several thousand Amtech AVI tags to volunteers. These tags were placed behind the rear view mirror of vehicles. Since then, most of these tags have been replaced by those for toll roads in the region. The transponder tag is read by antennae/readers mounted on overhead roadway structures. As a car passes under the antennae/readers, time and location are recorded so that travel times and average speeds can be calculated. Field controllers transmit location, time, and tag identification information to a central processor. Software matches the tag identification numbers to determine which roadway segments the vehicle traveled. By knowing the link traveled and the beginning and ending time volumes, travel times can be determined. Special software was developed that would eliminate bad data. This software analyzes the data and removes anomalies such as extremely long or short travel times or travel between two non-adjacent points. The current system processes approximately one million tags per day. Many more reads occur but they are not processed. Dial-up phone lines are used to communicate data from the field to the central controller. Each of the field computers can hold information for fifty tags. The system encompasses approximately 130 sites throughout Houston.

- TRANSMIT (New York City, New York) – Operational since 1995, TRANSMIT is a system that began as an operational test to evaluate the use of AVI technology as an incident detection tool. The current system uses 22 reader locations and covers 19 miles of the New York Throughway and Garden State Parkway. TRANSMIT is currently under expansion as part of the TRIPS123 (formerly "iTravel") ITS Model Deployment Initiative. The expansion is both in coverage, including 200 miles of the New York metropolitan area, and functionality, including travel time determination. The expanded TRANSMIT was originally planned to be operational in 1997. It is now expected to become operational by the end of 2000. The Management Information System for Transportation (MIST) freeway management software is needed to utilize TRANSMIT. The system uses vehicles equipped with transponders as traffic probes. Mark IV Interagency Group tags and readers are used. Tag-equipped probe vehicles are assigned a random identification number as they enter a system populated with AVI readers spaced one kilometer apart. Software analysis is used to help identify:

  - Incidents;
  - Travel times; and
  - Speeds.

  When a vehicle does not arrive within a specified time (three standard deviations of the average travel time), the system records it and increases the confidence level on an incident thermometer. The more vehicles that are late or the longer the time the vehicles do not arrive, the higher the confidence level. When this level gets to a user-defined threshold, the system triggers an alarm alerting the operator that there may be an incident. The operator would then analyze the data and determine whether to call the Thruway or Parkway personnel to verify the incident at that location.

Appendix C

Additional Information Related to Probe Data Collection via the Tracking of Cell Phones

The following provides detailed descriptions of the different location solutions under development to meet the FCC's E-911 mandate:

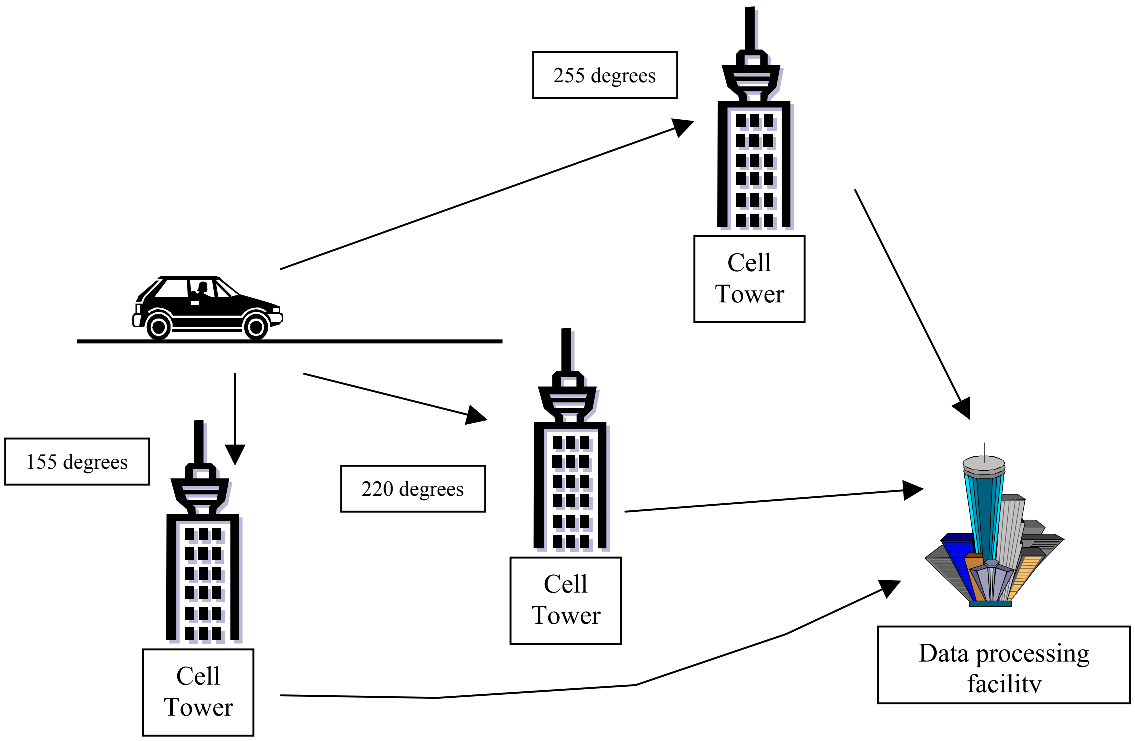
- Network-Based Solutions *(Figure C.1)*

    - AOA and TDOA – Both AOA and TDOA techniques rely on triangulation from multiple points in order to determine the location of a wireless device.

      TDOA – Utilizes an algorithm to pinpoint the location of the mobile phone by triangulating the time of arrival of the signal as seen by at least two cell sites. Typically, TDOA approaches the FCC's accuracy requirements only when three or more cell sites are used.

      AOA – Locates the mobile phone by measuring the angle that the phone's signal is received by two or more sites (requires the addition of specialized antennas to achieve accurate location measurements).

Figure C.1 – Network-Based Solutions

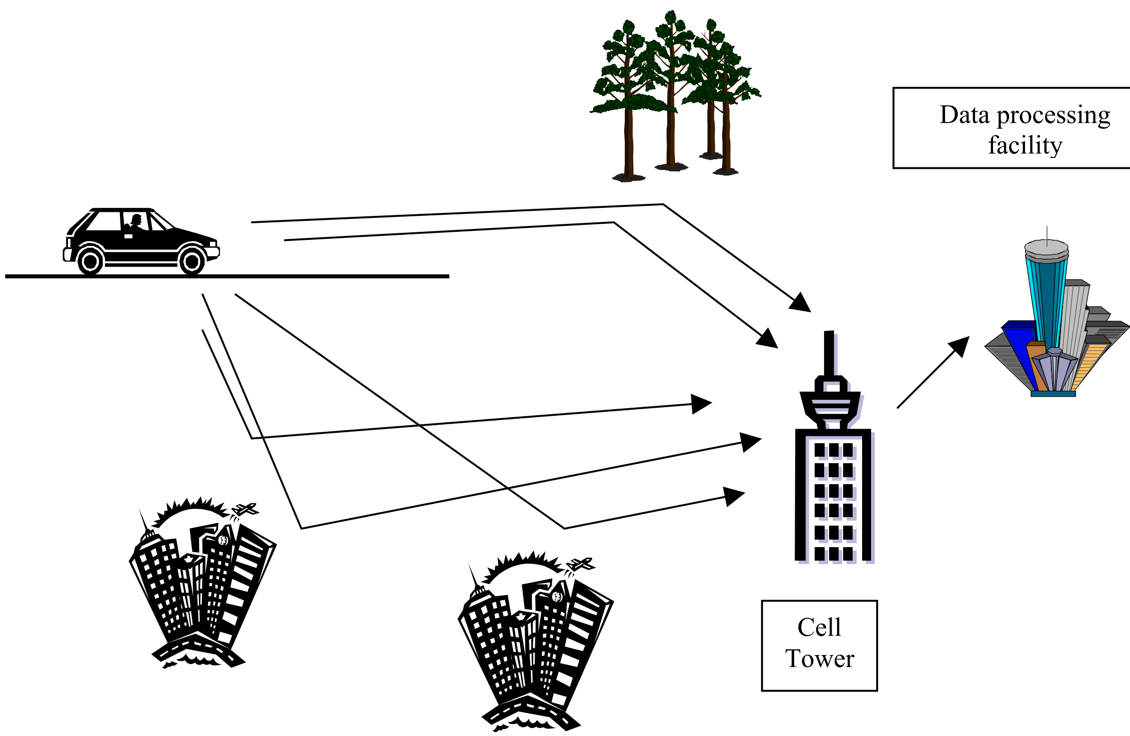


The above diagram describes the AOA method of locating a wireless caller. In this method, a call is placed from the handset. Nearby cell towers receive the caller's signal and determine the angle at which the signal is arriving at the tower. AOA equipment at the data processing facility combines the AOA data from at least two towers to determine the location from which the call originated.

TDOA works on a similar concept, except the system makes a determination of caller's location by differentiating between the times at which the caller's signal arrives at nearby cell towers instead of via an analysis of the angles at which the call is received by the nearby cell towers. Information from at least three towers is required for a high degree of accuracy.

- LPM, also referred to as the RadioCamera system, was developed by the US Wireless Corporation to address the challenges associated with geolocation in dense urban and sparse rural environments. In contrast with systems that locate wireless devices via triangulation of the cell phone signal from multiple points, LPM systems recognize the distinct patterns of incoming radio frequency (RF) signals that were previously logged into a reference database and associates them with the specific locations from which they originated.

Figure C.2 – US Wireless' RadioCamera Technology

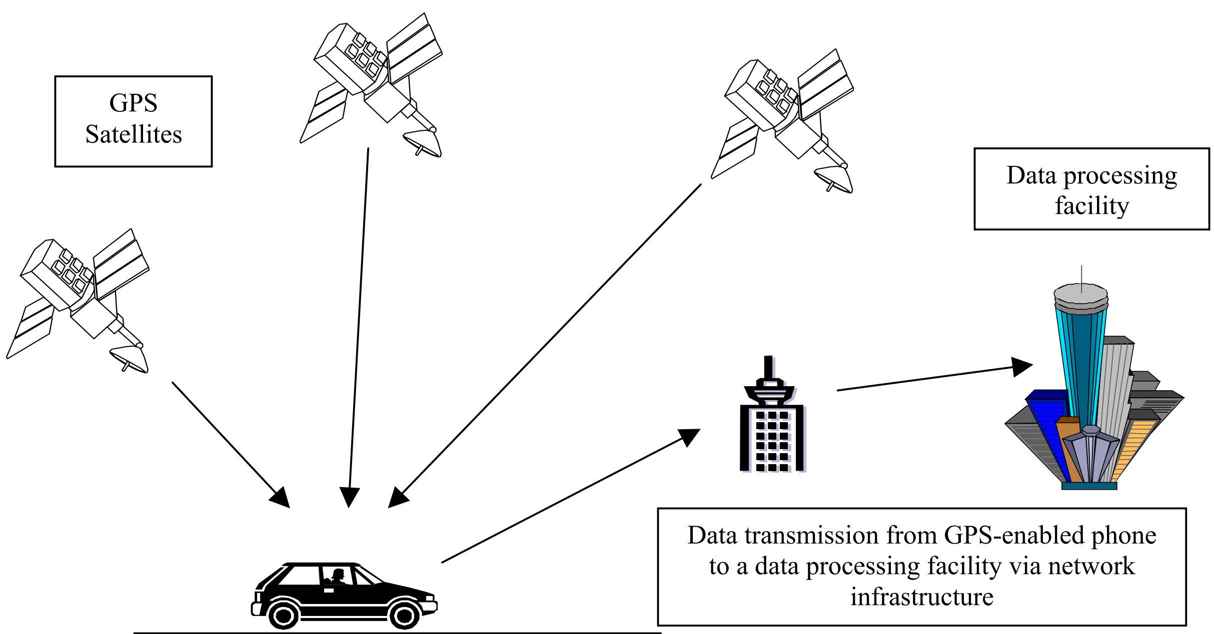


US Wireless' RadioCamera Technology locates a vehicle by examining how the signal being received at a cell phone tower has been altered by the buildings and natural features in the area from which it is being transmitted and comparing that modified signal with a database of what signals look like when emitted from different places within the service area. Other network-oriented cellular location technologies make use of systems that triangulate a cell phone's position by analyzing differences in the angle at which the signal arrives at different towers or the difference in the time when the signal arrives at different towers.

- Handset-Based Solutions

  o GPS-Oriented Handsets – This type of location technology requires the deployment of new handsets that have been integrated with GPS technology, thereby allowing existing GPS satellites to triangulate the handset's position and subsequently communicate that information to the receiver in the handset. This location information would then be transmitted to the network via the phone's cellular link.

Figure C.3 – GPS-Enabled Mobile Phone Technologies



Above is an example of how a GPS-enabled mobile phone would receive location information from a group of GPS satellites and then transmit that data to a central processing facility for the region via the cell phone towers that handle mobile phone transmissions.

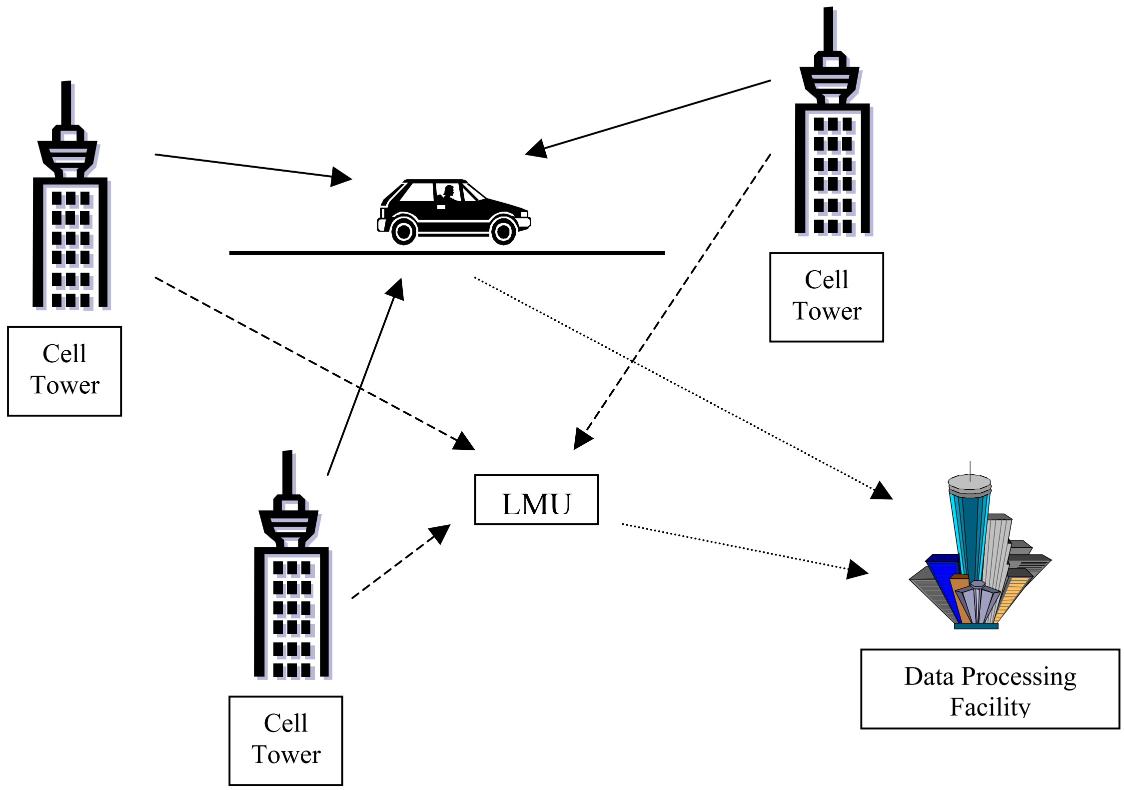
To overcome the deficiencies of more conventional GPS systems, a technique known as network-assisted GPS, or AGPS, has been developed. AGPS systems employ a stationary GPS server/receiver that has an unobstructed view of the sky and continuously monitors signals from all observable GPS satellites.

Whenever a GPS-enabled mobile phone requests information about its location, the AGPS server transmits current GPS satellite information through its radio link to the mobile. This information includes a list of observable GPS satellites and their orbital parameters as well as data that enables the mobile receiver to synchronize its receiver with transmissions from the satellites. This process provides the GPS receiver in the phone with enough information to make a location determination within a much shorter period of time than traditional GPS units. Within an AGPS system, wireless phones are not required to continuously track satellites' paths and signals and are, therefore, able to conserve battery power. Moreover, this technology raises mobile unit receiver sensitivity and allows it to acquire GPS signals inside most buildings.

Some AGPS systems also make use of an AGPS/Advanced Forward Link Trilateration (AFLT) hybrid method which utilizes pilot signals from base stations in place of signals from GPS satellites when only one or two are available for use by the GPS-enabled unit (i.e., one or two GPS satellites and one or two pilot signals from base stations to assist in locating the unit).

- A non-GPS handset based alternative utilizes E-OTD. The E-OTD positioning method measures the time at which signals from three network towers, called base transceiver stations (BTS) arrive at the mobile phone and a fixed measuring point known as the location measurement unit (LMU). Handset location is calculated at a central computer by comparing the time differences of arrival of the signals from each BTS at both the handset and the LMU.

Figure C.4 – E-OTD Location System Calculation



Above is an example of how an E-OTD location system calculates caller location at the data processing facility based on the comparison of time differences of arrival of the signals from each base station (cell tower) to the handset and the LMU (whose location is already known).

- Mobile Assisted Network Location System (MNLS) – This system is based on the mobile assisted handoff technology that is part of TDMA phone systems (a digital format for wireless services that allows more than one conversation on a channel at a time. Mobile assisted handoff is built into TDMA phones to enable them to measure and report signal strength from surrounding cell towers, thereby enabling the carrier's mobile switching center to decide which tower the call should be handed off to. The MNLS system matches the RF strength reported by the handset to a stored database of measured and predictive measurements to calculate the most likely position of the handset.

  Questions remain concerning whether MNLS technology will ever be able to provide location accuracy for distances greater than about 250 meters. This is because the signal strength measurements on which MNLS are based vary depending on conditions such as antenna position, fading, etc.

Appendix D

Summary of the CAPITAL Test to Use Cell Phones as Traffic Probes

The following is a summary of the Cellular APplied to ITS Tracking and Location (CAPITAL) test that used cell phones as traffic probes:

The CAPITAL Project was an ITS operational test conducted jointly by the FHWA, the Virginia Department of Transportation, the Maryland State Highway Administration (MSHA), Raytheon E-Systems (ES), Farradyne Systems Inc. (FSI), and Bell Atlantic NYNEX Mobile (BANM). The test was conducted over a 27-month period that ended in November 1995 in the Washington, D.C., area included I-66, I-495, and various state routes in the Virginia suburb. According to the Project's final report, "The CAPITAL project was undertaken to assess the viability of using cellular-based traffic probes as a wide-area vehicular traffic surveillance technique. From the test, cellular technology demonstrated the technical potential to provide vehicle speed and geolocation data that, under the proper circumstances, can provide additional information on freeway traffic conditions."

Sufficient data was not available to conduct a complete evaluation of the project's goals. However, the best analysis possible was performed with the following results:

- Geolocation Accuracy – The cellular telephones operating in the test area were geolocated to just over 100 meters on the last day of testing.

- Speed Estimation Algorithm – insufficient data collected.

- Incident Detection Algorithm – Incident detection was not acceptable because the algorithm was too sensitive to speed change, resulting in a high false alarm rate. Even so, almost all police-recorded incidents were identified by the system.

- CAPTIAL Final Recommendations – It was recommended that cellular-based surveillance systems be studied further as an alternative to more traditional types of traffic data collection, particularly as technological developments occur in geolocation and signal tracking/receiving technology.

Appendix E

Important Dates Related to Implementation of E-911 Wireless Location Service in the United States

The following important dates are related to the implementation of E-911 wireless location services in the United States:

- November 9, 2000 – The date for carriers to file E-911 Phase II implementation reports from ?????????? (originally October 1, 2000).
- October 1, 2001 – The date for carriers to begin selling and activating ALI-capable handsets (originally March 1, 2001).

For handset solutions, the following requirements have been established:

- December 31, 2001 – At least 25 percent of all new handsets activated are to be ALI-capable.
- June 30, 2002 – Fifty percent of all new handsets activated are to be ALI-capable.
- December 31, 2002 and thereafter – One hundred percent of all new digital handsets activated are to be ALI-capable.
- Once a PSAP request is received and within six months (or by October 1, 2001, whichever is later), the carrier shall:
  - Install any hardware/software necessary to enable provision of Phase II E-911 service; and
  - Begin delivering Phase II E-911 service to the PSAP.
- For handset-based solutions, the FCC has set an accuracy requirement of 50 meters for 67 percent of calls and 150 meters for 95 percent of calls.

For network-based solutions, the following requirements were established:

- As of October 1, 2001, within six months of a PSAP request for Phase II E-911 service, carriers employing network-based location technologies must have the ability to provide Phase II E-911 information for at least 50 percent of the PSAP's coverage area or population. Within 18 months of a PSAP request, carriers must be able to provide Phase II information for 100 percent of the PSAP's coverage area or population.

- For network-based solutions, the FCC has set an accuracy requirement of 100 meters for 67 percent of calls and 300 meters for 95 percent of calls.

The following is an update of the FCC's Phase II E-911 mandate enforcement from an FCC press release distributed on October 5, 2001:

The FCC has taken action in response to requests from several wireless carriers and one public safety agency regarding the timely deployment of wireless E-911 services. It conditionally approved, with certain modifications, the compliance plans of five nationwide carriers – Nextel, Sprint, Verizon, and the GSM portions of AT&T Wireless and Cingular's networks. It also said that the FCC Enforcement Bureau would be charged with enforcing wireless phone company deployment schedules to phase in these E-911 capabilities and taking enforcement action against non-compliant companies.

In response to a request by Richardson, Texas, the FCC also amended its rules to clarify the actions that need to be taken by 911 call centers in order to make a valid request for Phase I and II E-911 service.

The FCC's rules, adopted in 1996, after successful negotiation of a Consensus Agreement between wireless carrier and public safety representatives, were divided into two phases – Phase I and Phase II. Phase I rules require carriers, subject to certain conditions, to provide PSAP's with the telephone number of the originator of a 911 call and the location of the cell site or base station receiving a 911 call. Phase II rules require wireless carriers to begin providing more precise ALI, subject to certain conditions and schedules, and to complete the transition by December 31, 2005. Each carrier's precise method of achieving E-911 capability varies depending on whether they are employing a handset or network-based system for their ALI capability.

Specifically, the FCC has taken the following actions, approving plans to implement E-911 Phase II for the six nationwide wireless carriers (VoiceStream's implementation plan was approved in September 2000), which together serve more than 75 percent of the subscribers in the country.

- With respect to three companies (Nextel, Sprint, and Verizon) that had met FCC requirements to provide a clear, detailed, and enforceable plan to phase-in its ALI capabilities, the FCC agreed to take into account the companies' showings about equipment availability and allow them to implement Phase II E-911 according to a modified schedule for some of the initial 2001 and 2002 deployment milestones. It said it would strictly adhere to enforcement of these modified plans for meeting these alternative intermediate milestones and for completing E-911 deployment by 2005.

- With respect to two companies, AT&T and Cingular, that submitted E-911 compliance plans for the GSM portion of their wireless networks, the FCC provided similar relief, also conditioned on strict FCC enforcement of their new schedules.

- The FCC noted that while AT&T and Cingular had submitted compliance plans for the TDMA portion of their networks, the timing of those submissions did not permit FCC consideration. Accordingly, discussions have been initiated between these carriers and FCC Enforcement and Bureau staff concerning possible consent decrees with the FCC to resolve this compliance issue.

- To track carrier compliance with the revised schedules, the FCC imposed specific reporting requirements on the carriers regarding the implementation of both Phase I and Phase II of E-911. Carrier quarterly progress reports will be filed starting next year on February 1st, May 1st, August 1st, and November 1st.

- The FCC will conduct an on-going inquiry on E-911 technical issues, including the evaluation of reports and submissions by technology vendors, network equipment, and handset manufacturers and carriers concerning technology standards issues, the development of hardware and software, and supply conditions.

In addition to acting on the major carriers' requests, the Commission took the following actions:

- In response to a request from Richardson, Texas, the FCC amended its rules to clarify the actions that need to be taken by 911 call centers in order to make a valid request for Phase I and II E-911 service. This decision should reduce current uncertainties regarding the validity of various service requests by those centers. It should also help direct resources to deploying Phase I and II capabilities in communities that in fact are or will soon be ready to use the information to save lives, without imposing overly burdensome requirements on the public safety community or the local governments that support them.

- The FCC also established an additional period for carriers other than the six nationwide carriers to submit requests for relief in recognition of the challenges faced by many smaller and rural carriers. Any of these carriers who cannot comply with the FCC's E-911 deployment rules must file a petition seeking relief by November 30, 2001, if they do not already have such a request on file. Carriers are permitted to file jointly and, to the extent they believe they are facing similar deployment issues, are encouraged to do so. The FCC will evaluate the filings, including those already on file, and decide how best to address E-911 compliance by these carriers as soon as possible after this period. During this extended filing and evaluation period, the FCC will not initiate enforcement action under the E-911 Phase II rules against such carriers.

The FCC noted that under the plans approved today, with certain limited exceptions, these major carriers will be required to provide Phase II information to PSAP's that are ready to receive and utilize the information next year so they can honor all their valid PSAP requests by the end of the year. Also, these carriers will achieve complete deployment of Phase II, in full compliance with the FCC's accuracy standards, in all areas across the nation where 911 call centers are ready and able to use this information by the end dates in the existing FCC rules – i.e., no later than December 31, 2005.

The FCC also noted that despite the substantial progress to date, especially given the ground-breaking nature of these technologies, much remains to be done to achieve the FCC's fundamental goal of having wireless 911 Phase II capabilities deployed throughout the country. It stressed that all necessary participants – carriers, the public safety community, technology vendors, network equipment and handset vendors, local exchange carriers, and the FCC – must continue to work aggressively in the coming months and years to ensure the promise of this new life-saving technology becoming a reality.

Appendix F

Full Description of Choices Made by the Major Wireless Carriers Operating in Florida for Meeting FCC Phase II Requirements of the E-911 Location Mandate

Table F.1 – Full Description of Choices Made by Major Wireless Carriers Operating in Florida for Meeting FCC Phase II Requirements of the E-911 Location Mandate

	FCC requirement	Voicestream	Nextel	Cingular (a)	Cingular (b)	AT&T Wireless (a)	AT&T Wireless (b)	Verizon	Sprint	Alltel	US Cellular (a)	US Cellular (b)
Air Interface	---	GSM	iDEN (GSM-based)	GSM	TDMA/AMPS	GSM	TDMA	CDMA	CDMA	CDMA	CDMA	TDMA
Solution Type	---	E-OTD	AGPS	E-OTD	TDOA/AOA	E-OTD	TDOA/AOA	AGS/AFLT	AGPS/AFLT	AGPS	AGPS	AGPS
Interest in Traffic Data Collection using their E911 Network?	---	Not willing to talk about location services	Focused on implementation of E911 Phase II	Not at present	Not at present	Not willing to talk about location services	Unlikely	Possibly, but not near-term	**Yes**	No response	No response	No response
Location Solution Vendor	---	CPS ??	Snaptrack - Motorola ??	CPS ??	TruePosition	CPS ??	TruePosition or Grayson Wireless	Snaptrack or Lucent ??	Snaptrack and Qualcomm (handsets)	??	Snaptrack, Lucent, or Nortel ???	???
Scheduled Start Date	10/1/2001	10/1/2001	10/1/2002	10/1/2001	2000 cell sites by 12/31/02	40% network by 12/2001	12/31/2001	12/31/2001	10/1/2001	7/1/2002	12/31/2001	---
					full deployment by 2004/2005	full deployment by end 2002	full deployment by mid-2002					
Handset/Hybrid Solutions												
25% of new handsets	12/31/2001	---	12/31/2002 (10%)	12/31/2001	---	---	---	7/31/2002	---	9/30/2002	---	---
50% of new handsets	6/30/2002	---	12/31/2003	6/30/2002	---	---	---	3/31/2003	---	3/31/2003	5/31/2002	---
100% of new handsets	12/31/2002	during 2002	12/31/2004	9/30/2002	---	---	---	12/31/2003	12/31/2002	9/30/2003	2/31/2004	---
95% of all customers	12/31/2005	12/31/2005	12/31/2005	12/31/2005	---	---	---	12/31/2005	12/31/2005	12/31/2005	12/31/2005	---
Current Accuracy												
67%	50 meters	100 meters	50 meters	100 meters	---	100 meters	---	50 meters	50 meters	50 meters	50 meters	---
95%	150 meters	300 meters	150 meters	300 meters	---	300 meters	---	150 meters	150 meters	150 meters	150 meters	---
Accuracy Compliance Date	10/1/2001	10/1/2003	10/1/2002	10/1/2003	---	10/1/2003	---	12/1/2001	10/1/2001	3/31/2002	---	---
Network Solutions												
Accuracy												
67%	100 meters	---	---	---	100 meters #	---	100 meters #	---	---	---		
95%	300 meters	---	---	---	300 meters #	---	300 meters #	---	---	---		

\# - Cingular and AT&T have stated that although their selected location solutions may not currently provide this level of accuracy, the vendor has guaranteed that it will improve the solution's accuracy to this level over time.

Appendix G

Detailed Information about Wireless Carriers' Filings with the FCC Related to Wireless E-911 and the Testing of Various Location Solutions

The following is detailed information regarding wireless carriers' filings with the FCC related to wireless E-911 and the testing of various location solutions from vendors:

- Nextel Communications, Inc. [provider of specialized mobile radio (SMR) services using Motorola's iDEN handset/network technology] – As of November 9, 2000, Nextel decided to pursue implementation of a handset-based AGPS location technology developed by Motorola. Although Nextel's testing of this location technology took place utilizing CDMA handsets rather than those using its iDEN communications technology, Nextel indicates that using an AGPS technology should allow them to locate their subscribers within 50 meters 67 percent of the time and within 150 meters 95 percent of the time.

  Nextel outlined the following dates for deployment of the AGPS-enabled handsets:

  - Initial deployment on October 1, 2002; ten percent of all new iDEN handsets sold beginning on December 31, 2002;
  - Fifty percent of all new iDEN handsets sold beginning on December 31, 2003;
  - One hundred percent of all new iDEN handsets sold beginning on December 31, 2004; and
  - Ninety-five percent of Nextel's customer base by December 31, 2005;

  As Nextel's proposed deployment plan for ALI technology is behind that ordered by the FCC, they have submitted a request for waiver. This waiver is based upon the following stream of logic:

  - PSAP's must make significant changes to their networks and hardware before they will be able to use the ALI data provided by wireless service providers. Consequently, even if wireless service providers were ready to deploy ALI technology by the FCC's October 1, 2001, deadline, few PSAP's would actually be able to make use of it.

  - Deployment of an AGPS-based technology provides the most accurate solution. Nextel states that sacrificing long-term accuracy for the sake of a somewhat speedier deployment of less accurate technology will eventually deprive PSAP's and the general public of the maximum benefits of ALI services.

  - The FCC has already granted a waiver to Voicestream, who's "proposed system will provide meaningful public safety benefits and may be the only solution available for Global System for Mobile Communications (GSM)."[7] Nextel claims

[7] Nextel Communications Joint Report on Phase II Location Technology Implementation and Request for Waiver. Submitted to the FCC on November 9, 2000. CC Docket 94-102.

that as their iDEN technology is only provided by Motorola and Nextel is the only United States' market for iDEN location services, many technology vendors showed no interest in customizing their location technologies for iDEN.

- Motorola is still in the process of developing a prototype iDEN handset with AGPS technology that is not scheduled for completion till mid-2001 and then will require about 18 months of testing. Consequently, no location capable iDEN handset will be available until October 1, 2002. Moreover, due to the increased cost and size of the initial ALI capable handsets that Nextel puts on the market, they estimate that these sets will account for at most ten percent of all new activations. However, further refinements of the technology should allow Nextel to decrease the price of ALI capable handsets five to ten percent more than non-ALI capable handsets, thereby resulting in ALI-capable handsets making up a more significant portion of all new activations over the next few years. Nextel also states that the addition of location-oriented commercial features and the deployment of 3G telecommunications services will also enhance the desire of existing customers to switch to the new ALI capable handsets.

As part of its application for a waiver of the Phase II implementation dates laid out by the FCC, Nextel proposes to commit $25 million over two years to assist PSAP's in upgrading their facilities to use ALI information.

- Test Results

  - AGPS Solution – As indicated above, results of tests of the AGPS technology indicated that within the context of a CDMA system, this solution was able to locate 911 callers within 50 meters at least 67 percent of the time and 150 meters 95 percent of the time. (Please note that because the AGPS requires the integration of a unique chipset that does not yet exist and deployment of technology that will allow the transmission of location-assistance data from the wireless network which has not yet been implemented, the trial utilized only the GPS location capabilities of the handset without the network's assistance. At this time, Motorola has committed to developing an iDEN AGPS handset for deployment according to the timeline Nextel has laid out for the FCC.

  - Motorola iDEN E-OTD Solution – Although the iDEN communication technology is based on GSM, iDEN channels are one-eighth the size of GSM channels and the two systems use different air interfaces and timing mechanisms. As the air interface plays an important role in the location accuracy of E-OTD location solutions and the timing capabilities of GSM are more sensitive than those in iDEN, coupled with GSM's greater channel width) it was determined that iDEN is not highly suitable for an E-OTD overlay.

Motorola's simulation model testing estimated that the accuracy provided by an E-OTD solution for iDEN would be approximately 382 meters 67 percent of the time and 1,327 meters 95 percent of the time without the addition of significant infrastructure to enhance the timing synchronization at each cell site in the iDEN network. With these infrastructure additions, Motorola estimated that location accuracy would be 147 meters 67 percent of the time and 643 meters 95 percent of the time. Although Motorola and Nextel have not had an opportunity to test the most recent version of the E-OTD solution for iDEN, the above estimates are based on laboratory simulations.

Nextel also determined that aside from its inferior location capability, due to the fact that E-OTD performs its location measurement prior to connecting a call, the use of this technology would delay 911 calls by as much as three seconds.

- Network-Based Solution – Results of this field trial indicated that the best location capability it could provide was 120 meters 67 percent of the time and 442 meters 95 percent of the time. In addition to failing to meet the FCC's location accuracy requirements, the addition of equipment to cell sites and base station controllers would require time and effort that is simply not achievable within the six months the FCC has allotted to service providers to meet any PSAP request for ALI data.

- Nextel also tested the US Wireless multipath network solution. Findings indicate that it was able to locate the caller within 567 meters 67 percent of the time and in excess of 1,000 meters 95 percent of the time. However, Nextel staff was concerned about the need to add new tracking antennas to the existing network, something they see as being no small feat.

- Voicestream Wireless Corporation (provider of GSM wireless services) – As of November 9, 2000, Voicestream decided to pursue implementation of a two-pronged approach to meeting the FCC's Phase II E-911 requirements. The FCC has granted Voicestream a waiver of its handset accuracy requirement in order to allow this service provider to implement the network software solution (NSS)/E-OTD approach to ALI described below:

  - Implementation of an interim "safety net" solution, referred to as the NSS, using cell site identification and timing advance information to provide more accuracy than is required by Phase I cell site location capability – that is, an accuracy of 1,000 meters for 67 percent of all calls. At this time, NSS technology is on track for deployment during the fourth quarter of 2001 (deployed by Nortel, Erikson, and Nokia). Voicestream has suggested that this interim location technology will also serve a long-term purpose as a means of supporting 911 location services for all Voicestream subscribers using pre-E-OTD GSM phones, as well as all other roaming callers who dial 911 (regardless of handset type).

- To more fully meet the FCC's Phase II requirement, Voicestream plans to implement an E-OTD location solution, which is a hybrid of handset and network technologies. At this time, Voicestream plans to deploy both high end and low-end handsets. Although they expect delivery of commercial shipments by October 1, 2001, they plan for only limited deployment of this technology before next year due to delays in provision of E-OTD network equipment from their vendors (Nortel, Erikson, and Nokia).

- Testing Information – Testing carried out from October 4-6, 2000, using the proposed E-OTD location technology indicate that 67 percent of all calls will be locatable within 75.7 meters, 77.1 percent within 100 meters, and 98.3 percent within 300 meters.

- Cingular Wireless LLC [provider of PCS 1900 and TDMA (digital)/AMPS (analog) cellular services] – On November 9, 2000, Cingular outlined its plan for meeting Phase II of the FCC's E-911 ALI requirement. Its approach is broken up as follows:

  - PCS 1900 (GSM) Markets – Cingular plans to deploy an E-OTD location solution for its GSM markets.

  - TDMA/AMPS Markets – Cingular plans to deploy a network-based location technology (from TruePosition) for analog and TDMA markets. Cingular claims that this technology will be capable of location information for TDMA and AMPS subscribers, as well as roamers.

  On August 20, 2001, Cingular submitted a petition for limited waiver of the FCC's Phase II deadline. According to Cingular, granting of this waiver by the FCC would allow them to deploy TruePosition's network-based location technology on 2,000 of their cell sites in TDMA/AMPS markets during 2002. From that point forward, Cingular claims they will be able to deploy this Phase II location solution in accordance with FCC rules, with full deployment of this technology on Cingular's TDMA/AMPS networks by late 2004/early 2005.

  As of August 30, 2001, Cingular had not actually tested the current version of TruePosition's technology on a TDMA/AMPS network.

  - Testing Information

- TruePosition – According to AT&T, a test of TruePosition's location solution failed to meet the FCC's accuracy requirements. However, TruePosition claims that this test failed to utilize the most recent version of their technology. TruePosition currently claims that its improved location solution can locate TDMA callers within 100 meters in 67 percent of all cases and 190 meters in 95 percent of all cases.

- SnapTrack – In December 1999, Cingular tested SnapTrack's technology on a GSM network in Charlotte, North Carolina. A "backpack-based" system was used to conduct the test, because no GSM or TDMA handsets are currently available that make use of SnapTrack's AGPS technology. According to Cingular's report to the FCC, this technology worked well in outdoor environments, but worked very poorly in indoor tests.

- SigmaOne – In August and December of 2000, Cingular tested SigmaOne's TDOA/AOA equipment in a TDMA market. Overall results provided by SigmaOne indicated that the technology did not meet the FCC's accuracy requirements for network-based solutions.

- CPS – Between July and October of 2000, CPS carried out tests on the accuracy of its E-OTD location solution. These tests demonstrated that the CPS system was unable to locate an E-911 caller within the FCC's accuracy requirements.

- US Wireless – In August 2000, Cingular tested the US Wireless Multipath mapping technology in two TDMA markets. In areas calibrated for Multipath testing, the US Wireless system failed to meet the FCC's Phase II accuracy requirements. According to Cingular's report to the FCC, indoor testing was not possible.

- Polaris Wireless – Multiple tests of the Polaris location solution for Cingular's GSM network resulted in a final accuracy of 157 meters for 67 percent of all calls and 689 meters for 95 percent of all calls.

- US Cellular Corporation (USCC) – USCC is a predominantly rural provider of CDMA and TDMA digital wireless services. In its petition for waiver submitted to the FCC on September 10, 2001, USCC indicates that it plans to deploy a handset-based solution for its CDMA network and a MNLS hybrid solution for its TDMA network.

    o CDMA – In June 2001, USCC began preliminary work surrounding the identification of components necessary to support implementation of a handset solution for its CDMA networks. It has discussed development of a location solution with Snaptrack, Lucent, and Nortel. USCC plans to upgrade its CDMA network once Phase II-compliant GPS handsets become available.

Based on discussions with these vendors, USCC has laid out the following deployment schedule for Phase II on its CDMA network:

- Advanced purchase orders placed by December 3, 2001, to receive handsets for testing during the first quarter of 2002 and commercial sales commencing during the second and third quarters of 2002.
- Fifty percent of new handset sales are GPS capable – second quarter, 2002.
- One hundred percent new handset sales are GPS capable and 100 percent upgrade of existing subscribers to GPS cable phones – second quarter 2004.
- Full penetration of GPS capable handsets – December 31, 2005.

In their request for waiver, USCC also states that they need to make upgrades to their switching system in order for the handset-based phones to work. The vendors for this technology (Nortel and Lucent) indicate that the required software is scheduled for release during the fourth quarter of 2001.

- TDMA – Over three years (1998-2001), USCC initiated discussions with TruePosition, Grayson Wireless, and Cell-Loc concerning implementation of a TDOA location solution. However, they have been unconvinced that these technologies will provide the coverage necessary for their primarily rural customers (primarily due to a lack of cell site density).
- USCC also investigated US Wireless' multipath technology, but decided that although the RF "snapshot" should provide stable results when first deployed, frequent changes in the RF environment would likely lead to the database quickly becoming outdated.

Based on responses to USCC's request for a quote (issued April 25, 2001), USCC claims that vendors have failed to provide a solution for TDMA location requirements that USCC believes will work in a rural market. Moreover, USCC is currently planning to replace its TDMA system with a new air interface that it states will be Phase II compliant from the outset. In the interim, USCC plans to deploy a MNLS system that uses signal strength measurements to determine a phone's location. At present, USCC is awaiting a decision from Nortel concerning whether they will support USCC's efforts to deploy this solution. Although USCC admits that the

MNLS system does not yet meet the FCC's accuracy requirements, they claim that its functionality will improve as the location algorithm is improved.

- Verizon Wireless – In its petition for waiver submitted on July 25, 2001, Verizon Wireless requested permission to deploy an AGPS/AFLT handset solution for its CDMA and personal communications systems (PCS) networks. AFLT is a handset modification incorporating additional software that allows the handset to utilize pilot signals from cell sites in order to improve the handset's location accuracy. This additional application assists the handset in calculating its location in areas where sufficient GPS satellites cannot be located by the handset.

  Verizon has laid out the following schedule for deployment:

  - Begin deployment of the network assistance portion at switches and cell sites of the system by October 1, 2001, for markets using Lucent technologies, completing the upgrade by April 1, 2002. For Nortel technologies to complete the upgrade by August 30, 2002, deployments should begin January 1, 2002. For markets using the Motorola technology to complete upgrade by March 1, 2003, the deployment should begin November 1, 2002.

  - Begin sale of AGPS/AFLT Phase II compliant handsets by December 31, 2001.

  - Twenty-five percent of new handsets sold by July 31, 2002, are Phase II compliant.

  - Fifty percent of new handsets sold by March 3, 2003, are Phase II compliant.

  - One hundred percent of new handsets sold by December 31, 2003, are Phase II compliant.

  - Ninety-five percent of the existing customer base is Phase II compliant by December 31, 2005.

  Although Verizon's initial report to the FCC on its Phase II technology selection indicated that they planned to pursue a network-based solution, they have since determined that the AGPS/AFLT solution will provide the best location capability. Verizon is currently in the process of conducting preliminary tests of this technology, with test results expected in late September.

  In the interim, prior to handset deployment, Verizon plans to pursue two additional technologies to bridge the transition period. These include:

- o Installation of an interim network-based technology during the fall of 2001 in St. Louis, Missouri; Chicago, Illinois; and Houston, Texas.

- o Continued testing of Enhanced Forward Link Trilateration (EFLT) – A signal-strength, measurement-based technology that has demonstrated the ability to locate callers to an accuracy of 250-350 meters (with an average location accuracy of 300-350 meters for moving handsets). This technology will potentially be deployed in markets using Lucent and Nortel switches in addition to its AGPS/AFLT technology. Deployment of this technology should provide basic location information somewhere between that required for Phase I and Phase II for legacy handsets and non-Verizon CDMA caller's roaming on Verizon's network.

- Sprint PCS – In its petition for waiver dated July 30, 2001, Sprint requests that the FCC allow it to deploy an AGPS solution for its CDMA network. They state that by October 1, 2001, it will have taken a number of steps toward implementation of Phase II services, but will not be able to complete a national rollout of services.

  Sprint states that they will require four to five months to complete modifications to network infrastructures that will facilitate implementation of Phase II service.

  Sprint states that they will begin selling location-capable handsets by October 1, 2001, with 100 percent of all new handsets sold being GPS-compatible by December 31, 2002. However, due to scheduled conversion to 3G wireless technologies, they do not believe that they will meet the interim goals of 25 percent of all new handsets by December 31, 2001, and 50 percent of all new handsets by June 30, 2002.

  In their request for waiver of implementation deadlines, Sprint also states that they will be unable to estimate when they will be in full compliance with FCC rules until they have had an opportunity to test modifications to portions of their network infrastructure.

  As with most wireless service providers deploying AGPS service, Sprint plans to deal with legacy and roaming handsets by providing cell site information and ANI.

  - o Testing Information – Sprint and Lucent technologies have conducted joint tests to validate the accuracy of AGPS technology. These tests were conducted using Lucent and Qualcomm prototype mobile phones. The results of these tests indicate that the AGPS technology has an estimated accuracy within 27 meters for 67 percent of all calls in rural, suburban, and urban areas (99 meters for 95 percent of all calls) and within 51 meters for 67 percent of all calls in dense urban areas (107 meters for 95 percent of all calls).

- Alltel Communications, Inc. – In its petition for waiver dated July 25, 2001, Alltel requests that the FCC allow it to deploy an AGPS solution for its CDMA network. Alltel further asserts that the current unavailability of Phase II compliant AGPS equipment and software from various handset and network equipment vendors make it necessary to request a nine-month deferral for each of the implementation benchmarks set out by the FCC. (A portion of this delay is related to Alltel's lack of willingness to procure GPS capable handsets using current technology when it is their belief that 3G phones with integrated GPS chipsets will become commercially available in mid to late 2002.)

  - Testing Information

    - Network-Based Triangulation Solution – It was determined that rural areas with limited numbers of cell sites (primarily strings of pearls along roadways) would result in poor triangulation accuracy.

    - Network-Based Multipath Mapping – It was determined that such an approach would require extensive maintenance and testing, which would be difficult in rural areas with few phones.

    - Handset-Based Solutions (GPS and hybrid AGPS) – Although challenges exist in dense urban areas, this solution provides widespread coverage and fewer infrastructure modifications, thus allowing for a more centralized approach to operations.

- AT&T Wireless Services, Inc. – In its petition for waiver dated April 4, 2001, AT&T Wireless (AWS) indicated plans to deploy a handset-based hybrid E-OTD solution on its GSM network and a second hybrid handset-based technology, MNLS, on its TDMA network, which it eventually plans to overlay and replace with its GSM network in order to provide customers with higher speed data capabilities and a wider array of mobile devices. However, due to concern expressed by the public safety community concerning the accuracy of MNLS, on September 17, 2001, AWS revised its waiver filing in order to seek permission to deploy a TDOA/AOA location solution on its TDMA network.

  While AWS admits that the E-OTD solution does not currently meet the FCC's accuracy requirements, they claim that the technology will eventually exceed the FCC's accuracy requirements and therefore require a waiver during the interim period. AWS expects to complete deployment of the GSM solution across 40 percent of its network by the end of 2001 and across its entire network by 2002. Testing indicates that E-OTD should initially be able to locate GSM users within 100 meters 67 percent of the time and 300 meters 95 percent of the time. AWS has also set a goal of refining this technology to meet the FCC's accuracy requirements for handset-based solutions of 50 meters 67 percent of the time and 150 meters 95 percent of the time by October 1, 2003.

With regard to the AWS's TDMA network, the company continues to assert that MNLS technology deployment would have begun by the end of 2001, with system-wide implementation by the end of the first quarter of 2002. Although MNLS also fails to meet the FCC's requirements for network-based solutions (299 meters for 67 percent of calls and 703 meters for 95 percent of calls in the Denver Field Tests; 290 meters for 67 percent of calls and 606 meters for 95 percent of all calls in Redmond; and 301 meters for 67 percent of calls and 708 meters for 95 percent of all calls in Bellevue), AWS states that this is comparable to the accuracy demonstrated by other network-based solutions. MNLS does not work with analog phone systems due to interference.

In their September 17 filing, AWS states that they will work with their selected location vendor (either TruePosition or Grayson Wireless) to deploy E-911 services in jurisdictions with current Phase II implementation requests (about 1,600 cell sites) by December 31, 2002. After this date, AWS states that they will be able to deploy Phase II technology within six months of any new PSAP requests.

Appendix H

Geographic Coverage of Wireless Carriers Operating in Florida

Figure H.1 – Coverage for AT&T

Home Calling Area
When placing or receiving calls in this area, home airtime rates apply. Long distance charges for international calls will apply.

Roaming Area
For the Local Calling Plan, make and receive calls in the U.S. for 85¢ per minute where service is available. Roaming in the U.S. is included in the National Calling Plan. Long distance charges for international calls will apply.

AT&T Digital PCS Features Area
Your Digital PCS features are available including Extended Battery Life, Message Waiting Indicator and in certain areas, AT&T Text Messaging service and AT&T Caller ID.

No Wireless System
No wireless system constructed in this area.

This map is a general representation of wireless coverage, and the areas shown are approximate. Actual coverage depends on system availability and system capacity, system repairs and modifications, customer's equipment, terrain, signal strength, weather and other conditions.

Figure H.2 – Coverage for Cingular

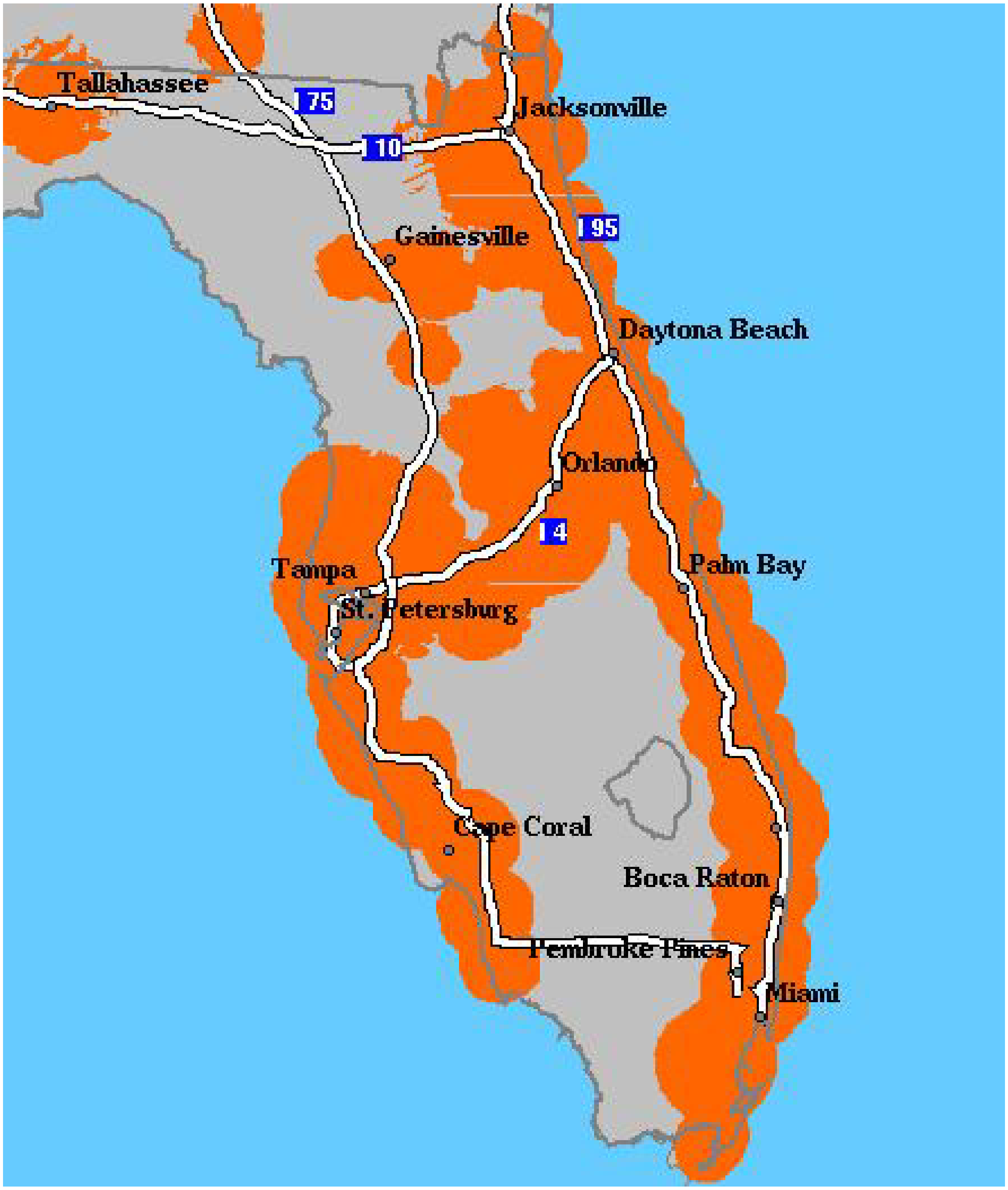


Figure H.3 – Coverage for Nextel

Figure H.4 – Coverage for Verizon

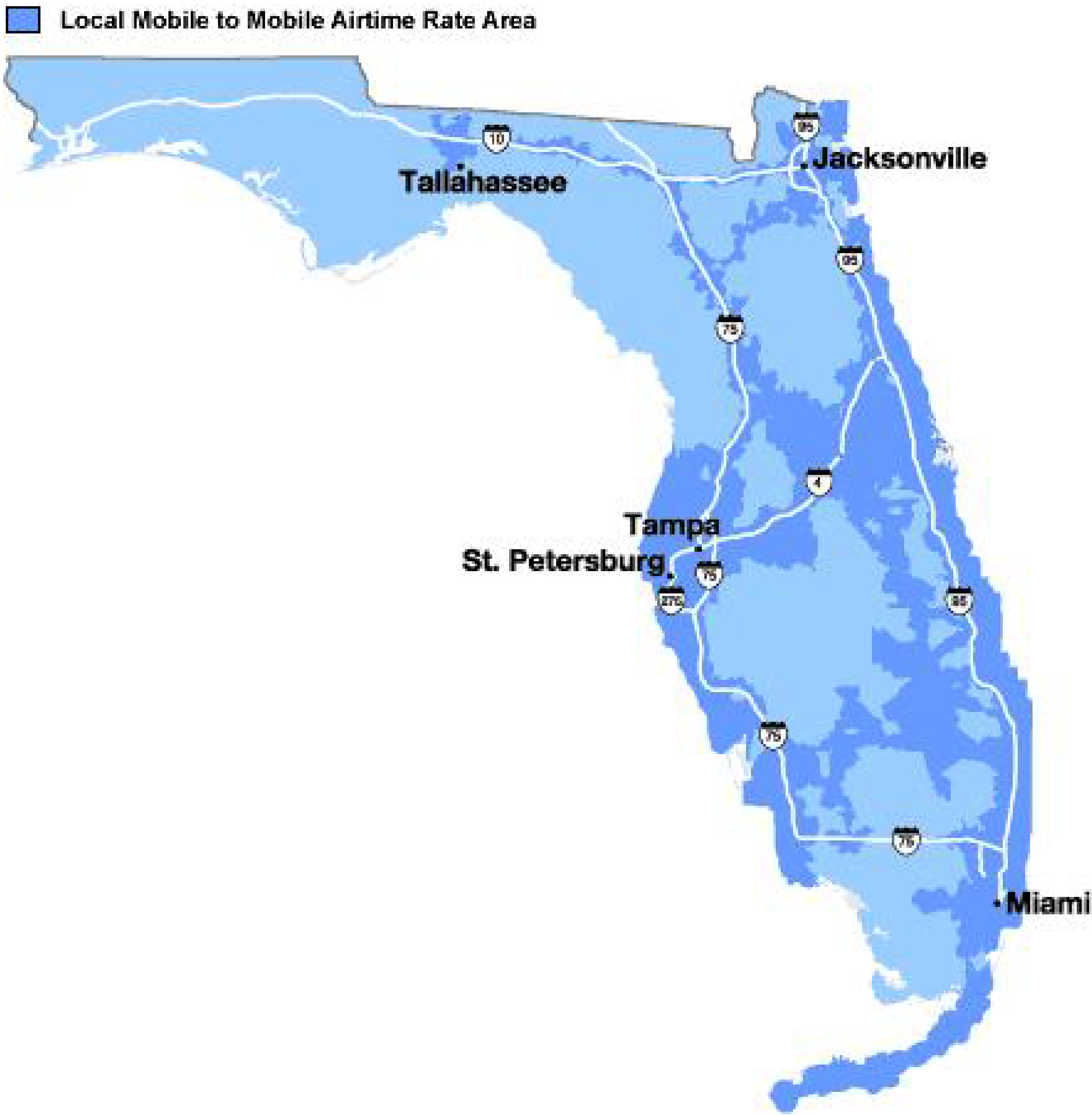


Figure H.5 – Coverage for Voicestream

Figure H.6 – Coverage for Sprint: Central Florida

Figure H.7 – Coverage for Sprint: Northern Florida

Figure H.8 – Coverage for Sprint: Panhandle

Figure H.9 – Coverage for Sprint: Southern Florida

Although we have been unable to locate coverage maps for Alltel and US Cellular, we have been able to piece together lists of the counties in which they currently provide service.

- Alltel
  - Alachua
  - Bay
  - Calhoun
  - Citris
  - Dixie
  - Gadsen
  - Hamilton
  - Jefferson,
  - Leon
  - Marion
  - Okaloosa
  - Putnam
  - Wakulla

  The following systems were recently acquired from GTE Wireless:

  - Charlotte
  - Citrus
  - Collier
  - DeSoto
  - Hardee
  - Hendry
  - Hernando
  - Highlands
  - Hillsborough
  - Jefferson
  - Lee
  - Manatee
  - Pasco
  - Pinellas
  - Polk
  - Sarasota
  - Sumter
  - Walton

- US Cellular

  - Alachua
  - Bradford
  - Calhoun
  - Dixie
  - Franklin
  - Gasden
  - Gulf
  - Holmes
  - Jackson
  - Jefferson
  - Leon
  - Liberty
  - Putnam
  - Wakulla
  - Walton
  - Washington

  The following were recently acquired from Larsen Cellular:

  - Columbia
  - Hamilton
  - Suwannee
  - Union

Appendix I

References

References

Abernathy, B. and Kolcz, A. "I Saw What You Did…" *Traffic Technology International*. August/September 2000: 62-66.

Apogee Research, Inc. (1997*) Intelligent Transportation Systems - National Investment and Market Analysis.* Prepared for ITS America and U.S. Department of Transportation.

Berka, S. and Lall, B. "New Perspectives for ATMS: Advanced Technologies in Traffic Detection." *Journal of Transportation Engineering.* January/February 1998: 9-15.

Black, J. (1997) "Inductive Loop Detectors." From website located at www.path.berkeley.edu/~leap/TTM/Incident_Manage/Detection/loopdet.html

Booz-Allen and Hamilton. (2000) *Telematics: Lessons Learned from International Experiences.*

Bray, H. "Something to Watch Over You." Boston Globe. January 22, 2001.

Driscoll, C. (1998) "Wireless Caller Location Systems." From website located at http://www.gpsworld.com/1198/1198driscol.html

Edozien, F. "Traffic Jam of Bills to Restrict Car Phones." *New York Post*. December 20, 2000.

Fall Creek Consultants. (1999) "Wireless Location Services - E911." From website located at http://www.comm-nav.com/tech.htm.

Federal Communications Commission Website (www.fcc.gov). Submissions and Comments Surrounding Docket No. 94-102 – Issues Related to the FCC's Phase II E911 Mandate.

Fitzgerald, A. (2001) *GM's OnStar Expands Traffic Updates to 70 Areas*. www.auto.com (10/18/01)

Goodman, M. and Bents, F. (1997) *An Investigation of the Safety Implications of Wireless Communications in Vehicles*. Prepared by the National Highway Traffic Safety Administration of the U.S. Department of Transportation

Hadi, M. (2001) *Draft Technical Memorandum No. 3.2: ITS Corridor Concept Plans for Florida's Principal FIHS Corridors*. Prepared by PBS&J for the Florida Department of Transportation.

Hall, R. and Vyas, N. (1999) *Evaluation of the OCTA Transit Probe Systems*. Department of Industrial and Systems Engineering, University of Southern California.

Hallenbeck, M. (1998) *Choosing the Route to Traveler Information Systems Deployment*. Prepared by ITS America for the U.S. Department of Transportation.

ITS America and the U.S. Department of Transportation. (2000) *Closing the Data Gap: Guidelines for Quality ATIS Data*.

Juliussen, E. and Magney, P. (2001) *Telematics: Technologies, Trends, and Markets: Market Analysis, Forecast, Strategy, and Perspectives on the Emerging Telematics Industry*. Telematics Research Group.

Kelley, T. "Traffic Data Unplugged." *ITS World*. July/August 2000: 28-30.

Klein, L. (1997) "Vehicle Detector Technologies for Traffic Management Applications." From website located at http://www.itsonline.com/detect_pt1.html.

Lappin, J. (2000) *Advanced Traveler Information Services - What do ATIS Customers Want?* Prepared by the Volpe National Transportation Systems Center and EG&G Services.

Levinson, D., D. Gillen, and E. Chang. (1999) *Assessing the Benefits and Costs of Intelligent Transportation Systems: The Value of Advanced Traveler Information Systems*. Institute for Transportation Studies: University of California, Berkeley.

Lobo, A. "A Review of Automatic Vehicle Location Technology and its Real Time Applications." *Transport Reviews*. Vol. 18(2): 170-175.

Margiotta, R. (1998) *ITS as a Data Resource: Preliminary Requirements for a User Service*. Prepared by Science Applications International Corporation for the Federal Highway Administration.

Middleton, D., D. Jasek, and R. Parker. (1999) *Evaluation of Some Existing Technologies for Vehicle Detection*. Texas Transportation Institute: College Station, TX.

Mouskos, K., E. Niver, and L. Pignataro. (1998) *Transmit System Evaluation - Final Report.* Prepared by the Institute for Transportation - New Jersey Institute of Technology: Newark, NJ.

Mudge, R. "Cell Phones as Data Probes: Background and Recent US Wireless Experience." From PowerPoint presentation made on September 26, 2000. Prepared by US Wireless.

National Emergency Number Association (2000) *Wireless Phase II Matrix*.

Orski, K. "Transitory State." *Traffic Technology International*. Dec.2000- Jan.2001: 49-51.

PBS&J (2001) *Mobility Performance Measures: Needs, Issues, and Opportunities - An Issue Paper on the Possible Future Directions for the Mobility Performance Measures Program*. Prepared for Kittelson and Associates, Inc.

Pearce, V. and Subramaniam, S. (1998*) Incident Management: Detection, Verification, and Traffic Management*. Prepared by Booz-Allen & Hamilton.

Pretorius, P. and Markowitz, J. (2000) *ATIS Data Collection Guidelines Workshop - Show Me the Data.* Prepared by Kimley-Horn & Associates for the Metropolitan Transportation Commission - Oakland, California.

Probe Data Collection Phase 1 – Concept Study: Final Report (2000) Prepared by PBS&J for the Orlando-Orange County Expressway Authority.

Radin, S., S. Basev, and J. Lappin. (2000*) ATIS: Private Sector Perceptions and Public Sector Activities*. Prepared by the Volpe National Transportation Systems Center and EG&G Services.

Rappaport, T. J. Reed, and B. Woerner. "Position Location Using Wireless Communications on Highways of the Future." *IEEE Communications Magazine*. October 1996: 33-41.

Schuman, R. "Traveler Information - What to Do and How to Do It: A Public Agency Quandary." *ITS Quarterly*. Spring/Summer 1999: 13-21.

Schuman, R. and D'Angelo, M. (2000) *ATIS Data Collection Guidelines Input*. Prepared by PBS&J.

Science Applications International Corporation. (2000) *Automated Vehicle Identification Tags in San Antonio: Lessons Learned from the Metropolitan Model Deployment Initiative*. Prepared for the U.S. Department of Transportation.

Shaw, T. (2001) *Draft Technical Memorandum No. 2 – ITS Needs Model*. Prepared by PBS&J for the Florida Department of Transportation.

Shaw, T. (2001) *Draft Technical Memorandum No. 3.3 – ITS Corridor Master Plans for Florida's Principal FIHS Limited-Access Corridors*. Prepared by PBS&J for the Florida Department of Transportation.

Sipress, A. "Big Brother Could Soon Ride Along in the Back Seat." *Washington Post.* October 8, 2000.

Sipress, A. "Cell Phones Will be Used to Monitor Traffic." *Washington Post*. December 22, 1999.

Smith, B. and Lovell, B. (2001) *Transportation Management Applications of Anonymous Mobile Call Sampling*. Research project of the Universities of Virginia and Mayland.

SnapTrack. (no date) "SnapSmart." Technical product brochure.

Stilip, L. (1999) "Examining the Coming Revolution in Location Services." From website located at http://www.trueposition.com/forum.htm.

Sussman, J. (2000) "What Have We Learned About ITS? A Synthesis." Chapter 1 *in What Have We Learned About Intelligent Transportation Systems?* U.S. Department of Transportation.

Transportation Research Board - National Research Council. (1997) *AVL Systems for Bus Transit*. TCRP Synthesis 24.

Turner, S., W. Eisele, and R. Benz. (1998) *Travel Time Data Collection Handbook*. Texas Transportation Institute: College Station, TX.

UBS Warburg (2001) *United States Traffic Data Market*.

US Wireless - Year 2000 Annual Report. Released on June 29, 2000.

Weatherford, M. (2000) *Assessment of the Denver Regional Transportation District's Automatic Vehicle Location System.* US DOT – Volpe Center, DOT-VNTSC-FTA-00-04.

Yim, Y. and Cayford, R. (2000) *Investigation of Vehicles as Probes Using GPS and Cellular Phone Tracking*. California PATH Working Paper, UCB-ITS-PWP-2001-9.

Zenios, M. "Telematics, the Future is in the Car." *ITS World*. January/February 2000: 26-29.

Zhao, Y. "Mobile Phone Location Determination and Its Impact on Intelligent Transportation Systems." *Intelligent Transportation Systems (IEEE).* March 2000. Volume(1): 55-64.