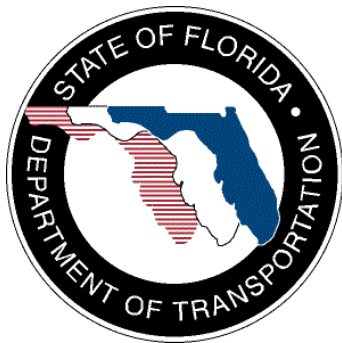


Technical Memorandum

Innovative Data Collection Research Project

Update on the State of the Innovative Traffic Data Collection Industry

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Final Version



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Table of Contents

List of Acronyms	3
1. Introduction	6
1.1 Point versus Probe-based Data Collection	7
1.2 Distinction between Probe-based Systems	8
1.2.1 Infrastructure-based Link Sensing	8
1.2.2 Remote Vehicle Monitoring.....	9
2. Probe-Based Data Collection Systems	11
2.1 Remote Vehicle Monitoring Systems	11
2.1.1 Cell Phone Location-based Systems	11
2.1.1.1 Individual Cell Phone Location Companies	12
2.1.1.2 Other Research	15
2.1.1.3 General Conclusions about Cell-Phone Based Data Collection Systems.....	22
2.1.2 GPS-based Probe Systems.....	24
2.1.2.1 Entities Involved in GPS-based Tracking.....	24
2.1.2.2 General Conclusions about GPS-based Tracking Systems.....	32
3. Infrastructure-based Link Monitoring Systems	32
3.1 Telematics – i.e., Vehicle Infrastructure Integration (VII) Initiative-like Systems	32
3.1.1 Overview of Technology	32
3.1.2 Entities Involved In VII-like Programs	33
3.1.2.1 Vehicle Infrastructure Integration Consortium (VIIC)	33
3.1.2.2 Car2Car Communication Consortium (C2C CC)	34

- 3.1.2.3 General Motors 36
- 3.2 General Conclusions about VII-like Programs 37**
- 4. Toll-tag and License Plate Reader-based (LPR) Data Collection Systems 37**
- 4.1 Overview of Technology..... 37**
- 4.1.1 Toll-Tag Based Systems..... 37
- 4.1.2 License Plate Reader Based Systems..... 39
- 4.2 General Conclusions about Deployment of Toll-Tag and License Plate Reader-based (LPR) Data Collection Systems 41**
- 5. Technology and Business Innovations in Traditional Data Collection Technologies.....41**
- 5.1 New types of Point Sensors..... 42**
- 5.1.1 Sensys Networks 42
- 5.1.2 MOTES Technology (Experimental Technology) 43
- 5.2 Extensively Available CCTV Video Feeds..... 45**
- 5.2.1 TrafficLand..... 45
- 5.3 Business Model Innovations..... 48**
- 5.3.1 SpeedInfo 48
- 5.3.2 Traffic.com (Mobility Technologies) 49
- 6. Final Conclusions and Recommendations51**

List of Acronyms

ALPR.....	Automated License Plate Recognition
AOA.....	Angle of Arrival
ATMS	Advanced Traffic Management System
ATRI.....	American Transportation Research Institute
AVI	Automatic Vehicle Identification
C2C CC.....	Car2Car Communication Consortium
CFVD	Cellular Floating Vehicle Data
CCTV	Closed Circuit Television
CVO	Commercial Vehicle Operations
DfT	Department for Transportation
DOT.....	Department of Transportation
DSRC.....	Dedicated Short Range Communications
EDMap.....	Enhanced Digital Map
ETC.....	Electronic Toll Collection
FCC.....	Federal Communication Commission
FDOT	Florida Department of Transportation
FHWA.....	Federal Highway Administration
FIU	Florida International University
FPM.....	Freight Performance Measures
FVD	Floating Vehicle Data
GDOT.....	Georgia Department of Transportation
Georgia Tech	Georgia Institute of Technology
GM	General Motors

Technical Memorandum — IDC Research
Update on the State of the Innovative Traffic Data Collection Industry

GPS.....	Global Positioning System
IDC	Innovative Data Collection
ITN	Invitation to Negotiate
IVI.....	Intelligent Vehicle Initiative
KDOT	Kansas Department of Transportation
LOS	Levels of Service
LPM.....	Location Pattern Matching
LPR	License Plate Reader
Mn/DOT.....	Minnesota Department of Transportation
MoDOT.....	Missouri Department of Transportation
MPH	Miles Per Hour
OCR	Optical Character Recognition
OOCEA	Orlando-Orange County Expressway Authority
PTFM	Passive Target Flow Measurement
RDS-TMC.....	Radio Data System-Traffic Message Channel
TDOA	Time Difference of Arrival
TERN	Trans European Road Network
TTI.....	Texas Transportation Institute
TTID	Transportation Technology Innovation and Demonstration Program
UC Berkeley	University of California at Berkeley
UDOT	Utah Department of Transportation
UK.....	United Kingdom
USDOT.....	United States Department of Transportation
V2V	Vehicle-to-Vehicle

Technical Memorandum — IDC Research
Update on the State of the Innovative Traffic Data Collection Industry

VDS..... Video Distribution System
VII.....Vehicle Infrastructure Integration
VIIC Vehicle Infrastructure Integration Consortium
Virginia TechVirginia Polytechnic Institute and State University
VSC..... Vehicle Safety Communications
WisDOT..... Wisconsin Department of Transportation

1. Introduction

Traffic data collection has traditionally been performed by public agencies charged with managing traffic flow, responding to incidents, carrying out planning activities, and maintaining the roadway. The traditional techniques deployed include inductive loop detectors, closed-circuit television (CCTV) cameras, 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 freeways and important arterials, thereby limiting its usefulness for operations and management purposes.

Nevertheless, recent advances in wireless communications and sensor technology have resulted in increased private sector interest in the development of innovative traffic data collection solutions. Based on these innovations, opportunities have begun to appear for public sector agencies to more cost effectively complement and, in some cases, replace traditional traffic data collection infrastructure. More importantly, the existence of these technologies may, over the near- to mid-term, result in a shift in the role played by the private sector from that of simple equipment vendor to provider of data products and services, reducing the public sector's need to invest in and deploy certain types of data collection infrastructure. The extent to which this occurs will depend upon the ability of these technologies to provide direct measurement of new performance metrics (e.g., roadway travel times), as well as support more traditional data collection needs (e.g., traffic volumes), along with the willingness of transportation agencies to explore alternative business models.

During 2001, the Florida Department of Transportation (FDOT) commissioned a research study on the current level of innovation in the traffic data collection industry. Since that time, significant changes have occurred within this industry, with a number of entities now promising to put disruptive technologies and/or business models into play that will revolutionize the manner in which data is collected.

The purpose of this memorandum is to provide an updated analysis on the state of the industry, focusing on two primary areas:

- Probe-based systems
 - Cell phones as probes
 - Global positioning system (GPS)-based probes, including fleet management systems
 - Toll tag and license plate reader (LPR)-based data collection systems

- Telematics, such as Vehicle Infrastructure Integration (VII) initiative-oriented systems¹
- Technology and business innovations in traditional data collection technologies
 - New types of point sensors
 - Extensively available CCTV video feeds
 - Other sensor-technologies

This analysis is not intended as an “either/or” assessment of traditional data collection versus innovative data collection (IDC). Rather, it is intended to characterize the relative attractiveness of these methods for use in Florida and to provide recommendations for further activities as may be appropriate.

The research methodology used as part of the development effort associated with this memorandum included the collection of information via the following avenues:

- The representatives of each entity listed in this memorandum were contacted.
- Existing research concerning each entity/product listed in this memorandum was reviewed.
- Additional Internet research concerning each entity/product listed in this memorandum was conducted.

1.1 Point versus Probe-based Data Collection

Point sensor-oriented traffic data collection systems monitor traffic conditions at individual points along a roadway, generating instantaneous (point) speeds at instrumented locations. Data from multiple point sensors can subsequently be run through specialized algorithms to determine estimated speeds and travel times along that section of road. 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 times and average speed estimates such systems produce.

Probe-based data collection applications utilize vehicle identification technologies to track vehicles as they pass predetermined points within a network of roadways. By knowing the length of the link of roadway traveled by the probe vehicle, and the beginning and end times at which travel on that link took place, a travel time can be computed for each probe vehicle.

¹ More information regarding the United States Department of Transportation’s VII initiative is available online at <http://www.its.dot.gov/VII/>.

1.2 *Distinction between Probe-based Systems*

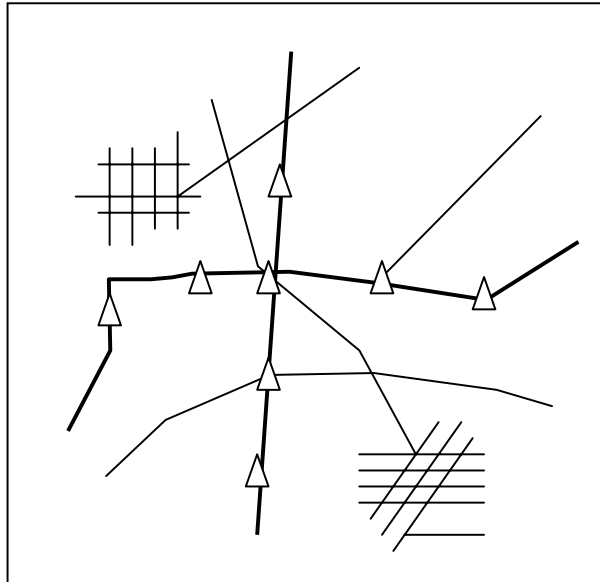
For the purpose of this study, probe-based data collection technologies are divided into two groups, those requiring the support of roadside infrastructure and those that do not. Examples of each include the following:

- Probe-based systems requiring roadside infrastructure (i.e., infrastructure-based link sensing)
 - Toll tag and LPR-based data collection systems
 - Telematics, such as VII initiative-oriented systems
- Probe-based systems not requiring roadside infrastructure (i.e., remote vehicle monitoring)
 - Cell phones as probes
 - GPS-based probes, including fleet management systems

1.2.1 *Infrastructure-based Link Sensing*

Link sensing applications utilize vehicle identification technologies to track vehicles as they pass instrumented points within a network of roadways. (Refer to Figure 1.1.) 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 along that link took place, the travel time for that link can be determined. As a result, the collection of data concerning a given section of road requires the installation and maintenance of roadside infrastructure, potentially resulting in many of the same infrastructure costs associated with the use of more traditional detection equipment, such as loop detectors.

Figure 1.1 — Link Sensing Infrastructure

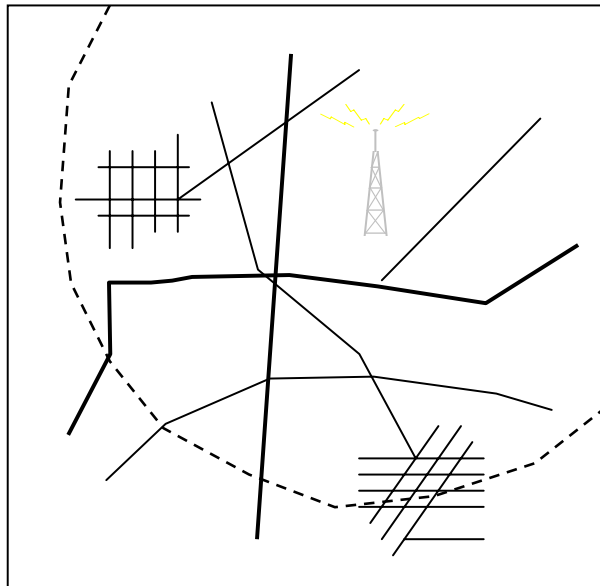


Δ = Sensor (i.e., toll tag or LPR, loop detector, VII data hub, etc.)

1.2.2 Remote Vehicle Monitoring

In contrast to link sensing applications, remote vehicle monitoring systems are designed to collect data for sections of a road network from a single, centralized location, such as a nearby cell tower. (Refer to Figure 1.2.) As all vehicles and roads within broadcast range of the tracking infrastructure have the potential to be monitored from that single location, the decision to add roads to the list of those under surveillance may involve only marginal additional costs, primarily related to the processing of the data at the managing entity's operations center. As a result, this technology could avoid many of the linear investments associated with more traditional traffic collection infrastructure investments.

Figure 1.2 — Remote Vehicle Monitoring Infrastructure



The dotted line indicates the area potentially covered by the remote vehicle monitoring system (e.g., based on the collection of data from cellular phones).

One caveat connected with this classification system concerns VII-oriented systems. If deployed as per existing proposals, VII-based systems would likely require significant roadside infrastructure to support data collection. However, the possibility exists that some vehicle-based systems will have the capability of transmitting data via other communications media, such as with the use of cellular phones. As a result, telematics-oriented systems could eventually be placed into both categories of probe-based systems.

2. Probe-Based Data Collection Systems

This section of the memorandum provides information on the state of innovation in the field of probe-based traffic data collection solutions described in *Section 1*.

2.1 Remote Vehicle Monitoring Systems

2.1.1 Cell Phone Location-based Systems

This section describes network-based data collection systems using cellular telephone technology. There have been significant changes in the technology since this topic was initially addressed in the 2001 IDC report. In 2001, there were three primary ways that cell phone systems purported to provide traffic information. These methods were:

- Time difference of arrival (TDOA) in which the different times at which cell phone signals reached the cellular antennas allowed for a determination of position
- Angle of arrival (AOA) in which the different angles at which cell phone signals reached the antennas allowed for a determination of position
- Location pattern matching (LPM) in which the location provider would map out all possible cell signal patterns and then compare cell transmission patterns in real-time to the database of patterns to determine the location

At that time, most of these location systems were being developed to support Enhanced 911 services (reflecting the FCC mandate that cell phone companies be able to geographically locate callers to 911), and traffic applications were primarily add-ons to the E-911 application.

In contrast, today's technologies rely in large part on data that the cell phone companies themselves already collect. In order to operate and optimize their systems, cellular carriers collect significant amounts of data that reflects the location of individual cellular handsets. For example, they know when a cell phone (either in use or simply turned on) is handed off from one cell tower to another. It is at these hand-off points that cell phone carriers have the most knowledge of the phone's location. They can make this data available to cell phone location companies, who combine it with other data, apply their proprietary algorithms, and estimate the speed of the phones. They then must determine which cell phones are in vehicles, assign those vehicles to specific roadways, and calculate speeds or link travel times for those roadways.

All of the companies surveyed use hand-off data and/or other location data from the cell phone providers in conjunction with their own analysis and modeling to derive traffic information. Additionally, all of the companies use a similar business model. In essence, they follow these three steps:

- Contract with one or more wireless carrier to obtain data (either nationally or market-by-market). Contracts may call for either fixed price contracts or contracts based on sales volume;
- Convert the carrier data into traffic flow information using proprietary intellectual property; and,
- Sell data to public agencies and private companies.

2.1.1.1 Individual Cell Phone Location Companies

The following table lists the major cell phone location companies, along with their key deployments and test results, if any, and any other relevant information. PBS&J staff contacted representatives of all of the companies listed. In some cases, the companies provided little or no information, and in other cases the information provided was little more than their pre-existing marketing materials.

*Technical Memorandum — IDC Research
Update on the State of the Innovative Traffic Data Collection Industry*

Company	Deployments	Test/Evaluation Status	Comments
iTIS Holdings ²	<ul style="list-style-type: none"> • Tel Aviv test • Baltimore test • Missouri Deployment (test currently underway) 	<ul style="list-style-type: none"> • Tel Aviv: A test result summarized in a recent NCHRP report³ found that (a) there was a good match between loop data and the cell phone system, though the cell phone system data had more variation and (b) the amount of cell phone data available at night decreased significantly. • Baltimore: The University of Maryland conducted a pilot test during 2006. • Missouri: Due to problems securing a cell phone carrier, MoDOT had received no cell phone data as of early 2007. 	<ul style="list-style-type: none"> • The Missouri deployment is to cover 5,500 miles of roadway, for a total cost of \$6.15M. Of that cost, approximately \$4.8M is for the data, and the remainder is for program management and systems development.
Cellint ⁴	<ul style="list-style-type: none"> • Tel Aviv test • Georgia (SR 400) • Kansas City 	<ul style="list-style-type: none"> • Tel Aviv Test results are available only under a non-disclosure agreement. • Georgia DOT has contracted with Cellint to provide speed data on 12 miles of SR 400. • Cellint conducted a no-cost pilot test during 2006. 	
IntelliOne ⁵	<ul style="list-style-type: none"> • Tampa 	<ul style="list-style-type: none"> • The system was evaluated for the feasibility of using it to provide information but not for accuracy.⁶ 	
AirSage ⁷	<ul style="list-style-type: none"> • Hampton Roads, VA • Georgia (I-75 between Macon and Atlanta) • Salt Lake City • Minnesota • Wisconsin 	<ul style="list-style-type: none"> • The Virginia Transportation Research Council/University of Virginia evaluated data from Hampton Roads. • The Georgia DOT is conducting a pilot test along 80 miles of I-75. • Traffic.com plans to use AirSage data in Salt Lake City to support its 511 service. According to Traffic.com's web page, the service is expected to be available in late 2007. • Minnesota DOT recently began a test of AirSage data on one freeway and two arterials in the Minneapolis area. • Wisconsin DOT chose AirSage to provide data on I-94 and parallel arterials. 	<ul style="list-style-type: none"> • The Hampton Roads deployment began in January 2004 and evaluation began in December 2005.

² Information is available at http://www.itisholdings.com/index_flash.asp.

³ University of Virginia Center for Transportation Studies and Virginia Transportation Research Council. 2005. NCHRP Project 70-01, *Private-Sector Provision of Congestion Data*, Probe Based Traffic Monitoring State-of-the-Practice Report (hereafter NCHRP 70-01 Report).

⁴ Information is available at <http://www.cellint.com/>.

⁵ Information is available at <http://www.intellione.com>.

⁶ Discussed in NCHRP 70-01 Report.

⁷ Information is available at <http://www.airsage.com/>.

Technical Memorandum — IDC Research
Update on the State of the Innovative Traffic Data Collection Industry

Applied
Generics⁸

- Holland
- Italy
- U.K.

- A consultant evaluated the data⁹ and found the system in the Netherlands to be accurate. It must be noted, however, that this is not an independent evaluation.

⁸ Information is available at <http://www.appliedgenerics.com/>.

⁹ Discussed in NCHRP 70-01 Report.

2.1.1.2 Other Research

There have been several recent research studies that have addressed whether cell phone location data is adequate to support traffic management and traveler operation needs, including:

1. Florida International University (FIU), *Travel Time Estimation Using Cell Phones (TTECP) for Highways and Roadways* (January 29, 2007). This study is referred to herein as the *FIU Report* and is available online at http://www.dot.state.fl.us/research-center/Completed_Proj/Summary_TE/FDOT_BD015_12_rpt.pdf.
2. URS Corporation, *Data Evaluation for Cellint Cellular Probe on Freeways* (April 2007).
3. Smart Travel Laboratory, Center for Transportation Studies, University of Virginia, *Wireless Location Technology-Based Traffic Monitoring Demonstration and Evaluation Project* (May 26, 2006). This study provides an evaluation of the AirSage deployment in Hampton Roads, Virginia.
4. University of Maryland, *Cellular Probe Data Evaluation Case Study: The Baltimore Multi-Modal Traveler Information System (MMTIS)* (October 2006). More information regarding the Baltimore MMTIS is available online at <http://www.baltometro.org/content/view/655/423/>.

With the exception of the *FIU Report*, each of these focused on a specific technology deployment.

2.1.1.2.1 Florida International University (for FDOT)

The FDOT's research office and FDOT District 6 sponsored a study performed by researchers at Florida International University. The scope of the study was to investigate the maturity and potential application of cell phone location technology for traffic management and traveler information. The researchers solicited input from over 30 companies, asking for descriptions of technology, patent numbers, deployment status, and so forth. Of the 30 companies contacted, the following provided enough information for the researchers to assess their technologies and deployments:

- AirSage
- Cellint
- Delcan / iTIS Holdings (*iTIS*)
- Globis Data, Inc.
- IntelliOne Technologies Corporation

Based on their review of these companies and their deployments, the researchers made the following findings:

- There were generally good results in free-flow conditions;

- There is no evidence that travel times and speed estimations are accurate in heavy congestion or for arterials;
- Many providers use “average error” as a metric to demonstrate accuracy. This is not a valid tool, as the average will, by definition, be dominated by times and segments when there is no congestion; and,
- More study is necessary to determine how effective cell phone location technology can be useful across a range of traffic applications.

2.1.1.2.2 Company Details

A. iTIS Holdings

iTIS is a company based in the United Kingdom that provides a cell-phone based data collection solution referred to as Cellular Floating Vehicle Data (CFVD).

Business Model

To the extent that the information is available publicly, this company’s business model is based on deploying its system in partnership with public agencies. It assumes much of the initial cost of the deployment and attempts to recover its outlay by selling data to private sector data users. It is presumed that there are some restrictions on how the public agency client may use the data.

System Costs

The only data point available for this solution’s cost is the recent contract that iTIS entered into with the Missouri Department of Transportation (MoDOT) to provide statewide traffic data. That contract, in which iTIS is a subcontractor to NET, has a value of \$6.15M over two years. It is not clear as of the time of this writing what the per-mile cost of data is.

Test Results

Baltimore Metropolitan Area

This pilot project, conducted by Delcan and iTIS for the Maryland State Highway Authority, was one of the earliest deployments of the current generation of cell phone location systems. The data was tested during 2006 by the University of Maryland. (Refer to Item 4 in *Section 2.1.1.2* of this paper.) The report found that average errors were approximately 10 miles per hour (mph) on freeways and 20 mph on arterials. The quality degraded significantly during a.m. and p.m. peak periods, rendering the average error metric somewhat suspect. Quality also degraded significantly during periods of low levels of service (LOS).

The *FIU Report* discussed the findings as well, and found that results were generally good on most freeways but speeds were over predicted on arterials. It also noted that congestion affected data quality. At LOS F, in particular, more than 80 percent of the sample was off by more than 100 percent.

Missouri Statewide Data Collection Project

This project, deployed by Delcan and iTIS for the MoDOT, began in January 2006. The original contract called for 5,500 miles of coverage within six months of the notice to proceed. As of June 2007, the contractor had provided data for 70 miles of freeway and had not conducted any evaluation of the data.

B. Cellint

Cellint is an Israeli company that provides a cell-phone based data collection solution referred to as TrafficSense. Unlike most of the other systems, Cellint does not rely on cell tower hand-offs. Instead, it uses a pattern matching approach similar in concept to the radio-frequency pattern matching performed by U.S. Wireless and described in the precursor to this report. Rather than using radio frequencies, however, Cellint relies on matching various parameters of the communications between the handsets and the cell towers on the signal channel.

Business Model

It is unknown whether Cellint plans to sell data to private sector companies or will simply provide a fee-based data service to government agencies.

System Costs

It is unknown at this time.

Test Results

Georgia State Route 400 — Atlanta Metropolitan Area

The Georgia Department of Transportation (GDOT) has contracted with Cellint to provide speed information on 12 miles of the SR 400 freeway, along with arterials both parallel to and intersecting with the freeway. Information in this section comes both from discussions with Mark Demidovich, as well as from the URS report referenced in Item 2 in *Section 2.1.1.2* of this document. The GDOT started the project to get some detection in place quickly after fiber optic cable was destroyed during construction. The GDOT used an informal bid process and selected Cellint. The project was up and running three and one-half months after the contract was signed. In general, the GDOT has been very happy with the project data. The URS report, which compared the cellular location data to data from the GDOT's advanced traffic management system (ATMS) and floating car data, found that the cellular data was comparable to the ATMS data.

The report's findings, however, suggest that Cellint also has accuracy issues during low speeds. For example, the 90 percent confidence interval was 24 mph at speeds ranging from 10 to 20 mph. In other words, between 10 and 20 mph, the system could only guarantee that a data point was accurate within a range of 24 mph. Thus, data reported as 15 mph could, in reality, be

anywhere between 3 mph and 27 mph. This suggests that the system does not necessarily provide accurate data at low speeds. The GDOT and URS believe, however, that these results might be caused, at least in part, by small sample sizes during low flow periods.

Kansas City Scout

Cellint, working with the Kansas Department of Transportation (KDOT), collected speed information and generated slowdown reports for portions of the Kansas City Metropolitan Area in Kansas and Missouri. This was done as part of a no-cost pilot test conducted during 2006; the test is no longer running. Mark Sommerhauser, a MoDOT employee and the ITS Project Manager for Kansas City Scout, said that the KDOT was not actively planning to do any kind of cell phone project, but Cellint approached them with the offer of a no-cost pilot test, since Cellint already had the infrastructure to support services it was providing to its cell phone carrier. The KDOT and Kansas City Scout looked at this as an opportunity to assess the feasibility of a cell phone location system. There was no official evaluation but an informal analysis by Kansas City Scout staff showed the following:

- A red-yellow-green speed map provided by Cellint matched reasonably well with camera views;
- Speed trends tracked speeds reported by detectors, but were often off by 5 mph;
- There was not enough data during overnight periods to provide speeds, but Cellint admitted that at the beginning of the project;
- Cell phone data matched the trend line of detector data, but seemed to exaggerate the peaks and valleys; and,
- There was a lag of as much as 8 to 10 minutes, according to Kansas City Scout, or as little as 3 to 4 minutes, according to Cellint, between when slowdowns occurred and when they were reported.

In general, Mr. Sommerhauser felt that the technology shows promise, subject to the constraints mentioned above, but that it is very important to understand the ultimate use of the data.

Because there was no formal evaluation, the *FIU Report* noted that there is not enough data, nor are there sufficient metrics, to assess the accuracy of the information provided by Cellint.

C. IntelliOne

IntelliOne, based in Atlanta, Georgia, provides both traffic data as well as other location-based services. Unlike most of the other providers described here, IntelliOne does not use cell-tower handoffs to calculate position or to generate traffic data. Instead, it collocates equipment at the cellular phone company's switching center. Depending on the configuration, this will allow IntelliOne to capture data from several hundred cell phone antenna towers with one installation. Unlike cell-tower hand-off-based solutions, the IntelliOne solution requires a cell phone to actually be in use, not simply turned on. The data then goes through position-determining

algorithms to determine where the cell phone is. If it is determined that it is on a roadway, the data point is then investigated to determine whether it makes sense to use it as a traffic probe.

IntelliOne's primary deployment is being conducted in partnership with Cingular in the Tampa Bay region.

Business Model

IntelliOne sells data to transportation agencies, but also focuses on other markets where location-based information has value to private sector entities.

System Costs

Specifics of the cost structure are unknown, but prices are based on mileage.

Test Results

Tampa, Florida

IntelliOne performed its own test in the Tampa area in which it purported to demonstrate the accuracy of its data. There is no independent evaluation of the test. The *FIU Report* noted that the test was done with cell phones in continual use, which makes them much easier to track and locate, as compared to cell phones that are on but not in use. Consequently, this test is not a valid demonstration of IntelliOne's accuracy, as it did not match real-life conditions.

D. AirSage

AirSage, based in Atlanta, Georgia, provides traffic location information to a variety of customers.

Business Model

As of late 2006, AirSage was the only cell-phone based data collection service provider with an exclusive contract with a cell phone carrier (Sprint-Nextel). AirSage believes that this arrangement enables it to be ready to have a national footprint in the field, without having to negotiate for cellular data on a state by state or city by city basis.

System Costs

It is unknown at this time.

Test Results

Hampton Roads, Virginia

AirSage covered 90 centerline roadway miles in the Hampton Roads area. The project began its deployment in December 2002. Originally scheduled to last 12 months, the evaluation was finally concluded in December 2005. AirSage claimed that, at that point, it only had 25 percent of the data that it would ultimately have. No evaluation was conducted based on the purported full data set. The results, which were documented in the University of Virginia report, show that data was generally good at high speeds, but not good at lower speeds.

The researchers concluded by noting that:

- The data could not support the Virginia Department of Transportation's (VDOT) operations for traffic management;
- Data was acceptable at high speeds, but errors were 20 percent or higher when speeds were below 30 mph;
- Travel time was not reliable on arterials or congested freeways. There were errors exceeding 15 mph 84 percent of the time;
- AirSage could not provide data on reversible high occupancy vehicle (HOV) lanes on Interstate 64 (I-64); and,
- AirSage could not provide a confidence measure to allow the VDOT to assess how accurate the data was.

When the team from FIU reviewed this deployment, it noted that in addition to the above, when speeds were slower than 22 mph, the average error was 25 mph or 113 percent of the actual speed.

Interstate 75 between Atlanta and Macon, Georgia

The GDOT has been conducting a pilot test of AirSage technology on approximately 80 miles of I-75 between Atlanta and Macon, Georgia. This project was not discussed in the *FIU Report*, nor has there been any evaluation to date. All information in this section comes from a conversation with Mark Demidovich, GDOT Assistant State Traffic Engineer.

The project was started to test whether cell phone location technology could provide the acquisition of data in rural areas at a lower cost. To date, AirSage has not been able to completely meet the project limits. The middle segment of the project still does not have data. The GDOT originally had a good working relationship with AirSage, but that relationship has deteriorated over time, and AirSage has not been able or willing to correct some problems with the project.

URS will be evaluating the data, but has not yet completed its report.

Salt Lake City, Utah

Traffic.com is currently assessing AirSage data for use in its traveler information program, but has no public information on data quality. Traffic.com staff would not comment on the status of their assessment. The *FIU Report* discussed AirSage's claims as to the accuracy of the data, and found that, even though the red-yellow-green color maps from Traffic.com and Utah Department of Transportation (UDOT) roughly matched each other, it was not sufficient to confirm that the data was accurate. This is because:

- The assessment is not independent;
- The maps were mostly green, which means the roads were not congested, so it says nothing about AirSage's ability to provide accurate data during congested periods; and,
- Three colors, as opposed to actual speeds, do not provide enough granularity to provide meaningful analysis.

Minnesota

The Minnesota Department of Transportation (Mn/DOT) has recently begun a test of AirSage's data on one freeway and two arterials in the Minneapolis metropolitan area. Information in this section comes from a conversation with Bernie Arseneau, Mn/DOT Project Manager, and from a presentation Mr. Arseneau made at the ITS America 2007 Annual Meeting.

The project began because AirSage contacted high-level officials at the Mn/DOT and urged them to conduct a test. Mr. Arseneau, as state traffic engineer, was tasked to manage the project. He views it as a test and thinks it is a worthwhile exercise. At the same time, he is skeptical about whether the data quality will be good enough to support the Mn/DOT's needs, particularly on arterials.

Because the project has just begun, they do not yet have any data available for analysis.

Interstate 94 and Parallel Arterials between Milwaukee and Madison, Wisconsin

This project is in the early implementation stage. All information comes from discussions with Dean Beekman, Project Manager for the Wisconsin Department of Transportation (WisDOT). This project began with a request for proposals for non-infrastructure based traffic data collection. The intent of the project is to assess the quality of data collected, with the ultimate result being use of this data for traffic management and as part of an eventual 511 system. The WisDOT selected AirSage to provide data along I-94 and parallel arterial roadways, but also selected INRIX to provide data on another route using a GPS based probe solution. Roadway links have been defined and AirSage has provided some initial data, but the data has not yet been integrated into any WisDOT systems, nor has an evaluation been conducted. It is anticipated that the University of Wisconsin will evaluate the data.

E. Applied Generics

Applied Generics, a British company, has developed the RoDin24 traffic data collection system. On January 12, 2006, TomTom, a Dutch navigation systems company, announced that it had purchased Applied Generics. It is unclear as of this writing how that will affect its work in the traffic data market. Applied Generics's solution does not use the hand-off method. Instead, it gets continuous position reports from individual cell phones and uses them to continually hone the accuracy of its estimate of each phone's location. When the data is considered to be accurate enough, it is then used to generate traffic information.

Business Model

It is unknown at this time.

System Costs

It is unknown at this time.

Test Results

LogicaCMG is using Applied Generics's data to provide traffic information to the traffic department of the province of Noord-Brabant in the Netherlands.¹⁰ An evaluation of this data found that Applied Generics's solution provided travel times consistent with those provided by loop detectors along highways, but was not as accurate along regional roads and urban arterials.

2.1.1.3 General Conclusions about Cell-Phone Based Data Collection Systems

As in 2001, many in the transportation community are excited about the prospects of using cell phones to provide traffic information, in order to dramatically increase coverage on virtually all of our roadways. While both the business models and the technology seem to be much stronger now than they were then, it is still not clear that these systems will meet DOT expectations. This is not to say that these efforts should not be continued; however, given the findings contained herein the technology and the business models might still be less mature than needed to support a full range of deployments.

The concerns are in the following areas:

- **Technology:** Simply put, there have been no independent evaluations of the data published that would allow Departments of Transportation (DOT) to assess whether the system provides accurate speed or travel time data under a variety of conditions (freeway

¹⁰ LogicaCMG, *MTS Quality Assessment Results*. Additional information is available from Mr. Bart Bartels, LogicaCMG (infops@logicacmg.nl) or from Mr. Peter de Wolff, Province of Noord-Brabant (info@brabant.nl).

vs. arterial; parallel routes; low flow conditions; rural areas). Evaluations are currently underway that we hope will confirm whether these systems provide accurate, useful data.

- **Intellectual Property:** All of the companies described above claim patents on their technology. It is not unlikely that infringement or validity claims will need to be addressed before any large-scale commercial deployment.
- **Privacy:** While all of these systems maintain anonymous data, the very idea of cell-phone “tracking” has the potential to frighten citizens. In fact, a legislator in Missouri has raised these concerns, among others, related to the project currently underway in that state.¹¹
- **Business Model:** All of these systems and the hand-off-based solutions in particular, require the cooperation of the cell phone carriers themselves. This gives those companies significant power over price, and even over whether to participate in the market at all.¹²

Given these concerns, it is recommended that the FDOT approach this arena cautiously. Rather than deploying a full-scale project based on cell-phone location systems, it is suggested that a project be conducted to answer some of the open technical questions. It would be structured as follows:

- Select an appropriate test area with a reasonably complex network of limited access roadways and arterials and with robust data collection;
- Develop specific performance requirements for data relating to accuracy, timeliness, and reliability. The Guidelines for Quality Advanced Traveler Information System (ATIS) Data¹³ developed jointly by ITS America and the U.S. DOT would be a good starting point;
- Release an Invitation to Negotiate (ITN) to all cell-phone location companies to ask them to participate;
- Enter into agreements with all willing companies;
- Collect data from existing data collection systems, cell phone location companies, and floating car runs (for additional validation); and,
- Evaluate the results.

¹¹ <http://www.mydjconnection.com/articles/2006/01/30/community/news2.txt%C2%A0>.

¹² At the December 14 Travel Time workshop sponsored by Caltrans and the Center for the Commercialization of ITS Technology, Mr. Cy Smith, president of AirSage, commented that the cell phone companies are unlikely to be interested in this market until it has a revenue potential of \$100 million. He maintained that until revenues approach that point, the cell phone companies would incur significant opportunity costs by entering this market; they would rather spend their resources ensuring that their networks are accurate and reliable.

¹³ http://www.itsdocs.fhwa.dot.gov//JPODOCS/REPT_MIS/13580.html.

The reader should note that this could be expanded to test other data collection methodologies as well.

Performing this research would ensure the FDOT that it had the most current information available about the state of the cell-phone location industry, enabling policy-makers to come to correct decisions about ITS data collection.

2.1.2 GPS-based Probe Systems

The GPS is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations. GPS has found its way into cars, boats, planes, construction equipment, and even laptop computers. The basis of GPS is triangulation from satellites by measuring distance using the travel time of radio signals. While only a few years ago accuracy was about 100 meters, today GPS can pinpoint location within 20 meters. The base data provided by GPS is location (latitude and longitude) and time as frequently as every 2 seconds. Using this data, point velocity, stop durations, space mean speed and travel time can be calculated.¹⁴ GPS systems are categorized as either “active” or “passive.” In passive systems, the GPS information is stored on-board and subsequently downloaded into a database when either the vehicle is in proximity for data download or the on-board storage device capacity has been met. In active systems, data transfer occurs in real-time via an integrated communications system.

2.1.2.1 Entities Involved in GPS-based Tracking

2.1.2.1.1 INRIX

INRIX, based in the Seattle area, was founded in July 2004 by former Microsoft and Expedia executives. In April 2005, INRIX completed a \$6.1 million Series A funding led by Venrock Associates and August Capital.

A. Technology

INRIX aggregates data from anonymous, real-time GPS probes from more than 500,000 commercial fleet, delivery, and taxi vehicles across the U.S., and integrates this with toll tag probe data, occupancy, and speed measurement data from state DOT sensor networks, along with information on construction, road closures, incidents, and weather. Using this data, INRIX offers real-time and predictive travel time estimates, predictive dynamic routing, incident data, and traffic speeds.

¹⁴ Vaishali Shah and Dr. Karl Wunderlich, Sources and Applications of Vehicle Probe Data: A Comparative Assessment of Existing Technologies, Federal Highway Administration, October 2004, page 14.

INRIX's data products are designed to be compatible with a wide variety of map databases and universal traffic location codes. Their services are delivered via XML data feeds and customized client applications, and include:

- Real-Time Traffic Service—Delivers high quality, real-time reporting of traffic flow and incident information, including proprietary error detection and correction of flow sensor data;
- Predictive Traffic Service—Anticipates conditions on specific routes for the next few minutes or for several hours; and,
- Forecast Traffic Service—Provides forecasts for traffic conditions on specific roadways for days, weeks, months or even a year ahead of time.

B. Business Model

INRIX is targeting a number of customer markets, including: regional and federal agencies, car manufacturers, personal navigation device manufacturers, satellite radio, location-based services, cell phone operators, telematics providers, and fleet management solution providers.

C. Costs

Not available at this time.

D. Existing Deployments

INRIX currently has real-time flow data for 100 U.S. markets and real-time incident data for 122 U.S. markets, covering more than 25,000 centerline miles of roadway. This real-time information is backed up by nearly 500,000 centerline miles of historical conditions data.

INRIX was recently selected by the WisDOT to provide real time traffic flow data for nearly 250 centerline miles of US 41, I-43, and WIS 172. The WisDOT is currently in the process of integrating INRIX data into its Traffic Management software and intends to conduct a demonstration in the near future.

E. Test Results

Testing carried out by Frost and Sullivan involved an analysis of INRIX and Traffic.com real-time traffic and speed information, focusing on accuracy, nationwide coverage, and total road miles covered. The report indicated that while both INRIX and Traffic.com provide strong and comparable levels of accuracy in reporting travel times (accuracy in excess of 70 percent - with the average measured travel time being within one minute of the actual travel time), INRIX's real-time flow data is available for significantly more roadways across the country, including 33 percent more metropolitan areas and three to seven times the miles of roadway

coverage within each metropolitan area. A copy of this study can be requested at: www.INRIX.com/accuracy.asp.

2.1.2.1.2 American Transportation Research Institute (ATRI) and U.S. DOT Federal Highway Administration (FHWA)

Given the widespread deployment of fleet management systems such as Qualcomm's OmniTRACS (currently installed on over 300,000 long-haul trucks in North America), there has been increasing interest in employing 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.

In 2002, the Federal Highway Administration (FHWA) contracted with the American Transportation Research Institute (ATRI) to develop and test a system for monitoring freight performance measures (FPM) on interstate corridors using long-haul fleet trucks as probe vehicles.

ATRI, the research arm of the trucking industry, collects and processes truck position data in order to calculate average travel rates, travel time indices, speeds, and buffer/reliability indices along interstate corridors by using advanced vehicle tracking technologies and advance data processing software and algorithms.

A. Technology

Several agreements have been struck with freight carriers partnered with GPS and satellite-based fleet management service providers (e.g., Qualcomm) to share real-time and near real-time data about the movement of the freight carriers' vehicles with ATRI. At this point, data ownership is not considered an issue as the FHWA has stated that the individual carriers providing the data are the sole owners of that data.

B. Business Model

Research and Design Phase – No business model at this time.

C. Costs

ATRI was awarded an unknown amount of money by United States Department of Transportation (USDOT) to develop and test the FPM system. The contract amount is not publicly available.

D. Existing Deployments

The project is currently being conducted on five (5) interstate highways, chosen in part with help from freight carriers to identify heavily traveled or otherwise significant corridors (See Table 1).

Interstate Corridor	States on Route	Major Cities on Route	Total Miles
I-5	California, Oregon, Washington	San Diego, Los Angeles, Portland, Tacoma, Bellingham, Olympia, Seattle	1,381
I-10	California, Arizona, New Mexico, Texas, Louisiana, Mississippi, Alabama, Florida	Los Angeles, Phoenix, Las Cruces, El Paso, Houston, Beaumont, San Antonio, New Orleans, Gulfport, Mobile, Pensacola, Tallahassee, Jacksonville	2,460
I-45	Texas	Galveston, Houston, Dallas	285
I-65	Alabama, Tennessee, Kentucky, Indiana	Indianapolis, Louisville, Nashville, Birmingham, Montgomery, Mobile	887
I-70	Utah, Colorado, Kansas, Missouri, Illinois, Indiana, Ohio, West Virginia, Pennsylvania, Maryland	Cove Fort, Denver, Topeka, Kansas City, St. Louis, Indianapolis, Springfield, Wheeling, Breezewood, Hagerstown, Frederick, Baltimore	2,153

E. Test Results

ATRI has completed the first and second phases of FPM testing, and is currently working on the third phase. Phase I of the project focused on the collection and analysis of historical rather than real-time data, and was analyzed manually. Phase II, focused on the use of near real-time data. Phase III of the project will focus on issues of data privacy and how those issues may affect the sharing of data.

During the second phase of FPM testing, ATRI concluded the following:

- Use of satellite-derived vehicle position data to measure average truck travel times/rates is feasible.

- Reliability indices and other additional measures are not only feasible, but desirable as well.
- In order to meet the demands for increasing levels and types of data, the software used for analysis must be updated on a regular basis.
- There is highly sensitive data used in this study. Therefore, it is necessary to use legal and technical data privacy tools to protect such data.
- To ensure future data compatibility and analysis, standards should be developed for freight performance measures.

Daniel Murray, Vice President of Research for ATRI, suggested that the FDOT request to be put on the list of potential reviewers/case study participants to be involved in future FPM related testing.

2.1.2.1.3 iTIS Holdings

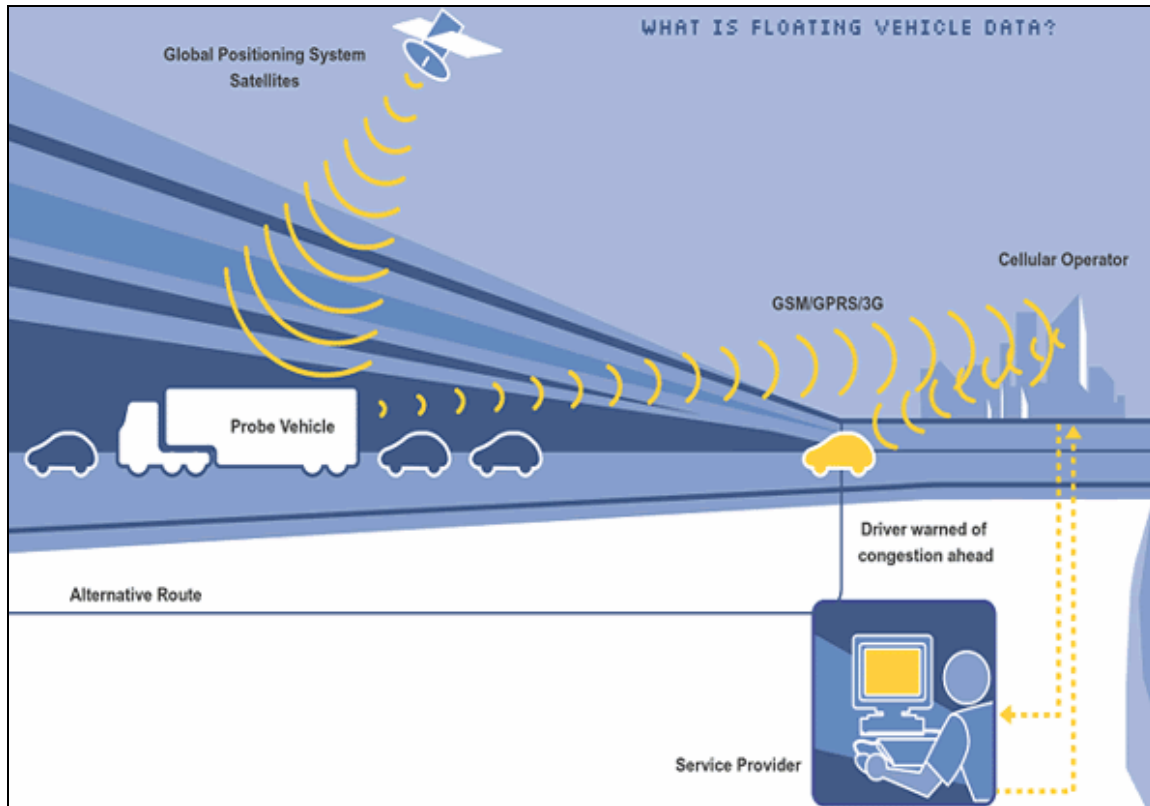
A leading user of passive GPS, iTIS, has instrumented almost 50,000 “Floating Vehicles” in the United Kingdom with GPS-based units. Vehicles selected for instrumentation tend to be “high-mileage” vehicles (e.g., express buses, delivery trucks, service patrol vehicles, etc.). Staff subsequently downloaded data after hundreds of hours of vehicle trips have been stored captured. This data is subsequently analyzed and sold to a variety of entities for traffic management, planning, performance monitoring, and traveler information applications.

In situations where detailed real-time data is needed concerning conditions on a certain roadway, iTIS examines its historical database to determine, based on past experience, which vehicles have typically traversed that roadway in the required direction at that time of day and on that day of the week. Based on this list of vehicles, iTIS’ floating vehicle system requests position information from those vehicles most likely to be on that road at that time.

Real-time Floating Vehicle Data (FVD) is used to support a number of commercial services provided by iTIS. These services include the provision of traffic information via cell phone and in-vehicle congestion avoidance advice, congestion analysis and journey time predictions.

A. Technology

GPS based FVD units are deployed in over 50,000 vehicles around the United Kingdom. Although generally operating as passive probes, these FVD equipped units have the capacity to behave as active probes, transmitting location and speed data to iTIS’ traffic management center via GSM/GPRS as conditions warrant.



* Image available at: <http://www.itisholdings.com/whatfvd.asp#>

B. Business Model

According to *iTIS*, there are three primary commercial services based on the use of passive and FVD GPS-based probes that are either already operating or are in development. These three services are:

- Network Monitoring – the provision of both archived (for performance monitoring and planning) and real-time (to support real-time traffic management) data to the public sector.
- Radio Data System-Traffic Message Channel (RDS-TMC) – an advanced traffic messaging system that delivers real-time content via the RDS-TMC (integrated with either the car audio system or another navigation device) to support dynamic routing.
- National Express Coaches – a fleet management application with the ability to provide estimated time of arrival services for participating carriers based on existing traffic conditions.

C. Costs

The value of contracts with Scottish Executive and United Kingdom (UK) Department for Transport is not currently available.

D. Existing Deployments

Existing public agency network monitoring-related deployments include contracts with the Scottish Executive and the UK's Department for Transport.

- Scottish Executive – *iTIS* provides predictive travel times and real-time delay alerts on the Trans European Road Network (TERN) in Scotland, composed of 19 key routes covering 1500km of roads, including roads in and around Edinburgh, Glasgow, Carlisle, Inverness and Dundee. (<http://scottishexecutive.itisholdings.com>)
- UK Department for Transport - In February 2004, *iTIS* announced a three year contract with the Department for Transport (DfT), which licenses *iTIS*' historic FVD to measure congestion across the road network. This will enable DfT to produce detailed reports on the pattern and location of congestion, identifying congestion hot-spots and showing the impact of measures taken to address problems in heavily congested areas. The resulting information will be available for use by DfT, the Highways Agency, Transport Direct and local authorities.

E. Test Results

Results of testing conducted by *iTIS* to demonstrate the quality of the data collected by its FVD system to the Welsh Assembly Government indicate that:¹⁵

- A small number of dedicated probes can contribute useful data even in a short period of collection about trunk road conditions, particularly on well-used routes.
- At any time, a maximum of about 50-60 percent of the equipped fleet is likely to be available on the network to collect data, due to relatively short trips and staggered journey times.
- Data can be interpreted using maps to show overall levels of performance and also identify travel trends either across the whole network or in selected areas.
- The network monitoring plots show the effect of road geometry and isolated congestion with even relatively few data points.
- FVD is an excellent source of off-line historic information on journey times for motorways, to look at network performance and compare use of routes.

¹⁵ FLOATING VEHICLE DATA FOR NETWORK MANAGEMENT: A PILOT STUDY, page 9

- Real-time FVD could provide a useful monitoring mechanism for motorways and trunk roads on the Welsh network during incident conditions.

2.1.2.1.4 Georgia Institute of Technology – “Commuter Atlanta” Floating Car Data Project

Commuter Atlanta is an ongoing research effort that involves the passive monitoring of approximately 450 vehicles in the Atlanta metropolitan area. Second-by-second speed and position data are collected for every instrumented vehicle trip. When the study is complete, vehicle data will have been collected from each vehicle for two to three full years.

Drivers taking part in the study allowed Georgia Institute of Technology (Georgia Tech) researchers to install a “GT Trip Data Collector” in their vehicles. The device uses a GPS unit to record the movement of each vehicle and various engine data, as well as where, when and under what conditions people drive in the Atlanta area.¹⁶ The information is uploaded, via a cell phone connection, to a computer at Georgia Tech, where researchers monitor participants’ travel patterns. Data is then used to identify locations of recurrent traffic congestion on highways and arterial roads.

A. Technology

Vehicle-based GPS unit integrated with cell phone to transmit data.

B. Business Model

Research and Design Phase – No business model at this time.

C. Costs

Commuter Atlanta is a \$2.3 million joint value pricing initiative sponsored by the Federal Highway Administration and the Georgia Department of Transportation.

D. Existing Deployments

In the Atlanta metropolitan area.

E. Test Results

Researchers have monitored more than one-million vehicle trips (more than 350,000 vehicle-miles per month). During 2005, the Commuter Atlanta households began participating in road pricing experiments (cent/mile pricing, as well as real-time congestion pricing). The research team is assessing consumer response to these pricing mechanisms. Secondary research activities

¹⁶ <http://www.gatech.edu/news-room/release.php?id=211>

include the analysis of speeding, journey to work route choice, trip chaining, activity-based demand, household trip-making variability, household and vehicle range of travel, long-distance travel, freeway operations, engine load, start and soak distributions, transit bus operations, etc.

2.1.2.2 General Conclusions about GPS-based Tracking Systems

“GPS-based technologies are relatively mature and have been coupled with an array of additional data monitoring features that can subsequently transmit these data and receive real-time information.”¹⁷ Although recent tests indicate that position accuracy of within 50 meters can be consistently achieved and that data produced by such systems can consequently be used to generate speed and travel time information for selected routes, the cost of deploying sufficient numbers of active GPS systems (systems that transmit current GPS data to a centralized location for processing in real-time) for use in generating accurate probe data presents a major obstacle for public agencies interested in implementing this technology. It is much more likely that public agencies will use passive GPS systems to develop large archives of traffic conditions data for use in better informing decision-makers. However, based on the investments made by the FHWA and the private sector described in this section, the potential exists for data resources to become available that could be utilized by public sector agencies to derive GPS-based speeds and travel times without the need to deploy stand alone systems of their own. Such data could instead be bought from larger regional data providers who market their data products to a variety of clientele.

3. Infrastructure-based Link Monitoring Systems

3.1 Telematics – i.e., Vehicle Infrastructure Integration (VII) Initiative-like Systems

3.1.1 Overview of Technology

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. The greatest collective effort in this area (involving the USDOT, state DOTs, automobile manufacturers, and a range of other private sector equipment suppliers) currently revolves around the design and development of the Vehicle Infrastructure Integration (VII) Initiative. The goal of the VII program is to facilitate the deployment of a communications infrastructure that supports both vehicle-to-infrastructure and vehicle-to-vehicle communications, for a variety of vehicle safety and operations-related applications. In addition, VII is planned to enable the deployment of a

¹⁷ Sources and Applications of Vehicle Probe Data: A Comparative Assessment of Existing Technologies, October 2004, page 23.

variety of applications that support private sector applications, especially those of the automobile manufacturers.

The VII program builds upon work previously completed under the auspices of the US DOT's Intelligent Vehicle Initiative (IVI) program, Vehicle Safety Communications (VSC) project, the Enhanced Digital Map (EDMap) project, and the Federal Communications Commission's (FCC) spectrum allocation for Dedicated Short Range Communications (DSRC) in the 5.9 GHz band. Use of the research results and operational tests from these independent projects enables the VII program to bring a wide range of initiatives under a single umbrella with clearly defined goals and objectives, as well as clearly defined roles for the public and private sectors.¹⁸

DSRC technology makes real-time communication possible between a vehicle and roadside stations and from one vehicle to another. With the aid of car-to-car communications, the selective forwarding of information could help to optimize traffic flow and enhance traffic safety. For example, if a vehicle encounters a critical situation such as congestion, fog, ice, or an accident, it can pass the relevant information to all road users in the immediate vicinity of the danger spot. Within this information network, each vehicle can take on the role of a sender, receiver, or router, allowing a chain of information to be passed on.

Several subcommittees of the National VII Coalition's Working Group are currently examining various facets of the program, including:

- Technical issues (including operational tests, standards development and prototyping);
- Institutional issues (security, privacy, data ownership, product liability, Certification and registration);
- Business models (including the development of use cases or "killer applications");
- Deployment costs for roadside units); and,
- Outreach needs.

3.1.2 Entities Involved In VII-like Programs

3.1.2.1 Vehicle Infrastructure Integration Consortium (VIIC)

A Vehicle Infrastructure Integration Consortium (VIIC) was formed in early 2005 by a group of light-duty vehicle manufacturers to actively engage in the design, testing and evaluation of a deployable VII system for the US. To accomplish this evaluation, the VIIC is working under a cooperative agreement with the USDOT. All partners and contractors are coordinating their

18 ITS America - VII White Paper Series, Primer on Vehicle-Infrastructure Integration, October 2005, page 5.

evaluation activities with the National VII Coalition, which is ultimately tasked with deciding, based on the information gathered during evaluation, whether to recommend national deployment of a VII system. This decision on whether to recommend national deployment is expected to be made in late 2008.

A. Technology

Probe vehicle data collected through VII and dedicated DSRC technology will give roadway operators a rich database of anonymous information describing factors such as speed, location, acceleration, pavement conditions, weather, and vehicle operating condition. Travelers will also be able to receive information in the vehicle that is relevant to their specific location and position in the traffic stream.

B. Business Model

It is unknown.

C. Costs

Unknown, but will involve substantial investments by the FHWA, other federal and state agencies, and automobile manufacturers to deploy sufficient in-vehicle equipment and roadside infrastructure to achieve the critical mass necessary for this program to be successful.

D. Existing Deployments

None at this time; however, it is likely that over the next decade, VII equipped vehicles will become a significant part of the vehicle fleet in the United States. This technology, when combined with smart highway infrastructure will make possible the next major incremental improvement, in highway safety and reliability.

E. Test Results

N/A

3.1.2.2 Car2Car Communication Consortium (C2C CC)

In Europe, six car manufacturers: Audi, BMW, DaimlerChrysler, Fiat, Renault, and Volkswagen have combined forces in the nonprofit Car2Car Communication Consortium (C2C CC). Suppliers and other researchers have been encouraged to join and contribute to this effort.¹⁹

¹⁹ Aei, August 2005, page 45.

The mission and the objectives of the C2C CC are:

- To create and establish an open European industry standard for car to car communication systems based on wireless LAN components and to guarantee European-wide inter-vehicle operability;
- To enable the development of active safety applications by specifying, prototyping and demonstrating the Car2Car system;
- To promote the allocation of a royalty free European wide exclusive frequency band for car to car applications;
- To develop realistic deployment strategies and business models to speed-up the market penetration; and,
- Ensuring high availability, reliability and the necessary data security and anonymity of the Car2Car system

Much as with the US-based VII Program, anticipated benefits of the C2C CC fall into three primary areas:

- Advanced driver assistance - increasing road safety by reducing the number of accidents, as well as reducing the impact of non-avoidable accidents;
- Decentralized floating car data - improving local traffic flow and efficiency of road traffic via the availability of real-time traffic data; and,
- User communications and information services -- provision of personal and business applications to driver and passengers.

A. Technology

In-vehicle sensors and communication systems to support vehicle-vehicle and vehicle-roadside communications.

B. Business Model

It is unknown.

C. Costs

Unknown, but will involve substantial investments similar to those required to deploy the VII in the United States.

D. Existing Deployments

None at this time.

E. Test Results

None at this time.

3.1.2.3 General Motors

Although General Motors (GM) is a participant in the VII initiative, it is also working on an alternative system, referred to as vehicle-to-vehicle (V2V), which it claims is less expensive and will be more sophisticated than what is deployed as part of VII. The V2V system is an extension of GM's OnStar vehicle-to-service center driver assistance communications service and is supported by the same satellite- and cellular-network-based GPS technology as OnStar.

A. Technology

Using an antenna, on-board computing power, and GPS geo-location technology, the V2V system is designed to enable a vehicle to detect the position and movement of other vehicles up to a quarter-mile away in a 360-degree radius. This technology will enable vehicles to assess the potential for collisions to occur and let all V2V enabled cars around them know an impact is about to happen. The vehicle will also be capable of taking pre-emptive actions to avoid or reduce the severity of the impact.²⁰

B. Business Model

It is unknown.

C. Costs

It is unknown.

D. Existing Deployments

GM demonstrated V2V equipped vehicles during the 2005 Intelligent Transportation Systems World Congress in San Francisco. GM claims that by 2007, all GM cars will be equipped with OnStar technology to support V2V communications.

²⁰ GM system lets cars talk to each other, Detroit Free Press, February 2, 2006.

E. Test Results

According to GM, tests indicate that a 2 percent market penetration of V2V equipped GM vehicles should be sufficient to generate accurate estimates of traffic speed over a freeway section.

3.2 General Conclusions about VII-like Programs

Research indicates that with as little as 2 percent market penetration of vehicle probes, travel time can be estimated within an accuracy of 5 percent. Consequently, as deployment of VII-type technology and other telematics products and services increases over the next decade, real opportunities will arise for the collection and aggregation of traffic data based on the movement of equipped vehicles. It is similarly likely that this will result in the obsolescence of many of the other types of probe vehicle technologies described in this memorandum. It will likely require a number of years before sufficient numbers of equipped vehicles are deployed such that it becomes possible to use them to generate accurate and reliable probe data.

4. Toll-tag and License Plate Reader-based (LPR) Data Collection Systems

4.1 Overview of Technology

4.1.1 Toll-Tag Based Systems

Toll transponder-based electronic vehicle identification technologies, also referred to as Automatic Vehicle Identification (AVI), are currently in use by public agencies across the United States for an assortment of purposes, including electronic toll collection (ETC), commercial vehicle operations (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/other 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.

Examples of travel time data collection systems based on the use of toll tags include:

- TRANSMIT – The New York/New Jersey region’s system for managing incidents and traffic, known as TRANSMIT, was initiated to establish the feasibility of using AVI equipment for traffic management and surveillance applications. Systems are typically installed at toll booths where they classify oncoming vehicles, then identify them and collect the toll by reading data stored on a vehicle-mounted transponder through wireless communication with a roadside antenna. In the New York City Metropolitan Area, this application of electronic toll collection is called E-Z Pass. The current system includes AVI transponder readers installed overhead at approximately 2.4-kilometer (1.5 mile) intervals in both directions of the roadway. The spacing between readers was selected to maximize the probability of incident detection by minimizing the false alarm rate (maximum of 2 percent) and the mean time to detect an incident (maximum of 5 minutes). Twenty-two locations were included in the project with a total of 65 antennas. TRANSMIT generates link travel time estimates within a 95 percent confidence interval.²¹ Incident detection rates ranged from 67 percent to 95 percent on various facilities.²²

²¹ Niver, E., Mouskos, K.C., Batz, T., and P. Dwyer. “.Evaluation of the TRANSCOM’s system for managing incidents and traffic (TRANSMIT).” Dept. of Electrical & Computer Engineering., New Jersey Inst. of Technology. Intelligent Transportation Systems, IEEE Transactions Volume: 1, Issue: 1, pages: 15-31 Mar 2000.

²² Mouskos, Kyriacos; Edip Niver; Louis Pignataro; Stuart Lee; Nicholas Antonious; and Leonidas Papadopoulos. “Transmit System Evaluation Final Report” New Jersey Institute of Technology. June 1998.

- Orlando-Orange County Expressway Authority (OOCEA) – OOCEA has deployed supplemental, non-toll collecting transponder readers across the entirety of its system. Data from these toll tag readers (as well as data from FDOT toll tag and license plate readers) is analyzed by the OOCEA Data Server for the purpose of obtaining a variety of travel statistics, including average link speeds, average travel times, and travel delay.
- TransStar – As part of the comprehensive traffic management and traveler information system deployed in Houston that includes loop detectors and closed circuit television, supplemental toll tag readers have been installed along significant portions of the City of Houston’s freeway network. It is estimated that freeway incident time savings stemming from information provided by this system is between 5 and 30 minutes depending on the size of the incident.²³
- TransGuide – TransGuide was a toll tag deployment test in San Antonio (a city with no toll system) where a set of 53 tag readers were installed to collect travel time data/support traffic management. Tag capture rates ranged from 50 percent to 83 percent along arterials, while freeway readers' tag capture rate ranged from 79 percent to 95 percent. A controlled test of travel time accuracy found AVI estimates within 2 percent of GPS travel time estimates.²⁴

4.1.2 License Plate Reader Based Systems

License plate reading technology, also referred to as automated license plate recognition (ALPR) is a video camera-based system that utilizes infrared illuminators and image-processing technology for the purpose of identifying vehicles by their license plates. ALPR systems are prevalent in the enforcement of signal violation, parking, and tolls, and have over the past few years begun to be used in the calculation of travel times. ALPR systems have essentially the same functionality as transponders-based systems, but as all vehicles have a license plate, each has the potential to be used as a probe vehicle. Consequently, ALPR-based systems have the potential to operate successfully even in areas where toll transponder penetration is low or non-existent.

Examples of travel time data collection systems based on the use of ALPR technology include:

- Trafficmaster - a United Kingdom-based firm specializing in the collection, aggregation, and dissemination of traffic data, uses license plate number recognition technology to

²³ Parsons Transportation Group and Texas Transportation Institute. “Estimation of Benefits of Houston TRANSTAR.” February 1997.

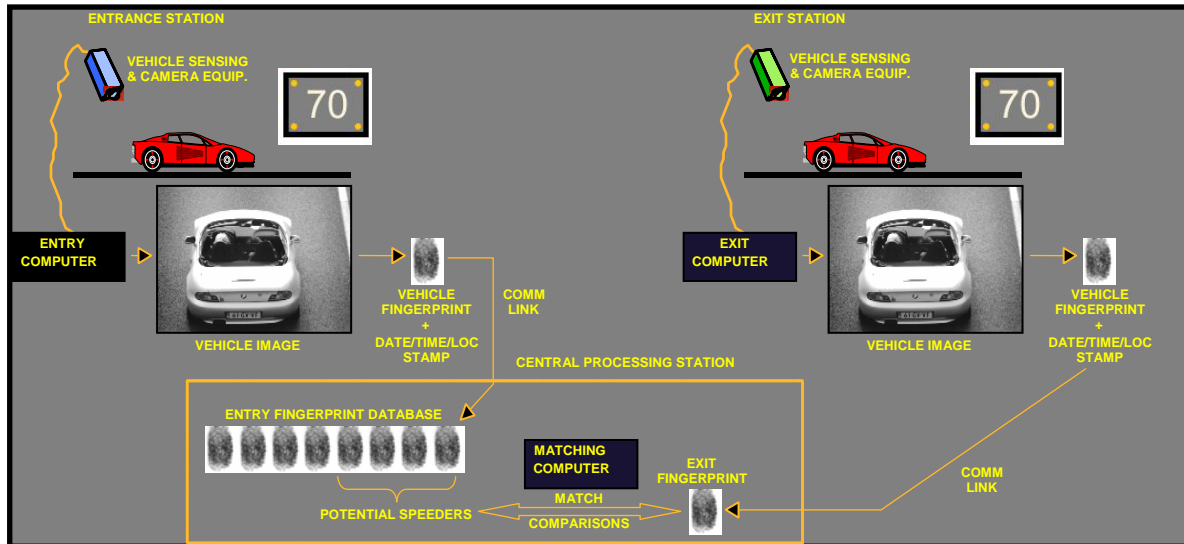
²⁴ Hicks, Luttrell, and Carter. "Automated Vehicle Identification Tags in San Antonio: Lessons Learned from the Metropolitan Model Deployment Initiative." SAIC. Oct 2000. EDL# 13230.
http://www.itsdocs.fhwa.dot.gov/JPODOCS/REPTS_TE/13230.html

“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 optical character recognition (OCR) technology, after which the record is time-stamped with data about the location at which it was spotted. 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. 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.

- The Arizona SR 68 Work Zone project, in which an ALPR system monitored area traffic along SR 68 to ensure that work zone travel times were maintained at a certain minimum thresholds during construction.
- Dutch Section Control²⁵ - Section control is based on the use of license plate number recognition technology to detect and record the passing of individual vehicles past consecutive camera stations. A centralized processor is then used to calculate vehicular travel times (and based on this, average speeds) along the segment(s) of roadway being monitored. If the average speed of a given vehicle between two checkpoints is determined to be in excess of the posted speed limit, then the system automatically generates a ticket; if the read quality of a license plate image is low, then a manual comparison of the plate images is made before ticketing takes place.

²⁵ Presentation by René Korevaar, Rijkswaterstaat Transport Research Center, August 3, 2005.

Dutch Section Control Architecture²⁶



4.2 General Conclusions about Deployment of Toll-Tag and License Plate Reader-based (LPR) Data Collection Systems

Where tolling functions are already in place and a large population of drivers is equipped with toll tags, the existing toll systems in conjunction with the installation of supplemental toll tag readers can prove to be an accurate and valuable source for continuous real-time travel time estimation. Data from such system can be used for a variety of applications, including: traveler information, incident detection, fleet management, and regional performance measurement.

License plate reader-based video image processing has a wide range of potential applications from toll and signal enforcement to border crossing, and travel time estimation. This technology has the potential to capture a greater percentage of the roadway vehicular traffic without the need for in-vehicle device presence (e.g., toll tags). It is, however, susceptible to environmental factors and can be costly to deploy on a regional basis as compared to systems that leverage existing tolling infrastructure.

5. Technology and Business Innovations in Traditional Data Collection Technologies

This section of the memorandum provides information on various technology and business innovations in traditional data collection technologies.

²⁶ Presentation by René Korevaar, Rijkswaterstaat Transport Research Center, August 3, 2005.

5.1 New types of Point Sensors

5.1.1 Sensys Networks

VSN240 sensors are a new type of wireless magnetic traffic monitoring sensor manufactured by Sensys Networks, Inc (<http://www.sensysnetworks.com>). They are the result of a three-year research project at the University of California at Berkeley's (UC Berkeley) Center for Information Technology Research in the Interest of Society (Professor Pravin Varaiya was the lead researcher). The VSN240 sensor was developed for use as a replacement for traditional loop detectors and uses magneto-resistive sensor technology to detect changes in the earth's magnetic field caused by the presence or passage of vehicles.²⁷

A. Technology

In a VSN240 network, traditional inductive loops are replaced by small, hardened, VSN240 wireless sensors that are either glued to the pavement (in a fashion similar to pavement markers) or placed in a 2" deep cored hole (in areas where snowplows are used during winter months). Like loop detectors, VSN240 sensors are capable of providing presence, vehicle count, occupancy, and point speed measurements. According to Sensys Networks, life expectancy of these battery operated sensors is 5-7 years.

In a typical deployment, VSN240 sensors are deployed in conjunction with an AP240 access point; mounted on poles at the roadside. The AP240 collects (via wireless data transmission) and aggregates data from all of the VSN240 sensors in its network (up to over 1000 sensor nodes – range of each AP240's network is augmented by the deployment of signal repeaters used to transmit data from more distant VSN240 sensor nodes), formats the data, and relays the data back over a GPRS, Ethernet, or RS485 connection to the end user.

B. Business Model

It is unknown.

C. Costs

Cost information is unavailable at this time.

D. Existing Deployments

VSN240 evaluation nodes have been placed on I-880 in CA, two Texas freeways (for evaluation by the Texas Transportation Institute [TTI]), one freeway in Scottsdale (for evaluation by Arizona DOT), and at a number of other intersections and parking facilities.

²⁷ Phone interview with Professor Pravin Varaiya (UC Berkeley) – January 19, 2006.

E. Test Results

The results of testing conducted by UC Berkeley in late 2004 indicated that the VSN240 sensor provides count accuracy exceeding 98 percent, approximately 90 percent accuracy in average vehicle length and speed estimates.

Testing by TTI indicated that errors in speed estimation were found to be between 0.3 percent and 6.9 percent. There was no apparent pattern for the percentage error at any particular speed.²⁸

5.1.2 MOTES Technology (Experimental Technology)

A. Technology

Motes technology, also known as ‘smart dust’, consists of tiny, low-cost, low-power robots used as sensors for a range of different applications. A programmer writes software in an operating system called “TinyOS” to setup the mote to monitor any of a number of conditions, including: levels of light, position, acceleration, vibration, weight, pressure, chemical contents, etc. The sensor subsequently transmits the data it collects back to a centralized server via wireless communications. The most common radio links allow a mote to transmit at a distance between 10 to 200 feet.

MICA mote is a commercially available product (developed by a company call Crossbow) that has been used by researchers and developers to test mote-related applications. Crossbow makes two types of commercially available products:

- Rectangular, measuring 2.25 x 1.25 by 0.25 inches (5.7 x 3.18 x.64 centimeters), it is sized to fit on top of two AA batteries that provide it with power; and,
- Circular, measuring 1.0 by 0.25 inches (2.5 x .64 centimeters), it is sized to fit on top of a 3 volt button cell battery.

University researchers have also been able to manufacture motes that are as little as 3 millimeters per side; it is intended that production processes will eventually result in devices no bigger than a grain of sand or dust particle.

Researchers believe that real potential exists for networks of motes to be utilized as traffic sensor networks, providing DOT staff with the ability to measure traffic flows, detecting speeds and recognizing when incidents occur. As the motes themselves are very inexpensive and require no hookup to power or communications, the cost of installation and ongoing maintenance would likely be very low.

²⁸ Ashkan Sharafsaleh, Ching-Yao Chan, Experimental Evaluation of Commercial-Available Off-The-Shelf Sensors for Intersection Decision Support Systems, 2005, page 7.

In a recent conversation with Ashwin Amanna, Manager, Wireless Infrastructure at Virginia Polytechnic Institute and State University (Virginia Tech) Transportation Institute he indicated that they are beginning to work on the idea of applying motes technology to transportation applications (e.g., deploying motes at major interchanges to assess their ability to collect traffic counts and vehicle presence data, as well as assess speeds, and potentially, travel times). He believes that state DOTs will be able to adopt the use of motes sensor nodes as an alternative to more traditional forms of data collection, deploying thousands of motes sensor at a time and replacing them when they reach the end of their usable lifespan.

During this conversation, Mr. Amanna indicated a willingness to collaborate with any parties interested in developing transportation applications based on this technology; potential partners currently include Cisco System, Marshall University, and the Virginia Transportation Research Council. He suggested that if interested, the Florida Department of Transportation should simply contact him to initiate talks.²⁹

B. Business Model

It is unknown at this time.

C. Costs

While costs have averaged \$25 per mote until fairly recently, developers believe they now have the capability of manufacturing 3 square millimeter mote chips for less than \$1 each when mass produced.

D. Existing Deployments

Motes (and networks of motes) have been utilized in a wide variety of experimental applications, including: monitoring leaks in water pipelines, maintaining the temperature in buildings, measuring bridge vibrations in San Francisco, tracking growth of forest fires. It is anticipated that industrial applications for motes will begin to appear sometime during 2006.

E. Test Results

Motes have been fruitfully utilized to support data collection across a range of experimental applications. For example, as part of one study, researchers examined the feasibility of using motes for risk/health monitoring in buildings. Although not 100% successful, the study indicated that using motes for this purpose showed a great deal of promise.³⁰

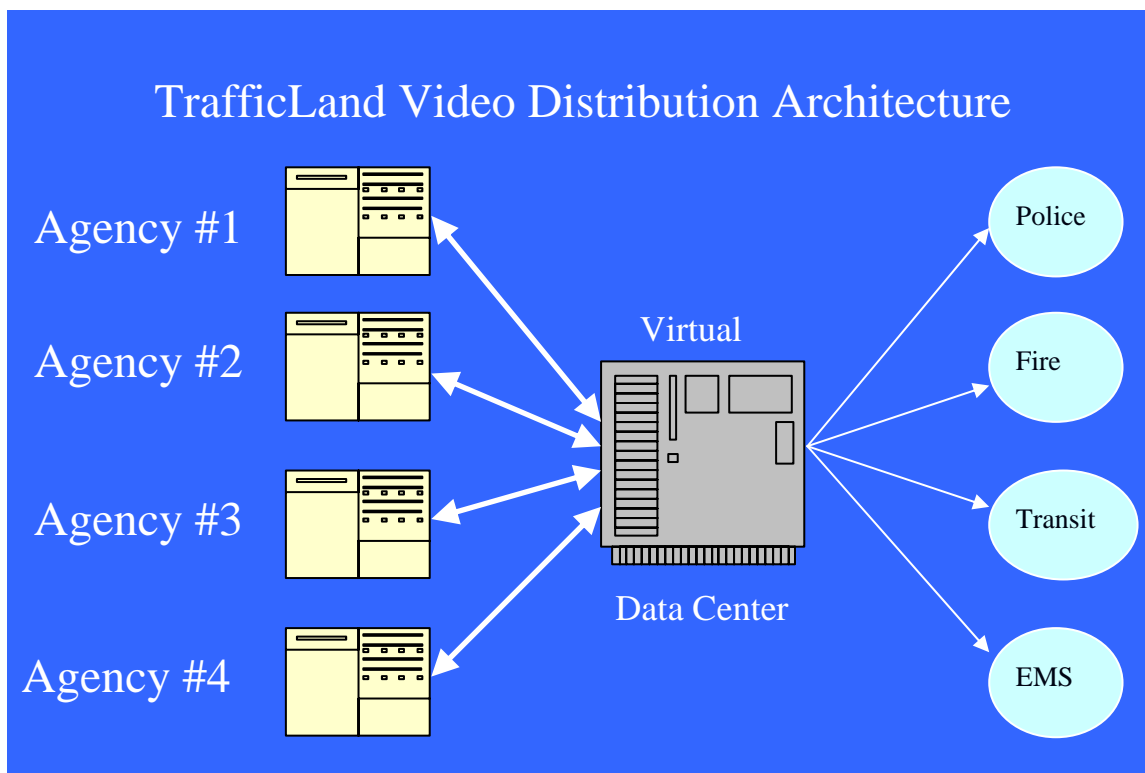
²⁹ Phone interview with Ashwin Amanna – January 19, 2006.

³⁰ N. Kurata, B. F. Spencer, Jr. and M. Ruiz-Sandoval, Application of Wireless Sensor Network Mote for Building Risk Monitoring, 2004, page 4.

- Hurricane Evacuation;
- Port Security;
- Critical Infrastructure Protection;
- Military Deployment; and,
- National Security.

In addition, TrafficLand is currently providing operators of Web sites for radio stations, newspapers, DOTs and other agencies with the ability to embed camera displays into their Web sites that will allow users to view live streaming video.

Figure 1.3 – TrafficLand Video Distribution Architecture



C. Costs

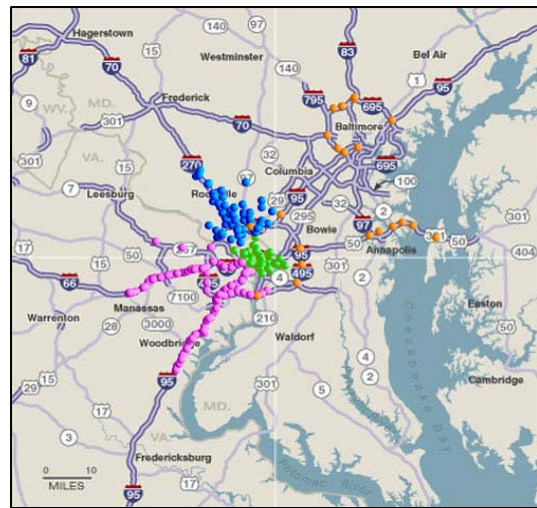
Cost of provision of this service to the public sector will vary based on deployment requirements. However, representatives of TrafficLand have indicated that they are currently in discussion with the FDOT concerning provision of their services.

The TrafficLand Web site allows users to view video from hundreds of CCTVs from across the United States for free.

D. Existing Deployments

TrafficLand's Video Distribution System (VDS), currently deployed in the Washington, DC area displays live streaming video from over 70 cameras at 20 to 30 frames per second and video images from an additional 320 cameras at 1 to 3 frames per second. Users of this video include:

- Virginia State Police Barracks 7
- Virginia State Police Headquarters
- Metropolitan Police
- DHS HSOC
- Fairfax County Police
- Federal Protective Service
- Fairfax County 911 Center
- Prince William County 911 Center
- VDOT Transportation Emergency Operations Center
- WMATA Bus Operations Center
- Maryland State Highway Administration
- Montgomery County Maryland DPWT
- DC Department of Transportation



Live Web-based video is also currently available for:

- Baltimore, MD
- Baton Rouge, LA
- Hampton Roads, VA

E. Test Results

N/A

5.3 Business Model Innovations

5.3.1 SpeedInfo

SpeedInfo Inc. is a private company based in Cupertino, California, that has developed an extremely low-cost, roadside-mounted, traffic speed measurement sensor. This sensor is entirely self-contained – it is solar powered (with a battery backup) and utilizes a GPRS-based wireless data connection to transmit/receive data to/from SpeedInfo’s server. The sensor mounts quickly on existing poles or other structures (approximately 20-30 minutes mounting time for experienced staff) and requires no hook-up to local power or communications infrastructure. Finally, SpeedInfo maintains that their sensors are capable of performing without the need for maintenance for at least five (5) years. As a result, each sensor can be deployed and operated at a fraction of the cost of traditional non-intrusive traffic data collection technology.

A. Technology

The SpeedInfo DVSS-100 Speed Sensor uses Doppler radar technology to measure the speed of vehicles in its field of view, calculate average speed at that location (for both directions of travel), and transmit that data back to the SpeedInfo server for analysis. Each Doppler sensor is controlled and operated remotely from the SpeedInfo server using its GPRS data link.

In general, data from SpeedInfo’s sensors is reported to end users (e.g., state DOTs) via a standard XML data feed at least once per minute during the day (5:00 am – 9:00 pm) and once every 5 minutes at night (9:00 pm - 5:00 am) (“DATA”).

B. Business Model

SpeedInfo typically contracts with public agencies to deploy sensor networks under one of two business models:

- The customer purchases the sensors and the data they generate – in this case, the customer has unrestricted rights to redistribute or resell all data. As part of this purchase, the customer pays for SpeedInfo to warranty the sensors and provide an XML data feed for a certain number of months/years.

- The customer pays for SpeedInfo to deploy, operate and maintain the sensor network for a contracted term. Under this contract type, SpeedInfo owns the sensors, as well as the data they generate – the customer licenses the data from SpeedInfo and may distribute it to government agencies within the state. However, in this case SpeedInfo maintains the exclusive right to resell the data to commercial third parties. For example, SpeedInfo recently signed a licensing agreement to provide TrafficGauge, Inc. with data from its sensor network in San Francisco.

Once it has deployed larger numbers of sensors across the United States, SpeedInfo anticipates the ability to license its data stream to a range of third-party commercial users, including: satellite radio, automobile navigation system providers, traveler information ISPs (similar to TrafficGauge, Inc.), cell phone providers, etc.

C. Costs

In December 2005, the North Carolina Department of Transportation purchased forty (40) SpeedInfo DVSS-100 Speed Sensors for \$130,000. This contract includes the provision of aggregated data from these sensors via XML feed and an equipment warranty for a period of 30 months.

No cost information is currently available for the SpeedInfo business model under which public agencies do not own the equipment that is deployed, instead licensing the resulting data stream from SpeedInfo.

D. Existing Deployments

SpeedInfo has evaluation sensors installed in Washington, DC, New York City, Los Angeles, and Tampa, FL. Full sensor networks are currently installed in the San Francisco Bay area (300 sensors along more than 900 miles of roadway as part of the 2005 ITS World Congress), along the I-95 corridor between the Virginia border to Raleigh-Durham, NC (20 sensors along 100 miles of roadway), and along I-40 in through Raleigh-Durham, NC (20 sensors along 30 miles of roadway).

E. Test Results

SpeedInfo's DVSS-100 Speed Sensor utilizes traditional Doppler radar to calculate vehicular speed data. Independent ground truth evaluations of SpeedInfo's sensor data quality by TrafficGauge found that a difference of between 3-5 miles per hour.

5.3.2 Traffic.com (Mobility Technologies)

Traffic.com is one of the largest independent providers of traffic information in the United States and supplies traffic information in 28 markets to such entities as state DOTs, XM Satellite Radio, telematics providers, and the Weather Channel. The company makes use of state DOT loop detectors and other sensors, as well as its own extensive network of sensors deployed as part of

the U.S. DOT's Transportation Technology Innovation and Demonstration Program (TTID). In addition, the company employs operations staff in each market it covers for the purpose of monitoring conditions and supplementing information collected from automated sensor collection infrastructure.

A. Technology

Traffic.com deploys pole mounted speed sensors capable of providing spot speeds, traffic volumes, vehicle occupancy, and vehicle classification data. The sensors transmit the data over a wireless network to a company data center for aggregation and archiving, and for distribution to customers via Internet, radio, TV, etc. Traffic.com indicates that it has recently been using GPS-based probe, anonymous cellular probe, and toll-tag data as additional supplements.

B. Business Model

The bulk of Traffic.com's sensor deployments have been funded under the TTID. This program, which was originally authorized as part of the TEA-21 transportation bill in 1998, provided up to \$50 million in federal funds to pay for the deployment of traffic data collection infrastructure in many (approximately 25) of the country's most congested cities; with Traffic.com being the sole contractor these cities are allowed to use. Traffic.com is required to sign individual agreements with the appropriate state/local transportation agencies in each city identified in the TTID program legislation before they can deploy their technology. Copies of these contracts are available at: http://www.itsonline.com/ttid/ttid_agreement_table.html. In most cases, federal funding pays for 80 percent of the cost of these deployments. Interestingly, as part of most of its contracts, Traffic.com has itself provided the 20 percent local funding match required to access federal funds. Due to ongoing controversies surrounding the TTID program, including both the exclusivity enjoyed by Traffic.com, as well as data use limitations that Traffic.com has imposed on a number of its public sector clients, questions exist concerning the extent to which Traffic.com will be able to access additional TTID funds in the future.

C. Costs

The TTID Program generally provides each city with \$2.5 million dollars (\$2 million of federal funds and \$.5 million local match) to support traffic data collection. Traffic.com uses this funding to deploy and operate/maintain approximately 100 vehicle detection sensors.

D. Existing Deployments

Traffic.com currently has sensors deployed in 28 markets. Details of these deployments are available at: http://www.itsonline.com/ttid/ttid_agreement_table.html.

E. Test Results

According to a study conducted by Frost & Sullivan, ground truth analysis of Traffic.com's data showed accuracy in excess of 70% - with the average measured travel time being within one minute of the actual travel time. A copy of this study can be requested at: www.INRIX.com/accuracy.asp.

6. Final Conclusions and Recommendations

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

- Traditionally, funding for traffic data collection has gone toward the procurement and maintenance of infrastructure owned by the public entities involved. With that in mind, will it be possible to engage in the purchase of traffic data from the private companies operating the data collection systems described in this study?
- Data collection solutions need to fit a purpose. What data requirements has the FDOT defined and how can the various technologies described in this paper help to meet them?
- For any of the technology solutions 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 program implemented by the FDOT adhere to ITS America's Fair Information and Privacy Principles. In addition, any third party selected to implement one of the solutions described in this memorandum should be required to submit an affidavit indicating that they will not use any data collected by the data collection system in an inappropriate manner, including:
 - Renting, leasing, selling, or otherwise providing data to any entity without explicit written permission;
 - Using data for any purpose(s) other than those described as part of the project requirements; and,
 - Attempting to identify the ownership of individual vehicles whose personal information is collected as part of the system's data collection infrastructure.

In addition to dealing with the issues described above, it is essential that a comprehensive Traffic Data Monitoring Plan be developed by the FDOT that outlines a methodology for advancing traffic data collection and integration efforts throughout the state. This plan should:

- Establish a vision and purpose for traffic data collection and the integration of data from other resources, including how it will be used to support operations, planning, and traveler information applications.

- Determine the facilities for which data is to be collected (including key roadways and intersections), the density of coverage, and the required data quality parameters.
- Use existing corridor plans to assist in the selection of the data collection and communication technologies to be used, taking into account the extent to which the technologies selected support the existing corridor concept and plans.
- Identify modifications to the regional architectures/systems necessary to incorporate data into statewide, regional, and local operations as desired, as well as share data with other agencies.
- Establish performance monitoring metrics that will be used to assess the overall impact of the technology solutions being deployed.

Furthermore, the FDOT should continue to monitor developments in the field of innovative traffic data collection and, as appropriate, cultivate partnerships with both those companies and public agencies seeking to deploy wide-area traffic data collection systems, as well as other companies seeking to utilize innovative business models to facilitate enhancements in traffic data collection. By establishing these relationships now, the FDOT can help to ensure that it will play a key role in ongoing research and testing efforts in the future.

Table 2: Summary of Technology Solutions Discussed in the Memorandum

	Point-based Sensors	Tracking of Electronic Toll Collection (ETC) Transponders and License Plate Readers	GPS-based Traffic Data Collection	Telematics-based solutions (including VII)	Tracking of Cell Phones
Operator	Private/Public Sector	Public Sector	Private Sector	Private/Public Sector	Private Sector
Nature of the Data Collected	Point Oriented	Link Oriented	Network Oriented Probe Vehicle Data	Network Oriented Probe Vehicle Data	Network Oriented Probe Vehicle Data
Functionality of Data Collected	Volume, Vehicle Class, Point Speed and estimated travel times, and Incident Detection	Average Speed and Travel Time Between Various Readers, Estimated Volumes, and Incident Detection	Point Velocity, Stop Durations, Space Mean Speed and Travel Time	Speed, Location, Acceleration, Pavement Conditions, Weather, and Vehicle Operating Condition.	Link Speed and Travel Time and Incident Detection
Type of Infrastructure Used	Sensors embedded in the road or at the roadside	Antennas track ETC tags/Optical plate readers track license plates	On-board GPS devices and wireless data transmission	GPS/wireless telecomm. based or roadside communication stations (e.g., VII)	Cellular network infrastructure and back office processing
Maturity of the system	Very Mature	Mature	GPS is mature, back office systems still being developed	Early generations exist, but need further refinement	Test results indicate further refinement is needed
How system collects information on vehicles - flow of data	Detectors store data or send it via modem to ATMS center	Antennae/Optical readers send data to roadside processors which transmit the data to ATMS center	Probe vehicles transmit data on their movement to back office processor	Probe vehicles transmit data on their movement to back office processor	Back office processors use network data to estimate roadway speeds and conditions
Range of Detection Area	Detection area immediately around the sensor	Area within range of each ETC antenna/optical plate reader	Area within range of wireless data transmission (if satellite based, then nearly unlimited)	Area within range of wireless data transmission (if satellite based, then nearly unlimited)	Areas where cell phone companies have sufficient cell tower infrastructure

Technical Memorandum — IDC Research
Update on the State of the Innovative Traffic Data Collection Industry

Provision of Real Time Data?	Depends	Yes	Yes	Yes	Yes
Other needs	Placement of sensors in roadway right of way.	Need sufficient penetration of vehicles to calculate accurate link travel times.	Need cooperation of management company and/or fleets themselves	Need cooperation of telematics providers and/or vehicle owners	Need cooperation of carrier, technology vendor, and/or cell phone subscribers