

**An Analysis of the Impact of Wireless Technology on Public vs. Private  
Traffic Data Collection, Dissemination, and Use**

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Submitted to the Department of Urban Studies and Planning  
in partial fulfillment of the requirements for the degrees of

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and  
Master of Science in Transportation


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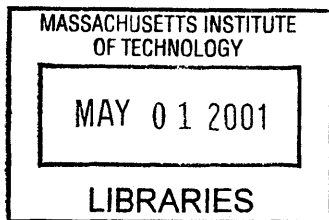
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**ROTCH**

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## **ABSTRACT**

The collection of data concerning traffic conditions (e.g., incidents, travel times, average speed, traffic volumes, etc.) on roadways has traditionally been carried out by those public entities charged with managing traffic flow, responding to incidents, and maintaining the surface of the roadway. Pursuant to this task, public agencies have employed inductive loop detectors, closed circuit television cameras, technology for tracking electronic toll tags, and other surveillance devices, in an effort to monitor conditions on roads within their jurisdictions. The high cost of deploying and maintaining this surveillance equipment has precluded most agencies from collecting data on roads other than freeways and important arterials. In addition, the "point" nature of most commonly utilized surveillance equipment limits both the variety of data available for analysis, as well as its overall accuracy. Consequently, these problems have limited the usefulness of this traffic data, both to the public agencies collecting it, as well as private entities who would like to use it as a resource from which they can generate fee-based traveler information services.

Recent Federal Communications Commission (FCC) mandates concerning E-911 have led to the development of new technologies for tracking wireless devices (i.e., cellular phones). Although developed to assist mobile phone companies in meeting the FCC's E-911 mandate, a great deal of interest has arisen concerning their application to the collection of traffic data.

That said, the goal of this thesis has been to compare traditional traffic surveillance technologies' capabilities and effectiveness with that of the wireless tracking systems currently under development. Our technical research indicates that these newly developed tracking technologies will eventually be able to provide wider geographic surveillance of roads at less expense than traditional surveillance equipment, as well as collect traffic information that is currently unavailable. Even so, our overall conclusions suggest that due to budgetary, institutional, and/or political constraints, some organizations may find themselves unable to procure this high quality data. Moreover, we believe that even those organizations (both public and private) that find themselves in a position to procure data collected via wireless tracking technology should first consider the needs of their "customers," the strength of the local market for traffic data, and their organization's overall mission, prior to making a final decision.

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Thanks are also due to my thesis reader, Professor Joseph Ferreira, not only for his comments and suggestions, but more importantly for encouraging me to delve a bit into some of the more technical aspects concerning the sharing of spatial data.

Some of the initial ideas for a research topic came directly out of conversations that I had last summer with employees of the Volpe National Transportation Systems Center and EG&G Services. Consequently, I must extend a great deal of thanks to Allan DeBlasio, David Jackson, and most especially Jane Lappin, for the advice they provided.

A great deal of the information contained in this thesis was developed from interviews I carried out with people knowledgeable about the collection of traffic data and/or the implementation of probe vehicle programs. Accordingly, I would like to thank these individuals for their assistance. They include: Bill Twomey, Brian Smith, Dave Lovell, David Aylward, Dick Mudge, Eli Sherer, Evan Lemonides, Jane Lappin, JR Robinson, Mark Hallenbeck, Mike Zezeski, Paul Najarian, Peggy Tadej, Pete Briglia, Phil Tarnoff, and Rick Schuman.

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This thesis is dedicated to the memory of my grandmothers, Rose Maccarone and Thelma Gale.

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# CHAPTER 1

## INTRODUCTION

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### 1.1 Purpose and Scope of Study

Public sector investment currently represents the lion's share of funding for basic Intelligent Transportation Systems (ITS) infrastructure. However, with advances in wireless technology and the potential for providing value-added information and other in-vehicle services to drivers, there has recently been a significant increase in private sector interest in the collection and delivery of real-time, consistent traffic information. The primary goal of this thesis is to analyze the issues surrounding the collection of traffic data by the public and private sector entities. The results of this analysis will then be utilized as a foundation from which we will develop a group of frameworks describing some of the future relationships that might coalesce around traffic data collection, sharing, and use.

### 1.2 Definition of Intelligent Transportation Systems (ITS)

Intelligent Transportation Systems (formerly known as Intelligent Vehicle Highway Systems or IVHS) "apply well-established technologies in communication, control, electronics, and computer hardware and software to improve surface transportation system performance" - e.g., reduce congestion, enhance safety, mitigate the environmental impacts of the operation of transportation systems, enhance energy performance, and improve productivity.<sup>1</sup> Due to the increasingly widespread availability of a large number of different ITS products and services, decision-makers now have a range of choices from which to choose the measures they will utilize to address a given transportation system design. This thesis is about those choices.

---

<sup>1</sup> Sussman, J. "What Have We Learned About ITS? A Synthesis," p. 3.

### 1.3 Background

For some time now, the population of drivers in the United States has been on a rapid upswing, while the number and capacity of our roads has remained comparatively static. As a result, traffic congestion has had an increasing impact on driver safety and the livability (both economic and environmental) of our cities. Two Intelligent Transportation System (ITS) activities that have been undertaken to help manage this problem are Advanced Transportation Management Systems (ATMS) and Advanced Traveler Information Systems (ATIS).

a) ATMS - collect data and provide transportation decision-makers with better data with which to make choices concerning how to best improve the operational efficiency of transportation networks. In more sophisticated deployments, the ATMS itself is able to make decisions regarding network operations. ATMS infrastructure has traditionally been publicly financed and operated. This infrastructure typically operates in and around roadways in conjunction with public traffic management facilities, in order to provide traffic surveillance, incident management, automated signal control, and roadside display of traffic information to drivers via usage of variable message signs. In general, transportation management systems are composed of a range of services that can include:

- Traffic control;
- Incident management;
- Traffic demand management;
- Support of transportation planning functions; and
- Policing and enforcement of traffic regulations.

Altogether, by determining current traffic conditions, traffic management systems can be utilized to improve the distribution and flow of traffic on roadways.

b) ATIS - provide travelers and businesses/commercial carriers with information that will improve the quality and efficiency of their trips. Basic traffic information (typically available free) can be provided to drivers via mechanisms ranging from highway advisory radio, the Internet, and cell phones. Drivers can also access more detailed traffic information by using in-car telematics services (which cost several thousand dollars to purchase and install and require monthly fees) that enable them to receive real-time traffic data, dynamic route guidance, and other services. Although the direct benefits of ATIS are to the individual



driver, it is generally agreed that there are indirect benefits that accrue to the public as a whole *if* the use of private ATIS services improves overall traffic conditions. Traveler Information services typically include:

- Pre-trip information about traffic;
- In-trip driver information about traffic;
- Personal information services; and
- Route guidance and navigation.

Although some public ATMS agencies also provide basic ATIS services (via variable message signs, the Internet, and intermediary Information Service Providers [ISPs]) based on the notion that benefits will accrue to the road network as a whole if a certain percentage of drivers are routed around congested areas, there are major differences in the philosophies underlying public vs. private sector activities. Whereas public sector agencies are concerned first and foremost with the management of road infrastructure and maximum efficiency in the flow of traffic on that infrastructure, they collect traffic data that will provide them with the ability to carry out their management and planning activities, while providing drivers with basic congestion and incident information - without regard for each driver's individual preferences. In contrast, private ATIS providers' only concern relates to the improvement of driving conditions for their customers. Consequently, they are primarily interested in traffic data that will provide their customers with the greatest benefit (via reductions in travel time).

Using loop detectors, video cameras, electronic toll tags, and other surveillance devices, public agencies have in the past attempted to monitor traffic conditions on portions of their networks and utilize this information in an effort to optimize traffic conditions via signal timing, ramp metering, incident management, provision of information to drivers via variable message signs, advisory radio messages, as well as other public services. Simultaneously, private sector interests have sought out this data (as well as data that they have been able to collect on their own) in order to provide specially packaged traveler information meant to enable drivers to make better travel decisions, both pre-trip and in-route.

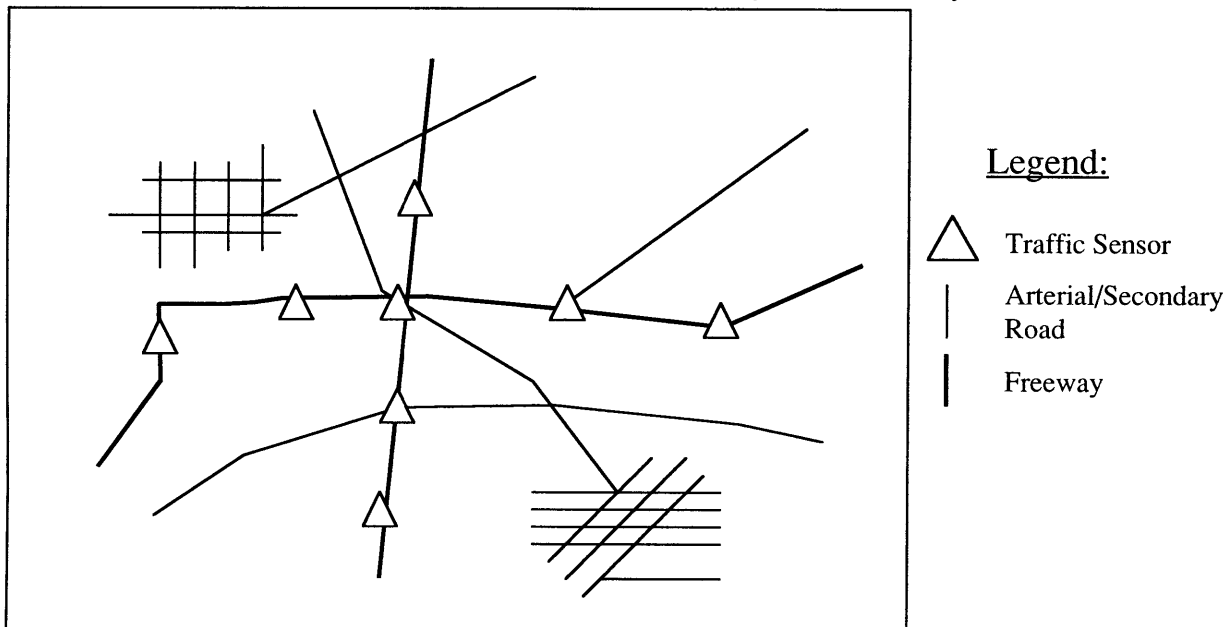
During the past several decades, the bulk of traffic data has typically been collected by the public sector for ATMS purposes and subsequently provided to interested private sector companies at little or no cost. Unfortunately, due to their own limited resources and sometimes poorly

maintained traffic detection equipment, most public agencies have only been able to gather partial information about their networks. Moreover, for the reasons just mentioned, much of this data is either highly inaccurate or of uneven quality. Consequently, private sector companies interested in using publicly available data generally do so with the understanding that this data will not necessarily be very accurate or complete. These companies must also contend with the difficulties associated with having to develop data sharing relationships with the multitude of state and local traffic agencies having (sometimes overlapping) jurisdictions, as well as the fact that some of these agencies have simply been unwilling to share their data.

Another problem (primarily for private entities wanting to use public data as a resource for their ATIS services) stems from differences in the data types in which the public and private sectors are generally interested. This has resulted in a "data gap" concerning the information that private sector entities would like to have for ATIS purposes, and the data that is actually available to them from the public sector. In response, the private sector has begun to deploy resources of its own (e.g., Closed Circuit Television Cameras (CCTV), etc.), to collect supplemental data to what is available from local traffic agencies.

Although Federal officials have discussed the possibility of instituting national standards concerning the manner in which traffic data is collected and stored, such a concept does not fully address the true problem; in most cases available traffic data is simply inadequate for either true ATMS or ATIS services. Even in cases where link speeds and/or travel time data is available, it is generally available for only a few roads (primarily freeways - and few, if any arterials and secondary roads). An example of how public sector resources might be laid out on a road network can be seen in **Figure 1.1** below. Consequently, this problem will continue to exist whether or not a national standard that governs data collection practices is created. Simply put, if the infrastructure for collecting certain types of data is not in place, then having standards that govern how data should be collected, fused, and shared will be will be relatively ineffective.

**Figure 1.1 - An Example of Traffic Sensor Deployment by a Public Entity**



#### **1.4 Increased Private Sector Interest in the Collection of Traffic Data**

A study presented by Apogee Associates in May of 1997 estimated that the market for ITS products and services would grow to approximately \$420 billion over the next twenty-years. This study also predicted that private sector investment in this market will eventually grow to encompass approximately eighty percent of all sales through the year 2015 (for details, see **Figure 1.2** below).<sup>2</sup>

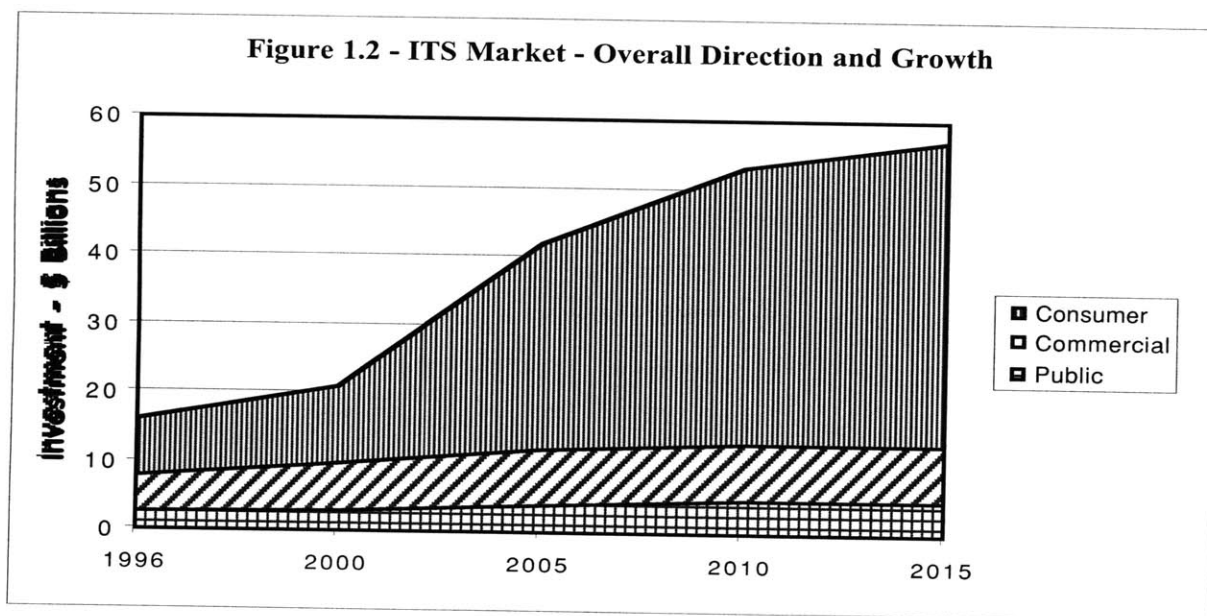
Implementation of many of the ITS applications involved in this market will require that private service providers first have access to highly accurate vehicle location information. Vehicle location-based applications use wireless locational technology to determine a vehicle's physical location, thereby facilitating the provision of a range of services, including the three listed below.

Apogee's breakdown of private sector investment (a combination of the consumer and commercial markets) in ITS over the next twenty years provides the following estimates:

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<sup>2</sup> Apogee Research, Inc., p. 2.

- Fleet Tracking - (\$52 Billion) Enables a commercial entity, e.g., United Parcel Service (UPS), to monitor the location and routing of its truck fleet;
- Mayday Systems - (\$70 Billion) Safety/security applications that provide drivers with the ability to broadcast a request for assistance and their vehicle's current position to a service center. An example of such a system is General Motor's (GM) On-Star System; and
- Dynamic Route Guidance and Information - (\$81 Billion) Provide drivers with driving directions that will get them from point A to point B in the least amount of time, based on the vehicle's current location, real-time traffic conditions, roadway construction and weather information, etc.



From "Intelligent Transportation Systems - National Investment and Market Analysis," Apogee Research, Inc., 1996.

In the United States, deployment of technologies for vehicle location was initially driven by regulatory mandates related to E-911 (Enhanced 911). On June 12, 1996, the Federal Communications Commission (FCC) established a timetable within which mobile phone companies were required to be able to locate wireless callers' physical locations when the caller dials 911. Phase II of this mandate, which must be met by October 1, 2001, calls for these carriers to be able to locate mobile 911 callers within one-tenth of a mile of their actual location

in at least 67% of all cases. In response, several companies initiated development of technologies that would satisfy this mandate. However, in the time since 1996, it has become clear to these companies that the ability to physically locate mobile phone users would allow them to provide these customers with numerous transportation-oriented services, including route guidance, emergency roadside assistance, automatic crash notification, other customized traffic information, concierge services, and asset tracking for commercial and public transportation carriers.

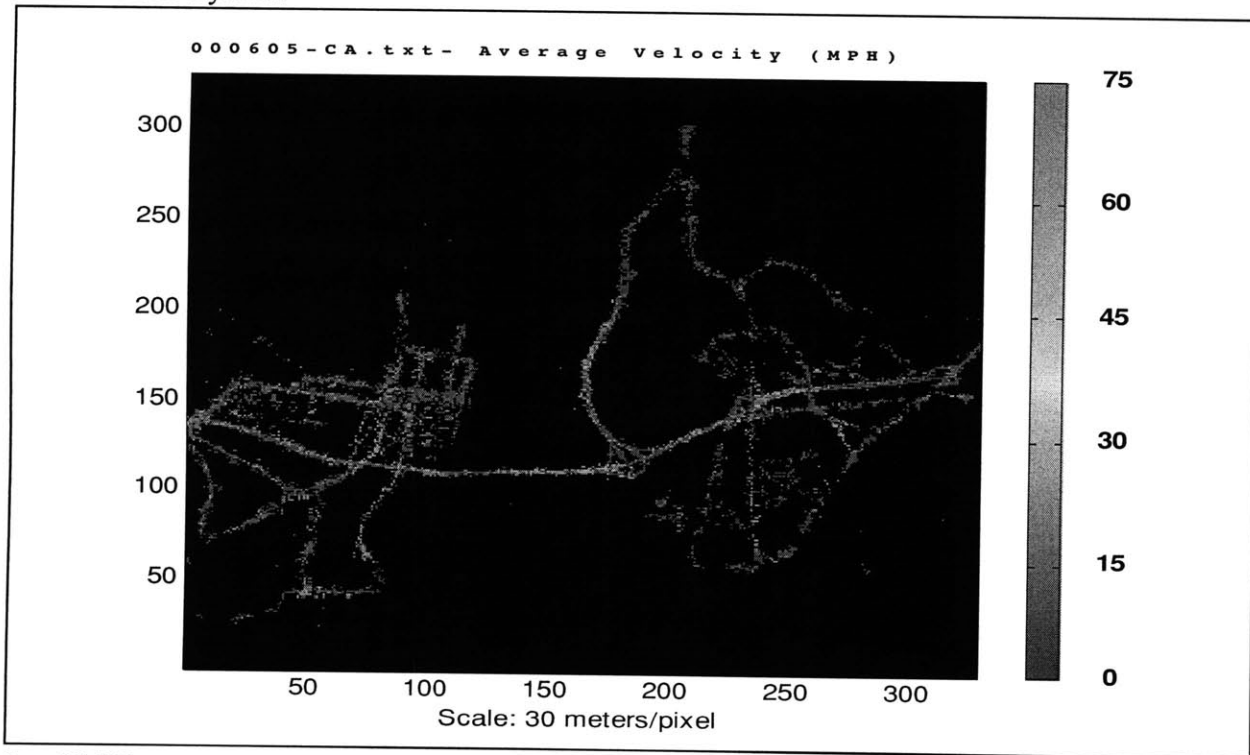
Given the lack of public sector traffic data currently available to ATIS providers, and the potential to profit from the markets described above, it is little wonder that numerous private sector entities have become interested in developing their own vehicle location/traffic data collection resources. At present, several private sector companies are investing large amounts in research and development projects that they hope will provide them with the ability to locate and gather information on large numbers of vehicles, thereby enabling them to provide drivers with mobile locational services (e.g., E-911 and dynamic route guidance), while at the same time turning these vehicles into "probes" from which they are able to gather vast amounts of traffic data. When examined as part of a traffic stream, such probes could be used to collect real-time information related to travel time and vehicular speed between two points on a link or even across a network of roads, incident detection, and congestion information. For an example of how this "network-oriented" traffic data appears on a map, see **Figure 1.3** below.

Currently, the Maryland and Virginia State Departments of Transportation are working in conjunction with US Wireless (a private developer of wireless locational technology) to field test this company's proprietary technology for collecting traffic data by tracking the movement of cell phones along certain roadways. Aside from the enormous number of cell phones already in use within the United States, "market penetration of new vehicles that are factory equipped [are delivered by the automobile manufacturer with wireless communications equipment integrated into the vehicle's electrical system] with wireless communications devices is poised to exceed 50% within the next five years...with the figure projected to rise to 100% within 10 years."

Consequently, the potential for using cell phones and/or other in-car telematics devices as the foundation on which a traffic probe system is based is substantial.<sup>3</sup>

Although a number of public sector agencies have begun utilizing electronic toll collection (ETC) transponders to collect traffic data at toll plazas and certain other important points along the roadways under their jurisdiction, this technology is fundamentally different from that being pursued by the private sector.

**Figure 1.3** - Example of a Network-Oriented, Vehicle Probe-Based Speed/Congestion Map from US Wireless' System



From "Cell Phones as Data Probes: Background and Recent US Wireless Experience," courtesy of Richard Mudge, President, Compass Service (US Wireless), September 26, 2000.

Foremost among the differences in these technologies is that although use of ETC transponders enables public entities to track individual vehicles, thereby providing higher quality traffic data than has generally been available in the past, ETC transponders have the capacity to transmit data over only very short ranges. Consequently, collection of data from along a road requires the

<sup>3</sup> Kelley, T., p. 28.

installation and maintenance of extensive roadside infrastructure, resulting in many of the same cost problems related to the use of more traditional detection equipment such as loop detectors. Moreover, for these systems to be effective for data gathering, relatively large numbers of transponders must be distributed to area drivers. According to people in the traffic industry, only New York and Houston have as yet been able to distribute enough transponders to collect enough data for traffic control purposes.

In contrast, private sector interest in traffic data collection focuses on the collection of data from across networks of roadways based on the ability to track large numbers of vehicles using limited infrastructure. For example, it is hoped that US Wireless' "RadioCamera" Technology will facilitate the collection of traffic data via the tracking of cell phones being transported and used in cars traveling along roads. Rather than requiring the installation of equipment at multiple intervals alongside the roads themselves, the ability to track these phones would rely on the installation of tracking infrastructure using existing cell phone towers that provide wireless service within that area. Each piece of tracking technology would potentially have the capacity to track cell phones traveling on roads within a radius of several square miles, thereby facilitating the collection of traffic data for entire networks (as seen in **Figure 1.3**). Finally, as US market penetration for cell phones is already between 85 and 100 million users, there is little, if any, indication that metropolitan areas would face a shortage of probes.

A more thorough comparison of the differences between traditional traffic surveillance equipment and technologies utilizing vehicles as probes can be found in **Chapter 2**.

In general, the arguments put forward to justify why a probe-based, wireless traffic data collection system (excluding the tracking of ETC transponders) represents a step forward from what the public sector currently uses include:

- It provides the potential to gather high quality traffic information from across entire traffic networks without requiring expensive investments in fixed detection equipment; an option not currently available to either the public or private sectors. Traffic agencies' currently rely on sensors embedded in or alongside the roadway. This only provides information about that

one location (referred to as "point data"). Consequently, even in areas that have made large investments in detection infrastructure, major sections of the road network remain in a large blind spot. Readers should compare **Figure 1.1** (representing public sector, point-oriented infrastructure - including ETC toll collection equipment) and **Figure 1.3** (representing the ability of private sector probe vehicle technologies to collect network-oriented data); this illustrates the basic differences in how these systems are arranged.

- Information Service Providers (ISPs), companies that take public data (and sometimes their own as well), re-package it, and provide it to their customers in the form of ATIS services, are currently limited in their ability to market their services due to the spottiness and unreliability of the data currently available. A large part of this problem is due to the fact that most public transportation agencies are either:
  - 1) uninterested in using their existing resources to collect the data in which private sector entities are interested (primarily travel times and real-time speeds); or
  - 2) unable to collect such data due to inadequate surveillance infrastructure investments or the poor maintenance of that infrastructure.
- As many public agencies currently focus almost exclusively on managing the condition of their roads, they have failed to make the necessary investments in infrastructure that would support true ATMS services. Even those public entities that have made significant investments in detection infrastructure face problems. For example, a recent issue of the Washington Post stated, "Traffic engineers have long complained that their current system of using road sensors to monitor traffic is too expensive and unable to generate comprehensive, reliable information about a daily experience so intimately shared by thousands of drivers."<sup>4</sup>

For these reasons, as well as to provide data for the ITS services (e.g., to facilitate dynamic route guidance) listed in the Apogee Study mentioned above, a large market potentially exists for the private collection of traffic data via vehicles equipped with wireless probes (excluding the usage

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<sup>4</sup> Sipress, A., "Cell Phones will be Used to Monitor Traffic."



of ETC technology). Additionally, the recent approval of a nationwide 511 number for traveler information provides another potential user group for privately procured traffic data.

## 1.5 Primary Research Questions

The main questions this thesis will attempt to answer are:

1. What factors might affect the manner in which traffic data is collected in the future?
2. What types of relationships might different entities (both public and private) establish (depending on their individual needs) with one of the private companies deploying wireless traffic data collection systems, thereby enabling the more efficient provision of both ATMS and ATIS services.

It should be noted that although we will describe and discuss two technologies currently being developed by the private sector for the wireless location of vehicles and collection of traffic data, GPS-based and cellular locational technologies (of which there are over fifteen technology development projects currently underway), this thesis will not attempt to determine which technology will eventually come into more common usage. The primary reason for this is that most of this technology is currently in the early stages of development, and it is simply too early to tell which will provide a more effective data source. Thus far, even the wireless community is split on whether to implement a cellular-phone (with integrated GPS chip) handset solution, or a network-based cellular phone signal tracking (cellular geolocation) solution. Moreover, reports by the Strategis Group predict that due to the massive profits that are likely to be gained from location-oriented services, "it can be assumed that more than one technology will succeed in at least the first generation of services."<sup>5</sup> Additionally, due to the speed at which technology has been evolving, the potential for new systems to be deployed (e.g., in-car telematics applications installed by auto-makers or their affiliates), and the lack of data concerning a market for advanced traffic/traveler information, results in this becoming a question that it is currently impossible to answer. Consequently, any conclusions elaborated within this thesis will not be based on the success or failure of the specific technologies described above, or in more detail in **Chapter 2.**

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<sup>5</sup> Fall Creek Consultant's Web-site, [www.comm-nav.com/tech.htm](http://www.comm-nav.com/tech.htm).

## 1.6 Thesis Structure

In the next chapter, we will provide an overview of the technologies currently in use by the public sector for traffic data collection, and contrast these with information about newer wireless technologies that could potentially provide real-time, network-oriented data.

**Chapter 3** will detail how the public and private sectors utilize traffic data and what each sectors' "customers" want. This chapter will also contain an overview of when and why public and private data needs have conflicted until now and the tensions that have resulted.

As one of the obstacles facing companies that want to collect and disseminate traffic data gathered via wireless technology will concern the problems to be faced in disseminating and sharing that data with customers having vastly different systems and needs, **Chapter 4** will contain an overview of relevant data collection/sharing issues and examples of how they have been addressed in other sectors (i.e., for Geographic Information Systems [GIS]).

**Chapter 5** will provide a summary of the interviews we have carried out with representatives of both public and private entities concerning the current situation, as well as how the ability to collect network-oriented traffic data via wireless technology might change the current paradigm. A portion of this chapter will be dedicated to an examination of the factors that might facilitate the usage of different traffic data collection technologies (e.g., quality of the data provided by wireless systems, imposition of regulations by the government, changes in the needs/willingness to pay of each sector, etc.).

Based on the information gathered for **Chapter 5** and an analysis of the issues raised in earlier chapters, **Chapter 6** will provide examples of some of the different frameworks for the usage of traffic data likely to emerge if and when the use of wireless technology for traffic data collection becomes more widely accepted. As the frameworks contained therein represent the synthesis of our research, the importance of **Chapter 6** cannot be overstated.

Finally, **Chapter 7** will provide an outline of our overall findings, present final thoughts on the transitions likely to take place in the collection of traffic data and the relationships which surround it, and suggest future research.

# CHAPTER 2

## REVIEW OF TECHNOLOGIES USED FOR TRAFFIC DATA COLLECTION

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### 2.1 Infrastructure Currently Used for Traffic Data Collection

Ever increasing traffic volumes combined with public entities' limited ability to construct new roads require that we make more efficient use of existing infrastructure. Consequently, traffic detectors and other surveillance equipment have been developed to allow public agencies to monitor and better operate their traffic networks. These detectors are an important element of modern traffic control systems. Their ability to collect certain types of data, as well as their cost, reliability, and accuracy, are critical considerations that public agencies examine when determining the types of detector(s) they will purchase. Such considerations become even more important in light of the recent quest that both public traffic management agencies and private information service providers have undertaken to obtain high quality real-time traffic data.

As the number of government agencies collecting traffic data has risen, so has the variety of sensors available for collecting that data. **Table 2.1** (below) summarizes the characteristics of the most important types of traffic surveillance technology described in this chapter. It is followed by **Section 2.1.1**, containing more in-depth descriptions of both the various traffic sensor technologies currently in use, as well as newer probe-oriented wireless technologies.

The contrast between **Figure 1.1** (representing public sector, point-oriented infrastructure - including ETC toll collection equipment) and **Figure 1.3** (representing the ability of private sector probe vehicle technologies to collect network-oriented data) is, we hope, instructive to the reader in understanding the basic differences in how these systems are laid out.

**Note: Graphic representations of each probe-based technology can be found in Figures 2.1 (page 31), 2.2 (page 36), and 2.3 (page 38).**

**Table 2.1 - Descriptions of Different Types of Traffic Surveillance Systems**

	<b>Loop Detectors</b>	<b>Closed Circuit Cameras (CCTV) using "Minnesota" Technology</b>	<b>Tracking of ETC Transponders See Figure 2.1</b>	<b>Tracking of cell phones - via GPS See Figure 2.2</b>	<b>Tracking of cell phones - Network Geolocation See Figure 2.3</b>
<b>Operator</b>	Public Sector	Public Sector or Private Sector	Public Sector	Private Sector	Private Sector
<b>Nature of the Data Collected</b>	Point Oriented	Point Oriented	Point Oriented	Network Oriented	Network Oriented
<b>Functionality of Data Collected</b>	Volume, Vehicle Class, Point Speed (when pairs of detectors are used) and estimated travel time, and Incident Detection	Speed of vehicles within range of camera and estimated Travel Time, Volume, Vehicle Class, and Incident Detection	Average Speed and Travel Time Between Various Antennae, Estimated Volumes, and Incident Detection	Location of Individual Phones for E-911/etc., Link Speed and Travel Time, Estimated Volumes, and Incident Detection	Location of Individual Phones for E-911/etc., Link Speed and Travel Time, Estimated Volumes, and Incident Detection
<b>Type of Infrastructure Used</b>	Sensors embedded in the road	Cameras used to monitor traffic conditions	Antennas track ETC tags as they pass underneath	GPS chipset embedded in cell phone	Cellular tracking technology placed onto cell towers
<b>How system collects information on vehicles - flow of data</b>	Detectors store data or send it via modem to ATMS center	Cameras feed video stream to traffic management center	Antennae send data to roadside readers which transmit the data via modem to ATMS center	GPS enabled phone transmits its location via cell phone signal	Infrastructure on cell towers tracks radio signals emitted by phones
<b>Range of Detection Area</b>	Area immediately above the sensor	Area within visual range of the camera	Area within 50 ft. to 100 ft. of each ETC antenna	Area within the range of each cell tower - #	Area within the range of each cell tower - #
<b>Provision of Real Time Data?</b>	Sometimes, but unlikely	Yes	Yes	Yes	Yes
<b>Capital Cost of System - @</b>	\$54,660 per detection site	\$69,600 per detection site	\$35,400 per detection site - ^	Estimated at about \$5 - \$10 per phone	Approximately \$70,000 per cell site - *
<b>Annual Maintenance and Operations Cost</b>	\$9,950 per detection site	\$5,340 per detection site	\$4,490 per detection site	\$0	About 10% of Capital Cost

Cost Data for Loop Detectors, CCTV, and ETC-based systems is taken from the report *Incident Management: Detection, Verification, and Traffic Management*, prepared by Booz-Allen & Hamilton for the Federal Highway Administration (based on the buildout for a 6-lane road). Data for the cost of GPS embedded systems is taken from the SnapTrack Data Sheet - "SnapSmart." Data for the cost of systems using cellular geolocation is taken from a US Wireless presentation entitled "Cell Phones as Data Probes: Background & Recent US Wireless Experience."

@ - Capital Costs do not include the expense of setting up and maintaining an operations center.

^ - The Capital Cost of ETC-based systems does not include the cost of acquiring and distributing sensors as this cost is assumed to have been paid for by the public entity's budget for developing an electronic toll collection system.

\* - It is estimated that there are currently 50,000 cell towers nationwide - and that number is rapidly growing.

# - The area that can be covered by each cell tower varies depending on local geography and the number of cell phones in the area. For example, while the range might be 5 miles in North Dakota, it is likely to be about .5 - 1 mile in New York City.

### 2.1.1 Detailed Descriptions of Traditional Public Sector Surveillance Equipment

- Inductive Loop Detectors - Historically, the inductive loop detector has been the primary technology used for freeway surveillance and incident detection. A detector consists of an insulated electrical wire placed on or below the surface of the road. Driving an electric current through the loop generates an electromagnetic field. Metal objects (e.g., cars) passing over the loop absorb a portion of this energy, resulting in a decrease in the inductance and resonant frequency of the field. When these aspects of the field take on certain pre-determined characteristics, the detector records the passing of a vehicle. New types of equipment and algorithms for processing data enable loop detectors to collect the following types of traffic data:
  - Traffic flow rate - by counting axles passing overhead, loop detectors are able to calculate the number of vehicles per day (or other interval of time). This enables interested parties to obtain an estimate of vehicles per hour at that point.
  - Vehicular speed - pairs of detectors (spaced from six to ten feet apart) are able to provide estimates of vehicle speed and therefore average traffic speed at the point where the detectors are located.
  - Vehicle classification - pairs of loop detectors are able to provide estimates of vehicle length based on the distance between axles. This facilitates the classification of those vehicles.
  - Loop detector occupancy time - provides estimates of the percentage of time during which the space above the detector is occupied.
  - Incident detection - algorithms have been developed to detect incidents based on traffic flow rate, vehicular speed, and loop detector occupancy time.

For collecting data on highways and other major roads, detector stations (pairs of loop detectors) are typically installed every 600 to 1200 meters. Detectors are also installed around access and exit points from areas under observation, as well as other areas where traffic management operations occur (e.g., at traffic lights).<sup>6</sup>

Problems - Although the most widely used type of traffic sensor, loop detectors have been criticized for having short life spans, providing unreliable data, and requiring lane closures

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<sup>6</sup> Black, J.

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

- Closed Circuit Television Video Detection Systems (CCTV) with use of Video Image Detection Systems (VIDS - also referred to as the "Minnesota" Technology). At present, this technology presents the strongest competition for the inductive loop detector.<sup>7</sup> Although more expensive on a per unit basis than loop detectors, CCTV/VIDS systems provide users with a much higher degree of flexibility. This improved usefulness exists because these detectors provide users with the ability to identify what is occurring at different points along the roadway both through visual inspection and electronic analysis of the video feed itself.

The primary uses for CCTV include:

- Traffic flow rate - the VIDS system provides users with the ability to estimate traffic flow for a given time interval.
- Speed measurement - provides users with the ability to create "virtual detection zones" on the video image generated by the system, thereby allowing estimation of vehicular speed at the detector's location.<sup>8</sup>
- Detector occupancy time - provides estimates of the percentage of time during which the detection zone is occupied
- Incident detection - incident detection can be based on traffic flow rate, vehicle speed, and detector occupancy time. As is not the case with loop detectors, CCTV systems allow users to determine the cause of incidents that have been detected via its ability to visually scan the roadway in real-time.

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<sup>7</sup> Berka, S. and Lall, B., p. 9.

<sup>8</sup> Mouskos, K., E. Niver, and L. Pignataro, p. 106.

Problems - Although such systems are in theory able to accomplish all of the above, most agencies merely use the CCTV aspect of the system and fail to take advantage of the opportunities that would be presented by operating a VIDS system. Consequently, these systems are primarily used to visually scan for incidents and confirm incidents reported via cell phone. As a result, few agencies are able to use these systems to gather data for anything other than incident management.

***Other surveillance equipment with modest market penetration:***

- Microwave Systems - These systems transmit electromagnetic energy at passing vehicles in order to measure their speed (by determining the time it takes for the vehicle to travel between two markers within the detector's field of view). Such detectors are small, light, and much easier to install than loop detectors. Moreover, they can operate over relatively long ranges. These detectors are commonly used at signal intersections and around road construction. They are generally useful for detecting:

- Traffic flow rate - based on the number of activations per interval, per day.
- Vehicular Speed - vehicle speed can be estimated by using two bursts of microwave energy and making assumptions concerning vehicle class.
- Incident Detection - based on traffic flow rate and vehicle speed.

Problems - Concerns about use of these detectors include: a) they can be subject to significant interference from other technologies utilizing microwave technology, and b) due to their placement above ground, they are subject to vandalism.

- Passive Infrared Detectors - This type of detector measures the infrared energy emitted by objects in its field of view. Using this information, these detectors are able to supply data about the passage and presence of vehicles, but not their speed. One major problem with this technology is that its ability to measure traffic flow can sometimes be reduced during inclement weather conditions.

- Active Infrared Detectors - These devices detect the presence of a vehicle by emitting a laser beam at the road surface and measuring the time it takes the reflected signal to return. If a



vehicle is present, the time that it takes for this signal to return to the detector will be reduced. These detectors are generally considered to be highly accurate at counting traffic on freeways. However, certain weather conditions such as snow, rain, fog, and heavy dust, have been known to cause these detectors to either undercount or overcount vehicles.<sup>9</sup> These detectors are typically utilized for signal control purposes (e.g., pedestrian crosswalks), and to monitor traffic speeds.

- Ultrasonic Detectors - These detectors operate by transmitting sound waves (above the audible spectrum) at the road surface. When a vehicle passes the detector, the range from the detector to the top of the vehicle (being less than from the detector to the roadway) is sensed and results in the detector recording the vehicle's passage. Although these detectors can be designed to record speed data (which results in them costing an order of magnitude more than ultrasonic detectors that do not)<sup>10</sup>, the types most commonly found are only able to provide vehicle presence data.
- Passive Acoustic Detectors - When a vehicle passes through the detection area, these detectors sense the increase in sound and generate a vehicle detection signal. Unfortunately, they have been found to be susceptible to both under and over-counting resulting from inclement weather conditions and the background noise that exists in certain environments (e.g., the echoing that occurs under bridges).

## **2.2 Usage of Traditional Traffic Detection Technologies**

As stated above, the inductive loop detector currently makes up the backbone of most public agencies' traffic data collection efforts. Although the other devices listed above are beginning to represent a more significant portion of the traffic detection infrastructure, no single device is currently able to provide all of the data required for advanced ATMS and ATIS services. As was mentioned in the description of inductive loop detectors, many agencies have no capacity to gather the data collected by their detection infrastructure and analyze it for real-time traffic management purposes. Instead, they collect data from the sensors every few weeks in order to

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<sup>9</sup> Middleton, D., D. Jasek, and R. Parker, p. 8.

<sup>10</sup> Klein, L.

determine traffic volumes, vehicular classification, and (some agencies) traffic flow on certain roads.

Another problem relates to the fact that all of the technologies are of a "point" nature. That is, even in cases where the data from these sensors is collected in real-time, it is only for the specific point at which each detector is located (See **Figure 1.1**). Large distances between detectors and poor detector maintenance can result in significant delays in detecting incidents, as well as reductions in the quality of other data. Finally, maintenance of equipment (especially loop detectors) requires putting work crews onto the roads themselves, inevitably resulting in traffic delays and possible safety hazards.

### **2.3 Using Probe Vehicles to Collect Traffic Data**

Note: Probe vehicle surveillance systems track the location and speed of target vehicles via the monitoring of a wireless device in the vehicle (e.g., transponders placed inside the vehicle [ETC toll tags], communication devices carried by the driver [cell phones], or other equipment that is part of the vehicle's electrical system.).

Technologies that enable the usage of vehicles as traffic probes have the theoretical capacity to provide:

- Real-time estimates of travel times and vehicular speeds;
- Incident detection capability; and
- Congestion information.

*For more information on these systems, please refer to the three rightmost columns on **Table 2.1**.*

Whereas traditional data collection efforts require the installation and maintenance of large amounts of expensive and difficult to maintain fixed infrastructure, probe vehicle systems are designed to require significantly less infrastructure, while at the same time providing improved information

across entire networks of roads. Probe vehicle systems are typically composed of (for details on infrastructure, see **Table 2.1 and Figures 2.1, 2.2, and 2.3**):<sup>11</sup>

- The vehicles themselves;
- A technology for determining vehicle location;
- A communication system between the vehicle or collection infrastructure and a management center; and
- Computing systems to analyze raw data.

In general, probe technologies can be characterized as having the following advantages and disadvantages as compared to more traditional traffic data collection methods:<sup>12</sup>

Advantages:

- Lower cost per unit of data - After the necessary infrastructure and equipment investments have been made, data may be collected easily and with much lower maintenance costs.
- Continuous data collection - By using probe vehicle systems, traffic data may theoretically be collected 24 hours per day. That is, once the system's infrastructure has been installed, data can be collected whenever probe vehicles are traveling through the system.
- Automated data collection - In probe vehicle systems, data are automatically transmitted from the vehicle to the ITS control facility.
- Data are in electronic format - All data collected by the system are automatically put into an electronic format. This facilitates the processing of raw traffic data for analysis.
- No disruption of traffic - Since data are collected from probes within the traffic stream, traffic is not affected by the probes themselves or maintenance of the system.

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<sup>11</sup> Sussman, J., *Introduction to Intelligent Transportation Systems*. See chapter concerning the "ITS-4."

<sup>12</sup> Turner, S., W. Eisele, and R. Benz, Chapter 5, p. 1.

Disadvantages:

- High initial implementation costs - Probe vehicle systems typically have high initial costs related to purchase and installation of the necessary equipment, as well as the training of personnel to operate the system.
- Requires skilled software designers - The software used for data collection is composed of complex programs that are typically customized for a particular probe system.
- Privacy issues - As probe vehicle systems require the tracking of vehicles during the course of their travels, concerns have been raised regarding the possibility of using such systems to issue traffic citations and monitor the travel habits of certain individuals.

Technologies for using vehicles as probes currently include (see Table 2.1):

- Transponders developed for use as electronic toll tags (ETC);
- GPS-enabled systems; and
- Network-Oriented Geo-location of cellular phone signals.

As stated in **Chapter 1**, the reader should bear in mind that significant differences exist between public sector efforts to collect probe vehicle data via the tracking of ETC transponders, and private sector efforts to gather similar data via network-based cellular geolocation and GPS-embedded cell phones. Additionally, the reader should be aware that data gathering systems relying on GPS and cellular locational technology would not attempt to track all wireless enabled vehicles at all times. Rather, these systems are planned to anonymously track a small percentage of available probes in order to enable their computing systems to develop a map of conditions on relevant roads.

### **2.3.1 Estimates of the Number of Probe Vehicles Required for Accurate Traffic Data**

A study by Boyce estimated the necessary sample sizes for a dynamic route guidance model based on the results of a "static, user-optimal route choice traffic assignment analysis." Their

results suggested that about 4,000 probe vehicles were required for a 520 sq-km (200 sq-mi) suburban road network.<sup>13</sup>

Srinivasan and Jovanis developed an algorithm to estimate the number of probe vehicles necessary for collecting real-time travel time data for advanced traffic management and information systems. Results of their study indicated that the number of probes needed increased "non-linearly as reliability criterion grew more stringent, that more probes were required for shorter time periods, and that the number of required probes increased as the proportion of link coverage increased."<sup>14</sup>

These estimates indicate that a significant number of vehicles be equipped with vehicle locational technology for any such system to work. As with more traditional infrastructure, the data that can be collected by such a system is limited by the amount of fixed infrastructure (e.g., the number and location of readers for communicating with the toll transponders) that has been deployed near or alongside a network of roads.

### **2.3.2 Use of Electronic Toll Collection (ETC) Transponders for Traffic Data Collection**

Vehicle Location technologies are currently in use by public agencies across the United States for an assortment of purposes, including: electronic toll collection, traffic data collection, incident management, provision of traveler information, and performance measure data collection. Although an increasing number of public agencies have begun using such equipment for traffic surveillance and incident detection purposes, its primary application remains electronic toll collection. The four primary components of Electronic Toll Transponder based systems are (see **Figure 2.1** for a graphic representation of the system):

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

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<sup>13</sup> Turner, S., W. Eisele, and R. Benz, Chapter 5, p. 5.

<sup>14</sup> Turner, S., W. Eisele, and R. Benz, Chapter 5, p. 5.

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 toll-booth. When the probe vehicle enters the antenna's range, a radio signal emitted from the antenna is reflected off of the transponder (with the signal being slightly altered to indicate the transponder's unique identification number). Probe data is collected by a roadside reader and assigned a time/date stamp and antenna ID stamp. This data is then bundled with other probe data and transmitted to a central facility via telephone line (using a modem) where it is processed and stored. In this manner, it is possible to track individual probe vehicles along the road network, calculating travel times 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, and the coverage area of the infrastructure.<sup>15</sup>

In some areas, modifications might be required to turn an existing electronic toll collection system into one capable of collecting accurate travel time data (e.g., additional antennas and readers might have to be located between toll collection areas). With such modifications, ETC systems could potentially become an abundant source of travel time and other traffic data.

According to the TRANSMIT (TRANSMIT is an ETC-based traffic data collection system operating in NY and NJ) System Evaluation (carried out by the Institute for Transportation at the New Jersey Institute of Technology), ETC-based probe technologies are capable of the following:<sup>16</sup>

- Vehicle Identification, Location, and Classification - Because each ETC transponder's identification number is unique, information can be recorded about where each transponder has traveled, when, and the type of vehicle it is in.
- Path/Link Travel Time - Because the system can identify individual transponders, travel time (and therefore average speed) between two antennae can be assessed by comparing the time stamps for when a given transponder passed between an upstream and downstream antenna.

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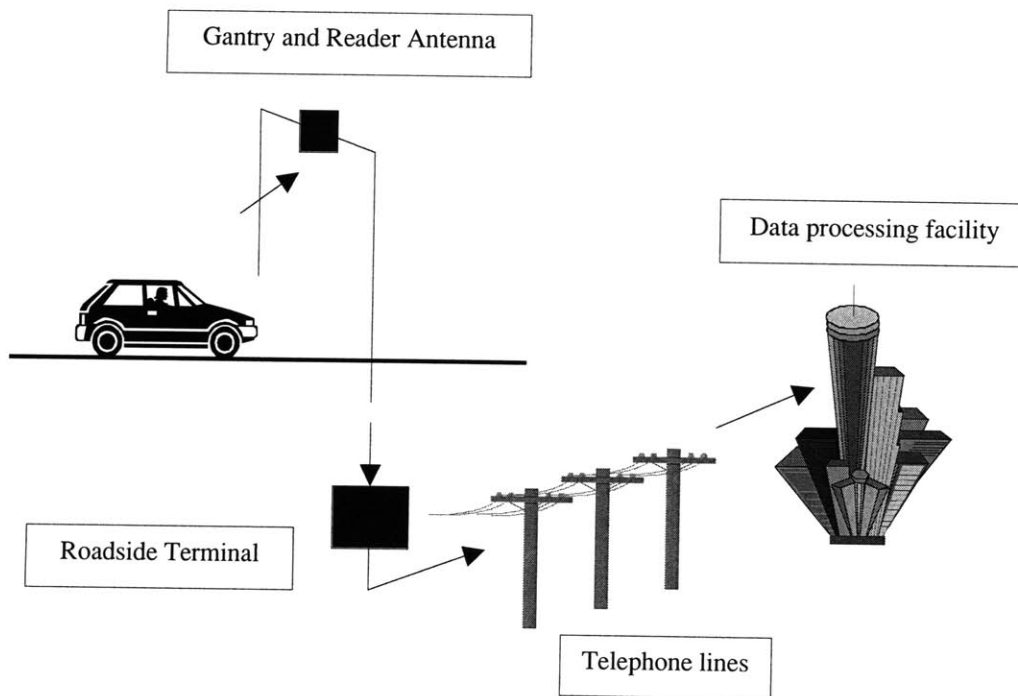
<sup>15</sup> Turner, S., W. Eisele, and R. Benz, Chapter 5, p. 8.

<sup>16</sup> Mouskos, K., E. Niver, and L. Pignataro, p. 104.

By assessing the travel times of multiple transponder enabled vehicles, average link travel time speed can be estimated.

- Incident Detection - By comparing historical travel times to real-time estimates of link travel time, possible incidents can be detected and investigated. According to a report produced by Booz-Allen & Hamilton for the United States Department of Transportation, during TRANSMIT's test phase, over half of its incident detections occurred at least eleven minutes prior to those incidents being detected by conventional traffic detectors.<sup>17</sup>

**Figure 2.1** - Structure of an ETC-Based Traffic Data Collection System



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

<sup>17</sup> Pearce, V. and Subramaniam, S., p. 9.

The advantages of using ETC probe vehicles for travel time collection include:<sup>18</sup>

- ❑ Continuous data collection - ETC systems enable traffic data collection on a constant basis during each day of the year.
- ❑ Reduced personnel requirements - As the ETC data collection process is completely automated, personnel are only needed to maintain the system and process data;
- ❑ Lane specific information - ETC systems are able to collect traffic data corresponding to specific lanes;
- ❑ Increased data availability - As data can be collected on a continuous basis, and the potential exists to collect data from large numbers probe vehicles over the entire year and in all types of weather, vast amounts of traffic data are available for planning purposes that were not available via more conventional data collection equipment.

The disadvantages of using ETC probe vehicles for traffic data collection include:<sup>19</sup>

- ❑ System Coverage - The system can collect traffic data only along street segments within the area covered by the detection infrastructure, that is, segments equipped with antennas and readers. Consequently, attempts to provide coverage on large sections of a road network could result in infrastructure costs similar to those associated with more conventional point oriented data collection efforts.
- ❑ Transponder dependence - Data collection is limited to the number of transponder-enabled vehicles in use within the area under surveillance.
- ❑ Privacy issues - Data collection requires that unique transponders be tracked between successive antennas. Individual vehicles can therefore be tracked along the entire length of the ETC enabled system. Consequently, it is important to assure transponder users that their privacy will not be violated.

### **2.3.3 Usage of Global Positioning Systems (GPS) for Traffic Data Collection**

GPS technology utilizes signals transmitted from a network of twenty-four satellites in orbit around the earth and received by a GPS antenna placed somewhere in or on each such enabled vehicle. Each GPS receiver calculates its position based on signals received from at least three of

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<sup>18</sup> Turner, S., W. Eisele, and R. Benz, Chapter 5, p. 22.

<sup>19</sup> Turner, S., W. Eisele, and R. Benz, Chapter 5, p. 22.



the twenty-four satellites. Since the satellites are already in orbit, the primary cost of the location technology is the receivers themselves.

Until mid-2000, the accuracy of GPS locational data was constrained to about 100 meters due to an intentional degradation imposed by the US military for security reasons. However, since that block was removed, the accuracy of GPS has improved to between ten and twenty meters.

GPS is considered by many in the ITS community to be one of the primary enabling technologies for ITS over the long term. According to Fall Creek Consultants, the GPS Industry Council has forecast that the market for GPS applications will be approximately ten billion dollars by the end of the year 2000.<sup>20</sup> Still, although there are a multitude of ITS applications to which GPS technology might be applied, its shortcomings, including poor coverage in dense urban areas, susceptibility to jamming, and high per unit cost, necessitate that significant modifications and improvements be made in the technology before it becomes usable for the collection of network-oriented traffic data. Until that time, GPS is likely to be used primarily in niche markets, including: transit vehicle location, management of commercial vehicle (trucking) fleets, and for other types of high precision navigation.

Until now, use of GPS technology for traffic data collection has focused primarily on collection of data from a small cadre of vehicles for Origin-Destination and link oriented Travel-time studies, with this data being stored by each device for subsequent downloading rather than it being beamed directly to a central processing facility for real-time application. One example of this is Batelle's GPS Leader travel data collection system (used primarily for household travel surveys). Its power management circuitry determines when the vehicle's engine is running and turned off, automatically activating when the engine is on.<sup>21</sup>

Data collected by GPS Leader can include:

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<sup>20</sup> Fall Creek Consultant's Web-site, [www.comm-nav.com/tech.htm](http://www.comm-nav.com/tech.htm), section on GPS.

<sup>21</sup> Batelle, *GPS Leader Travel Data Collection Specification Sheet*.

- Vehicle occupancy (individual driver and passengers);
- Trip purpose (driver and passengers);
- GPS location data (latitude, longitude);
- Travel speed between links; and
- Vehicle ignition state (on/off).

Although there are specific travel survey functions for which technologies such as this serve a useful purpose, equipment such as the GPS Leader faces major cost and functionality limitations with regard to E-911 and other commercially oriented locational applications.

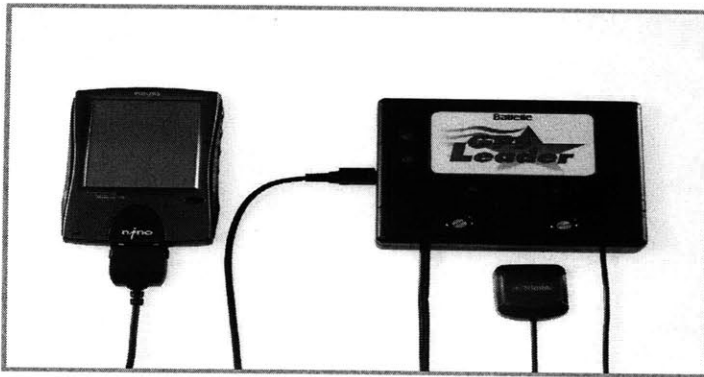


Photo of Batelle's "GPS Leader" Travel Data Collection System, thanks to Peggy Tadej, Batelle Transportation Division.

In contrast to existing GPS systems such as the GPS Leader, the primary technique under consideration for use in future real-time traffic data collection efforts is based on the following technology (see **Figure 2.2** for a graphic representation of the system):

- Integration of GPS technology into portable phones - Although it would be impossible to integrate GPS technology into all mobile phones currently in use by the FCC's deadline of October 2001, during December 1997, the FCC issued a Memorandum stating that it would consider the phasing in of technologies for E-911 locational purposes, especially if such technologies could potentially achieve improvements in accuracy. Based on the opportunity provided by this Memorandum, some private companies are currently attempting to develop locational capability via the integration of GPS technology (specifically, the installation of GPS chipsets) into mobile phones. In order to avoid some of the disadvantages of GPS listed below, some companies (e.g., SnapTrack) are developing their systems so as to combine GPS with the

ability to track the phone's cellular signal; similar to the systems described in **Section 2.3.4** (below).

The potential advantages of collecting traffic data using GPS-based systems include:<sup>22</sup>

- Low operating costs after initial infrastructure investment;
- Enables the continuous collection of highly accurate data along entire routes;
- GPS's increasing popularity as a consumer product should result in reduced cost of the technology over time, as well as a greater number of potential probes on the road; and
- Automatic collection of electronic data.

The potential disadvantages of collecting traffic data using GPS-based systems include:<sup>23</sup>

- Signals can be blocked in dense urban areas due to buildings, trees, tunnels, etc;
- Integration of GPS technology into mobile phones will almost certainly result in problems related to handset battery drainage. Consequently, any company attempting to pursue this path will be forced to find a technique to either reduce power consumption by the unit or increase battery life.
- Time to acquire a signal with relevant satellites - if a GPS enabled phone has been turned off or been in a location where it was unable to maintain a signal with nearby satellites, it can take several minutes for the handset to re-acquire a signal. This is a problem that will undoubtedly have to be addressed if GPS technology is to be used for locational (especially E-911) purposes.
- Privacy issues - Although privacy issues were somewhat of a concern for ETC-based systems, GPS-based systems can track individual vehicles almost anywhere they can travel. Consequently, it is important to ensure users that their privacy will not be violated.
- Use of a GPS-based system would necessitate the installation of a two-way communication infrastructure to allow the devices to send data to a central facility. As GPS devices receive information from satellites whose only role is to transmit location data to the GPS devices themselves, it will be necessary to establish a means for each GPS device to transmit this data to a centralized traffic data collection facility. Although multiple technologies exist for

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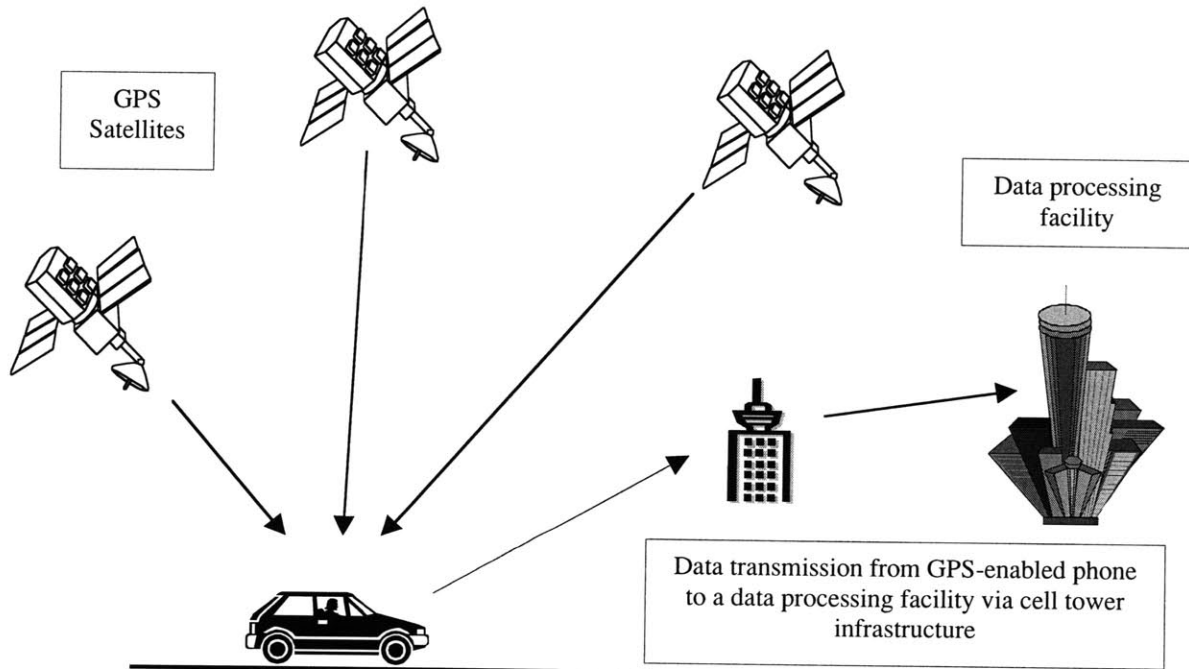
<sup>22</sup> Turner, S., W. Eisele, and R. Benz, Chapter 5, p. 54.

<sup>23</sup> Turner, S., W. Eisele, and R. Benz, Chapter 5, p. 54.

the transmission of this information, the need for this additional communication system is problematic because of the lack of available bandwidth for such communications.

- The amount of communications bandwidth available for use by these systems is limited. Consequently, it might be difficult and expensive to obtain a frequency for communications between the GPS units and a central facility, especially in large cities where such bandwidth is at a premium.
- As additional communications infrastructure must be built to support a GPS based system, the larger the area that must be covered, the more communications towers will be necessary to transmit data. Depending on the type of communication systems selected, a license from the Federal Communications Commission (FCC) might be required.

**Figure 2.2** - Structure of a GPS-Enabled Phone Traffic Data Collection System



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

### 2.3.4 Usage of Network-based Cellular Geolocation Technology for Traffic Data Collection

As described in **Chapter 1**, the Federal Communications Commission (FCC) has ordered cellular phone service providers to move forward with implementation of Enhanced 911 (E911) services for their cellular subscribers. This order requires that cellular phone service providers be capable of providing the location of cellular telephone calls within one-tenth of a mile of their actual location, in 67 percent of all instances.

Network-oriented cellular geolocation systems ascertain vehicular speed, link travel time, and the location of incidents by tracking the direction and speed of phones being carried along a given segment of road. For planning purposes, this information can be permanently stored in order to permit an analysis of traffic flow against historical data. By using geolocational data in conjunction with data obtained from other public and private traffic resources, it is hoped that comprehensive traffic coverage will be available anywhere that cell towers have been constructed. See **Figure 2.3** for a graphic representation of the system.

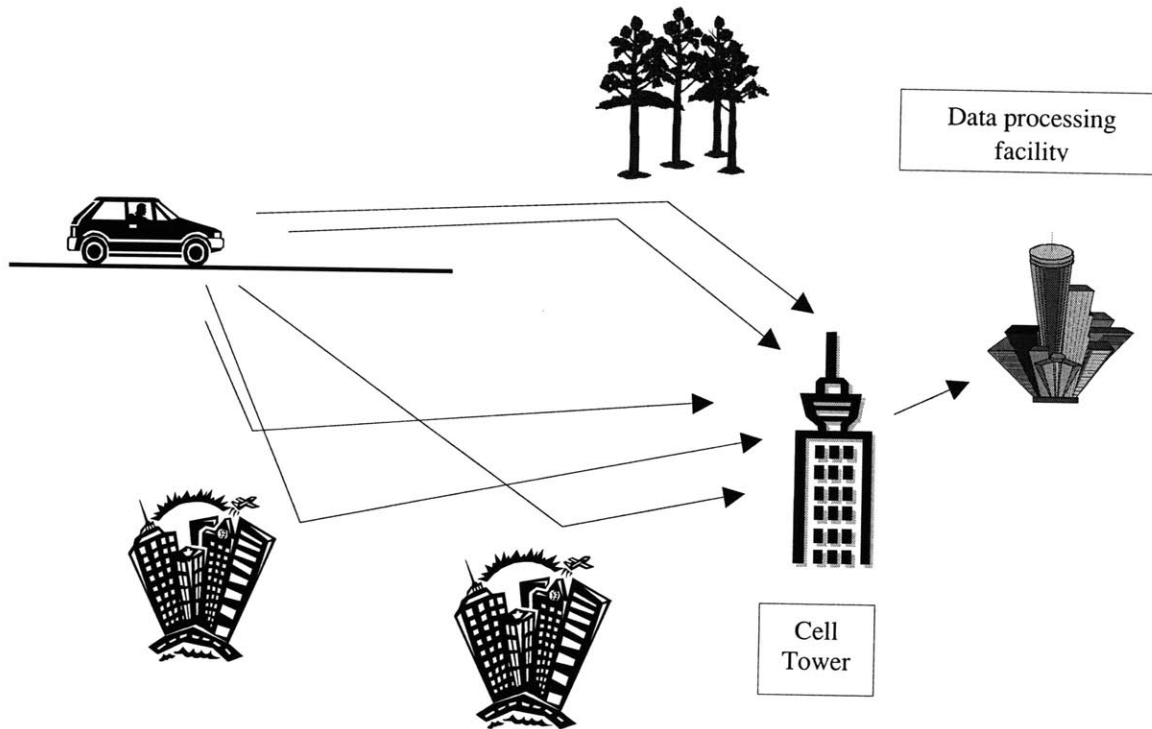
Different cellular geolocation tracking technologies currently under development include:

- Time Difference of Arrival (TDOA) technology (e.g., being developed by TruePosition) - computes a caller's location by differentiating between the arrival times of the caller's wireless phone transmissions at various cell towers located in the area from which the call is being made. TDOA systems can typically function using existing equipment.
- Angle of Arrival (AOA) technology - computes a caller's location by computing the angle at which signals transmitted by the caller's wireless phone arrive at various cell towers located in the area from which the call is being made. AOA systems generally require the installation of a separate network of antennas at already established cell sites.
- Radio Frequency (RF) Fingerprinting (e.g., being developed by US Wireless). This system is significantly different from those described above in that it uses signal pattern recognition as its primary means of locating a mobile caller. When a wireless subscriber initiates a call, radio waves radiate from the caller's handset to a cell tower. These radio waves are subject to reflections and obstructions from both man-made and natural structures. As a result of this interference, a "multipath" transmission is created in which the phone's signal arrives at the

cell tower with a radio frequency pattern (or signature) that is unique to the caller's location. By comparing the characteristics of this signal with a map of signal transmissions, the US Wireless "RadioCamera" system recognizes and associates these multipath characteristics with the specific location from which the call originated.<sup>24</sup>

Note: Questions continue to be raised concerning whether a call must actually be in progress for effective locational data to be collected by these systems.

**Figure 2.3 - Structure of a Network-Based Cellular Geolocation Traffic Data Collection System**



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

<sup>24</sup> US Wireless Annual Report - released on June 29, 2000.

The potential advantages of collecting traffic data using cellular geolocation include:<sup>25</sup>

- No driver recruitment is necessary - The system utilizes samples from the existing population of cellular telephones. Consequently, it is not necessary to recruit volunteers or designate personnel to collect data.
- No in-vehicle equipment to install (e.g., GPS transponder)
- Large potential sample - As cellular telephone ownership increases, the number of potential probe vehicles increases. Already there are estimates that over 100 million cellular phones are currently in use in the United States.
- Enables the collection of network-oriented data (**See Figure 1.3**) - As geolocation technology works by tracking signals from wireless phones, there is no need to invest in large amounts of fixed detection infrastructure along the roads on which interested parties would like to collect traffic data. In fact, the technology is meant to enable users to overlay locational information about the cellular phones being tracked over a map of the entire road network. This could result in cost savings related to reductions in capital and maintenance costs, at the same time that it provides users with increasingly accurate and useful network-oriented traffic data.
- In contrast with GPS Systems, cost is concentrated at each cell tower and locational information can be gathered without the need for expensive GPS technology being placed into the phones themselves (see section on locational technologies using GPS above).
- Although the technology has not yet been refined to the point that it can provide locational information that is as accurate as that from GPS systems, compatibility with the multitude of existing mobile phones facilitates the collection of traffic data in ways not achievable by a small number of GPS-based units.

The potential disadvantages of collecting traffic data using cellular geolocation include:<sup>26</sup>

- Cellular Geolocation is an experimental technology - Although several companies are currently working to develop this technology, and tests are currently being carried out by the Virginia and Maryland Departments of Transportation on US Wireless' technology, claims concerning the accuracy of this technology remain largely untested.

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<sup>25</sup> Turner, S., W. Eisele, and R. Benz, Chapter 5, p. 46.

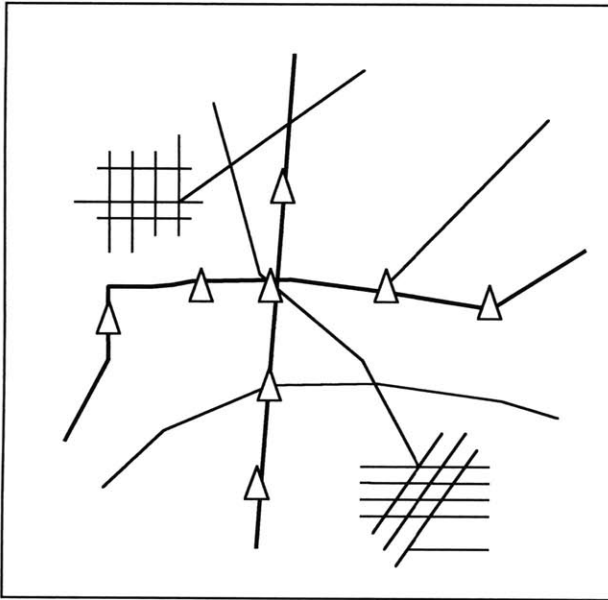
<sup>26</sup> Turner, S., W. Eisele, and R. Benz, Chapter 5, p. 46.

- Privacy issues - Cellular geolocation may concern some cellular phone users that their telephone calls are being monitored and their vehicles are being tracked. As with ETC and GPS systems, the identity of telephone signals should not be accessible to anyone operating the system.
- Somewhat infrastructure dependent - The system is constrained by the presence of cellular infrastructure. Consequently, this technology can only be deployed in areas where cellular phone infrastructure (towers) is already in place.
- The technology is highly dependent on cellular phone use - Depending on the proprietary technology used, the system's ability to collect traffic data can drop during periods of low cellular telephone usage.
- Cases of Insufficient cell tower infrastructure - As the density of cell phone use increases, existing cellular tower infrastructure may be insufficient for accurate geolocation of sufficient numbers of vehicles. Consequently, the installation of additional towers could become necessary.
- Utility of such a system depends upon the ability to get locational information both accurately and rapidly enough to 'snap' it to the relevant road link in real-time for network analysis use. As of yet, technologies for performing all the necessary functions have not yet jelled.



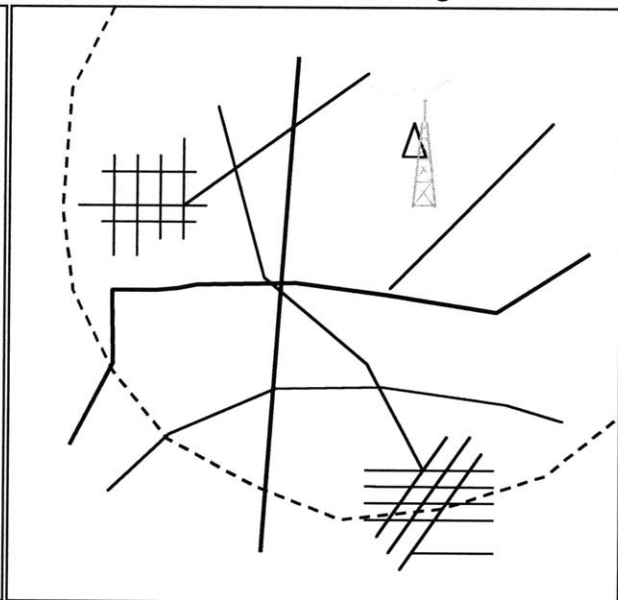
## 2.4 Overview of the Costs Involved in Deploying Different Traffic Surveillance Technologies on a Network of Roads

**Figure 2.4:**  
Deployment of Point-Sensor Infrastructure



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

**Figure 2.5:**  
Deployment of Wireless Tracking Infrastructure



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

As **Figures 2.4 and 2.5** demonstrate, there are significant differences in the manner through which each type of system collects traffic data. In **Figure 2.4**, we see that sensors must be positioned every so often in order to maintain surveillance on a given road. Consequently, adding even one road to the list of those under surveillance requires the procurement, installation, and maintenance of a number of sensors. In contrast, **Figure 2.5** demonstrates how wireless tracking technologies (e.g., network-based cellular geo-location and GPS-enabled handset tracking) monitor entire sections of a network of roads from a single centralized location (i.e., a nearby cell tower). As all vehicles and roads within broadcast range of the cell tower (which varies depending on local geography and density of buildings in the area) are potentially under surveillance from that single location, the decision to add roads to the list of those under surveillance involves only marginal additional costs - primarily related to processing the data at the ISP's traffic operations center. A rough outline of the costs involved in deploying these different systems is provided in **Table 2.2**.

**Table 2.2 - Estimated Costs of Deploying Various Types of Traffic Surveillance Systems**

	<b>Loop Detectors</b>	<b>Closed Circuit Cameras (using "Minnesota" technology)</b>	<b>ETC-based System</b>	<b>GPS-enabled cell phone</b>	<b>Network Geolocation</b>
<b>Area Covered by Single Sensor</b>	Area Immediately over the sensor	Area within visual range of the camera	Area within broadcast range of the sensor (50-100 ft.)	Area within range of each cell tower	Area within range of each cell tower
<b>Capital Cost Per Sensor Site</b>	\$54,660	\$69,600	\$35,400	\$5-\$10 per phone (paid by buyer)	About \$70,000 per tower
<b>Annual O&amp;M</b>	\$9,950	\$5,340	\$4,490	\$0	About \$7,000
<b>Cost of Covering One Freeway of 5 miles for 10 years.</b>	If one detector is place every half mile (10 loop detectors), cost equals: <b>\$1,541,660</b> + cost of operations center (TOC)	If one camera is placed every mile (5 cameras), cost equals: <b>\$813,600</b> + cost of operations center (TOC)	If one ETC reader is placed every mile (5 readers), cost equals: <b>\$401,500</b> + cost of operations center (TOC)	Costs for tracking related only to operations center and transmission of data from phones (currently an unknown factor)	Estimate need as being two towers - cost equals: <b>\$280,000</b> + cost of operations center and to transmit data from cell tower to TOC
<b>Cost of Covering Two Parallel Freeways of 5 miles for 10 years</b>	Double the coverage, cost equals: <b>\$3,083,320</b> + cost of TOC	Double the coverage, cost equals: <b>\$1,627,220</b> + cost of TOC	Double the coverage, cost equals: <b>\$803,000</b> + cost of TOC	Same as above	If both roads are within range of tower, cost: <b>\$280,000</b> + others as above
<b>Cost of Multiple (10) Intersecting freeways and arterials over a 5 sq. mile box for 10 years</b>	If each road is 5 miles long, then need 50 sensors, cost equals: <b>\$7,708,3000</b> + cost of TOC	If each road is 5 miles long, then need 25 cameras, cost equals: <b>\$4,068,000</b> + cost of TOC	If each road is 5 miles long, then need 25 ETC readers, cost equals: <b>\$2,007,500</b> + cost of TOC	Same as above	Estimate of 4 towers for coverage - cost equals: <b>\$560,000</b> + others as above (can monitor all other roads within range of towers)

*Note:* Cost Data for Loop Detectors, CCTV, and ETC-based systems is taken from the report *Incident Management: Detection, Verification, and Traffic Management*, prepared by Booz-Allen & Hamilton for the Federal Highway Administration (based on the buildout for a 6-lane road). Data for the cost of GPS embedded systems is taken from the SnapTrack Data Sheet - "SnapSmart." Data for the cost of systems using cellular geolocation is taken from a US Wireless presentation entitled "Cell Phones as Data Probes: Background & Recent US Wireless Experience."

As **Table 2.2** indicates, costs for all surveillance systems increase dramatically for all fixed point traffic data infrastructures (loop detectors, CCTV cameras, and ETC-based systems) as the number of roads under surveillance (or the amount of surveillance on a given road) increases. In contrast with is the cost of network-based geolocation, whose cost only increases with the deployment of tracking equipment on cell towers in previously unmonitored areas. Finally as the infrastructure for GPS-enabled cell phone tracking is part of the phone itself, the phones' buyers

pay for its costs. The only unknown factor concerning this technology concerns the cost of transmitting that data from the phone to a central operations center.

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Now that we have a better understanding of the types of traffic data that various surveillance technologies can provide, **Chapter 3** will explore differences in how the public and private sectors utilize this data and what each sectors' "customers" want. This chapter will also contain an overview of when and why public and private data needs have conflicted up till now and the tensions that have resulted.

# CHAPTER 3

## AN EXAMINATION OF THE MARKET FOR TRAFFIC DATA

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### 3.1 Introduction

The following scenario illustrates how ITS systems could, in the near future, be used to assist drivers during their daily commute:

It is the end of the day and Mr. Jones is preparing to leave his office for home. However, before logging off of his computer, he checks his e-mail for the message he receives on a daily basis from a local ATIS service provider informing him about local traffic conditions; based on a profile of Mr. Jones' travel information that the company maintains in its database. Upon reading this message, he learns that there has been a major accident on the route he generally uses to get home and that normal conditions are not likely to be restored until several hours later. Beneath this information is a map of the area in which Mr. Jones will be traveling and a description of potential alternative routes and modes (i.e., transit) he might utilize, along with current travel times for each. Although the message provides Mr. Jones with several alternative routes, all but one are predicted to be heavily congested within the next 20 minutes due to the diversion of traffic from the accident on Mr. Jones normal route. However, the estimated travel time for Mr. Jones to get home using the one uncongested route available is 50 minutes, not too bad considering that it normally takes him about 35 minutes on his typical route.

When Mr. Jones gets into his car, he turns on the vehicle's telematics equipment and receives an update on local road conditions. As it indicates that traffic conditions have not changed from those described in the e-mail he received while in his office, he programs the telematics system to provide directions for the alternate route he has selected. Although the route will take him through suburban areas with which he is unfamiliar, the combination of vehicle location technology and route guidance software installed in the telematics package make him confident that he will be able to find his way. Although the system provides Mr. Jones with a map of his route, indicating the current location of his car, the system also provides him with directions via

a voice synthesizer in order to reduce driver distraction. While en-route, Mr. Jones' telematics system provides him with updated traffic conditions every few minutes. A few minutes after beginning his commute, Mr. Jones learns that one of the other alternative routes that had been congested has now cleared up, and that using it will allow him to get home about 10 minutes faster than if he stayed on his current route. Consequently, Mr. Jones indicates to his route guidance system that he would like to take this second alternative route. In response, the system analyzes the route and begins providing revised directions for him to get home.

While on this revised route, Mr. Jones remembers that he has dry cleaning in the trunk of his vehicle that needs to be dropped off. As he is relatively new to the area, he is not sure which dry cleaner is located closest to his current route. In order to determine where he can most conveniently drop off his clothes, he pulls over and reviews the list of other locational services provided by his telematics system. Upon seeing that one of the services involves identifying the location of businesses along the route that the user is taking, he programs the system to locate dry cleaners on or near his current route home. Once Mr. Jones has chosen one of them, the route guidance system automatically modifies his route to facilitate this intermediate stop. Following these new directions, Mr. Jones is able to drop off his clothes and still be home in time for dinner, while avoiding the worst of the evening's traffic. The next morning, Mr. Jones checks his e-mail for information about the morning commute and the process begins anew.

Although this scenario might seem futuristic to some, recent advances in technology make it more than likely that most, if not all of the services described above will be available within the next few years. In fact, some of the services, including the provision of traveler information via the Internet and basic route guidance, are already obtainable. However, provision of the types of advanced traffic information necessary to facilitate some of these more advanced services, especially dynamic route guidance, continues to lag behind. It is this gap between the types of traffic information that ISPs and their customers would like to have, and that which is currently available from the public sector, that this chapter will explore.

### 3.2 Facing the Facts

ATIS services provide drivers with information that facilitates decision-making related to trip timing, route choice, and mode choice that cannot be made without up-to-date, accurate information about traffic conditions. Companies generally referred to as Information Service Providers (ISPs) are the driving force behind ATIS services (see **Section 1.3** for more detailed information about these services). Although some ISPs have in the past collected traffic information using small amounts of privately owned and operated traffic surveillance infrastructure (e.g., CCTV), this information has typically been used to supplement the larger data sets procured from public data sources - state DOTs, city traffic departments, and transit agencies.

ISPs generally fall into one of two groups, Data Wholesalers and Data Retailers:

- Data Wholesalers - ISPs that collect their own data and provide it in a raw format to other users (typically other ISPs) to use as they see fit.
- Data Retailers - ISPs that collect data from multiple sources (e.g., data wholesalers and public agencies), fuse it into a single data stream, and process and format it so that it can be used to meet their customers' needs.

In spite of the fact that there has been an expansion in public sector traffic data collection efforts over the past few years, it is generally accepted that the data collected by these agencies is inadequate, being insufficient in geographic coverage (primarily covering freeways and few, if any, arterials and secondary roads), data types collected (see **Table 3.1** for differences in the data types in which each sector is interested), and of inconsistent quality, for the needs of most ISPs wishing to provide ATIS services (e.g., pre-trip and in-vehicle information about traffic conditions, and route guidance/navigation). Moreover, as stated in **Chapter 1**, there are some cases in which public sector agencies have been unwilling to share their traffic information with private sector interests. These assertions provide a basic definition of the traffic information "data gap."

A considerable portion of this problem stems from the fact that deployment of public sector infrastructure for traffic data collection purposes has occurred much more slowly than initially

predicted. Additionally, this problem is further exacerbated by the fact that (as described in **Section 1.3**) the differing perspectives of the public and private sectors has resulted in the public sector collecting data that is not necessarily of much use to private ISPs. In spite of these obstacles, there has been increasing interest in the provision of traveler information by ISPs to consumers and other business clients through a variety of advanced communication technologies, an interest that will likely expand as the ability to provide in-car telematics related services becomes more of a reality.

The public sector's traffic data needs focus primarily on the collection of information concerning traffic management (see **Section 1.3** for details). These needs have typically been met via the deployment of surveillance infrastructure, including: inductive loop detectors and other types of sensors, CCTV systems, and in some cases probe vehicle systems making use of Electronic Toll Collection technology. These technologies have generally enabled public agencies to gather information about volume, vehicle classification, and in some cases average traffic speed. Nevertheless, limited funding prevents most agencies from being able to collect sufficient data to meet all of their ATMS needs, let alone provide ISPs with ATIS oriented data.<sup>27</sup>

A study carried out by the Volpe National Transportation Systems Center concerning public traffic data collection programs in large urban areas indicated the following:<sup>28</sup>

- State, County, Metropolitan, and City traffic data collection programs appear to focus primarily on the collection of traffic volume data, followed by vehicle classification data and finally on speed/travel time data (to a much lesser extent).
- The quality of urban area traffic data collection efforts, and presumably of the resulting data, varies widely. While some programs appear to meet currently accepted standards, many others do not, and in many cases no data collection efforts exist.

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<sup>27</sup> Pretorius, P. and Markowitz, J., p. 5.

<sup>28</sup> Mergel, J., p. xii.

- Within many areas, data is not collected in a coordinated fashion. Most data exchange is informal.
- Funding and staffing cutbacks have hurt data collection efforts in the recent past, and continue to pose a threat in the future.

For some time now, the public sector has provided drivers with a certain amount of traveler information - via advisory radio, variable message signs, and the Internet. In contrast, whereas this traveler information has typically been of a basic, homogeneous level, the objective of ISPs is to collect and analyze enough high-quality traffic data to provide customized, location-oriented ATIS information and eventually dynamic route guidance applications to their clientele; this again reinforces the different perspectives of the public (network optimization) vs. private (satisfy their customers) sectors. As the private sector has until now depended upon not very reliable public-sector traffic data as its primary resource, most ISPs have had little success convincing customers that this is a service worth paying much, if anything for.

As is indicated by **Table 3.1**, private sector traffic data collection priorities (which are directly linked to the interests of ATIS customers) heavily contrast with public sector traffic data collection priorities.

**Table 3.1 - Public and Private Sector Priorities for Traffic Data Collection**

<i>Private Sector Priorities:</i>	<i>Public Sector Priorities:</i>
1. Traffic Speeds and Travel Times	1. Current and Scheduled Work Zones
2. Incidents	2. Incidents
3. Road Conditions	3. Road Conditions
4. Current and Scheduled Work Zones	4. Emergency Routes and Procedures
5. Weather Conditions	5. Weather Conditions

Note: Priorities range from 1 - most important, to 5 - least important.<sup>29</sup>

<sup>29</sup> ITS America and the U.S. Department of Transportation, p. 10.



### 3.3 The Depth of the Data Gap

According to the paper "Show Me the Data," presented at the ATIS Data Collection Guidelines workshop held during February, 2000, the following areas define the breadth of the data gap.<sup>30</sup>

- *Data Coverage* -- There is a need to expand current real-time freeway data coverage, as well as to add arterial, and other roadway information.

*Note:* On average, areas with real-time data collection have greater traffic on their freeways than places without real time data collection. Although "private companies are less likely to be interested in places with little congestion, if they are providing a service for an entire corridor some of the less congested places may take on greater importance."<sup>31</sup>

- *Depth of Information* -- The exact level of detail required to provide ATIS customers with the depth of information they want, especially as concerns traffic speeds and travel times (see **Table 3.1** for more details concerning ATIS user interests), has not yet been established (and more than likely varies between different groups according to their needs). Even so, much of the data collected for ATMS purposes provides only basic traffic information -- likely too indeterminate to fulfill the data requirements necessary for advanced ATIS (or for that matter ATMS) services.
- *Data Accuracy* -- Data accuracy is another problem for which a solution is required. "What is of sufficient accuracy for ATMS may not necessarily be appropriate for ATIS purposes. Is an accuracy of within 10% or 20% needed, and can data collection devices consistently provide the required accuracy?"<sup>32</sup>
- *Timeliness of the Data* -- "The timeliness of data is very important in building credibility with users. Do we always need up-to-date, real-time data, or is it sometimes acceptable to

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<sup>30</sup> Pretorius, P. and Markowitz, J., p. 8.

<sup>31</sup> Radin, S., S. Basev, and J. Lappin, p. 8.

<sup>32</sup> Pretorius, P. and Markowitz, J., p. 9.

update only every 5 to 10 minutes, or longer? How does the requirement differ by type of user?"<sup>33</sup>

- *Data Consistency/Reliability* -- In order for a viable traffic information market to be developed, it will be important for ISP to be able to provide a uniformly consistent stream of data to their customers. Unfortunately, a data stream of this sort is currently unavailable via public sector data collection methods and infrastructure.
- *Data Transfer and Dissemination*<sup>34</sup> -- In addition to problems related to a lack of data collection, research indicates that some public agencies do not share data with ISPs. Other cases exist where public agencies charge a prohibitively high fee for access to their data. Research carried out for the study "ATIS: Public Sector Perceptions and Public Sector Activities," found that those agencies who provide traffic and incident information in response to requests from ATIS ISPs and others (e.g., the media) tended to be from areas with "somewhat greater amounts of traffic, as measured by the average daily traffic per freeway lane, than those agencies that do not transfer the information."<sup>35</sup>

Note: As it is generally believed that personalized wireless services (e.g., dynamic route guidance) will be the motivating factor behind the wireless services market, there is a need to improve all of the areas described above before provision of such services becomes a viable possibility.

#### **3.4 Description of Current ATIS Customers and Their Needs**

According to the paper "Advanced Traveler Information Services - Who are ATIS Customers?," presented at the ATIS Data Collection Workshop held during February, 2000, customer demand for ATIS information services is primarily based on four factors:<sup>36</sup>

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<sup>33</sup> Pretorius, P. and Markowitz, J., p. 9.

<sup>34</sup> Radin, S., S. Basev, and J. Lappin, p. 12.

<sup>35</sup> Radin, S., S. Basev, and J. Lappin, p. 13.

<sup>36</sup> Lappin, J., *Advanced Traveler Information Services - Who are ATIS Customers?*, p. 2.

- The regional traffic context - includes characteristics related to highway vs. other roadway capacity and usage, level of traffic congestion, and future highway and other roadway expansion plans. "Prime ATIS markets appear to be highly congested regions that have limited build-out options and frequent, unpredictable traffic events (e.g., weather and crashes)."<sup>37</sup>
- The quality of the ATIS services - Quality of the ATIS information available to consumers is a prime determinant of how often and with what degree of confidence consumers actually consult ATIS resources (public and/or private).
- The individual trip characteristics - "The trip purpose, the time of the trip in relation to peak congestion periods, trip length, and the particular route or route choices available to the individual traveler all have a significant effect on whether the individual will consult traffic information."<sup>38</sup>
- The characteristics of the traveler - Includes personal values related to timeliness, the need to have a constant link to traffic information and other services, and technology preferences. For more information see **Section 3.4.1** - Descriptions of ATIS Customers.

### 3.4.1 Descriptions of ATIS Customers

According to a report issued by Charles River Associates and the Volpe National Transportation Systems Center,<sup>39</sup> "attitudinal" factors across potential customers for ATIS services provide us with the ability to gain certain insights into the structure of demand for ATIS services.

The research on which this report is based comes from the 1997 Puget Sound Regional Council (PSRC) Household travel survey - mailed to about 2,000 households in the Puget Sound Region.

This research culminated in the elaboration of eight distinct customer types. Charles River Associates and the Volpe Center described these customer types as follows:

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<sup>37</sup> Lappin, J., *Advanced Traveler Information Services - Who are ATIS Customers?*, p. 2.

<sup>38</sup> Lappin, J., *Advanced Traveler Information Services - Who are ATIS Customers?*, p. 2

<sup>39</sup> Information about the report entitled *User Acceptance of ATIS Products and Services: A Report of Qualitative Research* (1997), is taken from *Advanced Traveler Information Services - Who are ATIS Customers?*, p. 3.

- 1) Control Seekers - (19% of the sample) These households were characterized by their desire to plan ahead and be "accessible at all times." They were also more interested in the ability to predict travel times accurately than any other group in the sample. Even so, "Control" and "Knowledge," rather than in interest in punctuality appears to underly their desire for this information. The members of this group typically had a very high interest in using new technology (including laptop computers and cellular phones).
  
- 2) Web heads - (16% of the sample) These households were found to be the most "technologically savvy." Members had a very high usage of computers and the Internet both at home and at work. However, in contrast with "Control Seekers" above, their usage of portable devices such as mobile phones and laptop computers was only low-moderate. "Control over schedule seems to be an important issue, as members are more likely to report that they get annoyed by traffic delays, like to predict their travel times accurately and worry a lot about being late. They are also more likely to budget their expenses carefully and are more amenable to planning ahead."<sup>40</sup> Members of this group expressed some dissatisfaction with the quality of traffic reports - primarily due to infrequent updates and/or outdated information.
  
- 3) Low-tech, pre-trip information seekers - (22% of the sample) This group of respondents indicated that they were most likely to make changes to their travel plans based on traffic information they obtained prior to leaving, while only rarely making changes in their travel plans based on information they obtained while in transit. In general, this group was less comfortable with new technology and indicated a preference to ask a person for information rather than relying on a computer. Consequently, the members of this group would be much more likely to make use of a resource such as a traffic television station, rather than gathering information from a traffic web-site.<sup>41</sup>
  
- 4) Mellow Techies - (6% of the sample) Although the members of this sample stated that they do occasionally make use of traffic information, they also stated that they had little interest in

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<sup>40</sup> Lappin, J., *Advanced Traveler Information Services - Who are ATIS Customers?*, p. 4.

<sup>41</sup> Lappin, J., *Advanced Traveler Information Services - Who are ATIS Customers?*, p. 4.

trip planning and little concern about being late. However, like Web-heads, they have high levels of computer and Internet usage and are more willing to take risks with new products and services.

The other four types of customers (accounting for 36% of the market) were:

- Buyers of Value Added Services (e.g, dynamic route guidance and emergency "Mayday" systems) - Low comfort with computers and the Internet. May prefer customized information services.
- Wired with Children - Younger, higher income, with more children in household, seek convenience in information acquisition.
- Trendy and Casual - Use pagers and cell phones, but express little interest in traffic information or time savings.
- Male Techno-Phobes - Less comfortable with technology, less likely to change behavior, less interest in traffic information.

In addition to the research carried out for the Puget Sound Region, similar ATIS customer satisfaction surveys were conducted with participants involved in US DOT's Metropolitan Model Deployment Initiative. Respondents to these surveys were subsequently divided into the same market segments used in the analysis of PSRC data. Breakdown of these respondents can be found in **Table 3.2**:

<b>Table 3.2 - Distribution of ATIS Market Segments</b>	Control Seekers	Web Heads	Low-Tech Pre Trip Info. Seekers	Mellow Techies	Other Segments
PSRC Survey - Seattle, WA	19%	16%	22%	6%	36%
WSDOT Survey - Seattle, WA	40%	26%	3%	14%	17%
KC Metro Survey - Seattle, WA	24%	39%	7%	11%	19%
<i>TransitWatch</i> Survey - Seattle WA	37%	14%	15%	9%	24%
<i>TrafficTV</i> Survey - Seattle, WA	37%	15%	12%	13%	25%
<i>TrafficCheck</i> Survey - Tempe, AZ	33%	9%	17%	7%	35%

### 3.5 Analysis of Demand for ATIS Services

The conclusions of the report "Who are ATIS Customers?" found that ATIS customers are primarily employed commuters who spend a large portion of their driving time in congested freeway traffic, in contrast to traveling on local streets, and are able to select among a number of alternative freeway segments. However, according to this study, high demand for ATIS services appears to be driven more by regional traffic conditions and the quality of the traffic data itself rather than the ATIS customers' characteristics. "While it is likely that there will be ATIS customers where these external conditions (e.g., heavily congested roads) do not exist, the greater number of customers will be found in regions" where traffic and highway network conditions and ATIS service quality align. Further, it seems unlikely that there will be strong consumer demand for fee-based ATIS services in regions that do not meet these criteria."<sup>42</sup>

According to the paper "What Do ATIS Customers Want?," for a fee-based ATIS service to be successful, it must provide value to the driver on a daily basis. "The service must be reliable, accurate, and easy to use, because continued customer use is a function of the quality of the information and how it is presented. Drivers want travel speeds and incidents on their primary and alternate routes at the time of their departure. They also want it later in the trip when they choose between alternate road segments. If the user consults the service while en-route, the service must be able to deliver location and route-specific information with minimal distraction to the driver. Even in extremely congested cities, which suggest high levels of consumer demand, low quality ATIS services will be ignored."<sup>43</sup>

Many questions have been raised concerning the salability of traffic information as a stand-alone service without first bundling it with other enhanced information services in order to create a commercially viable product. With regard to this question, the authors of "What Do ATIS Customers Want?," concluded the following:

- As many as 1/3 of respondents to their ATIS survey stated that when adjusting their travel plans due to traffic information they receive, they added stops and other errands that they

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<sup>42</sup> Lappin, J., *Advanced Traveler Information Services - Who are ATIS Customers?*, p. 9.

<sup>43</sup> Lappin, J., *Advanced Traveler Information Services - What do ATIS Customers Want?*, p. 9.

would not otherwise have made. Consequently, the authors conclude that it might be useful for ISPs to furnish customers with "location-referenced to-do lists," (e.g., electronic notices provided to drivers about errands they need to run - based on the route being taken or the vehicle's current location.) which could be integrated with real-time traffic data to provide effective routing information.

- Although many commuters work later than they normally do in order to avoid periods of heavy congestion, others ask themselves "What else could I be doing with my time?" In order to better serve such customers, ISPs might provide customers with entertainment databases linked to the personal preferences of each customer that would provide them with the ability to make alternate plans on days when traffic is particularly bad.

### **3.6 Other Research**

According to research conducted for the paper "ATIS: Public Sector Perceptions and Public Sector Activities," (based on interviews with private ISPs and state/local highway and arterial management systems) the problem ISPs most frequently cite with public traffic data relates to inadequate geographic coverage - resulting from incomplete and/or inconsistent data collection in adjacent jurisdictions within a single metropolitan area. According to their survey of public sector agencies, on average, freeway agencies reported that they collect real-time information on about one-third of the miles for which they are responsible, leaving the remainder without any surveillance. Responses for arterial management agencies concerning surveillance of their road networks and intersections was even lower.

This paper also found that:<sup>44</sup>

- Public agencies in major metropolitan areas collect more traffic data than agencies in smaller areas.
- Collection of data does not imply real-time usage of that data - such as would be needed for provision of ATIS services. For example, only 55% of the arterial management agencies they surveyed for their study reported that they had real time electronic collection of vehicle

volume, volume, speed, or density - with over one-quarter of these agencies reporting that they do not collect speed data.

- Geographic coverage is often inadequate, and more likely to be inadequate the larger the metropolitan area.
- Inaccurate data is the second most common quality problem, after inadequate geographic coverage.
- Agencies in a single metro area provide data inconsistent with other agencies in the area.
- Timeliness and update frequency problems occur for incident data.
- Public agencies are not necessarily willing to transfer data they collect.

This paper also concluded that: "The prospects for the future appear mixed. Freeway management agencies are likely to add miles of coverage to their current data collection. For ATIS products to extend to arterials, arterial data will need more substantial improvement than that necessary for freeways. One opportunity for gathering more complete traffic information is the increased use of electronic toll collection leading to potential toll tag use as probes." Despite these potential improvements, the study's authors believe that the institutional issues concerning data sharing, as well as differences in data collection priorities between the public and private sectors will continue to plague ISPs attempting to provide high-quality fee-based ATIS services.

### **3.7 The Impact of ATIS Services on Driver Decision-Making**

**Table 3.3** provides an overview of the impact of ATIS services on driver behavior based on the findings of a survey carried out for use in the report *Market Potential for ATIS in the I-95 Northeast Corridor*.

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<sup>44</sup> Radin, S., S. Basev, and J. Lappin, pg. iii.



**Table 3.3 - Impact of Traveler Information on Driver Decision-Making**

	<b>Change Route</b>	<b>Change Time</b>	<b>Change Mode</b>	<b>Postpone Trip</b>
<i>Commuters</i>	Moderate	Moderate	Weak	Weak
<i>Fleet Operators</i>	Strong	Strong	Weak	Weak
<i>Tourists</i>	Strong	Strong	Weak	Moderate
<i>Inter-city Travel</i>	Strong	Strong	Weak	Moderate

Additionally, according to a study carried out by Lerner and Llaneras for the Federal Highway Administration, ATIS information was found to influence en-route driver decision-making, thereby increasing the likelihood drivers' diverting to alternate routes.<sup>45</sup> This study further compared differences in the impact on driver decision-making based on whether drivers had access to Basic or Enhanced ATIS services. They found that "over twice as many individuals in the Enhanced ATIS group diverted to an alternate route compared to their Basic ATIS counterparts; observed diversion rates were 88 percent and 42 percent, respectively."<sup>46</sup>

These findings lead us to believe that although traveler information services have yet to produce real changes in the overall flow of traffic or reduce congestion levels, this does not mean that users fail to act on the information they receive. Instead, the lack of an observable impact on traffic flow may be the result of limited deployment. Consequently, the impact of ATIS services will need to be re-evaluated as their usage increases.

### **3.8 Conclusions**

The evidence presented in this chapter demonstrates that a shortfall currently exists between the breadth and quality of traffic data currently available to private ATIS ISPs and that which would likely be necessary to support fee-based ATIS services. Traffic management systems have a range of needs that are in many cases vastly different than the needs of private sector ATIS providers. Simply put, the data that public systems collect is inadequate for what private ATIS providers are trying to do. For example, even when vehicular speed or travel time data is available, it is generally for only a limited number of freeways and fewer, if any, arterials.

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<sup>45</sup> Lerner, N. and Llaneras, R., p. 62.

<sup>46</sup> Lerner, N. and Llaneras, R., p. 62.

Some experts in the public and private sectors believe that the public sector should consider increasing the data collection functionality of their infrastructure in order to better serve ATIS providers. Additionally, ITS America and the US DOT are working together to develop national guidelines for public agencies to apply in their ATIS data collection practices that would assist the private sector in understanding what data is available and where it can be located.

In our opinion, this problem will persist whether or not national data collection guidelines are developed and implemented, because, if public sector interest in and funding for the collection of certain data is not present, then having standards that simply state how data should be collected and processed will almost certainly be ineffective. While it is likely that traffic (particularly freeway) management agencies will over time extend the coverage of their traffic data surveillance infrastructure, as well as develop improved data sharing policies, the combination of budget constraints and differences in data priorities between the public and private sectors make it unlikely that this extension of infrastructure will (in most cases) result in private ISPs being able to access data of either sufficient quantity or quality to meet their needs. Instead, we must come to recognize that public sector traffic data will continue to be insufficient for the private sector's long-term needs, and that rather than merely seeking out improved public sector data, the private sector should begin looking for new and innovative ways to collect what they need. Whereas the possibilities of public-private partnerships to improve data collection do exist, another possibility that many stakeholders appear to have overlooked is that the elaboration of a private market for location-based data might in itself be enough to drive the development of new techniques for traffic-data collection that meet many, if not all, of the needs described in **Section 3.3**. One possibility for capturing the data needed for private ATIS services, that could also provide public agencies with a supplement to what they already collect, is the implementation of technologies which track the flow of vehicles carrying wireless electronic devices (e.g., cellular phones and, to a lesser extent, electronic toll tags) on nearby roads and highways.

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However, for such data collection to take place, certain issues must first be dealt with concerning how this data will be processed and distributed to a range of users with what are likely to be

vastly different needs. Accordingly, **Chapter 4** will review the issues involved in data collection and sharing as concerns both wireless traffic data collection and data collection in other sectors (i.e., GIS).

# CHAPTER 4

## TECHNICAL COMPLEXITIES RELATED TO THE SHARING OF SPATIALLY ORIENTED DATA

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Spatial (Geo-Spatial) Data - Information describing the relative positions of people, things, or events in terms of their geographic location. "Typically structured as geo-referenced names such as street addresses, zip codes, and census tract numbers"<sup>47</sup> that can readily be converted to geographic coordinates.

Data Sharing - A broad term that is typically used to describe either the use of a common set of data by different software applications residing on a "distributed computer system, or the distribution of the same database to different systems in order to achieve some consistent purpose."<sup>48</sup> However, data need not always be on a "distributed system" in terms of being online or networked with other computers, e.g., the exchange of CDs.

### 4.1 Background

The ability of either public or private entities to collect data about traffic conditions in a given area relies on the amount of traffic surveillance infrastructure that has been deployed in that area. Some of the types of data collected by such systems include: travel time, traffic speed, incident notification, and traffic volume. In some cases, organizations will simply wish to utilize their own infrastructure (e.g. for public agencies -- loop detectors, CCTVs, etc.) to collect such information - exclusively for use within their own systems. However, other organizations will wish to gather data from a number of sources (e.g. data from private entities such as US Wireless, as well as data from public entities) and "fuse" it together in order to assemble the most comprehensive set of data possible. A major obstacle to achieving this objective concerns the fact that there are no rules governing what data should be collected or the format in which it should be stored. Consequently, each of these functions is typically carried out in a different

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<sup>47</sup> Cooke, D., p. 364.

<sup>48</sup> Goodwin, C. and Siegel, D., p. 1.

manner according to the policies of the organization involved.<sup>49</sup> When considered in conjunction with the likelihood that an assortment of entities are carrying out traffic data collection activities within a metropolitan area, it becomes clear that any organization wishing to collect data from multiple entities will face compatibility problems in "fusing" it into a unified whole. Although efforts are underway within the ITS community to standardize the types of data collected, the electronic format in which it is stored, and the interfaces through which it is exchanged, in order to reduce this now complex job, this task remains incomplete. As stated in the ITS America report, "Choosing the Route to Traveler Information Systems," standardization will be particularly important in the development of privately owned ATIS "information reception devices." "Travelers will not buy these devices unless there is a consistent data stream to provide nationally available traveler information services. Also, device manufacturers want to build and market devices that can operate in any region of the country. That will only be possible if every region produces data that are similar, unless the device makers write region-specific software, a process that is too expensive to make economic sense."<sup>50</sup>

#### **4.2 Overview of the Technical Problems Related to Sharing Traffic Data for ITS**

For traffic-related data to be shared efficiently by different agencies either within a region or on a national basis, certain standards must be established for the exchange of data. Such standards are used to facilitate data transfer between the entities disseminating it, as well as the devices used by travelers (e.g. wireless personal digital assistants - PDAs) to gain access to it. "As applied to traffic data interchange, standards can include: models and procedures for data structure and representation, database languages, data transfer and communications."<sup>51</sup> Additionally, there is a need to consider standardization of the format in which spatial data is referenced on a map (locational referencing). This issue is described in more detail in **Section 4.4**.

For ITS systems to have the ability to share data, efforts must also be made to ensure both semantic compatibility and schema interoperability. Semantic compatibility means that the data definitions being used by the systems on both ends of the data transfer are the same. Semantic compatibility is difficult to achieve because of the "many different and sometimes conflicting

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<sup>49</sup> Hallenbeck, M., p. 5.

<sup>50</sup> Hallenbeck, M., p. 5.

worldviews held and languages used by the varied set of ITS. Database transfer standards such as Spatial Data Transfer Standards (SDTS) deal with the problem of semantic compatibility by the mechanism of 'metadata' (data about the data), and by enforcing a degree of commonality of language on anyone who uses it."<sup>52</sup>

Schema interoperability means that data can be automatically shared by different systems in spite of their different internal languages. "A level of schema interoperability is made possible for applications using SDTS by rigid specification of data concepts and limitation of data structures."<sup>53</sup>

Definition of SDTS - "The purpose of the SDTS is to promote and facilitate the transfer of digital spatial data between dissimilar Geographic Information Systems (GIS) software packages, while preserving information meaning and minimizing the need for information external to the transfer. Implementation of SDTS is of significant interest to users and producers of digital spatial data because of the potential for increased access to and sharing of spatial data, the reduction of information loss in data exchange, and the increase in the quality and integrity of spatial data."<sup>54</sup>

Despite the fact that SDTS facilitate spatial data transfer between different systems, the rigidity required and the large amount of information about the underlying structure of the data (e.g., attribute referencing, data quality report, data dictionary, and other supporting metadata) that must also be exchanged, has led many experts to question its suitability for applications that require the streaming of data in real time (e.g., ITS). Moreover, as billions of dollars have already been invested in proprietary datasets, it is highly unlikely that a single standard (of which SDTS is one of a group that includes DIGEST, SAIF, and others) will ever be agreed upon.

In response, a number of application programming interfaces (APIs) have been developed that provide a standardized method through which a GIS software package can access spatial data from a variety of resources. In contrast with database transfer standards, APIs are placed

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<sup>51</sup> Alfelor, R., p. 409.

<sup>52</sup> Goodwin, C. and Siegel, D., p. 2.

<sup>53</sup> Goodwin, C. and Siegel, D., p. 2.

<sup>54</sup> Federal Geographic Data Committee, p. 14.

between dissimilar GIS software packages and spatial data resources, creating an access point between the two. Transfers occur via a common logical query system which enables interested parties to request the specific spatial data in which they have an interest, without the need to deal with the enormous datasets (including both the spatial data and their underlying data structures [which facilitates translation]) as occurs with SDTS. Consequently, data transfer can occur much more quickly and easily, facilitating usage of the data for real-time applications (e.g., dynamic route guidance).

Note: In **Section 4.3**, we will discuss some of the issues related to the exchange of data for use in both traditional GIS applications, as well as ITS. In **Section 4.4**, we will go into more detail about the impact of location referencing on the interoperability of ITS systems making use of spatial data.

### **4.3 Facilitating the Exchange of Spatial Data for Geographic Information Systems**

While the issue of the sharing of spatial data for transportation management and information purposes is a relatively new one, other fields of study have been dealing with these issues for some time. Typically, agencies within these fields are faced with the need to respond to problems that involve a wide variety of spatially-oriented data sets (e.g., related to the environment, socioeconomic status, and natural resources). In order to deal with the issues surrounding management of these large amounts of geographically referenced data, technologies such as GIS have been developed. Realizing that coordination of spatial data could lead to greater efficiency (especially in the sharing of data between organizations) and reduce problems related to duplication of efforts, the Federal government organized the Federal Geographic Data Committee (FGDC), whose goals include:<sup>55</sup>

- promoting the development, maintenance, and management of distributed database systems that are national in scope for surveying, mapping, and related spatial data;
- encouraging the development and implementation of standards, exchange formats, specifications, procedures, and guidelines;
- promoting technology development, transfer, and exchange; and

- promoting interaction with other existing federal coordinating activities that have an interest in the generation, collection, use, and transfer of spatial data.

#### **4.3.1 How the TIGER Database has Facilitated the Sharing of Spatial Data**

One agency that has played a vital role in the development and sharing of spatial data for GIS is the U.S. Census Bureau. In cooperation with the United States Geological Survey (USGS), they developed the TIGER (Topographically Integrated Geographic Encoding and Referencing) database for use in the 1990 Census. This provided a major push forward for the growth of GIS technology. Prior to development of the TIGER database, there was "a shared sense both within the Census Bureau and by the data-user public that change was needed in the geographic support process. A primary incentive for developing the TIGER database was the large number of inconsistencies between the statistical and geographic products in the 1980 and earlier censuses."<sup>56</sup> "The growing importance of the information sector of the economy, and growing public demands for more accurate, cost-efficient, timely, and accessible data products helped to promote an environment receptive to the exchange of data, expertise, and experience with other governmental agencies at all levels, the private sector, and the academic community."<sup>57</sup> Consequently, the TIGER geographic database was developed using scanned versions of maps provided by the USGS (United States Geological Survey). The TIGER database provides government entities (even on the local level) with a practical starting point that is suitable for some GIS related applications using "small area census data, publicly available extracts of the TIGER database, and the appropriate hardware and software. More than 130 private vendors currently have the capability of processing TIGER files, and the number is growing."<sup>58</sup> These private entities typically take the raw TIGER files distributed by the government and manipulate them (possibly even providing additional information in order to add value to the data) for use in a multitude of uses not specifically related to analysis of census data, but which require a standard mapping format.

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<sup>55</sup> Frederick, D., p. 357.

<sup>56</sup> Sperling, J., p. 383.

<sup>57</sup> Sperling, J., p. 384.

<sup>58</sup> Sperling, J., p. 378.



Consequently, although the Census Bureau initially developed its TIGER database to facilitate dissemination of census data, the database's widespread accessibility and the ability to make use of it for referencing spatial data on a common, nationally updatable map, has facilitated an increase in the ability of both public and private entities to develop and share their spatial data.

#### **4.3.2 ITS Applications**

Although TIGER files are useful for many ITS related applications, their format does present certain problems. First of all, TIGER files are only available in scales of 1:100,000 (for most of the US) and 1:24,000 (for some metropolitan areas). Consequently, the positional accuracy which they are able to provide is not very high. However, the "major defect of TIGER files are the lack of street attributes (except for road classification), little and sometimes no street information outside of metropolitan statistical areas, positional accuracy, and the many errors such as missing streets, missing address ranges, or wrong locations of intersections."<sup>59</sup> As a result, although TIGER files can be used to build some ITS applications, they are not detailed or accurate enough for many others.

As more detailed basemaps may be needed for applications that require details concerning exit and entrance ramps (such as dynamic route guidance and the provision of highly accurate traffic data), or links to land use information, locations of transit stops, etc. As no one network representation can be utilized to meet the needs of all applications, maps of multiple scales need to be developed. For example, whereas a 1:100,000 or 1:24,000 map might be sufficient to provide an ATMS agency with the scale they need for developing a general congestion map, a map of much higher granularity, i.e., 1:2,000, might be required to enable advanced ATIS applications such as dynamic route guidance.

Whereas TIGER files are composed of location and attribute information for street segments (represented as centerlines) with intersections defined by nodes, there exist many other resources that can be used to generate GIS maps. This list includes privately procured files (e.g., Enhanced TIGER files from ETAK), USGS DLG (Digital Line Graph) files, and maps generated by state or metropolitan agencies. Unfortunately, due to differences in the accuracy and level of detail

between these different maps, it is in many cases difficult to link data from one to another. For example, high resolution maps (which are generally more positionally accurate) developed by a local government might be inconsistent with TIGER files, resulting in errors when geo-spatial data from one application is merged (conflated) with another other. Also, whereas street segments in TIGER files are represented by line segments connected by nodes, other resources represent the network using different data structures. Reconciling data from one type of file to another (e.g., from a 1:100,000 scale map to a 1:2,000 scale map) is therefore not just a matter of ensuring the positional accuracy of geo-spatial points representing vehicles and the location of various roads, intersections, on-off ramps, etc., but also dealing with differences in how the road segment is represented (i.e., how can maps that represent roads as line segments keep track of curvature in that road?). Consequently, the sharing of spatial data is not just a matter of coordinating interfaces between systems, but dealing with differences in topology on maps, especially those that present spatial data at different levels of aggregation.

A related problem deals with the fact that although GPS and other vehicle-location technologies may be able to provide highly accurate geo-locational data, many of the maps used for GIS purposes contain errors and/or lack the accuracy necessary to facilitate the correct placement of the that spatial data. Although this may not be a problem at scales such as 1:100,000 where data remains highly aggregated, as we get closer to street level this results in an inability to "snap" highly accurate geo-location data (e.g., GPS data about a vehicle's location, or information about congestion on a given road segment) to the correct point on the map. As a result, it may be impossible to tell if the traffic data you are looking at is actually for the road on which it is place, or one running parallel to it, but 50 meters farther west.

One final problem related to the usage of basemaps concerns the conflation problems that will occur when updated versions of the basemaps are released. To deal with this problem, the concept of version control (the process of documenting the integrity of files as they are being changed or updated) has been developed. Careful version control requires that any alteration

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<sup>59</sup> Azar, K., p. 237.

in the structure or content of the files involved should not be made without the ability to undo incorrect changes of the data. Moreover, all intermediate versions of the files involved are kept until the full edit is complete.

Overall, although the diversity of data collection formats presents some problems for the sharing and integration of traffic data, the ability to translate that data via computer algorithm is generally considered to be a relatively easy task. Obstacles that will be more difficult to resolve surround reconciliation of differences in the way road networks are represented, and differences in the accuracy and level of detail between mapping systems; making conflation of data between those systems much more difficult. In addition, the need to keep up with physical changes (e.g., additions to or changes in roads) in the road networks that these systems represent is another barrier that will present major challenges for those entities that seek to develop accurate, high-granularity traffic monitoring systems.

#### **4.4 Discussion of Obstacles to Locational Referencing of Spatially-Oriented Data in ITS**

Definition of Location Referencing (From the Oakridge National Laboratories Web-site):

"Location referencing is how we know where something is. If we want to tell someone where something is, we do it by making reference to something else, whose location is commonly known. There are many ways to do this, called location referencing methods. We can give a location with respect to some known point, for example the center of the earth, or K-Mart, or the junction of two streets, or the junction of the equator and the prime meridian. We can also refer to a location with respect to a set of points, for example a road, a field, or a shopping center. The known location is not enough to make the reference by itself. A location referencing method must also include details of measurement and how the references are to be made. For example, referencing by geographic coordinates requires that people must agree on the geodetic datum to be used (the mathematical shape of the earth), an origin for measurements (for example, the intersection of the equator and the prime meridian), and a system of measurement (latitude, longitude, and elevation measured on the geodetic datum and with respect to the origin."

"ITS is one of the real-time data management and support systems that will require integration and sharing of highway information and other geographic data by public and private providers of transportation services."<sup>60</sup> Specifically, implementation of advanced ITS systems requires the integration of digitized maps and location information concerned with locations of vehicles, locations of structures (e.g. bridges, service stations, and other utilities), type and duration of incidents, road construction activities. In the past, data related to each function has been stored

and managed separately by individual units in each organization. However, over the next few years we are likely to see a larger proportion of ITS applications being developed that will require integration of systems and the exchange of real-time data between dissimilar, heterogeneous databases - located within public agencies, private ISPs, in people's homes, and in vehicles themselves. Consequently, one of the main obstacles connected with the sharing of spatially oriented transportation data will concern incompatibilities in the types of reference systems used by different databases to store, manipulate, and transfer data.

#### *Examples of Common Referencing Methods*

- Link ID;
- Street Address;
- Cross-Street Offset Matching;
- Linear Referencing; and
- Coordinates - continuous coordinate fields, coarse coordinates, and hierarchical tessellations.

Systems utilizing GPS or other geolocation technologies to track individual vehicles must have the ability to link the location of each vehicle to a point on the transportation network. As different systems utilize different types of coordinate referencing systems, problems are likely to occur in the transfer of raw data from one entity to another. Consequently, one of the prerequisites for sharing of traffic data between different entities is the development of a common "Location Referencing Systems" that will facilitate the sharing of geo-locational information concerning the road network, the vehicles traveling on it, etc.

Spatially oriented traffic data can be used to support many ITS functions. However, to facilitate the efficient sharing of this data on a regional or national level, systems using different spatial data sets must be interoperable with respect to the use and exchange of certain elements of their data structure. "If the reference to a location can be transmitted unambiguously and accurately, and if the databases on either side of the communications link can locate the references within their own internal data structures, then different (heterogeneous) databases can be used."<sup>61</sup> Only

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<sup>60</sup> Alfelor, R., p. 399.

<sup>61</sup> Goodwin, C. and Siegel, D., pg 4.

in this way can drivers travel from "coast to coast with in-vehicle information systems products that interface with information and traffic management systems in any locality."<sup>62</sup>

Despite these difficulties, it is important to note that the issue of location referencing is quite manageable in comparison to many of the problems related to the spatial representation of geolocal data described in **Section 4.3.2**, that must now be applied to representing geo-spatial data for GIS purposes. As stated in that section, diversity in the format in which raw data is transferred is not a major issue as long as translation is feasible - and it is. Rather, much more difficult obstacles must be overcome concerning reconciliation of differences in the manner in which different systems represent the road network (e.g., using line segments vs. other formats), variations in the level of detail and accuracy of different maps, keeping up with changes in the physical makeup of the road system being represented, etc.

#### **4.5 Conclusions**

The community interested in sharing traffic data is composed of different types of organizations, both public and private, with what are sometimes vastly different goals. As each entity making use of traffic data has a tendency to develop a data management system tailored to its own needs, data sharing between heterogeneous databases becomes more difficult. This obstacle, as well as the existence of other technical barriers to the regional or national sharing of traffic means that there is likely to be a "messy transition period when not all the relevant organizations are fully equipped or conforming to new standards and theories for spatial data sharing."<sup>63</sup>

Questions remain concerning the best way to address differences in data structures, basemaps used for varying applications, the accuracy of maps of differing scales, and incompatibility across location referencing systems. Although some people have called for the creation of national standards to facilitate the interoperability of GIS systems, we believe that investments in existing infrastructure and the need for specially developed systems for certain applications will serve as a barrier to this ever happening. Instead, interested parties need to work on ensuring that various systems have the ability to interface with one another (e.g., via APIs). Moreover,

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<sup>62</sup> Goodwin, C. and Siegel, D., pg 1.

<sup>63</sup> Evans, J. and Ferreira, J., p. 449.

the federal and state governments should seriously consider making investments in the creation of a series of metropolitan basemaps of varying granularities and with a high degree of locational accuracy. Such an action on their part might serve to facilitate the more rapid development of applications such as dynamic route guidance by the private sector. One alternative to this could be the procurement of industry and government agreement on the usage of improved basemap information (e.g., TIGER files such as those developed by ETAK for transportation information) purposes. Either way, such agreement would assist GIS users in more readily conflating their spatial data across different maps; even those with dissimilar levels of granularity, or other attributes.

In any case, it is likely to take both time and significant dedication on the part of those involved before common interfaces or other data management tools are developed and accepted.

Unfortunately, until these problems are resolved, it will likely be very difficult to effectively disseminate and utilize highly accurate spatial data (e.g., from GPS devices) for advanced ITS applications such as dynamic route guidance.

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**Chapter 5** will provide a summary of the interviews we have carried out with representatives of both public and private entities concerning the current situation, as well as how the ability to collect network-oriented traffic data via wireless technology might change the manner in which traffic data is collected, disseminated, and used. A portion of this chapter will be dedicated to an examination of the factors that might facilitate the usage of different traffic data collection technologies (e.g., quality of the data provided by wireless systems, imposition of regulations by the government, changes in the needs/willingness to pay of each sector, etc.).

# CHAPTER 5

## SUMMARY OF INTERVIEWS AND REVIEW OF PRIMARY FACTORS INFLUENCING THE MANNER IN WHICH TRAFFIC DATA WILL BE COLLECTED IN THE FUTURE

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### 5.1 Introduction

The contents of this chapter include:

- Responses to interviews conducted with sixteen (16) interviewees knowledgeable about the collection of traffic data and/or the implementation of probe vehicle programs. In order to maintain the interviewees' anonymity, their responses have been organized into three broad categories based on the type of entity for which the interviewee worked - Public Agency, ISP, and Transportation Consultant or in some cases left entirely anonymous; and
- Information gathered during the course of our research concerning the issues that we believe will have the greatest influence over future traffic data collection techniques. This information is largely presented in **Section 5.6 - Conclusions Regarding the Future of Traffic Data Collection**.

Note: As the interviews were not recorded, the statements contained within this chapter are not direct quotes of the interviewees' statements, but paraphrases of what they related to us.

As was stated in **Chapter 1**, we are not seeking to determine which (if any) privately procured locational technology will eventually come into more common usage. Thus far, even the wireless community is split on which solution should or can be implemented. Even so, it is important to make an attempt to understand the factors that will influence the likelihood of public (ETC-probe based and maintenance of the status quo) vs. private (cell phones embedded with GPS chipsets and network-based cellular geolocation) procurement of traffic data. This chapter represents just such an attempt.

In places where we believed that clarification of interviewee statements were in order, we have placed our interpretation of what we believe they were trying to convey in brackets - i.e., [...].

## **5.2 Responses to Interview Questions Concerning the Current State of Traffic Data Collection/Usage and the Possible Impact of Data Collection Using Probe Vehicles**

### **5.2.1 What is your general sense of the quality of the real-time traffic data currently being collected? How could this data be improved in order to better meet your needs?**

*Summary: Most interviewees stated that the quality of traffic data being collected by the public sector could be characterized as poor (with regard to both geographic area covered, as well as the nature of the data collected). Even in cases where significant traffic surveillance infrastructure investments had been made by the public sector, the data being collected is point-oriented in nature (including ETC-based systems), thereby leaving large amounts of the road network without coverage.*

- (Transportation Consultant) At present, the data being collected is no good. Today's applications are based on what is available, primarily estimates of speed and travel times, but many times this is not very accurate. Detectors are not completely reliable and are expensive to maintain. Moreover, detectors cover only a small percentage of the highest volume roadways. Data could be improved by creating a more network-oriented traffic data collection system. Overall, we need broader coverage, greater accuracy, and lower costs.
- (Public Agency) Detection is based on loop detectors, and radar and microwave units. These systems are costly to build, operate, and maintain. Although detectors are spaced every mile, about half of them are down at any time. Right now the only information we have is average speed information, and no information on arterials.
- (ISP) It's spotty - point sensors aren't necessarily in the areas you need them to be, or they don't work - they don't provide a good sample of the network. Really need systems that allow you to get readings for whole segments of the roadway - won't necessarily be via cell phones, but also via other wireless in-car telematic devices.
- (ISP) In most places, it's either not available or of poor quality.
- (Public Agency) Most detectors use point collection methods. We therefore don't know what happens after/between these points. Use of toll transponders can only provide average speed between two points. Problems also revolve around maintenance. Additionally, current infrastructure doesn't provide any information about what's happening on parallel links.
- (ISP) Most public sector agencies have primarily been concerned with managing the road surface, and collecting information on volumes, etc., rather than congestion information and other information for traffic management purposes.



- (Transportation Consultant) Data is ok where it exists, but you cannot really tell people the quickest way to go without network-oriented data [by network-oriented data she means data about all roads in a given area, not just freeways and a few arterials], which no one has. You also need to know about incidents that will impair travel times.
- (Transportation Consultant) The Data Gap is the fundamental issue limiting traveler information. Even in areas in which freeways are covered, many important arterials have no surveillance. Basically, we want more roads covered - especially important arterials that the ATMS people don't really care about. [It is generally accepted that most ATMS systems focus their surveillance infrastructure almost entirely on freeways - to the exclusion of arterials and secondary roads.]
- (ISP) The public sector uses loop detectors and ETC transponders - hardware and communications are expensive. Also, there have been cases in which we have had problems getting some of this data from the public sector. Some agencies try to charge ISPs for their information - this prevents traffic data from getting to the traveling public.

**5.2.2 How might the ability to gather data via wireless tracking technology (tracking of cell phones, GPS transceivers, transponders, etc.) affect the quality of traffic data and the ways in which it is used?**

*Summary: Without exception, interviewees believed that the provision of traffic data via wireless probe-vehicle technology (excluding ETC-based systems) would result in vast improvements in the geographic areas under surveillance, as well as the varieties and quality of data available. Interviewees also commented on the ability of such systems to provide data at different levels of granularity, based on the customer's needs. Still, a few interviewees noted that they thought it might take a few years before the wireless technologies currently under development (network-oriented cellular geolocation and GPS chipsets embedded in cell phones) would be up to the task.*

- (Public Agency) There would be an enormous impact - such a system would give you ubiquitous data (probably) at a cost that is not prohibitive - i.e., don't need thousands of loop detectors of which 30-40% don't operate at any one time. Wireless location data also allows traffic data to be personalized for the individual user. [If vehicle location equipment is integrated with other equipment for the provision of traveler services, e.g., route guidance technology, then those services can be combined in order to provide personalized routing (based on current location), estimated route travel time based on local traffic conditions, etc.]
- (ISP) Like night and day -- would give accurate information about traffic speeds across the road network. Availability of such data would change how people plan and manage transportation resources. They'll also have a data archive that will provide historical speed data for freeway systems in all seasons and weather - for use in making short term predictions.

- (Transportation Consultant) Thinks that it would make the data much more valuable, especially to have network-oriented data - e.g., on parallel routes. Can also use network data for traffic planning purposes - e.g., comparing conditions of what is normal across the network to what is going on.
- (Public Agency) Wireless and geolocational technology will play a major role. Right now we get most incident management information from cell phone calls (i.e., 911). We verify what is occurring via use of CCTV cameras or failing that, state highway patrols. Such technology would also provide us with the ability to see what's happening on major arterials parallel to a major route.
- (ISP) This new technology could provide data for a range of users (public sector traffic management, data for ISPs, as well as services to shippers for fleet management, etc.). Due to the highly saturated cell phone market the possibility for this to work is pretty high. Data will be much more reliable because cellular providers won't let their infrastructure go down.
- (Transportation Consultant) Will enable ATIS Providers to tap into real-time data streams. It will also allow them to eventually get involved in dynamic route guidance. There will be a market for this data - but it will have to be high quality and reliable. Moreover, if toll transceivers get cheaper and are used more, the many public sector agencies will be unwilling to pay for this data. [It is believed by some experts that public sector ATMS agencies using ETC systems to collect traffic data will in most cases be unwilling to purchase traffic data from private sector entities using other vehicle tracking technologies.]
- (Public Agency) Such data would assist with both public (- ramp metering, signal timing, decision support for incidence response) and private applications. It is likely to enhance our ability to manage the network -- although at certain times there is saturation everywhere and nothing can be done [to lower congestion], there are other times that it could help. Network-wide data will help us see traffic impacts over a broader area.
- (Public Agency) If this works and a significant number of travelers start making decision based on the information, it might result in shifts travel patterns. If more than 20% of the vehicle fleet has real-time traffic information and makes decisions based on it, then there will be little or no improvement in the performance of the transportation network as too many people will be changing routes and clog up secondary roads/etc. From a performance standpoint, you can only squeeze so much performance out of a network.
- (Public Agency) Higher quality, more reliable data. This could be a tremendous tool for planners because we could get travel time information from across the entire network. It would take lots of guesswork out of planning.
- (Transportation Consultant) Real time data would help to validate planning models. It could also could be used for real time applications - e.g., dynamic route guidance.

- (ISP) Ultimately, people want accurate travel time information. The coverage of the areas and the quality/types of info. available would improve and people would be more willing to pay for ATIS services.
- (ISP) Such technology could provide different levels of granularity of data - e.g., from information about each 100 feet of road, up to travel times on entire links depending on the needs of the user. This would be equivalent to having 50 loop detectors per mile.

### **5.2.3 What types of real-time transportation data are ATIS and ATMS providers primarily interested in collecting/purchasing?**

*Summary: In contrast with much of what we learned from reviewing the relevant literature, most interviewees stated that the public sector did have an interest in speed and travel time data in addition to basic information about incidents and traffic volumes. Interviewees were consistent in stating that private sector entities were primarily interested in data related to vehicle speeds and travel times.*

- (Public Agency) Although, accurate travel time information hasn't been readily available in the past (only estimates) it could be highly useful for management purposes such as the real-time calibration of signal control timing over a network according to the current level of traffic.
- (Public agency) Our primary interest is in incident management - to detect and respond to incidents in order to clear them up as quickly as possible. Key information is to detect when an incident has occurred, as well as monitor traffic queues during the incident so that we know where to divert traffic.
- (ISP) Data that they're most interested in collecting are speed and travel times (which the interviewee stated was most important to most other ATIS providers well)
- (Public Agency) Information that they would want is related to latitude and longitude - for incident management purposes.
- (ISP) What consumers would like to see is how fast the traffic is moving on their route, as well as alternative routes they could use - and which is a better selection for them to use to get to their destination. In general, we're talking about a fairly high level of detail - primarily on highways. Also, in cities where major secondary roads carry significant traffic, there will be a need for this data - NY, LA, etc.
- (ISP) In the long-term, we are looking for applications for this data - congestion maps, incident detection algorithms, O-D estimates, etc. Even so, questions remain concerning how refined the data stream will be - will ISPs only produce data processed for macroscopic management by the public sector, or will they also provide data for private sector use for route guidance and other in-car services. Traffic data providers could potentially produce varying levels of data depending on the needs of the individual consumer.

- (Transportation Consultant) *Private sector* wants information about traffic speeds that can be linked with information about individual vehicle location for personalized routing and commercial fleet management. *Public sector* wants speed and travel time by link for incident management purposes. They would also, want to use the data for planning and O-D surveys. Such data could provide a true performance measure of how the road network is doing.
- (ISP) Public Sector wants volumes (e.g., for signal timing plans), speeds, link travel times, and O-D tables for distribution of the network. Private Sector wants more information about speeds and travel times for more personalized information such as trip routing and real-time dynamic guidance.
- (Transportation Consultant) For ATMS, they want to know where vehicles are at lights, ramps, and other road entrance/exit points, as well as about incidents. For ATIS, need to know travel times from point A to point B.
- (Public Agency) What the public and private sectors both want is real-time travel time data.

#### ***5.2.4 How will the availability of improved real time traffic data via wireless tracking change the way in which traffic data is utilized?***

***Summary:*** Interviewees believed that such data would facilitate the provision of dynamic route guidance and other location-based services on the part of the private sector and improved data for predictive modeling and a tool for measuring system performance for the public sector.

- (ISP) This data would provide the public sector with a true performance measure with which to analyze their level of success related to incident clearance and road maintenance. On the private side, it would facilitate the provision of personalized travel data - e.g., dynamic route guidance and fleet management.
- (ISP) The ultimate usage will be in-car provision of data (dynamic route guidance combined with information about current traffic conditions).
- (Public Agency) Such data would allow us to truly manage the flow of traffic on the network of roads under our jurisdiction. Also, the private sector would be able to get actual travel time data (not just estimates as today). This would be much more accurate and available on non-instrumented roads.
- (Transportation Consultant) This would change the way in which data is used - e.g., companies like Mapquest would be able to get real-time dynamic route guidance to the traveler. On-Star and other service providers would be able to transmit information about - e.g., routes to hotels and other value added locational and directional services. Businesses like UPS (United Parcel Service) would have a service to improve fleet management.

- (ISP) Most people need predictive information (not just about current conditions), so that if I leave the office in 5 minutes, I will know what the road will be like when I get to a certain point that is sometimes congested. Such a system would facilitate the creation of more detailed databases - containing historic data that will facilitate short term traffic forecasting.

**5.2.5 Who do you see as being the customers (not only drivers, but also public entities and other companies) for this improved data?**

*Summary: Although there was a consensus that private ISPs and other commercial entities (e.g., UPS and GM's On-Star) would have a real interest in this improved data (especially if the data could be procured on a nationwide basis), others stated that the public sector would want to continue using the surveillance infrastructure that they had already invested in despite the possibility that the privately procured data would be of a higher quality and of broader geographic coverage. Others believed that public agencies would be unable to procure funding to purchase such data from the private sector. Furthermore, several interviewees stated that ISPs would need to bundle traffic data with other services in order to have a saleable product.*

- (Public Agency) The public sector pays for huge investments in infrastructure, but hasn't contemplated buying network-oriented data from a private ISP. Most public sector employees don't think about operating costs, they focus almost entirely on capital investments. Consequently, they have a difficult time conceptualizing paying for such a service - e.g., on a quarterly basis. Additionally, questions persist concerning whether consumers will be willing to pay for traffic data - even high quality data specifically oriented towards their needs. Will there be a need to bundle this data with other information and services in order to make it saleable?
- (Transportation Consultant) Some DOTs could pay an ISP with capital projects budget money. However, State DOTs haven't had this data before and most of them won't be willing to pay a significant amount of money to acquire this data. Even though Traffic Operations has been gaining strength within public transportation agencies, the transition will take some time.
- (Transportation Consultant) At the minute, we don't know what anyone will be paying for such services, except that there will be different charges depending on the service provided.
- (Public Agency) The main problem transportation agencies will have paying for such data is that there is a lack of access to money for such services. Payment of costs of an ongoing nature is of concern to people in the public sector, primarily due to the preference of government agencies to build and own their own infrastructure. Right now, the main role of State DOTs is to build and improve highways. However, if the information is good, then O&M and capital budgets could be freed up and the infrastructure funds diverted to purchase the data. Still, public agencies will fear that ISPs could suddenly raise costs, thereby leaving them in a lurch (especially if they let their infrastructure system lapse). Consequently, it is unlikely that any government agency will cease data collection altogether.

- (ISP) ISPs and Entities needing fleet management services (FedEx, UPS, some transit agencies).
- (ISP) Wireless carriers will likely come into the market (when the FCC finally forces them to comply with E-911 [as per the FCC's mandate that all cell phone service providers must be able to locate users who dial 911]), but they'll also realize that such technology can provide them with a source of revenue. Consequently, they'll buy the technology from a provider (e.g., US Wireless) and install it across their networks for their own uses.
- (ISP) Many companies will become interested in probe-oriented data, for ATIS (ISPs), for fleet management (truckers and bus companies), car rental, in-car services On-Star, etc. However, this will occur more quickly if the service is provided on a regional and nationwide basis (either from a single ISP or a consortium of providers who share their networks).
- (Transportation Consultant) The combination of in-car telematics devices and regional/national data availability will create a larger market for integrated traveler information and other in-car services (traffic information, navigation and route guidance, automobile maintenance, e-mail, concierge services - different levels of service depending on your needs).
- (ISP) The reason that people are not currently willing to pay for traffic data is because it is of such low quality and there is an expectation that it will be available for free (via radio, cell-phone, etc.). The problem now focuses on the fact that once good information becomes available, people may not be willing to pay for it. Consequently, traffic information will have to be packaged with other services -- the question is how much the traffic data portion of this will be worth.
- (Transportation Consultant) In many cases, arterial and other roadway data isn't very important to public agencies. There are also questions regarding whether the provision of ATIS data about arterials is actually a good thing -- the diversion of too much traffic from freeways [as drivers get off during periods of heavy congestion in search of alternate routes] could result in arterials and other secondary roads becoming congested. Consequently, highly accurate traffic information is likely to be of low value to State DOTs and other traffic agencies.

With regard to the general consumer, people want a general understanding of how traffic is flowing, rather than wanting highly accurate travel times -- they typically don't believe travel times anyway. Mostly people want speeds data in a format similar to <35, 35-55, 55+, etc.. Consequently, he thinks that you can meet 85% of travel information needs even with simple data, so there won't be a huge consumer market for this data even if it is reasonably priced.

- (ISP) State DOTs will not be a revenue source at all, unless prices go down to almost nothing. However, local and regional governments will be potential customers if costs are reasonable. ATIS ISPs will want the data. Additionally, companies like On-star will take the data and package it with other things.

- (ISP) If the providers of such data can individually or as a group create a national travel information network, there will be lots of customers. Such a system could provide nationwide traffic information based on their data and the fusion of this data with that of public agencies (ETC probe-related and other).
- (ISP) It will be other firms [data retailers who take raw traffic data and manipulate it for re-sale - see **Section 3.2**] that buy the data from US Wireless and similar companies [data wholesalers that collect raw traffic data with their own resources - see **Section 3.2**] and process it for use by entities such as On-Star. Companies like US Wireless won't really want to get involved in the direct provision of service, instead leaving data processing, bundling, and transmission to third party ISPs.

#### ***5.2.6 How will data management issues (related to the collection and analysis of probe data) impact the ability of ISPs to make use of privately procured probe data?***

***Summary:*** Most interviewees stated that management of traffic data - e.g., fusion of data from multiple sources would not be a terribly difficult issue to resolve. Even so, others speculated that this could lead to some problems related to the sharing of data and interoperability of systems.

- Data fusion [combining data from multiple sources into a single stream] will be an issue - especially for regional and national level services that provide fused data compiled from multiple sources (both public and private). How do you fuse them together? This hasn't been an issue in transportation until now, but it will be.
- Granularity problem can be solved by the company (e.g., US Wireless) providing different data samples for different users.
- Granularity/Scalability of the data - Data collected via wireless device data would enable the company collecting the data to zoom in [request traffic data of greater detail] at certain times - e.g., during special events (like football games), or for the purposes of different users. This will facilitate processing of the data according to the needs of the individual customer.
- Data fusion will take some work, but will not be a huge problem (at least from a technical standpoint). However, a location reference standard will be important - e.g., if I am provided with speed data on a milepost-oriented basis, but my system used latitude and longitude, I will need a translator to use that data.
- Once the companies collecting data decide on their business models, they can take advantage of the ITS standards being developed so that all ISPs and public agencies will be able to rely on the data being available in one format.
- Data Harmonization - Issues include the need for different levels of granularity and data smoothing (if different vehicles are traveling at different speeds, you need to elaborate some sort of average speed for that segment of the road in order to make lumpy data appear smoother.).

- Issues of semantics and granularity are there, but these are more nuisance issues than anything else.
- The real problem is access to the data. Once the data become available, the applications will be developed and a market will coalesce around it - with all of the data eventually being in the same format in order to maximize the profits of the companies providing these services.

**5.2.7. Given innovations in private sector data collection, what will be the government's future role in traffic data collection?**

*Summary: Interviewees agreed that at least in the short-term, even government entities interested in working with or purchasing data from private ISPs would continue to collect traffic data using their own surveillance infrastructure. Time and time again, we heard that public agencies would continue to operate CCTVs, and loop detectors around signalized intersections and on freeway ramps (for traffic signal control purposes). We were also reminded that many public agencies might have problems locating funding to pay for data procured from an ISP. In a few cases, interviewees stated that public agencies with more advanced traffic surveillance infrastructure (e.g., heavily developed ETC tracking systems) would not be interested in working with the private sector entity and that the data they provide for free on the Internet or through another publicly accessible resource might even provide serious competition for the data from ISPs.*

- There will be something of a mix - not an either/or situation. At a minimum, the public sector will continue to need loop detector information for signal timing purposes and ramp metering. Consequently, they'll continue to collect at least some point-based data, possibly supplementing this with US Wireless-like data. In the end, this relationship will depend on the extent to which the new technology can support traffic management functions.
- The public sector will continue to use point sensors and video cameras to detect incidents on major roadways. They'll also continue to collect data on traffic volumes using detectors around lights and freeway on-ramps - unless a wireless provider can provide this data accurately and at a reasonable price.
- For the public sector to even consider giving up data collection, private providers will need to collect volume data and vehicle classification data. For traffic control purposes they'd also need to provide vehicle presence information at ramp meters and stop lights and incident data.
- The public sector will not put as much money into point detection systems if it can be provided by the private sector. However, public agencies are almost certain to continue using loop detectors to at least measure traffic volumes.
- Although the public sector would likely use such data to supplement their data, they would want to continue using existing infrastructure for ramp metering and signal control, as well as



CCTVs for visual surveillance. The main problem will relate to the fact that money for infrastructure cannot easily be transferred to paying for data from a service provider.

- If you talk to 50 different states about this you'll get 50 different answers. For example, Maryland has plans to pre-empt infrastructure investments until they can determine whether US Wireless' technology can replace their existing infrastructure. In contrast, Delaware feels that traffic data collection is a public responsibility and are unconvinced of the quality of the data that cell-phone based probe systems can collect.
- The public sector will have an open mind to purchasing probe-based data if it is priced appropriately. However, most traffic agencies will be slow to begin using this data in lieu of that which they can collect via their own data collection infrastructure.
- Competition with the public sector will occur (primarily in areas where ETC-based traffic data is collected). In such cases, private companies will have to provide a higher degree of personalized service. However, if there's a market, then there will be people who will be willing to purchase the higher level of service (especially if traffic data is bundled with other location-based services).
- Alternatives to private data collection via cell phones include ETC and the instrumentation of state and county vehicles to collect such data via in-vehicle GPS-based systems. Consequently, this market will be highly competitive (not only within the private sector, but between the public and private sectors). In the end, public agencies still need to count volumes, etc., so local infrastructure needs to continue to be in place.

### ***5.2.8 Interviewees' Comments Concerning the Strengths and Weaknesses of Various Traffic Data Collection Technologies:***

#### ***A) Integration of a GPS chip-set into the phone:***

- Due to the need for the phone to send its location to a centralized collection center, it will be easy for most people to instruct their phone to send location data only when making an E-911 call, thereby cutting down on the effectiveness of a system attempting to collect network-oriented traffic data.
- One advantage of this system is since people would be able to selectively use the locational technology, there are no privacy issues.
- (As reported by numerous interviewees) A phone using a GPS chipset would face problems regarding battery power due to the need for the phone to regularly transmit location data.
- There could be problems related to the GPS chip in the phone needing time to link up with enough GPS satellites to receive location information.
- (Mentioned by many interviewees) GPS is not currently very good for traffic because there is no network of GPS-enabled phones. Consequently, although GPS is useful for providing

information for commercially oriented fleet management and route guidance, it won't be useful for traffic data collection until sufficient GPS-enabled phones are on the market.

- There is simply too little frequency space for GPS signals to track millions of users all the time. Consequently, although this technology may actually be more accurate than cellular geolocation, it is not feasible to use it for a market that may eventually be comprised of hundreds of millions of cell phones.

- Note: Overall, interviewees believe use of GPS chipsets in phones could be feasible in the future, even becoming the preferred method, but changes to the system are required that include:

- A. How GPS enabled cell phones can effectively transmit data to a central location?
- B. How to deal with issues related to battery life?
- C. Can enough probes be put into the field to enable accurate data collection?

#### ***B) ETC Transponders***

- ETC Transponders-based systems provide better data coverage than loop detectors, including pretty good travel time data.
- Some problems might occur with ETC-based systems due to people getting on and off the road. For example, there are people who take 25 minutes to get from point A to point B, rather than the 5 minutes it normally takes, due to the fact that they get off of the road and then got back on that road a few minutes later.
- Public agencies already using large numbers of toll transponders (primarily places on the eastern seaboard) have a good chance of implementing such a system . However, in the mid-west and on the West Coast, where there isn't much tolling, it will be difficult to effectively implement such a system. In many places, transponders would have to be given away for free, which is expensive and might lead people to become concerned that "big brother" is watching them.
- Although such a system would allow you to collect real-time travel time and speed data, toll tags can only be scanned where equipment is in place. As the technology only allows communication over a short range, readers must be placed at regular intervals along any roadway under surveillance. This results in higher capital and maintenance costs than those seen for phone-based location technologies.
- Even in places with no toll authority, some agencies are putting out readers to collect data from transponders that have been given out for free. Such systems are most effective in areas with heavy use of tolls, e.g., New York and Houston. Although such systems can't collect data as comprehensively as a system such as would that suggested by US Wireless [data wholesaler that collects raw traffic data with its own infrastructure], they could potentially be used by public agencies to collect high quality data in strategic locations.

- San Antonio has no tolling system, but gave out transponders for local drivers to use. Unfortunately, their program met with only marginal success.
- Interviewees agreed that Houston and NY are the only agencies that have been able to distribute enough toll tags to collect useful probe-oriented traffic data.

**C) Cellular Geo-Location (includes all companies that want to perform cellular signal tracking)**

- Concerning the systems suggested by US Wireless and True Position - as these systems track a phone's radio waves, rather than a beacon type signal emitted by the phone as might occur with GPS [as described in **Chapter 2**], it is a relatively simple matter to create a wall between the location of the phone and the identification of its owner
- A random number could be assigned to a cell phone as it enters a geo-location network (e.g., around a major metropolitan area) for tracking purposes within that network. However, when 911 is dialed, that caller's location can be displayed for emergency response purposes.
- Integration of geo-location technology might facilitate the implementation of location-sensitive billing, i.e., linking monetary accounts to each phone's unique identification information and using this account to pay for different services (e.g., tolls, fast food, etc.). Of course, this would require that users be willing to give up quite a bit of privacy for the sake of convenience.
- Cell phone technology is not infrastructure free; it relies on the existence of cell phone infrastructure to work. [tracking of cell phones requires the presence of cell phone towers either as a base on which the tracking infrastructure is located, or to carry the signal containing location data from the phone to a central data collection facility.]
- The US Wireless technology uses a phone's radio signature like a fingerprint, matching it to their database which allows them to know where it is in order to track it. Consequently, tracking can only take place on the specific roads that they have already mapped. Therefore, such modeling will have to be carried out for every street in a system.

**5.3 Review of the Potential Impact of Privacy and Safety Issues on the Implementation of Probe-based Traffic Data Collection Systems**

Privacy Issues:

The greatest challenge to collecting data via the tracking of probe vehicles may not be technical, but instead may lie in convincing the public that such a technology will not violate their privacy. According to a recent article in the Washington Post, "These 'intelligent transportation systems,' as they've been named may help solve traffic problems and be a boon to marketers, but they also raise the fear of a new threat to privacy: the idea that drivers could soon be leaving electronic

footsteps whenever they leave home."<sup>64</sup> According to this same article, a 1996 survey by Priscilla Regan, of George Mason University, found that Americans overwhelmingly preferred that high-tech transportation systems collect only anonymous information, such as overall traffic counts.

In order to overcome such privacy-related fears, representatives of private companies interested in traffic data collection via cellular geo-location and GPS chipsets in phones have stressed that their systems will not enable them to monitor phone calls or identify individual users, but simply to track the location and speed of phones in order to collect data on local traffic conditions.

One option currently under consideration is the implementation of a feature would allow users to turn off the tracking functionality of their phones during times that the user doesn't wish to be tracked. Consequently, identification information would only be accessible with the user's consent.

Public officials have also been forced to think through how to implement systems for tracking electronic toll transponders for traffic data collection purposes. For example, Transcom, the traffic management organization which operates the ETC system in the New York area, has set up automated roadside readers that scramble each tag's identification number so that data gathered from the tracking of that tag cannot be linked to the tag's owner.

The issue of ITS' impact on privacy was addressed in the August/September 2000 issue of Traffic Technology International, in which it was stated that "ITS continues to deploy sophisticated sensors that can potentially compromise public privacy. Care must be taken during planning, design, and operation of ITS centers to protect the public and only maintain collected data until aggregated traffic management-related information can be extracted. Then the detailed data should be permanently destroyed."<sup>65</sup> Overall, this article concluded that the future success of ITS depended on its advocates seeking ways to protect the public's privacy. Failing to do so would likely result in the ultimate failure of most ITS programs.

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<sup>64</sup> Sipress, A., "Big Brother Could Soon Ride Along in the Back Seat."

For any of the probe vehicle systems described in this thesis to be successful over the long term, safeguards must be put into place to ensure that the privacy of the individual drivers being tracked is protected. This means that in no case should a link be established between the identity of the mobile phone user or ETC tag owner and the data about their current location, unless explicitly permitted by that user (e.g., for emergency purposes such E-911).

Although drivers might allow themselves to be anonymously tracked, they will most likely be willing to do so only if they see some potential value from it. Failing this, it is much less likely that they will be willing to give up that degree of privacy. As a consequence, it will be necessary for ISPs relying on this data source to provide their customers (who may also make up a significant portion of their probe vehicle base) with the types of data that truly meets their needs. Failing to do so may result in their base of probe vehicles declining as drivers decide that the benefits to be gained from allowing themselves to be tracked are outweighed by the cost of their loss of privacy.

*Interviewees' Comments about Privacy:*

- Identification numbers from cell phones need to be scrambled so that ISPs only have information about the movements of the phone itself, and not about who owns that phone. However, if location-based services are of a high quality, people may be willing to give up some or all of their privacy.
- A big deal is currently being made over the fact that tracking people will be an invasion of their privacy. However, we're forgetting that we're already given up our privacy in many other areas - e.g., credit cards and Internet cookies. Consequently, the privacy issue isn't likely to be a big deal as long as people perceive a benefit.
- People will accept some loss of privacy, in exchange for a benefit, if the companies clearly explain how the data is being used - and there are no abuses. Consequently, if locational data is not used for purposes for which it isn't intended, then there should not be a problem.
- Privacy will be less of a problem than is currently thought - it's simply a matter of making people understand that their individual movements won't be tracked and databased.
- Privacy is a main issue that many service providers are very concerned about - e.g., On-Star could collect lots of data on their customers' travel patterns, but they don't do it because they don't want their customers' privacy invaded.

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<sup>65</sup> Abernathy, B. and Kolcz, A., p. 62.

- We need to make cellular users understand that the technology doesn't allow us to access anything but the energy signature of their phone. We won't know who the caller is, or have the ability to pick up voice transmissions. If we do a good job in making the public aware of this, it won't be a big problem.

#### Safety Issues:

The growth in mobile phone usage over the last decade has been accompanied by growing concerns about hazards resulting from cell-phone usage by drivers. A National Highway Traffic Safety Administration report entitled "An Investigation of the Safety Implications of Wireless Communications in Vehicles," concluded that available evidence indicates that cellular phone use by drivers does, at least in isolated cases, increase the risk of a crash. This report further indicates that "increased phone usage will likely result in an increase in crashes unless changes take place in mobile phone technology, or its, use that mitigates this trend."<sup>66</sup>

These safety concerns are reflected in the growing number of legislative initiatives that have sprung up across the United States related to the use of wireless devices by drivers. For example, a recent article of the New York Post reported that "Using a hand-held cellular phone while driving is about to be outlawed in the city (New York)," and that "the whole point is to make it safer for the driver and obviously safer for the pedestrian. The New England Journal of Medicine indicates that it is just as dangerous driving while holding a telephone in your hand as it is if you're driving while drunk."<sup>67</sup> This article also indicated that similar measures had previously been passed in Rockland and Suffolk counties (located in New York State).

The impact of such legislation on each of the probe technologies under development would be as follows:

- Collection of Locational/Traffic Data via the tracking of Electronic Toll Transponders - as this technology is wholly unrelated to cell phone use, data collection would be unaffected.
- Collection of Locational/Traffic Data via network-oriented cellular location technology or use of GPS chipsets in mobile phones - two scenarios can be hypothesized.

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<sup>66</sup> Goodman, M. and Bents, F., p. 13.

<sup>67</sup> Edozien, F.

Scenario A - the technology is simply used to direct locational information to public safety officials when the user dials 911. In such a case, the locational technology would only be activated in cases where the mobile phone user dials 911. As implementation of the technology in such a manner would not facilitate the collection of traffic data [only used for E-911], legislation restricting use of tracking technology would have no impact.

Scenario B - the chipset in the mobile phone is used both for E-911 purposes, as well as to facilitate the collection of traffic data and locational data for other commercial purposes. In such a case, the impact of banning cell-phone usage would depend upon whether the technology in question is able to collect locational data in cases where the phone is simply turned on, or requires that the phone be in use for accurate tracking to occur. If the former is the case, then legislation banning cell phone usage is not likely to have a major impact on the technologies' effectiveness. However, should the technology rely on mobile phone users actually talking on their phones for accurate tracking to take place, then such legislation could render the locational technology completely ineffective.

*Interviewees' Comments about Safety:*

- Local legislation banning of the use of cell phones will be a problem at least during the near term.
- Lots of people advocate that phones shouldn't be used while driving. Methods for dealing this include tracking car passengers (rather than drivers), increased use of hands free units, and the tracking of ATIS devices put in the car by the manufacturer (not necessarily related to voice calls, but rather telematics data transmission).
- Even if talking on cell phones in cars is banned, cell phone technology will eventually be hard wired into cars to enable crash notification. Transmission from this and other telematics applications could be tracked instead.
- At present, driving while talking on a cell phones is as dangerous as driving drunk. Consequently, cell-phones will need to become hands-free and voice activated.

#### **5.4 Examples of the Goals of Public and Private Entities Currently Implementing or Attempting to Implement Different Locational Technologies, and their Progress to Date**

Note: The reader should bear in mind that there are many other companies (e.g., SnapTrack and TruePosition) and public entities (e.g., TRANSCOM) carrying out similar work.

**US Wireless (Using Network-based Cellular Geolocation - see Chapter 2 for details)** - "Our objective is to deploy and operate a nationwide wireless location network that supports the needs of wireless carriers and other customers and provides other value-added services. We intend to focus on the wireless carrier as our primary customer. To date, we have undertaken, or are undertaking, technology trials with Verizon, Nextel Communications, AT&T Wireless, SBC Communications and Western Wireless, for each to evaluate the effectiveness of our location technology. We believe that in the event a carrier selects our system to provide some or all of its E-911 services, we will be well positioned to market additional location-based service applications to that carrier. As our national footprint is built, our service bureau will enable us to:

- sell multiple services to each carrier, beginning with E-911 service, adding additional carrier network applications, such as location-based billing, and ultimately adding subscriber-driven location-sensitive applications;
- provide customized applications that will allow a carrier to create tailored services for its customer base; and
- offer applications such as intelligent transportation services and telematics to non-carrier customers (for traffic data collection, fleet management, etc)."<sup>68</sup>

US Wireless' Annual Report also states that they plan to provide accurate and cost-effective solutions for monitoring traffic flow and congestion. According to a representative of US Wireless, the company believes that aside from partnering with cellular phone service providers, many State DOTs can be convinced to help build out parts of the US Wireless network so that they will be able to gain access to better traffic data. Other potential markets that this representative made reference to during our conversation included: private ATIS ISPs (via development of a nationwide service), Fleet management/asset tracking on a national basis, and location-oriented services. He stated that it is not their goal to do true retailing of their data themselves, so they are partnering with companies who will work on data fusion and

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<sup>68</sup> US Wireless Annual Report - released on June 29, 2000.



harmonization issues. Overall, US Wireless' belief is that their network can use what is essentially the same stream of data to meet the needs of many different types of customers, consequently creating multiple streams of revenue.

Status of the US Wireless System - US Wireless has entered into trial agreements with the Maryland and Virginia State Departments of Transportation to provide them with traffic data. According to US Wireless' Annual report, these contracts are meant to subsidize the cost of developing their wireless location network, which when built out will serve as a platform for other commercial services. Data from the Virginia trials is also being utilized to fulfill agreements with Etak/Metro Networks and Cox Interactive Media - to distribute data in the form of commercial services and end user product offerings. In addition, other agreements are currently underway or planned for the following cities: Washington, DC; Oakland, CA; Billings, MT; San Diego, CA; Seattle, WA; San Francisco, CA; and San Jose, CA

SAN ANTONIO (ETC transponder) - "As one of four sites participating in the MMDI effort, San Antonio was committed to pursuing integrated deployments of Intelligent Transportation Systems (ITS) designed to address gaps in existing traveler services and to provide improvements in areas such as customer satisfaction, safety, and mobility. Of these gaps, the one receiving perhaps the most attention under the effort was in the quality and coverage of critical traveler information systems."<sup>69</sup>

San Antonio wanted to add arterial travel speeds data to its existing traveler information system. This information would then be disseminated through various media, including Web sites and variable message signs. San Antonio decided to use automatic vehicle identification (AVI) tags to collect this information - despite the fact that it does not have an electronic toll payment system.

Status of the San Antonio System - To successfully collect arterial travel times using vehicle tags, an adequate number of vehicle tags must be distributed. Because San Antonio does not have an electronic toll payment system, distribution of vehicle tags was undertaken via a

voluntary program. In all, about 38,000 drivers volunteered to have the vehicle tags placed on their cars. Although San Antonio officials assumed this would provide an adequate level of market penetration, this turned out not to be the case. Despite the fact that the AVI tags were found to accurately measure travel times during testing, their overall low market penetration made it difficult to measure travel times consistently throughout the day. As a result, San Antonio has now decided to use inductive loop detectors and other point-source infrastructure to measure speeds on arterials and other roads.<sup>70</sup>

### **5.5 Interviewees' Comments Concerning How Traffic Data Will Be Collected in the Future**

In addition to the specific questions that we asked interviewees, we also requested that they talk a bit about how they thought the future of traffic data collection would turn out. The following section presents what they had to say.

- (Expressed by several interviewees) The biggest problem with locational technology is determining the difference between cell phones in cars that are moving vs. those in parked cars, at lights, and in the pockets of users walking alongside roads (especially in urban areas). Consequently, until this problem is resolved, the technology will likely be most effective on freeways.
- GPS-based and cellular geolocation are technologies looking for a market. This is a chicken or egg type problem. There is no market at present because there is currently no data like that being proposed by these ISPs, but questions remain concerning whether a market will come into being once such systems are built out.
- Research is currently being carried out regarding the size of the sample needed to get accurate traffic data, that is, how many phones need to be tracked at one time. As most cell phone calls are very short, there are questions as to whether they will be able to provide the needed data - primarily in the case that the tracking system can only track the signal from actual calls, rather than being able to track the signal from phones which are simply turned on.
- If you have reasonably high rates of cell phone usage and not too much trouble with phone safety and privacy issues, then the US Wireless type of tracking system is likely to be successful. However, if many cars had toll tags and there was a high degree of [ETC tracking] infrastructure, then this could present real competition - at least as regards the collection of real-time traffic data.

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<sup>69</sup> Science Applications International Corporation, p. 3.

<sup>70</sup> Science Applications International Corporation, p. 9-10.

- The cost structure of private sector probe-oriented technologies distributes system costs across a range of possible services - of which traffic data collection is only one. Consequently, it presents tremendous revenue generating possibilities.
- Right now there are only a few cars with in-car telematics systems (one interviewee estimated that there are several hundred-thousand cars with basic systems now - e.g., On-Star). If many cars were to have these systems, they could be used as an alternative to either GPS-based or cellular geo-location tracking systems, in which case, phone based cellular geo-location and use of GPS chipsets would simply be used for E-911 purposes. Such in-car systems would likely combine GPS technology with cellular phones integrated into the car's electrical system - as has already happened with On-Star's Mayday (collision alert) System. Still, increased telematics usage would result in issues being raised concerning driver distraction and privacy.
- (Expressed by multiple people) Even though wireless probe systems will improve data overall, incident information will still be sketchy. Consequently, these will still need information from the state police, public CCTV cameras, which will need to be fused with the data they've collected.
- Local authorities don't have jurisdiction over adjacent roads and to this point have had little interest in ensuring that roads not within their jurisdictions are not congested, that is, they don't care what traffic on other roads is like, only that their own roads are clear. This can only be dealt with through cooperation between these agencies.
- Tracking of cell phone signals is currently more attractive due to the large market penetration. Eventually there will be other technologies, but as cell phones are already built out they will likely be dominant over the next few years.
- Competition from public agencies will primarily occur in areas such as public agencies are able to distribute large numbers of toll tags (NY and Houston), thereby enabling those agencies to collect large amounts of data. However, for such systems to collect the same types of data as privately operated cellular phone tracking systems, large amounts of field equipment, readers, and communications equipment will need to be procured. Consequently, although such systems might be more cost effective than loop detectors, they would in all likelihood be more expensive than the network-oriented systems being suggested by US Wireless and its ilk.
- What needs to be considered is not just which system provides better traffic data, but for what other services the technology can be used.
- Traffic agencies will still need traffic volume data for the maintenance of roads and bridges, for planning purposes. They will also need infrastructure for management at intersections and on-ramps, so they will be unlikely to give up their data collection infrastructure entirely.

- In the end, GPS-chipsets could potentially be integrated into mobile phones for cellular geolocation purposes (as proposed by Snaptrak [see **Chapter 2**]), or continue to be used simply for the types of Origin-Destination studies currently carried out by Batelle.
- One major barrier is that there are about 10 large cities in the country where there will be real interest in traffic data. In the absence of real congestion, most people won't be willing to pay for traffic data. Therefore, traffic data and other driver services might be saleable as part of a bundle.

## 5.6 Conclusions Regarding the Future of Traffic Data Collection

The data collection process we have pursued, including both the interviews from which most of the information in this chapter has been assembled and the background research conducted for chapters one through four, has led us to a number of conclusions about the future of traffic data collection in the United States. These conclusions cover a broad range of subjects, including:

1. The ability of private companies to build out their data collection networks and/or integrate GPS technology into large numbers of cell phones.
2. The market for this data. What is demand like for ITS services and how much will customers be willing to pay for them vs. what is available from public entities (for free) collecting data for ATMS purposes (including the possible impacts of widespread improvements in public sector traffic data collection practices)? This includes a discussion of the need for regional and national networks of data and the ability to provide different levels of service depending on the needs of the individual customer.
3. The future role of the public sector in traffic data collection.
4. The need for data (both public and private) to be collected and made available in formats that are easily usable by multiple entities.
5. The potential impacts of privacy and safety issues on the market for this data.

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*The ability of private companies to build out their data collection networks [for network-oriented cellular geolocation] and/or integrate GPS technology into large numbers of cell phones.*

Although there is some need to consider the capital costs of the various technologies (as described in **Chapter 2**), the overarching fact is that the FCC has mandated that cell phone companies **must** select a technology for locating E-911 calls on their networks. Consequently, a great deal of the technology (either network-based or integrated GPS chipsets) for this service

will most likely be paid for by the cell phone companies who need to address this mandate. Whether or not these cell phone service providers eventually take over the collection and provision of this data from US Wireless, etc., is irrelevant to the fact that the technology will be put into place and the relevant data collected. In addition, US Wireless has already demonstrated that there is at least some public sector interest in investing in this infrastructure (i.e., their work with the State DOTs in Maryland and Virginia.).

***The market for this data. What is demand like for ATIS services and how much will customers be willing to pay for them vs. what is available from public entities (for free) collecting data for ATMS purposes?***

At present, a large gap exists between the types, amounts, and quality of traffic data available from public sector agencies and the needs of both private ISPs and even some operations-oriented transportation agencies. Nevertheless, we believe that for customers to be willing to pay for the more detailed traffic information that could become available via wireless probe-based systems (using cellular geolocation or embedded GPS chipsets in phones), it will need to be provided conveniently (e.g., via wireless device), at a low-cost, and be highly accurate and reliable (i.e., the system must provide reliable data between 95-99% of the time, or customers will cancel their service and rely on free data provided by public sector resources). In addition, questions remain regarding the actual size of this market. In **Chapter 3**, we employed research findings which indicated that the number of ATIS users would not simply stem from individual consumer preferences, but also rely upon:

- The attributes of the individual region - major ATIS markets appear to exist primarily in those metropolitan areas facing the greatest congestion problems;
- Quality of the ATIS service - as above, users of must feel that the are gaining a real benefit from this service.

As no stream of high-quality, real-time traffic data currently exists, it is anybody's guess as to how this market will eventually coalesce. In the end, it is more than likely that traffic data will not be provided as a stand-alone service, but bundled with other location-based services to which drivers and commercial users and will subscribe. By doing so, retailers of this information will be able to expand their customer base to include not just people who have a real interest in real-

time traffic and routing services, but other locational services as well (e.g., concierge services, road safety, etc). **Table 5.1** provides examples of what some of these other services might be.

In contrast with traditional public data collection systems (e.g., loop detectors and CCTV systems) and even ETC-based probe technologies, wireless systems using either type of privately procured vehicle location technology described in this thesis have the potential to provide network-oriented traffic data concerning all roads within a given radius around their data collection infrastructure (e.g., tracking equipment placed on cell towers). Consequently, once a system is in place, there should be very low marginal costs to gather data from additional roads within the infrastructure's range. The data from such network could be used to provide data for multiple applications (E-911, ATIS, ATMS data, information to regional providers of 511 traveler information services, and other value-added commercial service [as in **Table 5.1**]). Moreover, cell phone geolocation could provide alternatives for electronic payments including electronic toll collection and other point of service applications, allowing fees to be charged directly to users' cell phone bills. Due to the potential for multiple revenue streams emanating from this single infrastructure build out, the service charge to any single customer can be expected to be quite reasonable.

**Table 5.1** - Examples of Services that could be Enabled Using Vehicle Locational Services:<sup>71</sup>

<i>Navigation</i>	<i>Safety &amp; Security</i>
<ul style="list-style-type: none"> <li>❖ <u>Dynamic (Real-time) Routing Instructions:</u> <ul style="list-style-type: none"> <li>• Route Travel Time Information;</li> <li>• Information on Alternate Routes;</li> <li>• Dynamic Route Guidance between two points ; and</li> <li>• Estimation of Traffic Delays.</li> </ul> </li> <li>❖ <u>Personalized "To-Do" Lists:</u> <ul style="list-style-type: none"> <li>• Information on entertainment and other activities of interest to the customer delivered via mobile device or computer.</li> </ul> </li> <li>❖ <u>Travel Support:</u> <ul style="list-style-type: none"> <li>• Location of Service Stations and parking facilities;</li> <li>• Other travel-related services; and</li> <li>• Information about nearby transit alternatives.</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>❖ <u>Road Safety:</u> <ul style="list-style-type: none"> <li>• Information about local roads and weather conditions;</li> </ul> </li> <li>❖ <u>Driver Safety:</u> <ul style="list-style-type: none"> <li>• Information about nearby accidents and related congestion;</li> </ul> </li> <li>❖ <u>Emergency Services:</u> <ul style="list-style-type: none"> <li>• Automatic Accident Notification</li> </ul> </li> <li>❖ <u>Anti-theft Devices:</u> <ul style="list-style-type: none"> <li>• Manual/Automatic Theft Alert</li> <li>• Remote Car Tracking</li> </ul> </li> </ul>

<sup>71</sup> Booz-Allen and Hamilton, p. 6.

In **Chapters 3 and 4**, we discussed the concept of ISPs collecting probe-oriented data being able to deliver different levels of granularity of traffic data, depending on the needs of their different customers. The ability of these data providers to do this will allow them to price discriminate among their customer base, charging higher fees for more detailed information and lower fees for more aggregate data.

Many of the new customers that will have an interest in gaining access to this probe-oriented stream of data will be large companies that want to use it for fleet management purposes (e.g., UPS), or other ISPs (e.g., GM's On-Star) that will use it to provide a service to their existing customer base. In order for these entities to have an interest in this data, it will have to be made available from either a private ISP with a nation-wide network [i.e., having a network of data collection infrastructure that covers the entire nation], or a consortium of ISPs working together to provide this service. The existence of regional or a national stream of high-quality traffic data could also be marketed by ISPs as a resource on which the public sector could base their 511 traveler information number.

As regards competition from public sector agencies collecting data using ETC-based probe systems, it has been demonstrated that there are only a few places in the US where there is enough demand for tolling transponders for this to truly be a feasible data collection technique (e.g., the failure of San Antonio's ETC experiment - see **Section 5.4**). Although public agencies that do provide their ETC-based probe traffic data to the public for free might furnish some competition to fee-based private sector entities, it is important to remember that public sector data will only provide information on certain roads, will be expensive for the public sector to procure, and will not provide users with the personalized information or value-added services such as those that private sector ISPs wish to develop.

One issue that was not been discussed in the relevant literature or mentioned during our interviews is the potential impact of competition between different data wholesalers on the market for high quality traffic data. Although several interviewees mentioned that ISPs might be willing to form consortia in order to facilitate the development of regional and/or national streams of traffic data, we are unsure of the level of interest that many companies would have in

such a venture. As traffic data collection technology is proprietary in nature, and the potential exists for there to be fierce competition between private entities trying to develop a market for their data and services over the next few years, we must question whether these competing entities would be willing to share their data with one another. Consequently, although it is possible that data sharing agreements will be elaborated between competing ISPs that will allow them to develop linked data streams that cover larger geographic areas, we question the degree of surety which many people have that this will occur.

***The future role of the public sector in traffic data collection.***

As has been demonstrated in both our research and the statements of our interviewees, the public and private sectors will in many cases have very different needs for traffic data. Although the traffic information that ISPs [data wholesalers - see **Section 3.2**] such as US Wireless collect will meet many of the needs of ATIS service providers [data retailers - see **Section 3.2**] and their customers, questions remain as to whether or not such technologies can provide data of the sort that many public entities use for basic traffic planning and road maintenance (e.g., volume data, information about vehicle presence at lights and on ramps for signalization and metering purposes, etc.). As was related by several of our interviewees, many public sector professionals want to control their own data collection infrastructure and it may therefore be difficult to convince them that purchasing privately procured data in lieu of what their systems can collect would provide them with a net benefit. Questions also persist concerning whether public agencies would be able to use funding that has traditionally been for the development and maintenance of their own data collection infrastructure, to now use the funding for the purchase of traffic data from ISPs. Given that almost all public agencies will probably want to continue collecting some basic data with their own infrastructure, it is likely that there will in most case be only a relatively small amount of funding available for the purchase of traffic data from private ISPs. Given all of these factors, and a certain level of mistrust within many public sector entities of the private sector, it is likely that private sector ISPs will discover that a high degree of variability exists in their ability to market their traffic data to public agencies.



*The need for data (both public and private) to be collected and made available in formats that are easily usable by multiple entities.*

In order for ISPs to provide network oriented data covering multiple regions, as well as the nation as a whole, there will be a need to fuse privately procured probe-oriented traffic data with data from public agencies (e.g., for better information concerning incidents) and even data from other private ISPs. Only by doing so can a single, unified picture of traffic conditions be developed.

At this point, the primary problem with traffic data is that it is simply not of sufficient quality or quantity to meet users' needs. However, once that data becomes available (as might occur after the implementation of privately operated probe-oriented system) there will be a significant interest in it.

ITS America has already formed a Steering Committee to address ATIS-related data collection issues (chaired by Joel Markowitz of the Metropolitan Transportation Commission of the Bay Area in California), with the goal of developing guidelines to facilitate public agencies' and private ISPs' use of traffic data without the need to translate it from the raw form in which they receive it, into one that they can actually make use of. Such guidelines would attempt to set standards concerning the types of data collected for ATMS purposes, thereby making an effort to close the "Data Gap," by having ATMS data collection infrastructures begin collecting data that ATIS ISPs actually find useful. Many of our interviewees stated that fusing data from multiple ISPs and public sector entities would not be a problem. However, as we saw in **Chapter 4**, in order for data fusion to take place, numerous technical obstacles must be overcome, many of which will be impossible to solve until institutional relationships concerning the sharing of traffic data are first established between potential partners. Consequently, we believe that the development of data sharing relationships will take a much greater amount of time and effort than was indicated by the bulk of our interviewees.

*The potential impacts of privacy and safety issues on the market for this data.*

As was discussed at length in **Section 5.3**, failure on the part of the ISP community to seriously consider the impacts of privacy and safety issues related to ITS could have quite negative consequences on the locational information and traffic data collection markets. In fact, the potential impact of these factors to adversely affect cellular geo-location is likely just as strong as the impact that would result if there was not a strong enough market for this data.

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In order to provide the reader with a more concrete idea of what the data gathered from our interviews and the conclusions elaborated in **Section 5.6** might mean in actual practice, **Chapter 6** will present a number frameworks enumerating many of the issues that different entities (both public and private) might want to consider prior to deciding whether or not to pursue a relationship with an ISP providing traffic data via one of the types of vehicle location technologies described in this thesis.

# CHAPTER 6

## FRAMEWORKS FOR TRAFFIC DATA COLLECTION

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### 6.1 Elaboration of Frameworks for Traffic Data Collection

Based on our research, we have developed a number of frameworks enumerating many of the issues that different entities (both *public* [e.g., Traffic Operations Centers] and *private* [e.g., ISPs]) might want to consider prior to deciding whether or not to pursue a relationship with an ISP providing traffic data via one of the types of vehicle location technologies described in this thesis. The types of entities we have developed frameworks for are:

Framework 1 - A metropolitan-wide agency providing ATMS and ATIS services;

Framework 2 - A multi-regional traveler information system run by a consortium of public agencies;

Framework 3 - A small, rural municipality with little traffic surveillance infrastructure and no data sharing relationships with abutting jurisdictions;

Framework 4 - A national provider of traveler information services; and

Framework 5 - A private ISP attempting to provide traveler information services with a single metropolitan area.

Note: In most cases we have provided real examples of the entities listed above in order to facilitate development of more realistic frameworks.

In each case, we have attempted to provide a thorough discussion of how local conditions or the need to meet certain goals will impact the entity's decision. Examples of some of these determinants include:

- The extent to which a public agency has invested large amounts of capital in traffic surveillance infrastructure;
- The amount of funding available for the purchase of privately procured data;

- The number of agencies from different jurisdictions participating in a metropolitan traffic management effort;
- The attitude of public leaders concerning the procurement of privately procured data and the extent to which such support can be developed; and
- The extent to which existing data meets the entity's (or its customers) real needs.

As the interplay between many of these issues remains unresolved, the frameworks that we have developed do not provide a final conclusion as to whether each entity should procure data from a private sector resource or not. Rather, they have been provided in an effort to promote a greater understanding of how determinants such as those described above will impact different groups - depending on their specific circumstances. Although no two entities will face the exact same set of conditions, we hope the examples we have provided will assist the reader in considering the decision factors affecting a much broader group of entities having traffic data needs.

**Table 6.1 - Outline of the Different Frameworks Described in Chapter 6**

	<b>Framework 1</b>	<b>Framework 2</b>	<b>Framework 3</b>	<b>Framework 4</b>	<b>Framework 5</b>
<b>Type of Entity</b>	Public ATMS	Multi-state Public Entity	City Transportation Department	National Traveler Service Provider	Private ISP focused on a single metro area
<b>Geographic Scope of Entity</b>	Metro Area	Multi-State	Small City	National	Metro Area
<b>Type of Data Needed</b>	Congestion on freeways and major arterials	Incident detection on freeways	Primarily incident management	Data to support dynamic route guidance applications on a national basis	Traffic information for local traveler information services
<b>Is that data currently available?</b>	Point-oriented surveillance equipment provides some coverage, but not of a network-oriented nature (many roads remain unmonitored)	Point-oriented surveillance equipment provides much of what is needed, possible use of ETC-based system for additional monitoring	In the center of the city, but not outlying areas	Not of sufficient quality for route guidance purposes	Low-quality data allows them to provide some services, but would like higher quality data for more advanced ATIS
<b>Current Resources for Traffic Data</b>	Loop detectors, CCTV cameras, reports from other agencies	Loop detectors, some CCTV cameras, possibly ETC transponder tracking	CCTV cameras	Could get data from ISPs with nationwide data collection capability (data primarily from public agencies), but data is of questionable value	Data from public agencies and some of their own resources
<b>Surveillance Investments?</b>	Yes	Yes	Small amount	No	Small amount
<b>What do they provide to their "Customers"?</b>	Management of freeways and arterials; some ATIS; data to ISPs	Management of incidents and coordination of freeway construction; data to ISPs	Incident clearance and emergency services dispatching	In-car traveler information and safety services	Currently, provide basic ATIS on the Internet, TV/Radio, and via phone
<b>Ability and/or Willingness to Pay for Data from a Private ISP</b>	Although funding is likely available, political feasibility is questionable unless more network-oriented operations are pursued	Although the entity has its own budget, we find it unlikely that they would be interested in high-quality traffic data given their goals	Small budget and low political support for the purchase of high-quality traffic data.	High interest in procuring high-quality traffic data for route guidance and other traveler services	Interest in high-quality data for advanced ATIS, but market for these services is questionable

\* - We can assume that privacy and safety regulations would have an impact on the feasibility of ISPs using wireless probe vehicle surveillance systems to collect traffic data in all of the above frameworks.

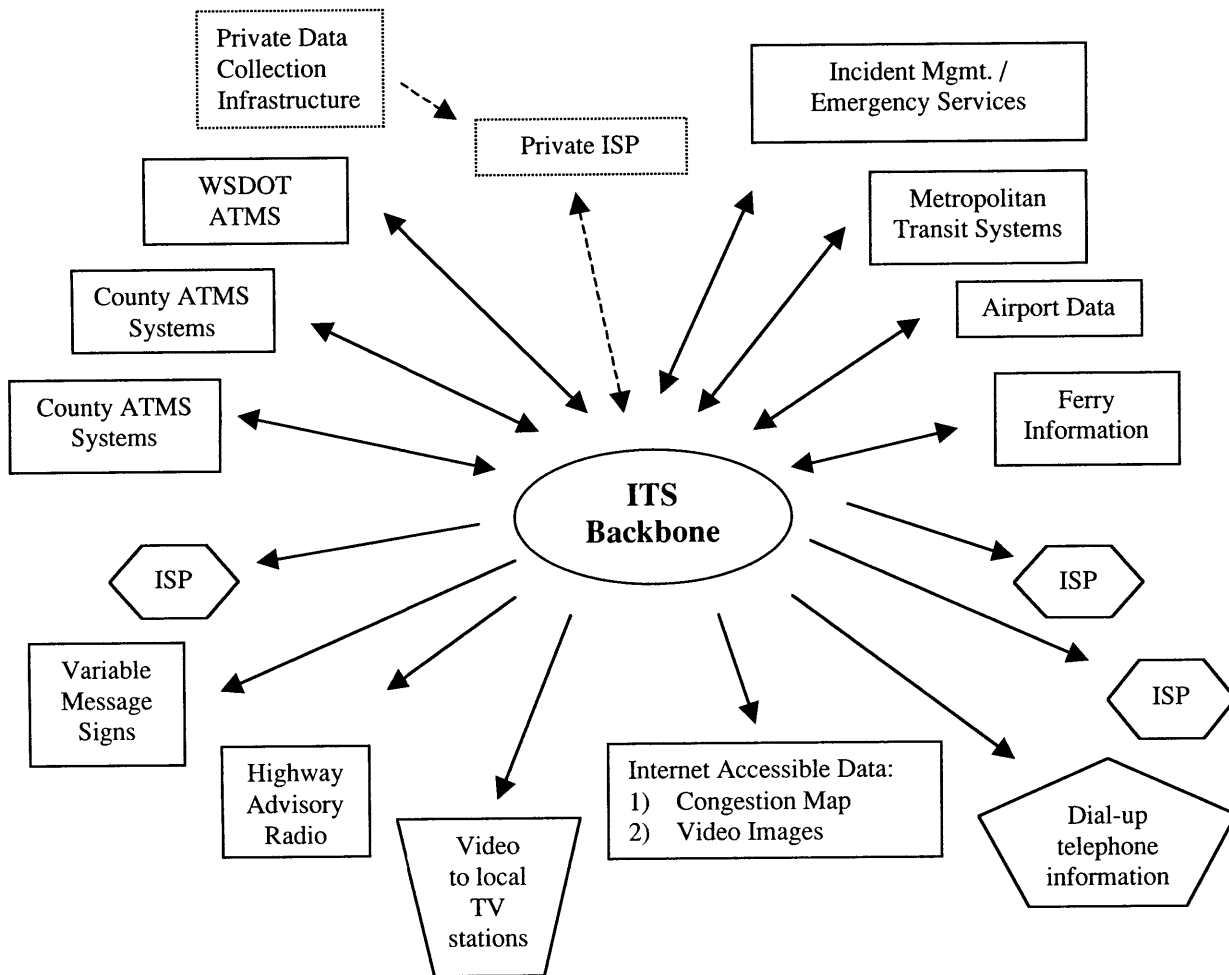
**Framework 1 - A metropolitan-wide agency providing ATMS and basic ATIS services - Smart Trek (Seattle, Washington)**

**Background** - Smart Trek is one of four demonstration projects that was selected as part of the US Department of Transportation's Model Deployment Initiative. The project is a partnership of 29 agencies and private companies, of which the lead organization is the Washington State Department of Transportation (WSDOT). The project's goal is to improve both traffic management and traveler information across the entire Seattle Metropolitan area by integrating existing ITS infrastructure (thereby optimizing the sharing of transportation information among public agencies and that made available to the traveling public.)

A major part of the Smart Trek project relies on the development of a regional multi-modal information network, referred to as the ITS Backbone. The ITS Backbone facilitates connections between existing, planned, and future ITS systems in order to improve their information-sharing capacity, thereby enabling the creation of a regional transportation information resource. Developers of this system utilized draft ITS standards concerning communications protocols and location referencing in order to facilitate the efficient exchange of data. This data is also made available to private ISPs (in either a raw or processed format), for use as the base of their traveler information systems.

Public agencies led by WSDOT provide the traffic information that has been used to develop real-time freeway congestion maps (for both ATMS and ATIS purposes), incident reports, and improved access to freeway traffic cameras; although they indicate that they have no interest in more advanced ATIS applications such as the provision of dynamic route guidance. The traffic surveillance system is composed of over 2,500 loop sensors and approximately 200 CCTV cameras. Additional infrastructure is being added over time in order to fill in existing gaps (on both freeways as well as arterials).

**Figure 6.1 - Outline of the Flow of Traffic Data in the Smart Trek System Framework**



Note: All shapes connected to the system with a dashed line represent potential links with private ISPs. However, these links do not exist at the present time.

ATMS response to congestion or traffic incidents is carried out via several methods, including: ramp control via ramp metering, dissemination of information to drivers via variable message signs and highway advisory radio, and working with the state police to clear incidents. Information is also provided by the public sector via recorded phone messages and on the Internet via the Seattle Freeway Management Systems' web-site. This site offers both a real-time freeway congestion map and access to still photos from the system's CCTV cameras. Aside from

these services, the web-site also provides information about road closures, construction, current incidents, and a link to the regional transit system's Internet site

Aside from WSDOT infrastructure, the Smart Trek system is expected to integrate traffic data from a number of city and county agencies in order to facilitate the more efficient management of arterials. Integration of this data would allow traffic management officials in each jurisdiction to use information from these other surveillance systems to better inform their own decision-making and increase the level of cooperation between neighboring jurisdictions. Such integration will also allow the WSDOT's traffic congestion map and other resources to provide arterial congestion information.

Finally, Smart Trek will utilize vehicle location data from the King County metro system's 1,200 buses to provide bus arrival information both on the Internet and at bus stops themselves. Although these vehicles are not currently used as probes to collect real-time traffic data to supplement what is collected via loop detectors and CCTV cameras, it is feasible that such a development could take place in the near future.

The Seattle Smart Trek system is one of only a very small number of places in the United States in which the public sector has made both major investments in traffic surveillance infrastructure, and developed institutional relationships to share that data across jurisdictions. The existence of this multi-agency partnership effectively creates an umbrella organization that combines freeway management, the provision of traveler information, integration of transit operations, etc.

#### Issues involved in this entity making a decision about whether to procure private sector data

Costs - Despite the accolades that an effort such as this deserves, it must at the same time be kept in mind that the cost of maintaining this level of traffic surveillance infrastructure will likely be tremendous. Such maintenance costs would include the communications costs associated with maintaining the large number of dedicated dial-up and fiber optic connections that would be needed both for the various entities involved to collect their data, as well as for those entities to transmit it to the ITS Backbone and for the Backbone to maintain a link for all of these entities to



access the fused data stream. Consequently, there are major financial considerations involved in maintaining such a system. As available information on Smart Trek details their interest in building out even more loop detectors and CCTV cameras in order to collect even more detailed traffic data on both freeways and arterials, these costs will only increase. These costs contrast with what would likely be a much smaller fee for the provision of data; kept reasonable by the fact that private data collection entities would be able to use this same traffic and location data for multiple applications, thereby resulting in several streams of revenue. Fees for this data would also be kept to a reasonable level due to the fact that private ISPs are, at least in the short-term, likely to face competition from other providers in what we think could be a highly competitive market.

Political Feasibility - Due to the large amount of infrastructure already procured by the entities involved in the Smart Trek partnership, there is likely to be a large amount of both political and institutional (within the public agencies themselves) inertia against abandoning public data collection in favor of the purchase of a stream of data from a private entity. An agreement on this would be especially difficult to reach due to the number of institutions involved in this partnership. One way to get around this problem might be to develop a data sharing relationship with one (of what could be several) of the private entities collecting private data (likely with the assurance that this data would simply be used for ATMS purposes and somehow walled off from the ISPs who currently have access to the ITS Backbone database. In this way, the public entity would be able to get around the issue of cost, and the private provider would gain access to improved information about incidents (from public safety agencies), scheduled construction, etc.

Funding - Whereas Smart Trek's partner agencies have apparently been able to procure large amounts of funding for the development of their surveillance infrastructure, our research indicates that there is likely to be less enthusiasm toward paying for data on a regular basis. If a data sharing relationship can be developed, then funding will be a non-issue. However, should such a relationship not be amenable to either entity involved, then convincing public officials of the need to invest in this data will be difficult - especially given the amount of publicly owned surveillance infrastructure already in the field.

Granularity of the data - Although the data provided by the current ATMS system is of truly high quality for a public agency, it continues to be constrained by the fact that sensor data can only provide information concerning what is occurring within the immediate vicinity of its "point" sensors. Private, network-oriented data would allow many of those gaps to be filled in. Moreover, the ability of private providers to "zoom-in", or provide higher levels of granularity when needed, would allow the managers of the Smart Trek system to request more specific data about areas that have traditionally been trouble spots, as well as areas in which an incident is taking place.

Provision of data concerning the entire traffic network - Although the data collected by the Smart Trek infrastructure is better than in most other areas, it does not allow traffic managers to get a sense of what is happening on arterials and other secondary roads not presently under surveillance. The ability of private systems to collect network-oriented data, in conjunction with the high level of integration between various public entities within Smart Trek would facilitate better traffic management - e.g., real-time calibration of signal control timing according to current traffic conditions. As Smart Trek promotional materials indicate that this is just the sort of advanced traffic management program in which they have an interest, it would make sense for them to get the best data available to meet that need.

Impact of public vehicle location technology on buses and other public vehicles - Although Smart Trek resources do not currently mention this possibility, it is feasible that the data collected from the vehicle location technology placed on metropolitan area buses for fleet management purposes could be utilized to produce probe oriented data much like what would be available from a private entity. Whereas the integration of transit and traffic management systems would typically be an issue, the integration of these systems' information through the ITS Backbone only increases both the likelihood and attractiveness of such an option. In addition to buses, other municipal and state vehicles could also be equipped with location tracking technology in order to increase the number of probes on the road. In spite of this possibility, questions remain concerning whether this relatively small number of probes would provide the ubiquitous coverage of a surveillance system tracking the movement of cell phones.

Privacy and Safety Issues - Due to the number of jurisdictions involved in this partnership, it is quite possible that one or more of them would impose either privacy regulations limiting the ability of cell-phone tracking technology, or safety regulations limiting drivers' usage of cell phones (which would have a major impact if the various tracking technologies are only effective at tracking phones that are actually making calls). This could create spottiness within the region's traffic coverage, thereby making such a system less attractive.

Impact on private ISPs involved in Smart Trek - At present, the ISPs involved in Smart Trek are provided with access to the fused data stream made available through the ITS Backbone. As they use this data to provide commercial services to their own customers, it is unlikely that a private data wholesaler would want local ISPs (primarily retailers) to gain access to any of the data that it sold or shared with the public sector for ATMS and basic, highly aggregated ATIS services (e.g., via congestion maps of freeways and major arterial accessible on the Internet). Consequently, although these ISPs would continue to be able to access publicly procured data, they would in all likelihood have to develop relationships with private data vendors on an independent basis. For more information on such relationships, see Framework 5.

Impact of Improved Data on relationship between ATMS and ATIS systems - As we have learned, some public officials fear that providing improved ATIS data about arterials and secondary roads will lead to a large amount of freeway traffic moving onto these roads, thereby having an adverse impact on the overall flow of traffic and their ability to manage the system. We believe that what many public officials have failed to consider is that even if they do not provide such data themselves, there are a large number of private firms that plan to do so through fee-based traveler information services. As more people will begin using alternate routes once real-time in-car traveler services become more advanced and widespread, it would probably be useful for the public sector to establish both institutional and data sharing relationships to help them deal with this potential problem.

**Framework 2 - A multi-regional traveler information system run by a consortium of public agencies - TRANSCOM (NY, NJ, CT)**

**Background** - TRANSCOM is a coalition of highway, transit, and public safety agencies in the New York, New Jersey, Connecticut area. It was originally started in the 1980s by the Port Authority of New York and New Jersey to help resolve construction conflicts between neighboring transportation agencies, but has over time become a player in the collection and exchange of region-wide transportation information. The system's underlying architecture has been developed in order to facilitate the exchange of data between member agencies via common standards for communications interfaces. Consequently, although each entity maintains its own autonomy, the data that each collects is automatically shared with other the other partners - information related to incidents, construction problems, etc. All incident data collected by TRANSCOM is passed on to Shadow Broadcast Services and Metro Traffic (ISPs), who broadcast this information over the radio, and SmartRoute Systems (see Framework 5 in this chapter), which combines this data with their own and disseminates it via telephone and over the Internet.

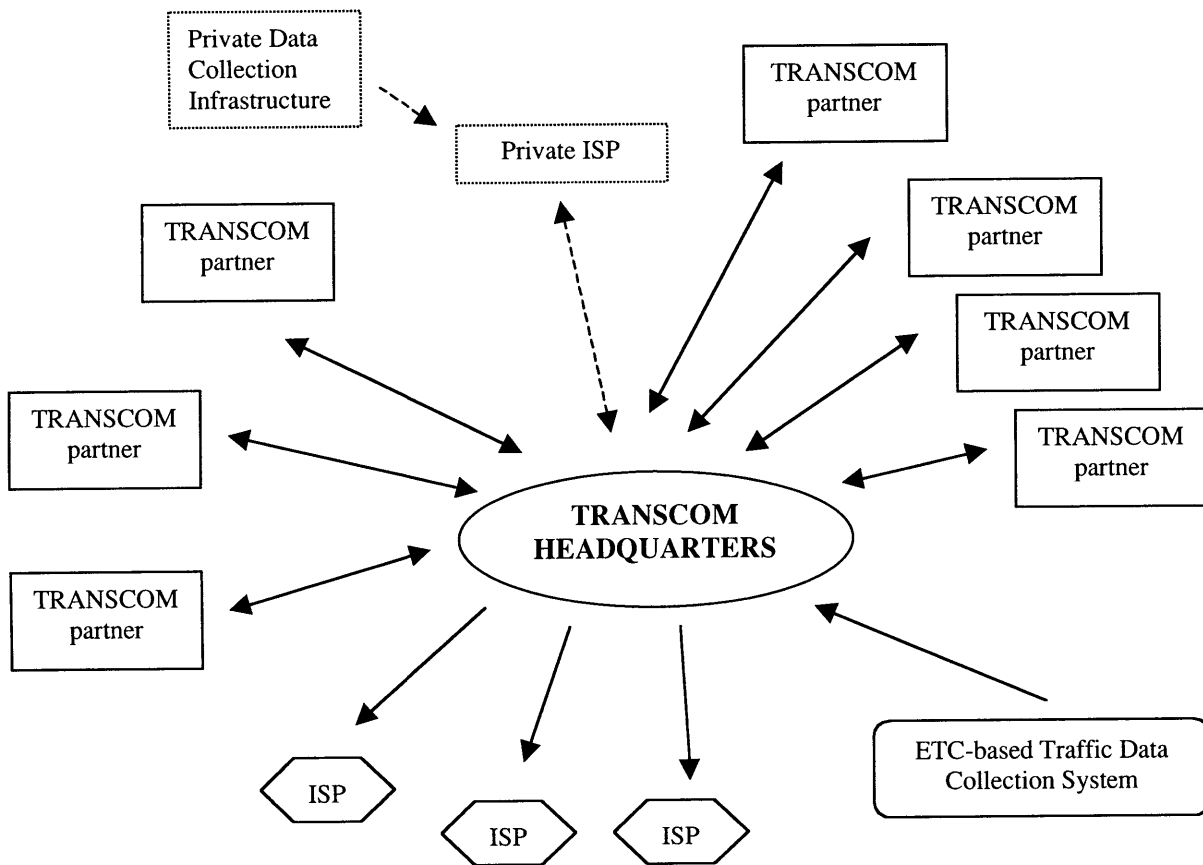
Recently, TRANSCOM partnered with the Federal Highway Administration to test the use of ETC-based transponders for incident detection purposes. It is hoped usage of this system will assist system managers in better identifying incidents and general areas of congestion.

**Issues involved in this entity making a decision about whether to procure private sector data**

**Interest in high-quality traffic data** - Given that TRANSCOM was organized around the principle of coordinating roadway construction activities [and has more recently become an intermediary for the dissemination of incident-related information], it is questionable whether they would have an interest in the type of high-quality network-oriented traffic data that a private entity could provide based on locational technology used to track cell phones. Although the members of TRANSCOM pay dues in order to participate, we must question whether many of these entities (especially the public safety agencies involved) would have an interest in information of such high detail and broad geographic scale. Of course, it is possible that the ISP providing such data

could restrict the data stream provided to TRANSCOM to include simply those freeways and major arterials of relevance. If that were the case, then the likelihood that such a system would be seen as useful by those involved in TRANSCOM would increase.

**Figure 6.2 - Outline of the Flow of Traffic Data in the TRANSCOM System Framework**



Note: All shapes connected to the system with a dashed line represent potential links with private ISPs. However, these links do not exist at the present time.

Alternative to gathering this data from the private sector - As mentioned in the background we have provided about TRANSCOM, they have recently participated in a test concerning the efficacy of using ETC transponders to collect data about traffic conditions on area toll roads (for a more in-depth description of this technology, see **Section 2.3.2**). Although this experiment was only carried out over a small area, the results indicated that a broader test was in order. Given

the large number of ETC transponders in use in the NY, NJ, CT area, the number of potential probes provided by this system is quite high (in contrast with the failed San Antonio ETC test described in **Section 5.4**). Although the data provided by such a system would be of a "point" nature, the fact that TRANSCOM is primarily interested in identifying and dealing with incidents on the freeway suggests that this type of data might satisfy their needs.

Costs and political feasibility - Although the provision of ETC data might well meet TRANSCOM's basic needs, decision-makers would need to consider the costs associated with building out such an infrastructure across freeways and relevant arterials in three states (including what would likely be high communication costs) vs. acquiring this data from a private provider. As in Framework 1, such data could either be acquired for a fee or for free, based on the establishment of a public-private partnership in which TRANSCOM helps pay for development of the private entity's data collection infrastructure in return for a regular stream of data. Moreover, as was also stated in Framework 1, the massive costs associated with building out public sector traffic surveillance infrastructure contrast sharply with what would likely be relatively small fees for the provision of similar (or better) data from the private sector. Fees for this data would also be kept to a reasonable level due to the fact that private ISPs are, at least in the short-term, likely to face competition from other providers in what we think could be a highly competitive market.

With regard to the typical problem associated with public agencies being unable to transfer funding from capital-related projects (e.g., construction and maintenance of infrastructure), the fact that TRANSCOM has its own budget [based on membership fees] might help to get around this problem by allowing the officials who make up the TRANSCOM board to make financial decisions. Of course, if each entity involved in TRANSCOM must get approval from relevant public officials concerning how TRANSCOM spends their dues, then getting approval for such an investment may be near to impossible.

Safety and Privacy Issues - Given the multi-state nature of the TRANSCOM partnership, there is a real possibility that legislation related to one of these issues might impact the ability to collect traffic data using vehicle locational technology in one or more of the areas involved. This would

likely result in such a data collection system being less attractive and would thereby increase the likelihood that TRANSCOM's decision-makers would pursue implementation of an ETC-based traffic data surveillance system despite the cost.

Impact on private ISPs receiving incident data from TRANSCOM - as with Smart Trek, we find it unlikely that a private data wholesaler (e.g., US Wireless) would allow the traffic data (except at the most basic of levels) that it sells or otherwise provides to TRANSCOM to then be passed on by TRANSCOM to a data retailer such as SmartRoute Systems [to whom TRANSCOM currently provides their construction and incident data at no cost] for their use. Consequently, although SmartRoute and other ISPs having relationships with TRANSCOM would continue to be able to access its publicly procured data, they would have to develop relationships with private data wholesalers on an independent basis. For more information on such relationships, see Framework 5 in this chapter.

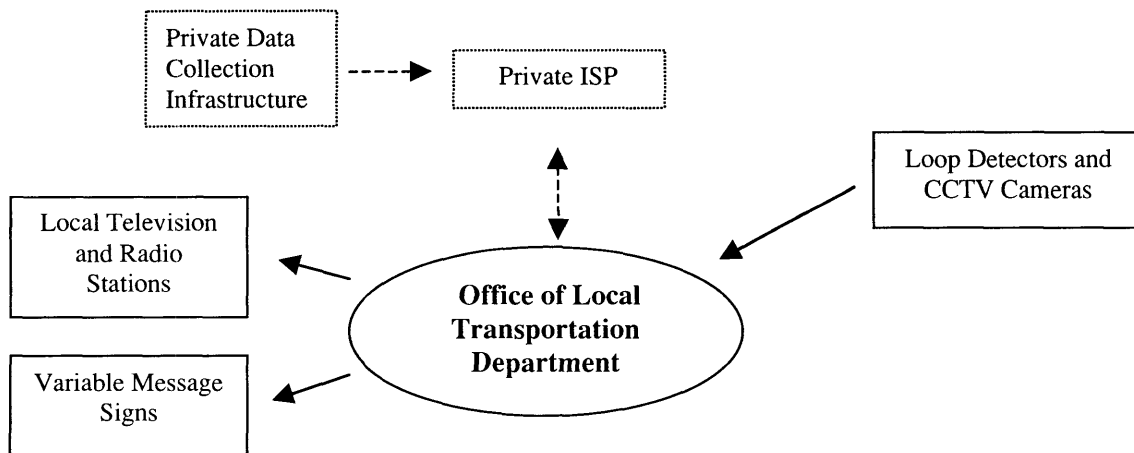
Possibility of transition to a Smart Trek-like agency (see Framework 1 in this chapter)- Although TRANSCOM does not currently have the high-level data sharing relationships required for operational integration such as has been achieved by Smart Trek, some of the institutional arrangements that do exist within TRANSCOM might facilitate the development of such integration at a later time. If this were to occur, TRANSCOM would be faced with many of the same issues that were enumerated in Framework 1, but with the additional consideration that decisions would have to be made by agencies within three adjoining states, rather than agencies from jurisdictions within a single metropolitan area.

**Framework 3 - A small, rural municipality with little traffic surveillance infrastructure and no data sharing relationships with abutting jurisdictions**

Although we have no specific example to represent this type of entity, we can easily imagine a small metropolitan area with the following characteristics:

- Little traffic data surveillance infrastructure (only a few loop detectors and a small number of cameras at major intersections) and a small ATMS budget;
- No institutional arrangements with adjoining jurisdictions for the sharing of traffic data;
- No interest in ATIS services - except possibly the notification of local radio and television stations to notify them of incidents and the usage of a small number of variable message signs;
- No ATMS operations center - all traffic operations handled within offices of transportation department of the city office building; and
- Small amounts of congestion typically in the downtown area during morning and afternoon commutes - generally brief.

**Figure 6.3 - Outline of the Flow of Traffic Data in a Small Metropolitan Area**



Note: All shapes connected to the system with a dashed line represent potential links with private ISPs. However, these links do not exist at the present time.



### Issues involved in this entity making a decision about whether to procure private sector data

Data Needs - In our opinion, a municipality such as this would be most interested in incident management more than anything else. As congestion is not currently a problem, and the ATMS budget is tiny, it is highly likely that public officials would want to use the available budget to maintain existing infrastructure - especially as the CCTV cameras serve a public safety function in addition to their traffic surveillance functionality. Consequently, any interest in purchasing privately procured traffic data would likely be related to using it for incident management purposes (primarily in more remote, rural areas).

Feasibility of the system - Given the rural nature of the area, real concerns might be raised regarding the efficacy of the types of wireless systems mentioned in the thesis. Although there are likely to be a sufficient number of cell phones carried by drivers within the most urbanized parts of the metropolitan area, it is unclear whether there would be either an adequate number of drivers with phones or a sufficient number of cell towers in place in more rural areas to provide the necessary data. As interest in the procurement of this data would likely be for incident management purposes, this problem might create a disconnect between the information that the system can provide and what is usable to municipal officials.

Political Feasibility - As there is currently no major congestion problem, and the public sector has already built out a small surveillance infrastructure, it might be difficult to convince public officials that the purchase of privately procured data would be worthwhile - especially as local interest in such data would likely be at a high level of aggregation in order to detect incidents. Additionally, the possibility of there being technical problems (as mentioned in the section about the feasibility of the system) and what would likely be tight budgetary constraints, puts the political feasibility of procuring traffic data from an ISP (data wholesaler) such as US Wireless into serious doubt. Officials would also be likely to fear that if they let their own infrastructure lapse, then they would be at the ISP's mercy - as the municipality would be hard pressed to find money to restore all of their infrastructure.

Interest in information on conditions in abutting jurisdictions - Some public officials have stated that one of their primary interests in network-oriented data is related to the fact that it would provide them with a better understanding of traffic conditions in abutting jurisdictions, thereby better enabling them to manage their own road networks. However, in this case, the overall lack of congestion and problems with the system likely eliminate such benefits. Still, officials in more urbanized, heavily populated municipalities would be more likely to see real benefits from network-oriented data.

#### **Framework 4 - A national provider of traveler information services - General Motor's On-Star Traveler Information and Safety Service**

**Background** - On-Star is a traveler assistance service provided by General Motors for its high-end automobiles. This system provides its clients with safety/security and other types of travel-related services. On-Star's melding of on-board cellular phone technology with a GPS transceiver and other electronic systems, provides a link between the driver and the On-Star Center. Examples of some of the services provided by On-Star include:

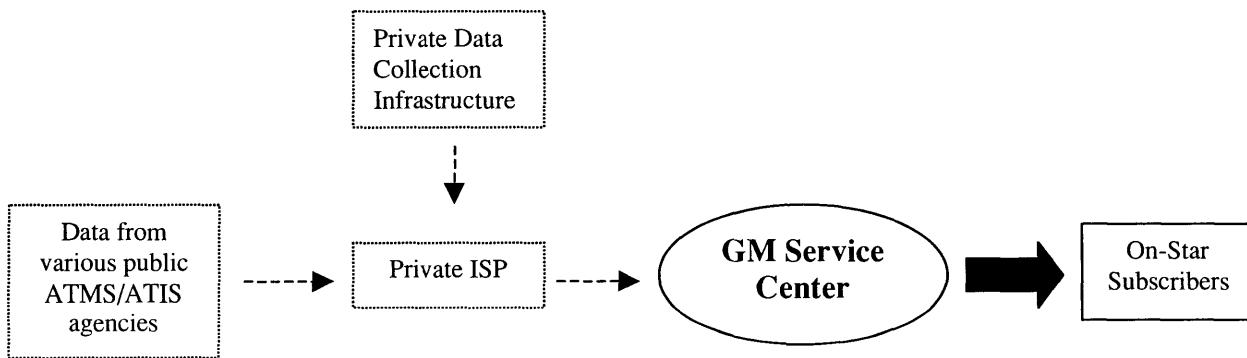
- 1) Notification of airbag deployment automatically sent to On-Star Center;
- 2) Two-way communication between the driver and the On-Star Center to enable service operator to check on occupants condition;
- 3) As the On-Star system is integrated with the vehicle's diagnostic system, the system can provide drivers with information about vehicle problems;
- 4) Automatic Vehicle Location - using the GPS system in the car, On-Star operators are able to locate the vehicle. This is used for purposes as widely varied as emergency dispatch of ambulances and other emergency services personnel, and the provision of directions from On-Star operators; and
- 5) Provision of other services - include everything from having On-Star operators provide information on nearby service facilities, to operators making reservations at restaurants.

Issues involved in this entity making a decision about whether to procure private sector data

Interest in Traffic Data - Although the On-Star system fully integrates vehicle location technology (via GPS) with wireless communication capability, and allows on-Star subscribers to receive travel assistance (e.g. directions) from an operator at the On-Star service center, no effort has yet been made by General Motors to procure traffic information from either public entities or private ISPs for usage in the provision of additional traveler services via an in-car telematics device. It is our belief that the primary reason behind this revolves around the following issues:

- insufficient geographic coverage of road networks;
- too much variability in the types and quality of data collected from jurisdiction to jurisdiction; and
- too many different types of data management and storage systems from which to collect and fuse data.

**Figure 6.4 - Outline of the Flow of Traffic Data in the GM On-Star Framework**



Note: All shapes connected to the system with a dashed line represent potential links with private ISPs. However, these links do not exist at the present time.

It is likely this combination of factors that make the collection of traffic data by General Motors a task in which they have neither the expertise nor interest. Due to the nature of the traveler services provided, On-Star is only likely to offer a dynamic traffic information and routing

service (computer instead of live operator) if they can gain access to a stream of high-quality, nationally uniform, real-time traffic data. As just stated, the traffic data currently available is of variable quality depending on the region, and, in best case scenarios (e.g. Seattle's Smart Trek, above), only available on a regional level - bringing with it all of the problems related to the existence of fusing data collected from systems using differing data storage techniques and formats. As GM would only utilize such data for the provision of a service to their customers, the cost of collecting this data would be prohibitive.

Existence of a National Network - Access to data from a nationally-oriented traffic data collection infrastructure would enable a company such as On-Star to gain access to the types of real-time traffic data that they could use as part of a new traveler service. In addition, it is highly likely that the private ISP would be interested in supplementing what it collects with data collected by public agencies in major metropolitan areas in order to procure additional information about incidents, construction and other local conditions (e.g., sporting events that might result in additional congestion) that would add value to their data stream. As there are likely to be multiple customers for such data (e.g., UPS - for fleet management purposes, or Regional entities interested in providing accurate traveler information via a 511 phone number) and therefore the potential for multiple streams of revenue, the development of such relationships and investment in the technology to fuse data from multiple public agencies would be much more feasible than for GM to do so with only its single revenue source.

Potential Obstacles:

- Safety and Privacy Issues - The potential exists for municipal, county, regional, state, or federal entities to pass legislation that will adversely impact the ability of private companies to collect traffic data using the types of vehicle location technologies described in this thesis. Depending on the geographic extent of such legislation, a national network could be created that contains areas with no coverage (which in some cases could be supplemented with lower quality public data), or no network at all (e.g., if Federal privacy legislation were enacted that banned the use of cell phone tracking technology for all but E-911 purposes.).

- No single provider - As there are likely to be multiple entities developing their proprietary networks over the next few years, it is unlikely that GM would be able to deal with a single private entity with a ubiquitous national network. Consequently, unless these ISPs choose to collaborate with one another in order to provide a nationally-oriented traffic data network based on a composite of their individual data, GM will have to gather data from multiple providers. If these companies chose to develop their systems using different electronic formats then the issue of fusing them into a single data stream becomes more complex. Although GM would likely be able to find a partner that would be able to fuse the data for them, the additional cost and complexity of doing so would make procurement of this data less attractive.

Telematics-based alternative - Given that GM and other automobile manufacturers are in the process of installing increasing amounts of telematics and locational technology in their own automobiles, the possibility exists that rather than relying on an ISP to provide this data, GM (or possibly a group of auto manufacturers) could begin using the technology they install themselves to track automobiles and collect traffic data. This possibility is interesting because it addresses several potential obstacles to traffic data collection via locational technology in cell phones:

- Privacy - As the owners of the automobiles using the installed telematics technology would receive direct benefits from allowing themselves to be tracked, via the provision of additional traveler information related to traffic conditions, they would be less likely to complain about being tracked.
- Safety - As the tracking technology would maintain contact with electronic equipment integrated into the vehicle's electrical system rather than a cell phone being used by the driver, legislation restricting cell phone usage by drivers would have no impact on the system's ability to collect data.
- Effectiveness of the Tracking System - Whereas questions have been raised concerning the ability of tracking technologies to differentiate between cell phones in cars and those being

carried by people walking along the road or sitting in restaurants, etc., the fact that this technology would actually be part of the car's system resolves this problem.

Market Considerations - Although GM has a customer base to which they can provide this service, they would have to make a decision concerning whether this investment is worthwhile in the face of other improvements/additions that could be made to the On-Star system. This would require market research concerning some of the issue affecting all ISPs interested in providing traveler information services - e.g., consumer interest and use of this type of data, the granularity of the types of data that customers want, the geographic coverage in which users are truly interested (e.g., only freeways and major arterials, or a wider range of smaller arterials and secondary roads as well). In the end, the major consideration for an entity such as GM would concern whether their investment of time and resources provides their customers with the type of service they want and the best return on their capital.

**Framework 5 - A private ISP attempting to provide traveler information services within a single metropolitan area - SmartRoute Systems (multiple projects across the United States).**

Background - SmartRoute Systems is a private company whose business centers on the collection, manipulation, and dissemination of ATIS services via partnerships it develops with public agencies to gain access to publicly procured data. SmartRoute ATIS services, provided under the name SmarTraveler, are typically managed out of an operations center that manages various traveler resources, including: dial-up travel information, an Internet web-site, broadcast services (e.g., regular broadcasts on local television), as well as the provision of services to private clients. SmartRoute Systems also offers private clients access to its database containing traffic data that has been collected from both public CCTV cameras and loop detectors, as well as their own resources (typically SmartRoute-owned CCTV cameras, but also commuters and truck drivers who report incidents and traffic conditions to the SmartRoute operations center) - and fused into a single data stream.

Typically, SmartRoute builds and operates an traveler information operations center in each city where it deploys its services (typically sharing the cost of its operation with local government for

the first three years, when it is anticipated that the cost of operations can be covered by revenues from advertising and fee-based services). Transportation agencies provide their traffic data to the center for free, which SmartRoute then manipulates in order to develop a usable traveler information service. The public entities that provide raw traffic data are then allowed to access this product for free, but exclusively for internal use.

In addition to acquiring the traffic data made available by public agencies, some private ISPs such as SmartRoute Systems collect additional information about traffic conditions from a range of sources including:

- small amounts of their own surveillance infrastructure (i.e., CCTV cameras);
- phone calls from commuters and truck drivers; and
- information from helicopters used specifically for traffic surveillance.

Although this data is fused with that provided by the public sector in order to furnish a fuller picture of traffic conditions, it still fails to provide the level of detail required for most advanced traveler information services (including dynamic route guidance).

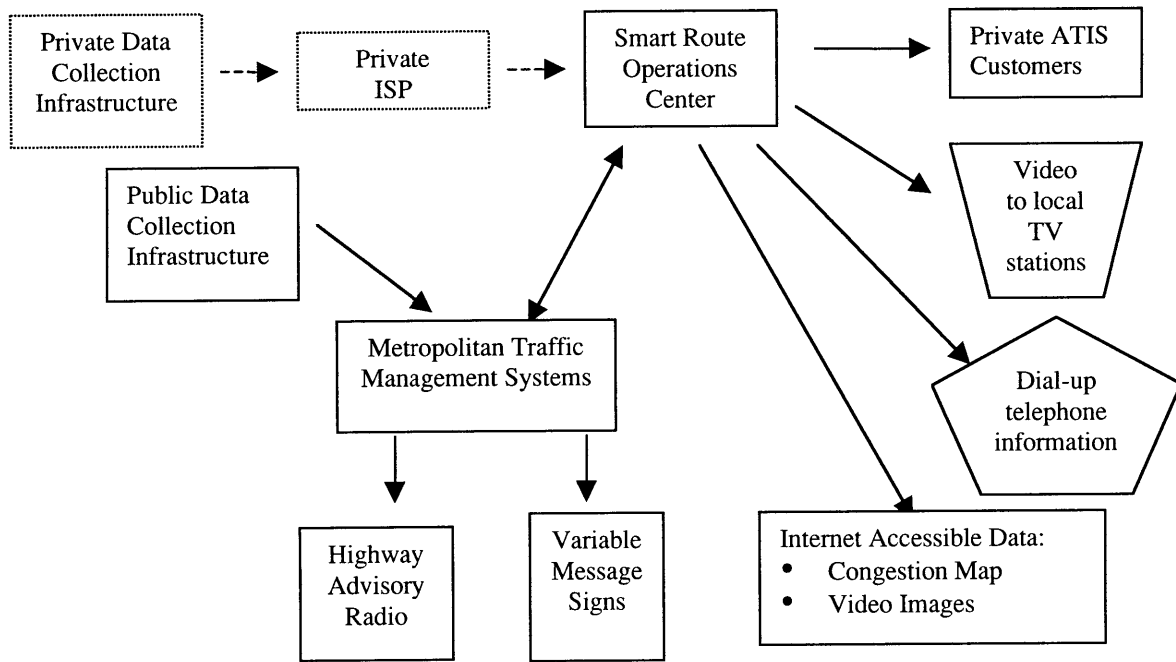
#### Issues involved in this entity making a decision about whether to procure private sector data

Note: For the purpose of this analysis, the reader should differentiate between a private ISP such as SmartRoute Systems (primarily a data retailer - although they sometimes do collect a small amount of traffic data themselves), and a private ISP such as US Wireless (a data wholesaler that would collect traffic data using its wireless location technology and then sell it to an ISP like SmartRoute Systems or a public entity).

Data needs - As our research has demonstrated, it is generally accepted that the data collected by public agencies is inadequate, being insufficient in geographic coverage (primarily covering freeways and few, if any arterials and secondary roads), data types collected, and of inconsistent quality, for the needs of most ISPs wishing to provide ATIS services (e.g., pre-trip and in-vehicle information about traffic conditions, and route guidance/navigation). Additionally, there are some cases in which public sector agencies have been unwilling to share their traffic information with private ISPs. Even cases in which well-integrated public agencies such as Smart Trek in

Seattle are able to collect relatively high quality data for ATMS purposes, this data may still fail to provide the level of detail required for the types of fee-based services that most ISPs wish to provide. One consequence of this problem is that ISPs such as SmartRoute Systems have been forced to rely on revenues from advertising (on their web-site and on their phone system) as their main source of income, rather than from the provision of fee-based traveler information services.

**Figure 6.5 - Outline of the Flow of Traffic Data in the SmartRoute System Framework**



Note: All shapes connected to the system with a dashed line represent potential links with private ISPs. However, these links do not exist at the present time.

Market for traffic data - Whereas a national entity such as GM already has a customer base that would likely be willing to pay the small increase in their monthly service fee that would accompany procurement of this service, questions persist concerning whether consumers would be willing to pay for high-quality real time traffic data (especially in the face of basic ATIS services provided in cities such as Seattle). As high quality data such as this has not existed in the past, most people involved in the traveler information industry remain unsure as to the depth of public interest in it. Additionally in **Chapter 3**, we learned that demand for real-time traffic



information is not simply related to the quality of the data, but also to local conditions (e.g., the overall amount of congestion and the possibility of using alternative routes). Consequently, simply providing traffic information as a stand-alone service might not be feasible. ISPs such as SmartRoute may need to become more involved in the provision of high-personalized, location-based services (both travel-related and others) described in **Table 5.1**.

Impact of competition from other local ISPs and the basic public sector ATIS - Differences in the types of traveler related information services provided by various ISPs are likely to be subtle. As a consequence, competition between ISPs interested in providing such services within what could be a modest market is anticipated to be intense. As it is unlikely that multiple providers of such similar service will be able to co-exist within the same market, one ISP will likely driver the other(s) out of business, or they will merge into a single entity. In some cases, where market demand for traffic information is relatively low, and a relatively high level of ATIS data is made available for free by the public sector, it is questionable whether there will be a sufficient market for fee-based ATIS services.

Cost of this data - Questions remain concerning how much data wholesalers will charge for their traffic data. Consequently, although we can be sure that the price will vary according to the geographic coverage and level of granularity provided, the cost of this data in relation to consumer willingness to pay, will have a major impact on the financial viability of the ISPs that retail this data locally.

Privacy and Safety Issues - The imposition of privacy or safety legislation preventing the usage of cell-phone oriented vehicle locational technology for the collection of traffic data, would restrict ISPs to gathering data from public sector infrastructure. However, in the long-term it is possible that alternative sources of probe-based tracking data will become available - e.g., via tracking of telematics devices in cars (as in Framework 4). Should this occur, the possibility exists that that ISPs such as SmartRoute might be able to purchase data for the metropolitan areas in which they are interested, thereby resolving this problem.

## **6.2 Summary of Issues Involved in the Frameworks**

A review of the factors involved in each of these frameworks attests to the fact that although there is a certain degree of commonality in the factors which must be taken into consideration prior to making a decision concerning the procurement of traffic data from an ISP such as US Wireless, many factors will also be unique to the circumstances in which each entity finds itself. In each case, the entity involved will need to consider its circumstances and make a final decision based on the impact that procurement of private data would have on them. In order to do this, decision-makers will need to:

- Identify key stakeholders;
- Make an inventory of their current data collection, fusion, and dissemination resources;
- Analyze organizational traffic data needs, as well as other stakeholders' policy priorities;
- Assess the manner in which the provision of privately procured traffic data would provide a benefit over existing conditions; and
- Assess both the costs and savings likely to accrue based on different decisions - including a determination of whether data should (and can) be procured via a traditional fee-for-service contract, or by way of some sort of data sharing partnership.

Traffic data is an important resource within the context of ITS, having the potential to play a vital role in ensuring many organizations' long-term operational success. However, a final decision concerning the source from which it is procured (i.e., traditional public surveillance infrastructure vs. privately operated wireless vehicle location technology), and therefore the types of applications for which it can be utilized, must take into account an organization's physical, institutional, and financial constraints.

### 6.3 Comparison of the Types of Data and Technical Support Needed for Different ITS Applications

Once the technology for collecting traffic data via wireless device has come into usage, the list of resources from which traffic data might be procured will include:

- Public Traffic Surveillance data - from loop detectors and CCTV cameras (of a point nature). Although this data is generally available for free from the public sector, the construction of infrastructure to collect and fuse it together is quite expensive;
- Privately collected data - from ISPs (both retailers and wholesalers) such as SmartRoute Systems using CCTV cameras and other data collection resources (e.g. helicopters) to supplement what they receive from the public sector (of a point nature); and
- Privately collected data - from ISPs (generally wholesalers) who will collect network-oriented traffic and other locational data using wireless technology.

Interested parties will also need to consider whether they are interested in simply acquiring the raw traffic data collected by each of the entities listed above, or would prefer to pay a bit more (exactly how much is currently uncertain) in order to obtain data that has already been analyzed and possibly fused with other relevant information. A significant portion of this decision must be based on whether the entity involved actually has the capacity to manipulate the data or can contract with a third party to do so. As the equipment and expertise required to procure and manipulate this data (e.g., fuse it to a map in a GIS system) in real time can be quite expensive, such a decision must be carefully considered.

Different entities' data needs are based on the types of services that they want to provide (e.g., basic congestion information on an Internet web-site or via telephone vs. dynamic route guidance via a telematics device in the car). These services require not only different types of data (e.g., degree of granularity and accuracy), but also different levels of technical support (e.g., GIS or simulation expertise). As it is unlikely that many organizations will be able to undertake all that is necessary to provide many of these services by themselves, there is a high degree of probability that partnerships will coalesce around their deployment. **Table 6.2** provides examples of ITS application requiring traffic data, as well as the specific kind of data involved, technical support needed, and potential partnerships that might develop around each service.

**Table 6.2 - Examples of Data and Technical Needs for Different ITS Services**

	<b>Incident Management</b>	<b>Real-time Traffic Signal Control</b>	<b>Pre-trip Traveler Information via the Internet</b>	<b>Dynamic Route Guidance and Traveler Information</b>
<b>Purpose of Service</b>	Enable ATMS agency to respond to incidents more effectively and provide drivers with information	Management of traffic signals to improve traffic flow	Provide drivers with info. about traffic on their route (primarily freeways)	Provide drivers with instructions on the quickest way to reach their destination
<b>Data Required</b>	Data about very low speeds and high travel times or external confirmation of the incident	Current info. about volumes and speeds on signalized roads; possibly location and speed info. about transit vehicles	Current traffic conditions (speed/travel time) on the route to be used	Current location of vehicle and real-time traffic conditions (speed/travel time), short term prediction of near term conditions
<b>Quality of Data Required</b>	Data about congestion and incidents - to approx. 1/4 mile granularity with updates every few minutes	Network-oriented traffic data of a granularity allowing surveillance every hundred feet or so; need constant updates	A high degree of granularity isn't needed; map requires update every few minutes;	Need high degree of granularity with constant updates
<b>Technical Support Needed</b>	Fusion of very basic real-time incident data from sensors, police, etc.; possible need to "snap" location to a GIS map in more advanced systems	Fusion of spatial data to a GIS map integrated with the signal control system; In some cases data about transit vehicle location for transit vehicle priority	Fusion of low granularity spatial data to a map of local freeways	Fusion of spatial data to GIS map with constant updates re: traffic conditions in order for the system to update optimal route; some modeling of data
<b>How the data is provided to "customers"</b>	Incident data to drivers via variable message signs; information to emergency services via phone call or computer	Knowledge of traffic conditions facilitates optimization of traffic flow and possibly improvement of transit service	Information about conditions can be accessed on Internet site, be received via e-mail, or "pushed" to a telematics device	In-vehicle guidance linked to location technology; transmits and receives info. about location and traffic conditions
<b>Other notes and potential to bundle with other services</b>	This is a basic application that can in most cases be carried out with existing infrastructure - especially on freeways and in more heavily populated urban areas	It is unlikely that any ATMS agency would be able to carry out this function without first making additions to their traffic surveillance capability; Network-based surveillance via wireless tracking seems more cost effective	The ability to "push" info. to drivers would allow the ISP involved to provide information about events or places (e.g., restaurants) along the route being taken in which the driver might have an interest, based on their previously surveyed preferences	The equipment involved in this service might facilitate the provision of other locational services to the driver such as electronic tolling, concierge services, and other personal services as on <b>Table 5.1</b>
<b>Potential Partnerships</b>	Except for the possible procurement of network oriented data for speed and travel time info. it seems unlikely that many partnerships would be required to implement this service	Aside from partnerships to procure network-oriented data, other relationships are needed to process the data in real-time and apply it to the signal control system; also, there needs to be a link to the transit system for transit vehicle priority	Partnerships could be established with public and private entities to procure data and with private companies who will provide other data that can be pushed to the customer; need to fuse data from multiple resources to a low granularity GIS system	Partnerships would be needed for the high level of processing required and to maintain databases of driver preferences linked to the drivers route; also need high degree of mapping accuracy and ability to fuse it all together

As can be seen from the contents of **Table 6.2**, there are significant differences between the types, quality, and timeliness of the data required for different ITS applications. Some applications require only very raw data, infrequent updates, and the ability to apply spatial data at a relatively low level of granularity (e.g., incident detection) and can therefore be carried out with existing surveillance infrastructure and require few, if any, additional partnerships. Others, such as real-time signal control and dynamic route guidance require a much wider range of traffic data of a very high quality and high granularity, and constant updates in order for the system to remain properly calibrated. Consequently, it is likely that partnering will occur in such cases, both to facilitate provision of the service itself, and in some cases to provide additional location-related services over and above traffic information and guidance instructions.

It is relatively obvious that more advanced ITS services such as dynamic route guidance will require the expenditure of far more resources than services such as the provision of pre-trip traffic conditions on a web-site, and will therefore be priced accordingly. However, what must also be considered is the possibility that ISPs (primarily data retailers) will seek to differentiate between the level of service provided (and therefore the fee charged), not only between such services, but also within each service itself. For example, whereas an ISP might have the capacity to provide detailed (down to the provision of directions and traffic data on residential streets) dynamic route guidance services, they would also be likely to provide less detailed services (e.g., covering freeways and major arterials), or even simply personalized traffic information without routing assistance, in order to segment the market and maximize the number of customers making use of their traffic and location-based data. This ability to differentiate between customers will be especially important given that questions exist concerning the strength of the consumer market for these services.

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Given what we've learned, **Chapter 7** will provide an outline of our overall findings, present final thoughts on the transitions likely to take place in the collection of traffic data and the relationships which surround it, and suggest future research.

# CHAPTER 7

## CONCLUSION

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**Chapter 7** is intended to provide the reader with an overview of this thesis' main findings, delineated according to the chapter in which they are found (see the italics next to the header in each section for this information).

### **7.1 The Problem [Chapters 1 & 3]**

The impact of traffic congestion in our cities has led to increased interest in ITS activities, specifically Advanced Transportation Management Systems (ATMS) and Advanced Traveler Information Systems (ATIS). Whereas public ATMS activities focus on managing and improving the overall flow of traffic on road networks, ATIS functions revolve around providing travelers and commercial carriers with travel-related information that will improve the quality and efficiency of their trips. Although some public ATMS agencies also provide basic ATIS services (via variable message signs, the Internet, and intermediary Information Service Providers [ISPs]) based on the notion that benefits will accrue to the road network as a whole if some drivers are routed around congested areas, there are major differences in the philosophies underlying public vs. private sector activities. As public sector agencies are concerned first and foremost with the management of road infrastructure and maximization of the flow of traffic on that infrastructure, they collect traffic data that will provide them with the ability to carry out their management and planning activities, while providing drivers with basic congestion and incident information without regard for each driver's individual preferences. In contrast, private ATIS providers' only concern relates to the improvement of driving conditions for their customers. Consequently, they are primarily interested in traffic data that will provide their customers with the greatest benefit (via reductions in travel time). Due to these distinctions, public and private sector interests in traffic data generally differ as per **Table 3.1**.

Despite the fact that public and private entities seek to perform these different functions, each having distinct traffic data requirements, to date private ATIS providers have for the most part been forced to rely on the traffic data collected by public sector agencies for ATMS purposes. Unfortunately, much of this traffic data fails to meet their needs, being both limited in geographic coverage (most surveillance focusing on freeways and major arterials), and the overall types and depth of data collected (e.g., focusing on traffic volumes and vehicle classification, rather than on accurate speeds and travel times). In addition, some public agencies have simply been unwilling to share their traffic surveillance data with ISPs, thereby creating geographic gaps in coverage.

In addition to acquiring the traffic data made available by public agencies, some private ISPs collect additional information about traffic conditions from a range of sources including:

- small amounts of their own surveillance infrastructure (i.e., CCTV cameras);
- phone calls from commuters and truck drivers; and
- information from helicopters and fixed-wing aircraft used specifically for traffic surveillance.

Although this data is fused with that provided by the public sector in order to furnish a fuller picture of traffic conditions, it still fails to provide the level of detail desired for sophisticated traveler information services.

**Table 3.1 - Public and Private Sector Priorities for Traffic Data Collection**

<i>Private Sector Priorities:</i>	<i>Public Sector Priorities:</i>
1. Traffic Speeds and Travel Times	1. Current and Scheduled Work Zones
2. Incidents	2. Incidents
3. Road Conditions	3. Road Conditions
4. Current and Scheduled Work Zones	4. Emergency Routes and Procedures
5. Weather Conditions	5. Weather Conditions

Note: Priorities range from 1 - most important, to 5 - least important.<sup>72</sup>

Private providers of ATIS services are especially interested high-quality traffic data as part of an effort to furnish drivers with dynamic route guidance. This application, referred to by some as "the Holy Grail of ATIS," would provide drivers with routing instructions on the most efficient (least time consuming) way to get from point A to point B - based on vehicle location, real-time

traffic conditions, roadway construction, weather, etc. Such a system would combine vehicle locational technology and a GIS-based mapping system in a telematics package that receives real-time traffic and other relevant data via wireless communication in order to calculate driving instructions that take current traffic conditions into account. Although systems currently exist that combine vehicle locational technology with GIS-based mapping systems, no one has yet been able to provide the quality of traffic data that would allow such a guidance system to make highly efficient routing decisions that incorporate traffic information.

Note: Although this thesis does not deal with how traffic data and other related services can be furnished to drivers, we believe that it is important to note that there is clearly a link between advanced telematics and the provision of data for dynamic route guidance and other applications.

## **7.2 The Market for High Quality Traffic Data [Chapter 3]**

According to the paper "Show Me the Data," presented at the ATIS Data Collection Guidelines workshop held in February, 2000, the following areas define the breadth of the gap between the traffic data made available by the public sector and that to which private ISPs would ideally like to have access:<sup>73</sup>

1. *Data Coverage* -- There is a need to expand current real-time freeway data coverage, as well as to add arterial, and other roadway information.
2. *Depth of Information* -- Much of the data collected for ATMS purposes provides only basic traffic information, much of which is too aggregate to fulfill the data requirements necessary for advanced ATIS (or for that matter ATMS) services.
3. *Data Accuracy and Consistency* -- The data collection infrastructure employed by the public sector for ATMS purposes is generally unable to consistently provide the level of accuracy and consistency required by ISPs to justify a service for which they expect customers to pay.

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<sup>72</sup> ITS America and the U.S. Department of Transportation, p. 10.

<sup>73</sup> Pretorius, P. and Markowitz, J., p. 8.



4. *Data Transfer and Dissemination*<sup>74</sup> -- In addition to problems related to a lack of data collection, our research indicates that there is a pattern of some public agencies not sharing data with ISPs or charging a prohibitively high fee for access to their data.

Even though private ISPs have continued to seek out improved traffic data, questions remain concerning the strength of the market for this refined data stream. Our research indicates that the strength of the market for traffic data varies according to four factors:<sup>75</sup>

- The regional traffic context - "Prime ATIS markets appear to be highly congested regions that have limited build-out options [related to the construction of additional roads] and frequent, unpredictable traffic events (e.g., weather and crashes)."<sup>76</sup>
- The quality of the ATIS services - Quality of the ATIS information available to consumers is a prime determinant of how often and with what degree of confidence consumers actually consult ATIS resources (public and/or private).
- The individual trip characteristics - "The trip purpose, the time of the trip in relation to peak congestion periods, trip length, and the particular route or route choices available to the individual traveler all have a significant effect on whether the individual will consult traffic information."<sup>77</sup>
- The characteristics of the traveler - Includes personal values related to timeliness, the need to have a constant link to traffic information and other services, and technology preferences. For more information see **Section 3.3.1** - Descriptions of ATIS Customers.

An examination of these factors indicates that high demand for ATIS services appears to be driven more by regional traffic conditions and the quality of the traffic data itself rather than the ATIS customers' characteristics. "While it is likely that there will be ATIS customers where

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<sup>74</sup> Radin, S., S. Basev, and J. Lappin ,p. 12.

<sup>75</sup> Lappin, J., *Advanced Traveler Information Services - Who are ATIS Customers?*, p. 2.

<sup>76</sup> Lappin, J., *Advanced Traveler Information Services - Who are ATIS Customers?*, p. 2.

<sup>77</sup> Lappin, J., *Advanced Traveler Information Services - Who are ATIS Customers?*, p. 2.

these external conditions (e.g., heavily congested roads) do not exist, the greater number of customers will be found in regions" where traffic and highway network conditions and ATIS service quality align. Moreover, "the service must be reliable, accurate, and easy to use, because continued customer use is a function of the quality of the information and how it is presented. Drivers want travel speeds and incidents on their primary and alternate routes at the time of their departure. They also want it later in the trip when they choose between alternate road segments. If the user consults the service while en-route, the service must be able to deliver location and route-specific information with minimal distraction to the driver. Even in extremely congested cities, which suggest high levels of consumer demand, low quality ATIS services will be ignored."<sup>78</sup>

Based on what we were able to learn about the market for ATIS-oriented data, we concluded that in spite of additional traffic surveillance investments on the part of the public sector, the traffic data that they collect for ATMS purposes will, in most cases, continue to be insufficient to meet the private sector's need to serve individual customers. Consequently, rather than merely seeking out improved public sector data, the private sector should begin looking for new and innovative ways to collect the data they need through various kinds of wireless tracking technology.

### **7.3 Alternative Technologies for Traffic Data Collection [Chapter 2]**

During 1996, the FCC mandated that mobile phone companies should be able to locate wireless callers' physical locations when the caller dials 911. Phase II of this mandate, which must be met by October 1, 2001, calls for these carriers to be able to locate mobile 911 callers within one-tenth of a mile of their actual location in at least 67% of all cases.

Factors related to mobile phone companies' need to meet the FCC's mandate and the lack of traffic data available to ATIS providers (as well as potential profit related to other ITS services relying on vehicle location technology), have induced several private sector companies to pursue research related to the development of wireless locational technology. The goal of this research is to enable the interested parties to locate and gather information on vehicle movement, thereby

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<sup>78</sup> Lappin, J., *Advanced Traveler Information Services - What do ATIS Customers Want?*, p. 9.

facilitating the provision of mobile locational services (e.g., E-911 and dynamic route guidance), while at the same time turning these vehicles into "probes" from which they are able to gather vast amounts of traffic data.

Public sector traffic surveillance technology is heavily infrastructure-dependent and can only provide information about the "point" at which each surveillance device is located. In contrast, the surveillance technology under development by the private sector focuses on the collection of high quality traffic information from across entire traffic networks without requiring infrastructure investments of the same magnitude as with traditional surveillance technologies.

As outlined in **Table 2.1**, the various types of public infrastructure traditionally used to collect traffic data, including newer surveillance technologies using ETC-based toll transponders in vehicles as "probes," exhibit characteristics that are vastly different in nature than those displayed by network-oriented traffic data collection technologies. As is discussed in the description of inductive loop detectors, many public agencies lack a communications link between their surveillance equipment and the traffic operations center that would allow them to assess, in real-time, the traffic data that their systems are collecting. Furthermore, even in cases where data is available for analysis in real-time, large distances between traffic detectors and poor detector maintenance can result in significant delays in detecting incidents, as well as reductions in the quality of other data. In response, some public agencies have begun using ETC-based traffic surveillance system. Although this technology does provide some benefits over more traditional systems, including: travel time and average speed between transponder antennae, increased capacity for incident detection, the ability to collect data on a continuous basis, and reduced personnel requirements, it continues to suffer from some of the same flaws as more traditional surveillance infrastructure. These weaknesses include the fact that the system's capacity to provide traffic surveillance is limited by the amount of transponder detection equipment that has been placed into the field. Consequently, attempts to provide coverage on large sections of a road network could result in infrastructure costs similar to those associated with more conventional point-oriented data collection efforts. One other problem with ETC-based systems, not seen with more traditional traffic surveillance infrastructure, concerns the fact that ETC-based traffic data collection requires the tracking of individually identifiable

transponders between successive antennas. As this means that individual vehicles can be tracked along the entire length of an ETC enabled system, privacy concerns abound.

The vehicle location technologies currently under development make use of either network-based cellular-geolocation or GPS-enabled cell phones to collect vehicle location data and are designed to require significantly less infrastructure, while at the same time providing high quality traffic information from across entire networks of roads. In general, these technologies are considered to be superior to traditional traffic surveillance infrastructure for the following reasons:

- Once initial infrastructure investments have been made, data may be collected easily and with much lower maintenance costs than via point-oriented equipment.
- As the systems collect data on a continuous basis, information about traffic conditions is available in a real-time manner.
- All data collected by the system are automatically put into an electronic format. This facilitates the processing of raw traffic data for analysis.

Even so, these systems have their drawback, among which is included an even greater potential to violate cell phone users' privacy than with ETC-based systems - as people carrying cell phones can potentially be located anywhere, at any time, whether or not they are driving on the road. Additionally, these systems are not infrastructure free, but rather depend on the presence of cellular phone towers which serve either as a base on which tracking equipment can be placed or act as a conduit through which locational information is transmitted. Consequently, these technologies will be most beneficial in areas where cellular phone infrastructure is already in place and a large number of drivers are presently carrying cell phones.

**Table 2.1 - Descriptions of Different Types of Traffic Surveillance Systems**

	<b>Loop Detectors</b>	<b>Closed Circuit Cameras (CCTV) using "Minnesota" Technology</b>	<b>Tracking of ETC Transponders <u>See Figure 2.1</u></b>	<b>Tracking of cell phones - via GPS <u>See Figure 2.2</u></b>	<b>Tracking of cell phones - Network Geolocation <u>See Figure 2.3</u></b>
<b>Operator</b>	Public Sector	Public Sector or Private Sector	Public Sector	Private Sector	Private Sector
<b>Nature of the Data Collected</b>	Point Oriented	Point Oriented	Point Oriented	Network Oriented	Network Oriented
<b>Functionality of Data Collected</b>	Volume, Vehicle Class, Point Speed (when pairs of detectors are used) and estimated travel time, and Incident Detection	Speed of vehicles within range of camera and estimated Travel Time, Volume, Vehicle Class, and Incident Detection	Average Speed and Travel Time Between Various Antennae, Estimated Volumes, and Incident Detection	Location of Individual Phones for E-911/etc., Link Speed and Travel Time, Estimated Volumes, and Incident Detection	Location of Individual Phones for E-911/etc., Link Speed and Travel Time, Estimated Volumes, and Incident Detection
<b>Type of Infrastructure Used</b>	Sensors embedded in the road	Cameras used to monitor traffic conditions	Antennas track ETC tags as they pass underneath	GPS chipset embedded in cell phone	Cellular tracking technology placed onto cell towers
<b>How system collects information on vehicles - flow of data</b>	Detectors store data or send it via modem to ATMS center	Cameras feed video stream to traffic management center	Antennae send data to roadside readers which transmit the data via modem to ATMS center	GPS enabled phone transmits its location via cell phone signal	Infrastructure on cell towers tracks radio signals emitted by phones
<b>Range of Detection Area</b>	Area immediately above the sensor	Area within visual range of the camera	Area within 50 ft. to 100 ft. of each ETC antenna	Area within the range of each cell tower - #	Area within the range of each cell tower - #
<b>Provision of Real Time Data?</b>	Sometimes, but unlikely	Yes	Yes	Yes	Yes
<b>Capital Cost of System - @</b>	\$54,660 per detection site	\$69,600 per detection site	\$35,400 per detection site - ^	Estimated at about \$5 - \$10 per phone	Approximately \$70,000 per cell site - *
<b>Annual Maintenance and Operations Cost</b>	\$9,950 per detection site	\$5,340 per detection site	\$4,490 per detection site	\$0	About 10% of Capital Cost

Cost Data for Loop Detectors, CCTV, and ETC-based systems is taken from the report *Incident Management: Detection, Verification, and Traffic Management*, prepared by Booz-Allen & Hamilton for the Federal Highway Administration (based on the buildout for a 6-lane road). Data for the cost of GPS embedded systems is taken from the SnapTrack Data Sheet - "SnapSmart." Data for the cost of systems using cellular geolocation is taken from a US Wireless presentation entitled "Cell Phones as Data Probes: Background & Recent US Wireless Experience."

@ - Capital Costs do not include the expense of setting up and maintaining an operations center.

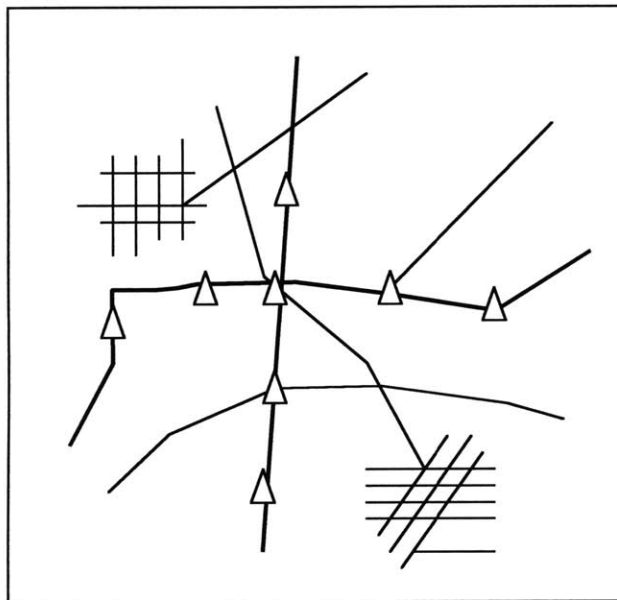
^ - The Capital Cost of ETC-based systems does not include the cost of acquiring and distributing sensors as this cost is assumed to have been paid for by the public entity's budget for developing an electronic toll collection system.

\* - It is estimated that there are currently 50,000 cell towers nationwide - and that number is rapidly growing.

# - The area that can be covered by each cell tower varies depending on local geography and the number of cell phones in the area. For example, while the range might be 5 miles in North Dakota, it is likely to be about .5 - 1 mile in New York City.

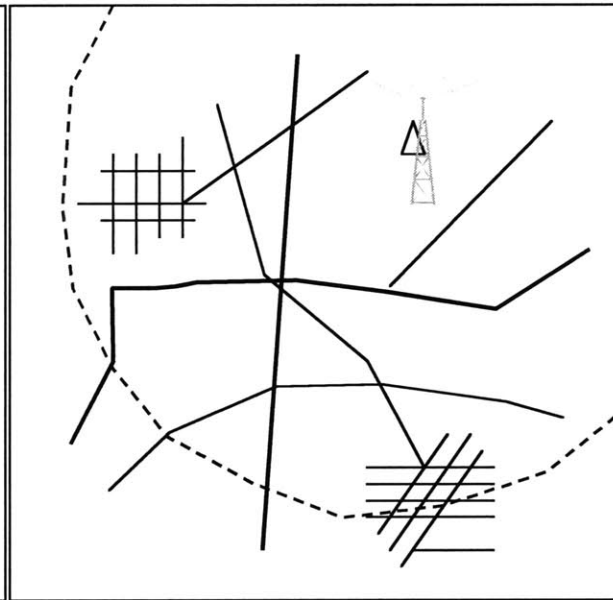
### 7.3.1 Costs Involved in Deploying Various Traffic Surveillance Technologies on a Network of Roads [Chapter 2]

**Figure 2.4:**  
Deployment of Point-Sensor Infrastructure



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

**Figure 2.5:**  
Deployment of Wireless Tracking Infrastructure



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

As **Figures 2.4 and 2.5** demonstrate, there are significant differences in the manner through which each type of system collects traffic data. In **Figure 2.4**, we see that sensors must be positioned every so often in order to maintain surveillance on a given road. Consequently, adding even one road to the list of those under surveillance requires the procurement, installation, and maintenance of a number of sensors. In contrast, **Figure 2.5** demonstrates how wireless tracking technologies (e.g., network-based cellular geo-location and GPS-enabled handset tracking) monitor entire sections of a network of roads from a single centralized location (i.e., a nearby cell tower). A rough outline of the costs involved in deploying these different systems is provided in **Table 2.2**.

**Table 2.2 - Estimated Costs of Deploying Various Types of Traffic Surveillance Systems**

	<b>Loop Detectors</b>	<b>Closed Circuit Cameras (using "Minnesota" technology)</b>	<b>ETC-based System</b>	<b>GPS-enabled cell phone</b>	<b>Network Geolocation</b>
<b>Area Covered by Single Sensor</b>	Area Immediately over the sensor	Area within visual range of the camera	Area within broadcast range of the sensor (50-100 ft.)	Area within range of each cell tower	Area within range of each cell tower
<b>Capital Cost Per Sensor Site</b>	\$54,660	\$69,600	\$35,400	\$5-\$10 per phone (paid by buyer)	About \$70,000 per tower
<b>Annual O&amp;M</b>	\$9,950	\$5,340	\$4,490	\$0	About \$7,000
<b>Cost of Covering One Freeway of 5 miles for 10 years.</b>	If one detector is place every half mile (10 loop detectors), cost equals: <b>\$1,541,660</b> + cost of operations center (TOC)	If one camera is placed every mile (5 cameras), cost equals: <b>\$813,600</b> + cost of operations center (TOC)	If one ETC reader is placed every mile (5 readers), cost equals: <b>\$401,500</b> + cost of operations center (TOC)	Costs for tracking related only to operations center and transmission of data from phones (currently an unknown factor)	Estimate need as being two towers - cost equals: <b>\$280,000</b> + cost of operations center and to transmit data from cell tower to TOC
<b>Cost of Covering Two Parallel Freeways of 5 miles for 10 years</b>	Double the coverage, cost equals: <b>\$3,083,320</b> + cost of TOC	Double the coverage, cost equals: <b>\$1,627,220</b> + cost of TOC	Double the coverage, cost equals: <b>\$803,000</b> + cost of TOC	Same as above	If both roads are within range of tower, cost: <b>\$280,000</b> + others as above
<b>Cost of Multiple (10) Intersecting freeways and arterials over a 5 sq. mile box for 10 years</b>	If each road is 5 miles long, then need 50 sensors, cost equals: <b>\$7,708,3000</b> + cost of TOC	If each road is 5 miles long, then need 25 cameras, cost equals: <b>\$4,068,000</b> + cost of TOC	If each road is 5 miles long, then need 25 ETC readers, cost equals: <b>\$2,007,500</b> + cost of TOC	Same as above	Estimate of 4 towers for coverage - cost equals: <b>\$560,000</b> + others as above (can monitor all other roads within range of towers)

Note: Cost Data are from the same resources as in Table 2.1.

#### 7.4 Technical Obstacles to Implementation [Chapter 4]

While the issue of the sharing of spatial data for transportation management and information purposes is a relatively new one, other fields of study have been dealing with these issues for some time. Typically, agencies within these fields are faced with the need to respond to problems that involve a wide variety of spatially-oriented data sets (e.g., related to the environment, socioeconomic status, and natural resources). In order to deal with the issues surrounding management of these large amounts of geographically referenced data, technologies such as GIS (Geographic Information Systems) have been developed. Still, numerous problems must be

overcome in order for more advanced ITS applications (e.g., dynamic route guidance) to be feasible. Some of these problems concern differences in the data structures utilized by different organizations, the need to have basemaps of different scales available for use with varying applications, and differences in the way that different GIS systems reference geo-spatial locations.

Some of these problems will be much more easily dealt with than others. For example, problems stemming from differences in location referencing systems are quite manageable in comparison to problems related to the spatial representation of geo-locational data [Described in **Section 4.3.2.**]. As described in that section, no single network representation (i.e., map) can be utilized to meet the needs of all applications. For example, whereas a 1:100,000 or 1:24,000 map might be sufficient to provide an ATMS agency with the scale they need for developing a general congestion map, a map of much higher granularity, i.e., 1:2,000, might be required to enable advanced ATIS applications such as dynamic route guidance. Unfortunately, due to differences in the accuracy and level of detail between different maps, it is in many cases difficult to link data from one to another. Moreover, whereas street segments in TIGER files (one type of GIS file) are represented by line segments connected by nodes, other GIS resources represent the network using different types of data structures. Consequently, reconciling data from one map to another (e.g., from a 1:100,000 scale map to a 1:2,000 scale map) is not just a matter of ensuring the positional accuracy of the geo-spatial points that represent vehicles and the locations of various roads, intersections, on-off ramps, etc., but also dealing with differences in how the road segment is represented (i.e., how can maps that represent roads as straight line segments keep track of curvature in that road?). Thus, the sharing of spatial data is not simply a matter of coordinating interfaces between systems, but dealing with differences in topology on maps, especially those that present spatial data at different levels of aggregation.

A related problem concerns the fact that although GPS and other vehicle-location technologies may be able to provide highly accurate geo-locational data, many of the maps used for GIS purposes contain errors and/or lack the accuracy necessary to facilitate the correct placement of the that spatial data. Although this may not be a problem at scales such as 1:100,000 where data remains highly aggregated, as we get closer to street level this results in an inability to "snap"



highly accurate geo-location data (e.g., GPS data about a vehicle's location, or information about congestion on a given road segment) to the correct point on the map. As a result, it may be impossible to tell if the traffic data you are looking at is actually for the road on which it is placed, or one running parallel to it, but 50 meters farther west.

Altogether, despite the fact that the current diversity of formats for storing spatial data will present some problems for the sharing and integration of traffic data, the ability to translate this information via computer algorithm is generally considered to be a relatively easy task. Obstacles that will be more difficult to resolve surround reconciliation of differences in the way road networks are represented, and differences in the accuracy and level of detail across mapping systems; making the movement of data between those systems much more difficult. In addition, the need to keep up with physical changes (e.g., additions to or changes in roads) in the road networks that these systems represent is another barrier that will present major challenges for those entities that seek to develop accurate, high-granularity traffic monitoring systems.

## 7.5 Interviews [Chapter 5]

In order to find out more about the impact that these new locational technologies might have on the manner in which traffic data is collected, we conducted interviews with sixteen (16) people knowledgeable about the collection of traffic data and/or the implementation of probe vehicle programs.

These interviewees responded to a number of questions. The questions, as well as summaries of interviewees' responses can be found below:

- **What is your general sense of the quality of the real-time traffic data currently being collected? How could this data be improved in order to better meet your needs?** *Most interviewees stated that the quality of traffic data being collected by the public sector could be characterized as poor (with regard to both geographic area covered, as well as the nature of the data collected). Even in cases where significant traffic surveillance infrastructure investments had been made by the public sector, the data being collected is point-oriented in nature (including ETC-based systems), thereby leaving large amounts of the road network without coverage.*

- **How might the ability to gather data via wireless tracking technology (tracking of cell phones, GPS transceivers, transponders, etc.) affect the quality of traffic data and the ways in which it is used?** *Without exception, interviewees believed that the provision of traffic data via wireless probe-vehicle technology (excluding ETC-based systems) would result in vast improvements in the geographic areas under surveillance, as well as the varieties and quality of data available. Interviewees also commented on the ability of such systems to provide data at different levels of granularity, based on the customer's needs. Still, a few interviewees noted that they thought it might take a few years before the wireless technologies currently under development (network-oriented cellular geolocation and GPS chipsets embedded in cell phones) would be up to the task.*
- **What types of real-time transportation data are ATIS and ATMS providers primarily interested in collecting/purchasing?** *In contrast with much of what we learned from reviewing the relevant literature, most interviewees stated that the public sector did have an interest in speed and travel time data in addition to basic information about incidents and traffic volumes. Interviewees were consistent in stating that private sector entities were primarily interested in data related to vehicle speeds and travel times.*
- **How will the availability of improved real time traffic data via wireless tracking change the way in which traffic data is utilized?** *Interviewees believed that such data would facilitate the provision of dynamic route guidance and other location-based services on the part of the private sector and improved data for predictive modeling and a tool for measuring system performance for the public sector.*
- **Who do you see as being the customers (not only drivers, but also public entities and other companies) for this improved data?** *Although there was a consensus that private ISPs and other commercial entities (e.g., UPS and GM's On-Star) would have a real interest in this improved data (especially if the data could be procured on a nationwide basis), others stated that the public sector would want to continue using the surveillance infrastructure that they had already invested in despite the possibility that the privately procured data would be of a higher quality and of broader geographic coverage. Others believed that public agencies would be unable to procure funding to purchase such data from the private sector. Furthermore, several interviewees stated that ISPs would need to bundle traffic data with other services in order to have a saleable product.*
- **How will data management issues (related to the collection and analysis of probe data) impact the ability of ISPs to make use of privately procured probe data?** *Most interviewees stated that management of traffic data - e.g., fusion of data from multiple sources would not be a terribly difficult issue to resolve. Even so, others speculated that this could lead to some problems related to the sharing of data and interoperability of systems.*
- **Given innovations in private sector data collection, what will be the government's future role in traffic data collection?** *Interviewees agreed that at least in the short-term, even government entities interested in working with or purchasing data from private ISPs*

*would continue to collect traffic data using their own surveillance infrastructure. Time and time again, we heard that public agencies would continue to operate CCTVs, and loop detectors around signalized intersections and on freeway ramps (for traffic signal control purposes). We were also reminded that many public agencies might have problems locating funding to pay for data procured from an ISP. In a few cases, interviewees stated that public agencies with more advanced traffic surveillance infrastructure (e.g., heavily developed ETC tracking systems) would not be interested in working with the private sector entity and that the data they provide for free on the Internet or through another publicly accessible resource might even provide serious competition for the data from ISPs.*

Additionally, we spoke with interviewees about the potential impact of privacy and safety related legislation on the implementation of the wireless probe technologies with which this thesis is concerned. Based on background research that we performed and their responses, we concluded the following:

- Privacy Issue - for any of the probe vehicle systems described in this thesis (including ETC-based systems) to be successful over the long term, safeguards must be put into place to ensure that the privacy of the individual drivers being tracked is protected. Consequently, no link should be established between the identity of the mobile phone user or ETC tag owner and their locational data, unless explicitly permitted by that user (e.g., for emergency purposes such E-911).
- Safety Issue - at least in the short-term, government regulations restricting cell phone usage by drivers have the potential to seriously impact the efficacy of the vehicle location technologies discussed in this thesis. Ideas for mitigating the impact of such regulations include increased usage of hands free cell phones by drivers, and the tracking of ATIS devices put in the car by automobile manufacturers rather than cell phones carried by drivers.

## **7.6 Conclusions Concerning the Future of Traffic Data Collection [Chapter 5]**

Based on what our interviewees' told us and our assessment of background information, we presented a number of our conclusions concerning the future of traffic data collection in the United States. Our most important conclusions assert that:

1. A large portion of the equipment (either network-based or integrated GPS chipsets) used to collect high-quality, network-oriented traffic data will be paid for by cell phone companies due to the FCC's mandate that they must select a technology for locating E-911 calls on their networks.
2. Traffic surveillance systems that collect data by tracking probe vehicles (excluding ETC-based systems) are able to monitor conditions on a network of roads within a certain radius of their location. Although such infrastructure is not without cost, the expense of developing a traffic surveillance system that is able to collect data of similar coverage and quality, but based instead on point surveillance infrastructure, would be so monumental as to make its implementation infeasible. Consequently, even if there were no FCC mandate requiring cell phone companies to make use of locational technology for E-911 purposes, development of infrastructure for the tracking of probe vehicles (via network-based geolocation or GPS-enabled cell phone) would still make economic sense for those entities interested in high-quality traffic and other locational data. For a more detailed comparison of differences in the costs associated with each type of surveillance system, see **Section 2.4**.
3. Market for data procured via vehicle location technology (excluding ETC-based systems) among consumers - consumer interest in traffic data is a function of the following factors: such data needs to be provided conveniently (e.g., via wireless device), at a low-cost, and be highly accurate and reliable (i.e., the system must provide reliable data between 95-99% of the time, or customers will cancel their service and rely on free data provided by public sector resources). Moreover, we can expect that the strongest markets for traffic oriented data will exist in those metropolitan areas facing the greatest amounts of congestion.
4. However, due to continuing doubts concerning consumer willingness to pay for traffic information, it is likely that it will not be provided as a stand-alone service, but bundled with other location-based services to which drivers and commercial users will subscribe. As described at the end of **Section 7.1**, one of the applications that will rely heavily on the integration of high-quality traffic information with vehicle locational technology is dynamic route guidance. Additional examples of services that are enabled by the same types of

locational technologies used to collect high-quality traffic data via wireless device can be found on **Table 5.1**.

**Table 5.1** - Examples of services that could be enabled using vehicle locational services:<sup>79</sup>

<i>Navigation</i>	<i>Safety &amp; Security</i>
<ul style="list-style-type: none"> <li>❖ <u>Dynamic (Real-time) Routing Instructions:</u> <ul style="list-style-type: none"> <li>• Route Travel Time Information;</li> <li>• Information on Alternate Routes;</li> <li>• Dynamic Route Guidance between two points ; and</li> <li>• Estimation of Traffic Delays.</li> </ul> </li> <li>❖ <u>Personalized "To-Do" Lists:</u> <ul style="list-style-type: none"> <li>• Information on entertainment and other activities of interest to the customer delivered via mobile device or computer.</li> </ul> </li> <li>❖ <u>Travel Support:</u> <ul style="list-style-type: none"> <li>• Location of Service Stations and parking facilities;</li> <li>• Other travel-related services; and</li> <li>• Information about nearby transit alternatives.</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>❖ <u>Road Safety:</u> <ul style="list-style-type: none"> <li>• Information about local roads and weather conditions;</li> </ul> </li> <li>❖ <u>Driver Safety:</u> <ul style="list-style-type: none"> <li>• Information about nearby accidents and related congestion;</li> </ul> </li> <li>❖ <u>Emergency Services:</u> <ul style="list-style-type: none"> <li>• Automatic Accident Notification</li> </ul> </li> <li>❖ <u>Anti-theft Devices:</u> <ul style="list-style-type: none"> <li>• Manual/Automatic Theft Alert</li> <li>• Remote Car Tracking</li> </ul> </li> </ul>

5. Market for data procured via vehicle location technology (excluding ETC-based systems) among public-sector agencies - due to differences in the public and private sectors' needs for traffic data, questions remain as to whether or not such technologies can provide data of the sort that many public entities use for basic traffic planning and road maintenance (e.g., volume data, information about vehicle presence at lights and on ramps for signalization and metering purposes, etc.). Our research also indicates that many public sector professionals want to control their own traffic data collection infrastructure. Consequently, it may be difficult to convince them that purchasing privately procured data in lieu of what their systems can collect would provide them with a net benefit. Finally, even in cases where public sector professional do have an interest in acquiring privately procured traffic data, there is a great deal of uncertainty concerning whether they will be able to utilize budget resources that have previously been used for the development and maintenance of their own data collection infrastructure for the purchase of data from private ISPs. Still, some public agencies could potentially avoid this problem by establishing public-private partnerships with

the private ISPs that seek to collect and disseminate this high quality traffic data, the nature of which would involve the public entity paying for all or part of the private ISP's infrastructure development costs. In return, the public agency could then be guaranteed a regular stream of traffic data at no additional cost. By doing so, the public agency would be making an infrastructure investment rather than paying for a service, potentially alleviating some decision-makers concerns regarding the use of public funds.

6. Overall, the ability of ISPs collecting and disseminating this privately procured data to deliver different levels of granularity of traffic data depending on the needs of different customers will allow them to price discriminate among their customer base.
7. Many of the new customers having an interest in this data will want it to be available on a nation-wide network [i.e., having a network of data collection infrastructure that covers the entire nation]. The existence of regional or a national stream of high-quality traffic data could also be marketed by ISPs as a resource which the public sector could utilize to support the 511 traveler information number.
8. Although public agencies that do provide their ETC-based probe traffic data to the public for free might furnish some competition to fee-based private sector entities, it is important to remember that public sector data will only provide information on certain roads, will be expensive for the public sector to procure, and will not provide users with the personalized information or value-added services such as those that private sector ISPs wish to develop.
9. Although several interviewees mentioned that ISPs might be willing to form consortia in order to facilitate the development of regional and/or national streams of traffic data, we are unsure of the level of interest that many companies would have in such a venture. As the wireless traffic data collection technologies described in this thesis are proprietary in nature, the ISPs that use them are likely to be competing with one another over the next few years as they try to establish markets for their services. Consequently, we must question the extent to which these companies will be willing to cooperate.

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<sup>79</sup> Booz-Allen and Hamilton, p. 6.

10. There will be a need to fuse privately procured probe-oriented traffic data with data from public agencies (e.g., for better information concerning incidents) and other private ISPs in order to develop a single, unified picture of traffic conditions. However, in order for data fusion to take place, numerous technical obstacles must be overcome, many of which will be impossible to solve until institutional relationships concerning the sharing of traffic data are first established between potential partners. Consequently, development of data sharing relationships will take a much greater amount of time and effort than was indicated by most of our interviewees.
  
11. Failure on the part of the ITS community to seriously consider the impacts of privacy and safety issues related to locational technology could have dire consequences on its long-term viability.

### **7.7 Frameworks for Traffic Data Collection [Chapter 6]**

Based on our research, we developed a number of frameworks enumerating many of the issues that different entities (both public and private) might want to consider prior to deciding whether or not to pursue a relationship with an ISP providing traffic data via one of the types of vehicle location technologies described in this thesis. The entities that we considered were:

- A metropolitan-wide agency providing ATMS and ATIS services;
- A multi-regional traveler information system run by a consortium of public agencies;
- A small, rural municipality with little traffic surveillance infrastructure and no data sharing relationships with abutting jurisdictions;
- A national provider of traveler information services; and
- A private ISP attempting to provide traveler information services with a single metropolitan area.

Note: For more information about these frameworks, see **Table 6.1**.

Based on our exploration of the factors that each of these entities might want to deliberate over prior to making a final decision about traffic data procurement we concluded that there were a number of physical, institutional, and financial issues that any entity considering such procurement should reflect on. These included the need to:

- Identify key stakeholders;
- Make an inventory of their current data collection, fusion, and dissemination resources;
- Analyze organizational traffic data needs, as well as other stakeholders' policy priorities;
- Assess the manner in which the provision of privately procured traffic data would provide a benefit over existing conditions; and
- Assess both the costs and savings likely to accrue based on different decisions - including a determination of whether data should (and can) be procured via a traditional fee-for-service contract, or by way of some sort of data sharing partnership.



**Table 6.1 - Outline of the Different Frameworks Described in this Chapter**

	<b>Framework 1</b>	<b>Framework 2</b>	<b>Framework 3</b>	<b>Framework 4</b>	<b>Framework 5</b>
<b>Type of Entity</b>	Public ATMS	Multi-state Public Entity	City Transportation Department	National Traveler Service Provider	Private ISP focused on a single metro area
<b>Geographic Scope of Entity</b>	Metro Area	Multi-State	Small City	National	Metro Area
<b>Type of Data Needed</b>	Congestion on freeways and major arterials	Incident detection on freeways	Primarily incident management	Data to support dynamic route guidance applications on a national basis	Traffic information for local traveler information services
<b>Is that data currently available?</b>	Point-oriented surveillance equipment provides some coverage, but not of a network-oriented nature (many roads remain unmonitored)	Point-oriented surveillance equipment provides much of what is needed, possible use of ETC-based system for additional monitoring	In the center of the city, but not outlying areas	Not of sufficient quality for route guidance purposes	Low-quality data allows them to provide some services, but would like higher quality data for more advanced ATIS
<b>Current Resources for Traffic Data</b>	Loop detectors, CCTV cameras, reports from other agencies	Loop detectors, some CCTV cameras, possibly ETC transponder tracking	CCTV cameras	Could get data from ISPs with nationwide data collection capability (data primarily from public agencies), but data is of questionable value	Data from public agencies and some of their own resources
<b>Surveillance Investments?</b>	Yes	Yes	Small amount	No	Small amount
<b>What do they provide to their "Customers"?</b>	Management of freeways and arterials; some ATIS; data to ISPs	Management of incidents and coordination of freeway construction; data to ISPs	Incident clearance and emergency services dispatching	In-car traveler information and safety services	Currently, provide basic ATIS on the Internet, TV/Radio, and via phone
<b>Ability and/or Willingness to Pay for Data from a Private ISP</b>	Although funding is likely available, political feasibility is questionable unless more network-oriented operations are pursued	Although the entity has its own budget, we find it unlikely that they would be interested in high-quality traffic data given their goals	Small budget and low political support for the purchase of high-quality traffic data.	High interest in procuring high-quality traffic data for route guidance and other traveler services	Interest in high-quality data for advanced ATIS, but market for these services is questionable

\* - We can assume that privacy and safety regulations would have an impact on the feasibility of ISPs using wireless probe vehicle surveillance systems to collect traffic data in all of the above frameworks.

Finally, the provision of different ITS applications requires not only different types of data (e.g., degree of granularity and accuracy), but also different levels of technical support (e.g., GIS or simulation expertise). As it is unlikely that many organizations will be able to undertake all that is necessary to provide many of these services by themselves, there is a high degree of probability that partnerships will coalesce around their deployment. **Table 6.2** provides examples of ITS application requiring traffic data, as well as the specific kind of data involved, technical support needed, and potential partnerships that might develop around each service.

**Table 6.2 - Examples Data and Technical Needs for Different ITS Services**

	<b>Incident Management</b>	<b>Real-time Traffic Signal Control</b>	<b>Pre-trip Traveler Information via the Internet</b>	<b>Dynamic Route Guidance and Traveler Information</b>
<b>Purpose of Service</b>	Enable ATMS agency to respond to incidents more effectively and provide drivers with information	Management of traffic signals to improve traffic flow	Provide drivers with info. about traffic on their route (primarily freeways)	Provide drivers with instructions on the quickest way to reach their destination
<b>Data Required</b>	Data about very low speeds and high travel times or external confirmation of the incident	Current info. about volumes and speeds on signalized roads; possibly location and speed info. about transit vehicles	Current traffic conditions (speed/travel time) on the route to be used	Current location of vehicle and real-time traffic conditions (speed/travel time), short term prediction of near term conditions
<b>Quality of Data Required</b>	Data about congestion and incidents - to approx. 1/4 mile granularity with updates every few minutes	Network-oriented traffic data of a granularity allowing surveillance every hundred feet or so; need constant updates	A high degree of granularity isn't needed; map requires update every few minutes;	Need high degree of granularity with constant updates
<b>Technical Support Needed</b>	Fusion of very basic real-time incident data from sensors, police, etc.; possible need to "snap" location to a GIS map in more advanced systems	Fusion of spatial data to a GIS map integrated with the signal control system; In some cases data about transit vehicle location for transit vehicle priority	Fusion of low granularity spatial data to a map of local freeways	Fusion of spatial data to GIS map with constant updates re: traffic conditions in order for the system to update optimal route; some modeling of data
<b>How the data is provided to "customers"</b>	Incident data to drivers via variable message signs; information to emergency services via phone call or computer	Knowledge of traffic conditions facilitates optimization of traffic flow and possibly improvement of transit service	Information about conditions can be accessed on Internet site, be received via e-mail, or "pushed" to a telematics device	In-vehicle guidance linked to location technology; transmits and receives info. about location and traffic conditions

Note: table is continued on the next page.

**Table 6.2 - continued**

	<b>Incident Management</b>	<b>Real-time Traffic Signal Control</b>	<b>Pre-trip Traveler Information via the Internet</b>	<b>Dynamic Route Guidance and Traveler Information</b>
<b>Other notes and potential to bundle with other services</b>	This is a basic application that can in most cases be carried out with existing infrastructure - especially on freeways and in more heavily populated urban areas	It is unlikely that any ATMS agency would be able to carry out this function without first making additions to their traffic surveillance capability; Network-based surveillance via wireless tracking seems more cost effective	The ability to "push" info. to drivers would allow the ISP involved to provide information about events or places (e.g., restaurants) along the route being taken in which the driver might have an interest, based on their previously surveyed preferences	The equipment involved in this service might facilitate the provision of other locational services to the driver such as electronic tolling, concierge services, and other personal services as on <b>Table 5.1</b>
<b>Potential Partnerships</b>	Except for the possible procurement of network oriented data for speed and travel time info. it seems unlikely that many partnerships would be required to implement this service	Aside from partnerships to procure network-oriented data, other relationships are needed to process the data in real-time and apply it to the signal control system; also, there needs to be a link to the transit system for transit vehicle priority	Partnerships could be established with public and private entities to procure data and with private companies who will provide other data that can be pushed to the customer; need to fuse data from multiple resources to a low granularity GIS system	Partnerships would be needed for the high level of processing required and to maintain databases of driver preferences linked to the drivers route; also need high degree of mapping accuracy and ability to fuse it all together

As can be seen from the contents of **Table 6.2**, there are significant differences between the types, quality, and timeliness of the data required for different ITS applications. Some applications require only very raw data, infrequent updates, and the ability to apply spatial data at a relatively low level of granularity (e.g., incident detection) and can therefore be carried out with existing surveillance infrastructure and require few, if any, additional partnerships. Others, such as real-time signal control and dynamic route guidance require a much wider range of traffic data of a very high quality and high granularity, and constant updates in order for the system to remain properly calibrated. Consequently, it is likely that partnering will occur in such cases, both to facilitate provision of the service itself, and in some cases to provide additional location-related services over and above traffic information and guidance instructions.

## 7.8 Final Thoughts

Our research has attempted to demonstrate how, at present, inadequate public sector traffic data collection infrastructure and differences in public and private sector data needs, have left private ISPs without the ability to provide the types of services for which they can justify charging a fee. In addition, this situation has also left ATMS agencies without the information necessary to carry out most traffic flow optimization activities. Despite this problem, it is more than likely that wireless technologies will soon furnish private ISPs with the ability to collect detailed, network-oriented traffic data both of a higher quality and broader geographic range than what any public sector traffic surveillance infrastructure is currently able to provide. Consequently, as was indicated by our background research and confirmed by the results of our interviews, the real constraints on the procurement of high quality traffic data will no longer be related to the fact that such data doesn't exist. Instead, numerous factors including: data accuracy and reliability, the strength of the market for this data (from private service providers who will bundle it with other services and provide it to their customers, other commercial users (e.g., UPS and GM), and public sector entities), competition from public sector entities providing lower quality traffic data at no cost, and privacy and safety issues.

Due to this large degree of uncertainty concerning the viability of traffic data as a stand-alone market, it will be important for the ISPs involved in its delivery to bundle it with other personalized location-based services such as those described in **Table 5.1**. By doing so, retailers of this information will be able to expand their customer base to include not just people with an interest in real-time traffic and route-guidance, but other locational services as well.

At the same time, we hold out hope that solutions can be found that will facilitate integration of private ATIS and public ATMS/ATIS data (whether via the sharing of information among these entities, or its sale), thereby enabling everyone involved to gain access to the broadest amount of data necessary to meet their specific needs. Such an endeavor could facilitate the initiation of efforts by ATMS agencies to optimize flow on the roads under their jurisdiction, at the same time that it provides ATIS ISPs with supplemental data that better enables them to develop dynamic routing recommendations and other services for their fee-paying customers.

Integration of data resources (e.g., via development of regional or national policies for sharing of information among ISPs and public sector agencies) could also begin to align public and private sectors' perspectives concerning what types of traffic data have value. Initiation of such relationships might also facilitate the provision of a stream of traffic data whose format is consistent across entire regions or the country as a whole, thereby enabling manufacturers of electronic devices to develop equipment with which users can procure data from different ISPs and public sector resources no matter where they happen to be traveling.

Nevertheless, as a number of long-standing institutional barriers will first have to be overcome, development of such relationships will be a time-consuming process requiring patience and persistence on the part of all participants. A large portion of the problem revolves around the fact that most public sector agencies, particularly those involved in freeway management, have focused their efforts on the provision and maintenance of physical infrastructure, to the exclusion of most operational functions occurring on that infrastructure. Although some public agencies have begun to realize that restrictions on their ability to procure new infrastructure will require that they begin thinking to a greater extent about how usage of existing infrastructure can be optimized, this paradigm shift must be accelerated.

Although the availability of improved traffic data via wireless device will not be a panacea that will solve all of our transportation problems, it should over time result in real changes in the market for traveler information and the public sector's ability to optimize the flow of traffic. It is our hope that these changes will result in our roads becoming safer and more efficient, producing economic and environmental benefit for everyone.

## **7.9 Areas for Future Research**

After considering the litany of unresolved questions that we have been left with after completing our research, we have drawn up a short list of some of the areas related to our research in which we believe further investigation would prove fruitful:

- Does the private sector's goals of providing customers with routing information (meant to minimize their individual travel time), conflict with the public sector's goal of optimizing

overall traffic flow on the road network. That is, will large numbers of drivers with access to real-time traffic data and in-car dynamic route guidance technology clog up alternative routes (e.g., arterials and local roads) in their efforts to avoid congested primary roads? If so, what arrangements will the public and private sectors need to develop in order to address this dilemma?

- Over the long term, how will competition between multiple data traffic data providers within a single metropolitan area impact the market for high quality traffic data?
- What level of public investment would be necessary to improve the public sector traffic surveillance infrastructure to the point that it can provide data of comparable quality to that which US Wireless and its competitors claim they will be able to provide?
- What types of relationships can/should different public sector entities establish with companies such as US Wireless in order to gain access to their data - e.g., partnerships via infrastructure investments, customer-client relationship, etc.? What are the potential costs and benefits of each type of relationship to each party?
- A comparison of the impact on ATMS systems (based on improved traffic flows, response to incidents, etc) and ATIS systems (in terms of time saved), resulting from the usage of data procured via public infrastructure (including ETC transponders) vs. the data procured via private wireless surveillance infrastructure.
- Although research has been carried out concerning the number of probes required to effectively operate a vehicle location-based traffic surveillance system (see **Section 2.3.1**), more research is needed concerning the sample size of probes required for a network-based cellular geolocation or GPS-enabled cell phone tracking system to provide accurate data.

# BIBLIOGRAPHY

- Abernathy, B. and Kolcz, A. "I Saw What You Did..." *Traffic Technology International*. August/September 2000: 62-66.
- Alfelor, R. (1995) "GIS and the Integrated Highway Information System." Chapter 24 in *Sharing Geographic Information*. The Center for Urban Policy Research: New Brunswick, NJ.
- Apogee Research, Inc. (1997) *Intelligent Transportation Systems - National Investment and Market Analysis*. Prepared for ITS America and U.S. Department of Transportation.
- Azar, K. (1995) *Strategies for Building, Managing, and Implementing Geographic Information Systems (GIS) Capabilities in Transit Agencies*. MIT Doctoral Thesis.
- Batelle Transportation Division. (no date) *GPS Leader Travel Data Collection Specification Sheet*.
- Berka, S. and Lall, B. "New Perspectives for ATMS: Advanced Technologies in Traffic Detection." *Journal of Transportation Engineering*. January/February 1998: 9-15.
- Black, J. (1997) "Inductive Loop Detectors." From web-site located at [www.path.berkeley.edu/~leap/TTM/Incident\\_Manage/Detection/loopdet.html](http://www.path.berkeley.edu/~leap/TTM/Incident_Manage/Detection/loopdet.html)
- Booz-Allen and Hamilton. (2000) *Telematics: Lessons Learned from International Experiences*.
- Bray, H. "Something to Watch Over You." *Boston Globe*. January 22, 2001.
- Briggs, V. "New Regional Transportation Organizations." *ITS Quarterly*. Fall 1999: 35-46.
- Charles River Associates. (1997) *User Acceptance of ATIS Products and Services: A Report of Qualitative Research*.
- Cooke, D. (1995) "Sharing Street Centerline Spatial Databases." Chapter 22 in *Sharing Geographic Information*. The Center for Urban Policy Research: New Brunswick, NJ.
- Diebold Institute for Public Policy Studies, Inc. (1995) *Transportation Infostructures*. Praeger: Westport, CT.
- Drane, C. and Rizos, C. (1998) *Positioning Systems in Intelligent Transportation Systems*. Artech House: Norwood, MA.
- Driscoll, C. (1998) "Wireless Caller Location Systems." From web-site located at <http://www.gpsworld.com/1198/1198driscol.html>
- Edozien, F. "Traffic Jam of Bills to Restrict Car Phones." *New York Post*. December 20, 2000.

Evans, J. (1997) *Infrastructures for Sharing Geographic Information Among Environmental Agencies*. MIT Doctoral Dissertation.

Evans, J. and Ferreira, J. (1995) "Sharing Spatial Information in an Imperfect World: Interactions Between Technical and Organizational Issues." Chapter 27 in *Sharing Geographic Information*. The Center for Urban Policy Research: New Brunswick, NJ.

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

Federal Geographic Data Committee. (1999) *NSDI Framework Transportation Identification Standard -- Working Draft #2*.

Frederick, D. (1995) "Coordination of Surveying, Mapping, and Related Data Activities." Chapter 21 in *Sharing Geographic Information*. The Center for Urban Policy Research: New Brunswick, NJ.

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

Goodwin, C. and Siegel, D. (1995) *Recommendations for Location Referencing for ITS Needs*. Prepared by the Oak Ridge National Laboratory and the University of Tennessee.

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

Hyman, W. and Radin, H. (1996) *Overcoming Barriers to ITS -- Lessons From Other Technologies*. Prepared by Cambridge Systematics.

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

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

Klein, L. (1997) "Vehicle Detector Technologies for Traffic Management Applications." From web-site located at [http://www.itsonline.com/detect\\_pt1.html](http://www.itsonline.com/detect_pt1.html).

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

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



Lerner, N. and Llaneras, R. "The Effect of ATIS on Driver Decision-Making." *ITS Quarterly*. Summer 2000: 53-63.

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

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

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

Mergel, J. (1997) *An Overview of Traffic Monitoring Programs in Large Urban Areas*. Prepared by the Volpe National Transportation Systems Center.

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

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

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

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

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

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

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

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

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

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

- Science Applications International Corporation. (2000) *Automated Vehicle Identification Tags in San Antonio: Lessons Learned from the Metropolitan Model Deployment Initiative*. Prepared for the U.S. Department of Transportation.
- Sipress, A. "Big Brother Could Soon Ride Along in the Back Seat." *Washington Post*. October 8, 2000.
- Sipress, A. "Cell Phones will be Used to Monitor Traffic." *Washington Post*. December 22, 1999.
- Smith, H. (1998) *Improving Transit with ITS*. ITS America.
- SnapTrack. (no date) "SnapSmart." Technical product brochure.
- Sperling, J. (1995) "Development and Maintenance of the TIGER Database: Experiences in Spatial Data Sharing at the U.S. Bureau of the Census." Chapter 23 in *Sharing Geographic Information*. The Center for Urban Policy Research: New Brunswick, NJ.
- Stilip, L. (1999) "Examining the Coming Revolution in Location Services." From web-site located at <http://www.trueposition.com/forum.htm>.
- Sussman, J. (2000) *Introduction to Transportation Systems*. Artech House: Norwood, MA.
- Sussman, J. (2000) "What Have We Learned About ITS? A Synthesis." Chapter 1 in *What Have We Learned About Intelligent Transportation Systems?* U.S. Department of Transportation.
- Transportation Research Board - National Research Council. (1997) *AVL Systems for Bus Transit*. TCRP Synthesis 24.
- Tsao, J. (1999) *A Decision-Oriented Framework for Evaluating Deployment Strategies for Intelligent Transportation Systems*. Institute for Transportation Studies: University of California, Berkeley.
- Turner, S., W. Eisele, and R. Benz. (1998) *Travel Time Data Collection Handbook*. Texas Transportation Institute: College Station, TX.
- US Wireless - Year 2000 Annual Report. Released on June 29, 2000.
- Whelan, R. (1995) *Smart Highways, Smart Cars*. Artech House: Norwood, MA.
- Zenios, M. "Telematics, the Future is in the Car." *ITS World*. January/February 2000: 26-29.
- Zhao, Y. "Mobile Phone Location Determination and Its Impact on Intelligent Transportation Systems." *Intelligent Transportation Systems (IEEE)*. March 2000. Volume(1): 55-64.