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Cross-Cutting Studies and State-of-the-Practice Reviews:
Archive and Use of ITS-Generated Data

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ACRONYMS

ADUS	Archived Data User Service
AFC	Automatic Fare Collection
APC	Automatic Passenger Counts
APTS	Advanced Public Transportation System
ATIS	Advanced Traveler Information System
ATSAC	Automated Traffic Surveillance and Control
AVL	Automatic Vehicle Location
BDS	Bus Dispatch System
CAD	Computer Aided Dispatch
CapWIN	Capitol Wireless Integrated Network
CD	Compact Disc
CIRF	Complaint/Incident Report Form
CRB	California Research Board
CVIEW	Commercial Vehicle Information Exchange Window
CVISN	Commercial Vehicle Information Systems and Networks
CVO	Commercial Vehicle Operations
DOT	Department of Transportation
DSI	Data Source Interface
DVRS	Digital Video Recording System
ECCO	Electronic Citation Component
EDR	Event Data Recorder
FARS	Fatality Analysis Reporting System
FHWA	Federal Highway Administration
FMS	Fleet Management System
FPS	Automatic Fare Payment System
FOT	Field Operational Test
HPMS	Highway Performance Monitoring System

ID	Identifier
IFTA	International Fuel Tax Agreement
IRP	International Registration Plan
IRS	Internal Revenue Service
ITS	Intelligent Transportation System
KCM	King County Metro
LADOT	Los Angeles DOT
MARS	Mobile Accident Reporting System
MOWI	Mobile Operating While Intoxicated
NCHRP	National Cooperative Highway
NHTSA	National Highway Traffic Safety Administration
RLR	Red Light Running
SAFER	Safety and Fitness Electronic Records System
SAPD	San Antonio Police Department
TMC	Traffic Management Center
TRIP	Travel and Recreational Information Program
TSP	Transit Signal Priority
VSIS	Vehicle Safety Inspection System

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1. INTRODUCTION

1.1 BACKGROUND

Intelligent Transportation Systems (ITS) provide and use information about transportation conditions to improve system performance in such areas as safety, mobility, efficiency and environmental impacts. Typically, ITS generates massive amounts of data about the state of travel that are used primarily by transportation authorities to effectively operate and manage their transportation systems, and by private individuals and industry to manage trips. These primary uses provide short-term, real-time information regarding the transportation systems' current conditions and driver and passenger choices.

The increasing deployment of ITS and the amount and variety of ITS-generated data throughout the nation also offer great potential for longer-term transportation planning. Often, ITS-generated data and information might be similar or better than that traditionally used in transportation planning, operations, administration, and research. Some types of ITS-generated data may have no traditional counterparts but offer the potential for new and extended applications in these longer-term planning areas. Archived ITS-generated data can provide a valuable resource for such longer-term uses. Therefore, the Archived Data User Service (ADUS) was incorporated into the National ITS Architecture in September 1999 to help realize the potential usefulness of ITS data.

A U.S. Department of Transportation multi-agency, 5-year ITS Data Archiving Program Plan was developed based upon the vision of "*improving transportation decisions through the archiving and sharing of ITS generated data*." The plan includes program elements that need to be accomplished to meet the plan's goals and objectives. Initial program elements of the plan (Wave I) include an "ADUS State of the Practice and Legacy Systems Review," and a "Study of Innovative Uses of ADUS" which are intended to cover the applications of ITS-generated data to various subject areas. These subject areas are: (1) roadway/traffic, (2) transit, (3) safety, (4) freight, commercial vehicle operations, and rail, (5) rural/statewide, and (6) metropolitan planning processes.

Many ADUS applications are now ongoing, or in the process of being implemented. Some of these systems for archiving traffic and highway monitoring data have been described in a report prepared by the Texas Transportation Institute[1.1]. However, archiving and using ITS data in highway safety have not been systematically documented.

1.2 PROJECT OBJECTIVES

A broad spectrum of stakeholders could benefit from ITS-generated data to meet their data needs in planning, operations and maintenance, administration, training, modeling, simulations, and development of control strategies. In the context of ADUS, the term "ITS-generated data" refers to those data generated by ITS that are primarily used "*in managing system operations and providing information on system conditions and choices to the public.*[1.2]" Specifically, ADUS refers to data generated from any one of the nine components that make up the ITS infrastructure: (1) freeway management, (2) incident management, (3) arterial management, (4) electronic fare payment, (5) electronic toll collection, (6) transit management, (7) highway-rail intersections, (8) emergency management, and (9) regional multimodal traveler information.

The overall objectives of this project are to provide information and reports that can:

1. Provide awareness and education for associated ITS and non-ITS related partners, users, and customers regarding real and potential improvements in transportation decisions

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[1.1] Texas Transportation Institute. "ITS Data Archiving: Case Study Analyses of San Antonio TransGuide Data." FHWA-PL-99-024. August 1999. Federal Highway Administration. U. S. Department of Transportation. Washington, D.C.

[1.2] U.S. Department of Transportation. "ITS Data Archiving, Five-Year Program Description." Federal Highway Administration. U. S. Department of Transportation. March 2000. Washington, D.C.

through:

- the use of archived ITS-generated data,
- the integration of ITS-generated and non-ITS data and data systems, and
- the sharing of archived ITS-generated data with other potential users.

2. Be used to develop future Technical and Institutional Synthesis Studies outlined in Wave II of the *ITS Data Archiving Five-Year Program Description*[1.3].

In particular, this project assesses the state-of-the-practice, identifies technological and institutional barriers and opportunities, and provides real-world examples of existing practices where ITS-generated data are archived and used for planning purposes. The assessments and analysis will be centered on four major ADUS applications: Operations and Maintenance, Planning, Highway Safety, and Transit.

1.3 REPORT ORGANIZATION

The next chapter discusses the general barriers to, and benefits of, ADUS. Chapter 3 describes the major information sources and methods used to conduct the state-of-the-practice reviews and to formulate ADUS opportunities. One requirement of this report is that the discussions on each of the four applications need to stand-alone. Hence, separate chapters are devoted to specific applications such as Chapter 4 on Operations and Maintenance, Chapter 5 on Planning, etc. Each chapter includes a review of the state-of-the-practice, a number of case studies, discussions on barriers to ADUS use and solutions to overcome the barriers, and an account of the innovative uses of, and opportunities for ITS-generated data. Discussion that is pertinent to more than one application is repeated in the appropriate chapters. For example, archiving and using ITS-generated

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[1.3] "ITS Data Archiving Five-Year Program Description." March 2000. Federal Highway Administration. U. S. Department of Transportation. Washington, D.C.

traffic volume data benefit not only the Planning application but also the Operations and Maintenance application, and the Safety application. Therefore, the discussion on archiving and using ITS-generated traffic data is repeated in the respective chapters. Recommendations on future research activities conclude the report.

2. BARRIERS TO AND BENEFITS OF ADUS

ADUS can be viewed as a progression in three phases with increasingly challenging activities: archiving data, using the archived data, and sharing the archived data. Consequently, the barriers to ADUS can be characterized into three categories: (1) barriers to *archiving* data, (2) barriers to *using* archived data, and (3) barriers to *sharing* archived data. The barriers and benefits of each of these phases can be considerably different from those in other phases, although similarities exist. The decision to archive and use ITS-generated data typically hinges on the trade-off between the costs to remove the barriers and the benefits from using the archived data.

It is difficult to quantify the costs and benefits of ADUS. In addition to the direct costs, the costs include efforts needed to:

1. Articulate and communicate the needs for archived data,
2. Save the data,
3. Re-format the archived data to a user-friendly format,
4. Re-vamp the existing software to accommodate archived data,
5. Address data quality issues,
6. Make archived data accessible on a timely manner,
7. Integrate the archived data with non-ITS data to meet broader data needs,
8. Reconcile data incompatibilities among different data sources, and
9. Forge mutually beneficial partnerships among data-producing agencies and data users.

2.1 BARRIERS

The nature of the aforementioned three types of barriers can be characterized as decreasingly technical and increasingly institutional. For example, the barriers to archiving data are typically more technical in nature, while the barriers to sharing archived data are largely institutional in nature. Table 2.1 attempts to summarize barriers pertinent to different phases of ADUS. Only when barriers in all three phases are removed would ADUS reach its greatest potential. Nonetheless, the benefits are still substantial even when barriers in only a single phase are overcome.

ADUS barriers include institutional inertia, concerns over privacy, proprietary, liability, data ownership, data liability, data integrity and quality, data compatibility, and other technical and technological issues. They can be categorized into five areas:

- Institutional impediments,
- Data issues,
- Lack of standardization,
- Privacy and liability, and
- Other technological barriers.

2.1.1 Institutional Impediments

In general, institutional concerns hinder the *archiving* and *sharing* of ITS-generated data. As with any "new" idea, there is initial inertia – a resistance to change. If the value of data archiving is not obvious to the data owner, why should additional cost and effort be expended to save the data? On the other hand, although the benefits of the archived data appear obvious in some cases (e.g., for long-term planning and managing incidents and operations), the actual implementation of archiving and using ITS-generated data is hampered by the lack of needed resources and "know-how." A common reaction from data suppliers and data users is: "...the benefits of using archived data to meet my data gaps are obvious, but it is not at all clear *how* I can use these data and for *what*." This barrier could be overcome by a combination of

Table 2.1 ADUS Barriers at Different Phases

Specific Barriers	Barriers to		
	Archiving	Using	Sharing
Lack of articulated needs	✔	✔	✔
Lack of resources to archive	✔		
Concerns over data quality	✔	✔	✔
Data format difficult to access and to use		✔	✔
Archived files too large		✔	
Lack of readily-available, easy-to-use analysis tools		✔	
Lack of standardization		✔	✔
Concern over privacy and liability	✔		✔
Concern over sharing proprietary information	✔		✔
Concern over data ownership	✔		✔
Lack of communication/awareness of archived data		✔	✔
Institutional inertia	✔	✔	✔
Lack of information on specific ADUS benefits	✔	✔	✔

"technology pushes" and "application pulls." The technology pushes could occur in the forms of generating and disseminating lessons learned, developing "how-to" guidebooks, and developing easy-to-use tools on calculating the expected range of costs and benefits of different ADUS applications. The application pulls could be in the form of deploying field testings of specific applications.

Other than the resistance within an agency to change or to adapt to new data systems, the traditional stove-pipe organizational structure also discourages data sharing among agencies. Furthermore, this disinclination to share data among agencies involves a number of non-institutional issues. During one of the field interviews, concern about the quality of one's own data was raised. It is clear that data should not be shared with other agencies until it is validated and quality-assured. Before ADUS can be widely adopted, this data stewardship/ownership issue needs to be addressed. Another institutional barrier is who should bear the cost of data archiving–data providers such as Transportation Management Centers (TMCs) or data users? In an increasing number of cases, this cost has been borne by the data user.

The lack of communication or the lack of awareness adds another barrier to sharing and using ITS-generated data. In many cases, potential users of archived data are unaware of the existence of these data collections. For example, officials in City X are aware of the data collected in their own area, but they may not be aware of the data collected in City Y. A transportation engineer in City Z might be unaware of either collection of data. This lack of awareness about the availability of archived data is a very real barrier.

Proprietary rights to value-added data (as such in the cases of freight and commercial vehicle operations (CVO) applications) can be another barrier to sharing the data. A lack of institutional cooperation among various data users might mean that disparate users duplicate data collection rather than jointly share in the costs of collections, ownership, and use.

Institutional concerns become a completely different challenge when data sharing risks violating individuals' privacy rights. Potential solutions to overcoming this barrier is a topic outside the scope of this project and will not be elaborated in this report.

2.1.2 Data Issues

Although data are powerful, the impacts of *mismanaged* and *misused* data are wide-ranging. In the context of ADUS, data issues are multi-faceted and arise usually when *using* or *sharing* ITS-generated data. Data quality, format, integrity, compatibility, and consistency often heighten the complexity of using the archived data.

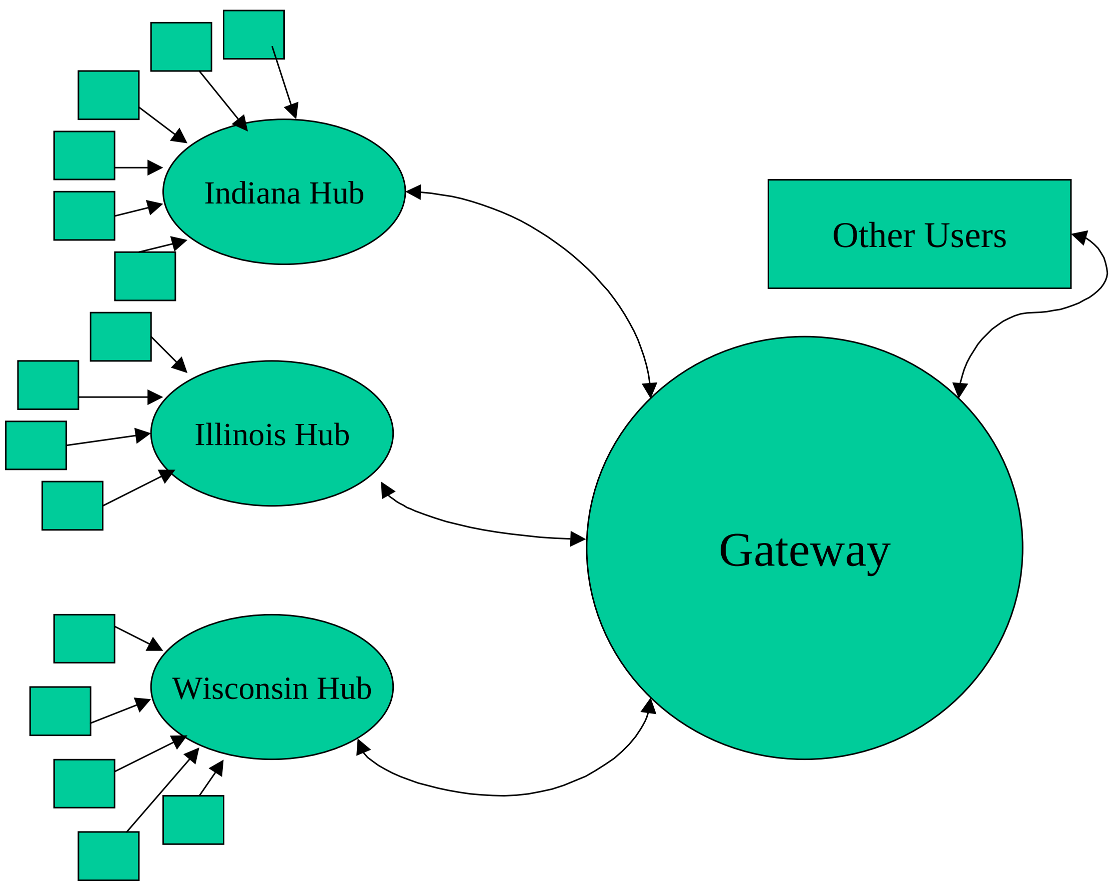
Furthermore, with ITS-generated data being so temporally extensive (e.g., collected every 30 seconds) but spatially limited (e.g., covering 30 miles of roads), ADUS data sometime need to be integrated with data from traditional sources in order to be useful. Then, data integration becomes an issue. Figure 2.1 shows an example of an integrated data environment. In this system, data goes from the original owners (represented by the small boxes), through regional hubs for data fusion and filtering, to the Gateway for final integration into a regional view of the data. After integration, data flows from the Gateway to many "new" viewers/users as well as back to the Hubs for distribution. The Hubs may edit their own data but they may not revise the regional data which are received from the Gateway.[2.1]

Data quality issues include erroneous data as well as missing data. It was obvious from our previous research[2.2] that the cost of using ITS-generated data to meet the information needs of traffic Monitoring is significant, particularly in terms of data "preparation." This data preparation is extensive and includes checking data quality, identifying and correcting questionable data, imputing missing data, and formatting data to a format that can be "plugged" into the existing software. Figure 2.2 demonstrates an example of unacceptable loop detector data.

2.1 Zavattero, David, and Bowcott, Syd. "Nontraditional Data Sources for the Gary-Chicago-Milwaukee Gateway Traveler Information System" *ITE Journal*, pp. 26-30, April 2001.

2.2 P. Hu, R. Goeltz, and R. Schmoyer. "Proof of Concept of ITS as An Alternative Data Resource: A Demonstration Project of Florida and New York Data." Oak Ridge National Laboratory. March 2001.

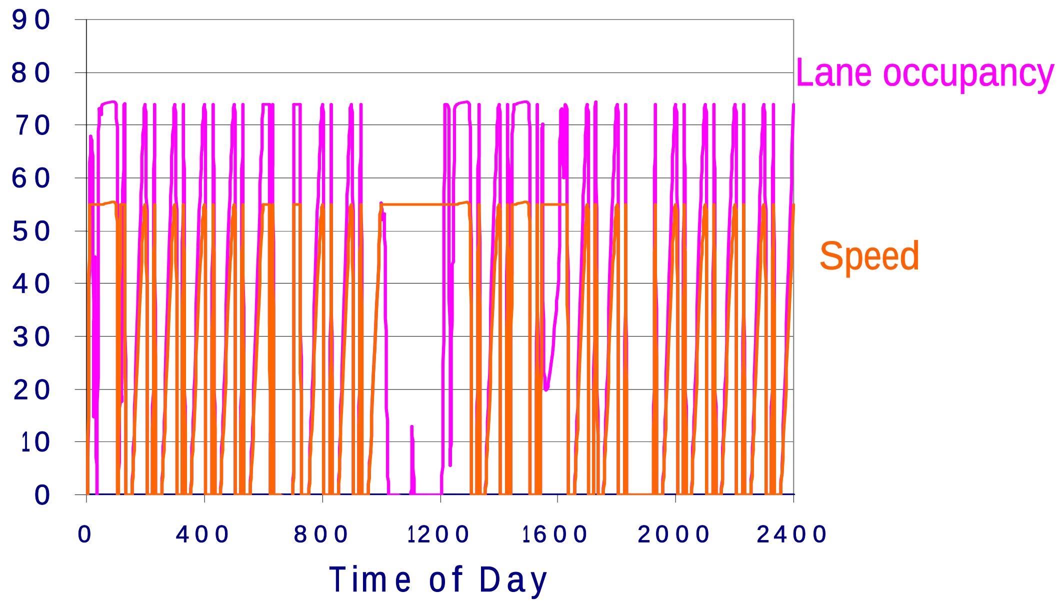
Figure 2.1 An Example Overview of an Integrated Data System



2.1.3 Lack of Standardization

The lack of standardization has hindered progress in many areas. A few examples of such barriers were observed in our previous study[10]. Although an efficient and compact way to store data, the 16-bit data-storage protocol can present technical challenges to users. This is because the 16-bit binary data might be recorded differently on different computers (e.g., little-endian vs. big-endian, which indicates which of the 2 bytes comes first).

Figure 2.2 An Example of Unacceptable ITS-Generated Loop Detector Data



Another example is the changing of sensor identification numbers (sensor ID). Although this type of change is documented by the data collection agency, the information is not integrated with the data file. The implication of not having this type of information integrated with the traffic data is that it is almost impossible to develop a traffic profile over time.

From the perspective of standardization, our previous project on traffic monitoring data[10] is rather straightforward in that it only focuses on augmenting or replacing traditional traffic monitoring data with ITS-generated traffic data. When ADUS advances to the point of integrating different information from multiple sources, then it will become important to develop standards to realize the full benefits of archiving and sharing ITS-generated data.

ADUS has 14 different stakeholder groups. These stakeholders assert that the lack of consistent standards is one of the greatest barriers to successful ADUS implementation. Recognizing the need to develop standards, an effort is underway[2.3]. Nine guiding principles have been established to develop standards related to archived ITS data[2.4].

2.1.4 Privacy and Liability Issues

In the context of ADUS, it is important to distinguish between the concerns about archiving and using personal information that might violate the 1974 Privacy Act, from the concerns about using and sharing proprietary information. The Privacy Act of 1974 concerns the privacy of individuals. As stated in an overview of the act provided by the Justice Department,

> *Broadly stated, the purpose of the Privacy Act is to balance the government's need to maintain information about individuals with the rights of individuals to be protected against unwarranted invasions of their privacy stemming from federal agencies' collection, maintenance, use, and disclosure of personal information about them.*[2.5]

Therefore, the term "privacy" pertains to individual or personal rights. On the other hand, "proprietary" rights relate to a company or profit-making organization having exclusive and legal rights to a process or product. These terms will be used in this report according to these definitions.

2.3 *"ITS Standards Development Support Project Plan - Archived Data User Service: Guidelines for Archiving ITS-Generated Data and Specifications for Archiving Travel Monitoring Data.*" American Society for Testing and Materials. July 2000.

2.4 "*Strategic Plan for the Development of ADUS Standards: Final*, prepared by Cambridge Systematic, Inc., May 5, 2000.

2.5 U.S. Department of Justice, "Overview of the Privacy Act of 1974: Policy Objectives," http://www.usdoj.gov/04foia/1974polobj.htm, update: May 2000.

The issue of privacy presents a legal barrier to certain types of data that may be collected and archived for needed analyses. Generally, the data used for traffic monitoring and transit operations such as loop detector data do not present a privacy concern. But the data needed for safety and CVO analyses may contain privacy related data which should be eliminated or protected to allow for needed trend analyses and findings.

As with all laws, privacy laws are subject to interpretation. It is, however, widely accepted that surveillance cameras in public areas do not violate the Fourth Amendment (unreasonable search and seizure) because people in public places do not have a reasonable expectation of privacy. In fact, video surveillance has been used by city police departments on streets throughout the country, as well as in airports, museums, stores, banks, and ATMs just to name a few. Video surveillance in public areas is largely accepted as a way of life and in those instances where law suits have been brought claiming a violation of civil liberties, the courts have generally ruled in support of the use of public surveillance cameras. An example is the ruling in the Supreme Court case of *United States vs. Knotts 368 U.S. 276, 281-82 (1983)*:

> *A person traveling in an automobile on public thoroughfares has no reasonable expectation of privacy in his movements from one place to another. When [an individual] traveled over the public streets he voluntarily conveyed to anyone who wanted to look the fact that he was traveling over particular roads in a particular direction, and the fact of his final destination when he exited from public roads onto private property.*[2.6]

If audio is recorded along with the video image, it becomes much more problematic, legally speaking. Title 1 of the Electronic Communications Privacy Act of 1986 limits the abilities of law

2.6 Nieto, Marcus. *Public Video Surveillance: Is It An Effective Crime Prevention Tool?* California Research Bureau, CRB-97-005, June 1997, http://www.library.ca.gov/CRB/97/05/crb97-005.html#liability .

enforcement to execute wire taps and to intercept other types of communications. If audio is recorded as a component of the video surveillance, then government agencies may be required to obtain a court order before the equipment may be installed.[2.7]

That said, the issue here is not whether surveillance recording devices can be installed in public areas. Rather, it is the issue of whether ITS-generated data that are recorded from these devices can be used for purposes other than the originally intended use. Some agencies have a far more open culture than others. Each state has its own public records laws, and some are more open than others. Ohio, for example, has a very open public records law that says that the public has the right to any information gathered with public funds for the price of a disk, stamp, or whatever it costs to physically duplicate that data.[2.8]

The most challenging barrier to overcome might be a closed-off, private culture within an agency. Some agencies who are reluctant to share information are concerned that they might provide someone with too much information about an individual, which might in turn lead to litigation. Even if the data collected appear to be harmless, when fused with other publicly available records, these data might result in information about a person which could be maliciously used. Part of the public sector's concern on privacy and liability issues stem from the standpoint that litigation is an unwanted and unnecessary hassle.

2.2 BENEFITS

In general, the benefits of using ITS-generated data are measured with respect to the value added by the ITS-generated data. Specifically, the benefits of ADUS can be categorized as

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[2.7] Nieto. CRB-97-005, June 1997.

[2.8] Personal Communication with Richard Paddock [(614) 539-4100]. Traffic Safety Analysis Systems and Services, Grove City, Ohio, July 26, 2001.

providing:

1. More detailed temporal data (i.e., collected in very short-intervals), thereby increasing the robustness of the estimates,
2. Alternative data to the existing data, thereby reducing the costs of data collection,
3. Data with greater geographic coverage, thereby increasing the geographic representativeness of the estimates,
4. Data that were too costly to collect in the past, thereby meeting unmet data gaps, and
5. Data that are on electronic media, thereby expediting data analysis and information dissemination.

Although the costs of ADUS are high at this early stage of deployment, it is anticipated that these costs will decrease while the benefits of using ITS-generated data will increase with increasing numbers of demonstration projects, sharing of best practices and lessons learned, making data “preparation” software and tools accessible and easy to use, and quantifying and demonstrating the benefits of ADUS.

Should there be barriers specific to each ADUS application (e.g., Operations and Maintenance, Highway Safety), they are discussed in detail in the appropriate chapters.

3. STUDY METHODOLOGY AND INFORMATION SOURCES USED

3.1 STUDY METHODOLOGY

The objective of the state-of-the practice review is to gain an understanding of which ITS project is collecting what data elements, and to identify which data are archived. If data are archived, then ORNL identified how these data are archived, for what purposes these archived data are being used, and by whom. If data are not archived, then ORNL summarized the barriers that prevent data from being archived.

The methodology used for this state-of-the-practice review attempted to first capitalize on the existing information, despite the fact that this information might not serve the specific needs of this study. Leveraging on the existing information, we then sought the specific data needed for this study through other means such as site visits and telephone interviews.

The first phase of the analysis inventoried which agency was archiving and using what ITS-generated data and for what purposes. A sweeping, but not-so-specific inventory of the state-of-the-practice on archiving and using ITS-generated data was developed using information collected in the ITS Deployment Tracking Surveys. Since this survey is not designed specifically to address issues addressed by this study, it does not provide all of the desired information. Other supplementary information sources were used – such as information reported in the Intelligent Transportation Systems (ITS) Projects Book - 2000, and findings from a literature search.

Findings from this tier of analysis helped identify a number of specific case studies for more in-depth examination. The combination of site visits, telephone interviews and literature review was used to more comprehensively understand the issues that were absent from the existing survey data and/or documents. Example issues include: how and how frequent data are archived, in what format the archived data are stored, how archived data are accessed by others, for what purpose the archived data are used, barriers that hinder sharing the archived data, etc.

The final goal of this project is to provide information that can be used to develop future Technical and Institutional Synthesis Studies outlined in Wave II of the *ITS Data Archiving Five-Year Program Description*. Opportunities for using archived ITS-generated data are formulated by matching the potential usefulness of archived ITS-generated data to data gaps and data needs that have considerably hindered the improvement of our nation's transportation systems. Rather than being complete in identifying all possible opportunities, this project focuses on exploring the utility of archived ITS-generated data in meeting the data needs that have the greatest and the most immediate potential for improving the planning, safety, and operations and maintenance of our surface transportation systems.

3.2 INFORMATION SOURCES

A combination of information sources was used for this study. In January 1996, the then-Secretary of Transportation set a goal of deploying the integrated metropolitan Intelligent Transportation System (ITS) infrastructure in 75 of the nation's largest metropolitan areas by 2006[3.1]:

> *"I'm setting a national goal: to build an intelligent transportation infrastructure across the United States to save time and lives, and improve the quality of life for Americans. I believe that what we do, we must measure . . . Let us set a very tangible target that will focus our attention . . . I want 75 of our largest metropolitan areas outfitted with a complete intelligent transportation infrastructure in 10 years."*[3.2]

3.1 Since the Secretary of Transportation's speech, the number of metropolitan areas that DOT will measure has been increased from 75 to 78.

3.2 Excerpt of a speech delivered by the then-Secretary of Transportation at the Transportation Research Board in Washington, DC on January 10, 1996.

In order to track progress toward fulfillment of the Secretary's goal for deployment, the U.S. Department of Transportation (USDOT) implemented the metropolitan ITS deployment tracking methodology. This methodology tracks deployment of the nine components that make up the ITS infrastructure: (1) Freeway Management; (2) Incident Management; (3) Arterial Management; (4) Emergency Management; (5) Transit Management; (6) Electronic Toll Collection; (7) Electronic Fare Payment; (8) Highway-Rail Intersections; and (9) Regional Multimodal Traveler Information.

The deployment tracking data were gathered through a set of surveys. These surveys targeted state, county, and local agencies within the metropolitan planning boundary for 78 of the largest metropolitan areas. Fifty-three of these 78 areas are among the top 68 most congested metropolitan areas[3.3]. Table 3.1 lists the 78 areas. The surveys gather information on the extent of deployment of ITS infrastructure and on the extent of integration among the agencies that operate the infrastructure. The survey was conducted in the years 1996, 1997, 1999 and 2000[3.4].

Approximately 2,000 surveys were sent in 1999, over half of which were sent to public safety agencies for emergency management information – fire, police and ambulance. Local transit agencies were contacted for transit information, and state DOTs provided freeway management and freeway incident management data. Arterial management surveys were sent to state, county, and city agencies that operated traffic signals. Toll authorities were contacted to provide electronic toll collection data. Additionally, surveys were sent to the Metropolitan Planning Organizations associated with each metropolitan area. The overall return rate in 1999 was around eighty-six percent.

[3.3] Annual congestion statistics compiled by Texas Transportation Institute.

[3.4] http://www.itsdeployment.its.dot.gov/

Table 3.1 Seventy-Eight Metropolitan Areas in the Deployment Tracking Survey

Surveyed By Deployment Tracking Survey	Congestion Rank*
Albany, Schenectady, Troy	63
Albuquerque	23
Allentown, Bethlehem, Easton	
Atlanta	7
Austin	30
Bakersfield	63
Baltimore	29
Baton Rouge	
Birmingham	
Boston, Lawrence, Salem	6
Buffalo, Niagara Falls	66
Charleston	
Charlotte, Gastonia, Rock Hill	22
Chicago, Gary, Lake County	4
Cincinnati, Hamilton	24
Cleveland, Akron, Lorain	44
Columbus	33
Dallas, Fort Worth	33
Dayton, Springfield	
Denver, Boulder	13
Detroit, Ann Arbor	13
El Paso	50
Fresno	41
Grand Rapids	
Greensboro, Winston-Salem, High Point	
Greenville, Spartanburg	
Hampton Roads	
Harrisburg, Lebanon, Carlisle	
Hartford, New Britain, Middletown	50
Honolulu	30
Houston, Galveston, Brazoria	26
Indianapolis	25
Jacksonville	41
Kansas City	60
Knoxville	
Las Vegas	19

Surveyed By Deployment Tracking Survey	Congestion Rank*
Little Rock, North Little Rock	
Los Angeles, Anaheim, Riverside	1
Louisville	28
Memphis	46
Miami, Fort Lauderdale	11
Milwaukee, Racine	33
Minneapolis, St. Paul	13
Nashville	40
New Haven, Meriden	
New Orleans	44
New York, Northern New Jersey, Southwestern Connecticut	21
Oklahoma City	54
Omaha	53
Orlando	33
Philadelphia, Wilmington, Trenton	30
Phoenix	12
Pittsburgh, Beaver Valley	61
Portland, Vancouver	9
Providence, Pawtucket, Fall River	49
Raleigh-Durham	
Richmond, Petersburg	
Rochester	61
Sacramento	13
Salt Lake City, Ogden	41
San Antonio	39
San Diego	8
San Francisco, Oakland, San Jose	2
San Juan	
Sarasota-Bradenton	
Scranton, Wilkes-Barre	
Seattle, Tacoma	5
Springfield	
St. Louis	38
Syracuse	
Tampa, St. Petersburg, Clearwater	26
Toledo	
Tucson	33
Tulsa	

Surveyed By Deployment Tracking Survey	Congestion Rank*
Washington	3
West Palm Beach, Boca Raton, Delray	
Wichita	
Youngstown, Warren	
Top 68 Congestion Areas Not Surveyed	
Beaumont, TX	
Brownsville, TX	
Colorado Springs, CO	
Corpus Christi, TX	
Eugene-Springfield, OR	
Laredo, TX	
Norfolk, VA	
Salem, OR	
Spokane, WA	

* Based on 1999 Texas Transportation Institute's Congestion Index.

Although the data gathered from these surveys in many cases exceed the needs to track the deployment, additional data were gathered to meet specific data requirements for several USDOT functional users, including detailed information concerning incident and transit management, deployment planning procedures, and *data archiving*. As a result, the deployment tracking database is a significant source of general information concerning ITS deployment in the nation's largest metropolitan areas and, in particular, about data archiving. For example, the freeway management survey contains questions about the following types of data: facilities, functions, and staffing of traffic management centers; traffic data collection technologies; data dissemination technologies; traffic control devices; use of standards; types of data collected and archived; and extent that data are shared with other agencies. Questions concerning freeway data collection and archiving cover the following: traffic volumes, traffic speeds, lane occupancy, vehicle classification, vehicle location, ramp queues, ramp meter preemptions, metering rate, road conditions, weather conditions, and incidents. Similar data collection and archiving questions are included in the transit management and arterial management surveys.

Many data elements collected in the deployment tracing surveys cannot be *explicitly* and *readily* identified as having any ADUS potential. For example, many data elements collected in this survey have safety implication but they are not explicitly and not conveniently labeled as "safety-related." To further understand which data elements could be used for what safety analysis, and how (e.g., analyze the data with respect to its applicability to rural or urban safety issues), ORNL assessed this data source with respect to its ability to be used in any of the four applications. Moreover, survey results were analyzed to explore the potential of using ADUS to help meet Federal data reporting requirements (e.g, the Highway Performance Monitoring System, Fatal Accident Reporting System).

Although these surveys contain a wealth of information on data collection and data archiving, they do not completely fulfill the goals of this project. Special approval was obtained from the Joint Program Office to contact a limited number of responding agencies in an attempt to further comprehend the issues of how archived data are being used, by whom, and the barriers to data archiving. Due to this deliberate decision to contact only a few agencies, findings reported in this memorandum should be considered as indicators of general trends, rather than as definitive conclusions.

It should be emphasized that this assessment only focused on in-place ITS deployments and field operational tests that have generated data that have the potential of being used in applications other than what was originally intended. This stage of the assessment has not attempted to identify ITS deployments that have not, but could have, archived and shared ITS-generated data. Examples of the latter are ample, such as the I-95 Corridor FleetForward project, and the in-vehicle signing system for school buses at railroad-highway grade crossings[3.5].

In addition to data collected in the deployment tracking surveys, ORNL used information reported in USDOT's annual report, *Intelligent Transportation Systems (ITS) Projects Book - 2000*. This report provides a comprehensive inventory of all ITS projects categorized in three areas: metropolitan, rural/statewide and commercial vehicle. Furthermore, a literature search was conducted to identify case studies and innovative uses of archived ITS-generated data.

To maximize the benefits of the case studies, six sites were selected based on the criterion that each of these sites has deployed ITS components that cross-cut at least two of the six ADUS topical areas (i.e., traffic/roadway, safety, statewide/rural, MPO, transit, commercial vehicle operations). Table 3.2 lists the six proposed case studies and the corresponding topical areas covered by the case study. The site visit to Los Angeles was productive in that considerable information was collected by directly interacting with local agencies and personnel. That site visit not only set a model for other site visits but also suggested that telephone interviews could be equally productive, less costly, and less burdensome to the to-be-visited agencies. A template was then developed to guide the subsequent telephone interviews (Figure 3.1). The case studies are discussed later in this report.

[3.5] "In-vehicle Signing for School Buses at Railroad-highway Grade Crossings: Evaluation Report." Prepared for Minnesota Department of Transportation by SRF Consulting Group, Inc., Minneapolis, MN 55447. August 1998.

Table 3.2 Proposed Case Studies and the Pertinent Topical Areas

Site/ ITS Deployment	Traffic/ Roadway	Safety	CVO	Transit	Rural	MPO
Atlanta: Navi**GA**tor	✔	✔		✔		✔
Los Angeles: – ATSAC – S. California Priority Corridor Showcase – PATH	✔	✔		✔		✔
Nashville, TN[a]	✔		✔	✔		
Arizona: CVO	✔		✔			✔
Smoky Mountains National Park[b]	✔				✔	
New York: INFORM	✔	✔				✔

[a] Nashville was eliminated from the list due to the lack of sufficient ITS deployments for a reliable ADUS assessment.

[b] Lack of sufficient ITS deployment, Smoky Mountains National Park was replaced by Branson National Park.

Figure 3.1 ADUS issues to be address in phone interviews

Data Generation
- What data are generated by your ITS system?
- What types of sensors/instruments are used to generate these data?
- How frequent (e.g., 30 seconds, 5 minutes) are these data generated?

Data Archiving
- How and how frequent (hourly, daily, ...) are the data being archived?
- Why do you archive these data? In what format?

Use Archived Data
- Who uses the data? And, for what purposes?
- Do you use the archived data to improve the performance of your ITS deployments?

Barriers
- Why don't you archive the data that your ITS system generate?
  1. Institutional barriers
     1. architecture/standard issues
     2. privacy
     3. data ownership/maintenance
     4. data liability
     5. institutional cooperation
     6. partnership
  2. Technological barriers
     1. data integrity
     2. data compatibility
     3. data quality
     4. data transmission/accessibility
  3. Budget/resource barriers

Factors that Overcome Barriers (for successful practices)
- Can you share your experience in overcoming the barriers in archiving and sharing ITS-generated data?
  - partnerships with other public agencies, with the private sector?
- Specifically, did you encounter concerns over archiving and sharing data with sensitive nature (e.g., video imagine from CCTV)? If so, how did you overcome them?

4. OPERATIONS AND MAINTENANCE APPLICATIONS

In order to effectively identify which ITS-generated data are relevant to operations and maintenance applications, it is important to understand the functions to which transportation operations and maintenance refer. Although "safety, reliability, and security" seem to be the terms that effectively convey the key goals of transportation operations, a clear concise definition of operations that articulates the scope and intent of the activities it comprises is being developed[4.1].

Nonetheless, "*optimizing the performance of the existing system to meet or exceed varying customer expectations under varying conditions*" seems to be a reasonable objective for beginning the process of building the future of transportation operations[4.2]. To reach that objective, Dr. Johnson urged solving the four "real" transportation problems facing the nation: congestion, public safety, work zones, and weather response. Public safety refers to transportation safety and efficiency that are enabled by effective police, fire, and emergency operations. "Security" was added to the list, in response to the tragedy of September 11th.

The state-of-the-practice review of archiving and using ITS-generated data on operations and maintenance applications focused on data elements that have the potential to solve those aforementioned problems. This includes data generated from almost all of the nine ITS components.

[4.1] The 2nd National Summit on Transportation Operations. Columbia, Maryland. October 16-18, 2001.

[4.2] Dr. Christine Johnson's Opening Remarks to the National Summit on Transportation Operations. Columbia, Maryland. October 16-18, 2001.

4.1 STATE-OF-THE-PRACTICE REVIEW

4.1.1 Archiving and Sharing ITS-Generated Roadway/Traffic Data

The ITS infrastructure elements pertinent to generating traffic and roadway data include: traffic signal control systems in Arterial Management Systems, Freeway Management Systems, Incident Management Programs, Transit Management Systems, Electronic Toll Collection, Advanced Rail-Highway Crossings, Regional Multimodal Traveler Information, and Emergency Response. Many of these activities are concentrated within metropolitan areas. The objectives of these deployments range from reducing congestion and delays, to providing drivers/travelers with real-time choices, to saving lives through accessible emergency response, to improving on-time transit performance.

One hundred and six agencies responded to the Freeway Management Survey in both 1999 and 2000. Almost one in three responding agencies in 1999 did not collect any freeway data while this percentage increased to almost 40% in 2000 (Table 4.1). Data collected from this Freeway Management survey range from traffic volume, to information related to intermodal connections. By far the most commonly collected freeway data are: traffic volume, and information on scheduled work zones (Figure 4.1). The most common technique used to collect traffic data is loop detectors, followed by video imaging detectors. Figure 4.2 depicts the prominence of different techniques used to collect traffic data. It is obvious from this figure that less intrusive technologies are becoming popular in collecting traffic data. Traffic volume and vehicle classification data are the two data elements that are most likely to be archived. Eighty-seven percent of the agencies in 1999 that collected traffic volume data also archive them. And, seventy-six percent of the agencies that collect vehicle classification data also archive them (Table 4.1). The most noteworthy observation is the fewer number of agencies that generate and archive lane occupancy data, declining from 39 agencies in the year 1999 to 6 in year 2000. We

Table 4.1 Number of Agencies that Generated and/or Archived Freeway Traffic Data
1999 and 2000 ITS Deployment Tracking Surveys

Type of Data	1999		2000	
	Generated	**Archived**	**Generated**	**Archived**
Traffic volumes	68	59	56	45
Traffic speeds	47	31	49	34
Lane occupancy	39	27	32	26
Vehicle classification	49	37	40	30
Probe vehicles	5	3	N/A**	N/A**
Ramp queues	10	3	8	2
Ramp meter preemptions	1	1	2	0
Metering rate	12	6	12	6
Road conditions	40	21	36	20
Route designations	20	14	14	8
Weather conditions	40	23	41	25
Incidents	52	35	43	38
Current work zones	64	34	47	29
Scheduled work zones	60	34	43	28
Intermodal connections	3	3	2	2
Emergency/evacuation routes and procedures	29	22	19	16
Highway operations coordination information	30	18	22	16
Vehicle occupancy	N/A*	N/A*	6	3
Violation Rates for HOV lanes	N/A*	N/A*	2	2
Other	4	2	0	0
Agencies with none	32		40	

* These questions were not asked in 1999
** These questions were not asked in 2000

speculate that data reporting errors led to the downward trend from 1999 to 2000 in terms of fewer data elements being generated and/or archived.

Figure 4.1 Freeway Data Generation and Archiving
(Out of 74 Agencies Reported Data Generation and Archiving in 1999
Out of 66 Agencies Reported Data Generation and Archiving in 2000)

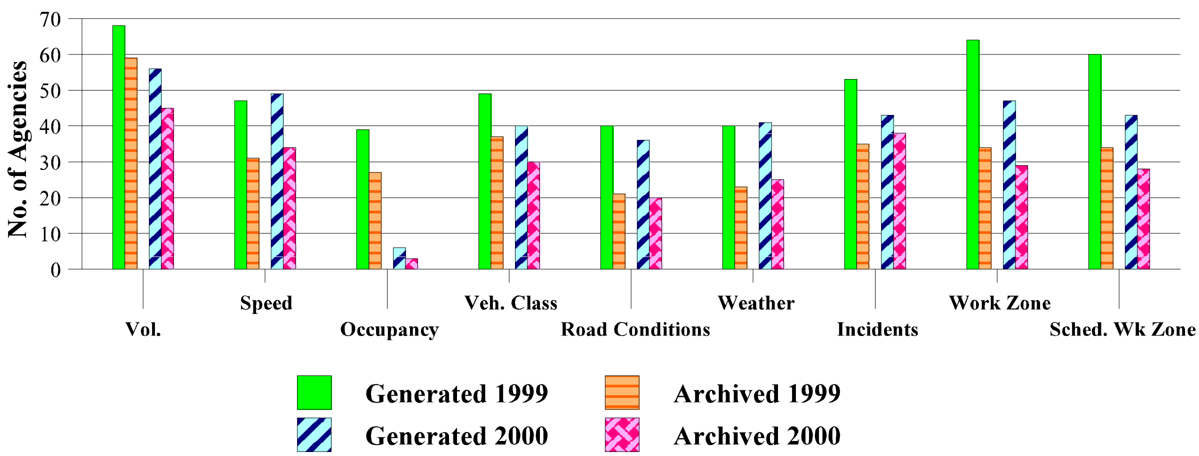
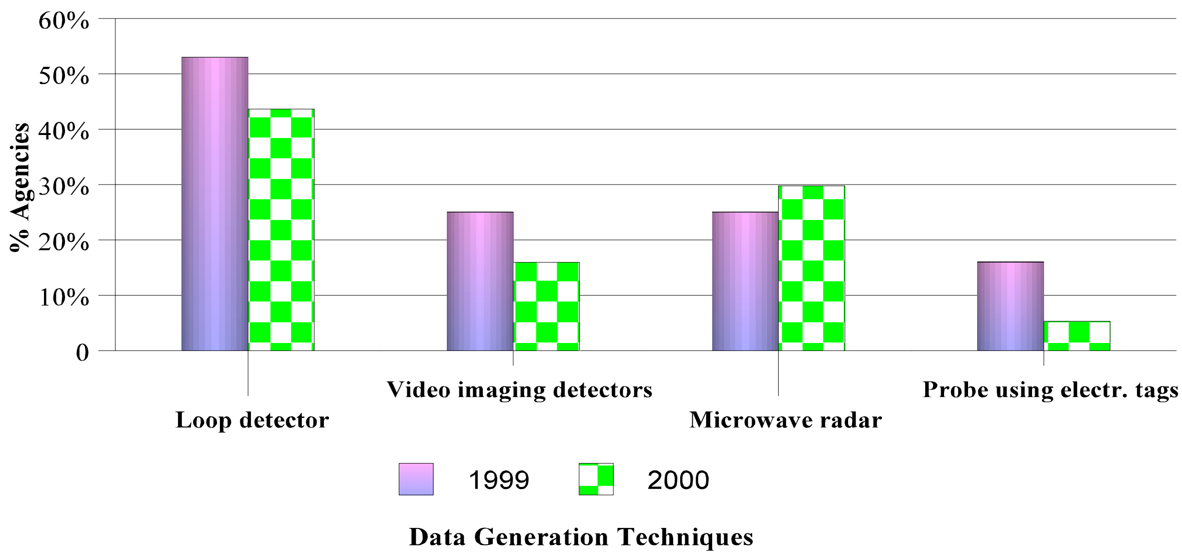


Figure 4.2 Techniques to Generate Traffic Data
1999 and 2000 ITS Deployment Tracking Surveys



Ramp metering has the potential to significantly reduce the traffic flow impediment. Thirty-nine of the 106 responding agencies reportedly operate entrance ramp meters within their planning boundary. However, less than one third of those agencies collect data related to ramp metering (Table 4.1).

Tables 4.2 and 4.3 show the propensity for data archiving in 1999 and 2000, with a significant downward trend. No agencies collect all seventeen data elements identified on the survey questionnaire. In 1999 one agency collected 14 of out the 17 data elements and it archived every data element collected. Overall, 31 of the 78 agencies in 1999 archived **all** of the traffic data collected (cells on the diagonal line) while the corresponding numbers are 19 out of 66 agencies in year 2000. In 1000 ten agencies reportedly collected traffic data but did not archive any (the “0“ column).

4.1.2 Usage and Users of the Archived Freeway Data

Based on the tracking survey results, the media is the largest archived data requester/user, followed by state Departments of Transportation (Figure 4.3). The archived traffic data are primarily used for traffic analysis and planning (Figure 4.4). However, the specific applications of the analysis are unclear from the surveys. It is also unclear which of the users use which of the archived data and for what purpose.

4.1.3 Barriers to Freeway Data Archiving

To avoid reporting burden, ORNL only contacted a limited number of agencies for questions more specifically related to data archiving. For those agencies that did not archive any data generated, the reasons given were: (1) lack of need to archive, and (2) lack of necessary hardware, storage capacity, and resources (either human or monetary) to archive. Lack of articulated needs was the overarching reason for those agencies that archived part, but not all, of the data elements.

Table 4.2 Distribution of Agencies by Number of Data Elements Generated and Number of Data Elements Archived
1999 ITS Deployment Tracking Survey

Number of Data Elements Generated	Freeway Management Survey (74 Responses)																	
	Number of Data Elements Archived																	
	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
17																		
16																		
15																		
14				**1**														
13					**1**	1									1			
12						**4**											1	
11								1	2			2	1				1	1
10								**4**							1		1	
9									**1**	1		1	1			2		
8										**5**		1	1			1		2
7											**2**	3		1		1	1	2
6														1	1	1		1
5													**7**		2	1		2
4														**1**				
3															**1**		1	1
2																**2**		1
1																	**2**	

Table 4.3 Distribution of Agencies* by Number of Data Elements Generated and Number of Data Elements Archived
2000 ITS Deployment Tracking Survey

Number of Data Elements Generated	Freeway Management Survey (66 Responses)																	
	Number of Data Elements Archived																	
	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
17																		
16																		
15															1			
14						1					1							
13					**1**													
12						**1**												
11								1	2	1	3	1	1					
10								**3**		1								
9										1		1				1		1
8										**3**	1		1		1			1
7											**3**	1		1		1		1
6													3	1		2	1	2
5															2	1	1	2
4															1		1	
3															**3**			
2																**2**		
1																	**0**	1
0																		

* Excludes agencies that archived more data elements than they actually collected.

Figure 4.3 Number of Agencies Responded to Freeway Data Requests by Requesting Institute

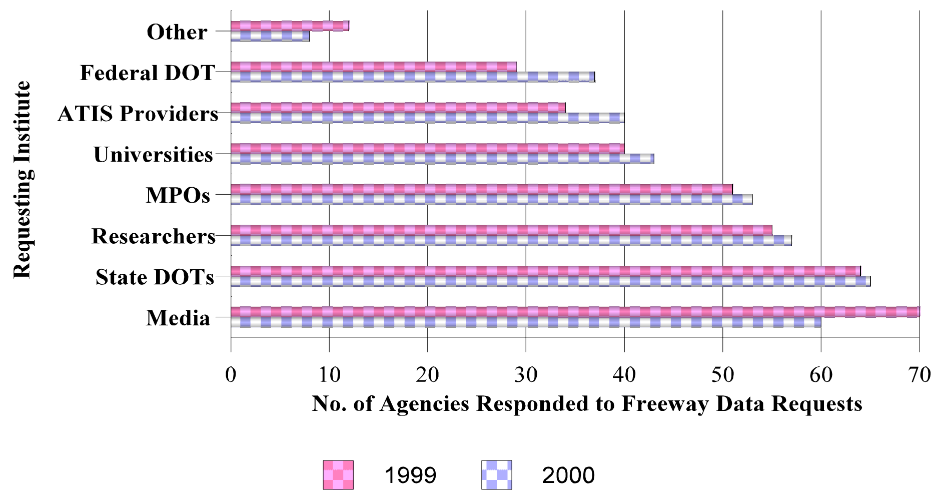
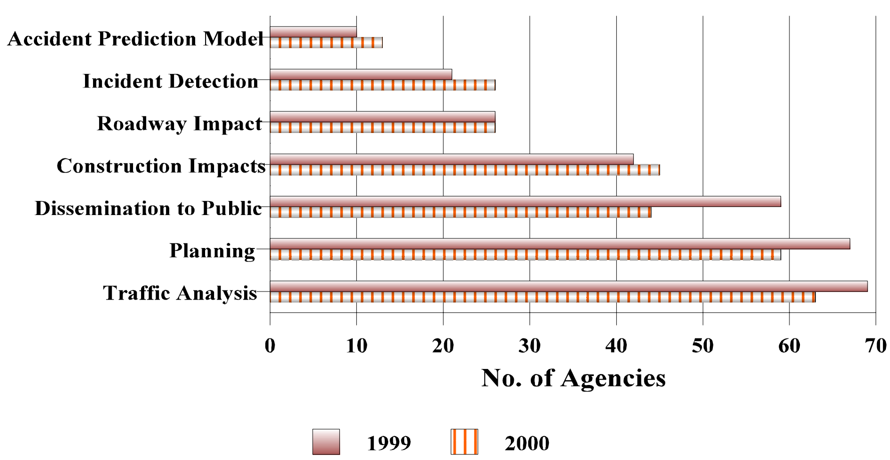


Figure 4.4 Archived Freeway Data Usage 1999 and 2000 ITS Deployment Tracking Surveys



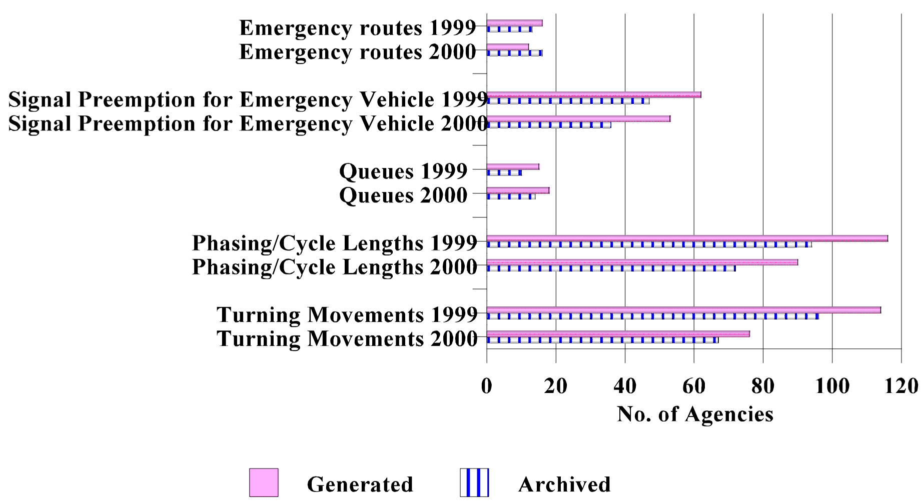
4.1.4 Archiving and Sharing ITS-Generated Emergency Response and Work Zone Data

Other data elements specifically pertinent to operations and maintenance application are:

- Information on *current and scheduled work zones*. Almost three quarters of the agencies that collected this information archive it.
- *Weather and roadway conditions*. Weather conditions and road conditions are archived by at least half of the agencies that collect/report weather and road conditions as part of their Freeway Management Systems as well as their Arterial Management Systems.
- Information on *ramp metering strategies* has the potential to shed light on the benefits of time-sensitive metering control strategies.
- Data archived on *emergency responses* and *emergency vehicle signal preemption* provide a foundation to evaluate the effectiveness of emergency management controls in saving lives. Unlike the Freeway Management Survey and the Arterial Management Survey, the Emergency Management Survey did not include questions specific to data generation and archiving. Consequently, no information is available on ITS-generated *emergency response* data.
- Information on *traffic signal controls* (turning movements, phasing and cycle lengths and queues) allows the development of more proactive, rather than reactive, traffic control strategies.

Three hundred eighty-eight agencies responded to the 1999 Arterial Management Survey. More than half of these agencies did not collect any data. Of those that reported data collection activities, more than two-thirds collected data on traffic signal controls (Figure 4.5). The percentage of agencies that archived their traffic signal data is very high (Figure 4.5).

Figure 4.5 Data on Traffic Signal and on Emergency Management



4.2 CASE STUDIES OF OPERATIONS AND MAINTENANCE APPLICATIONS

There was at least one case study for each of the four applications. The purpose of the case studies was to:

- gain better insight into why archived ITS-generated data are, and are *not*, used in terms of technological and institutional situations and barriers,
- identify additional opportunities for archiving and using ITS-generated data, and
- identify successful practices in archiving ITS data for transportation decision-making.

Specifically, the case studies addressed the following questions:

1. What data do ITS deployments generate?

2. How are data generated and archived?
3. Are the ITS-generated data shared?
4. If so, how, with whom and for what purposes?
5. Were there barriers to archiving and sharing the data? If so, what were they and how were they overcome?

It should be re-emphasized that this assessment only focuses on ITS deployments that have generated data that have the potential of being used in applications other than what was originally intended. This assessment has not attempted to identify ITS deployments that have not, but that could have, generated and archived data such as the I-95 Corridor FleetForward project, and the in-vehicle signing system for school buses at railroad-highway grade crossings. Specifically, the prerequisite for being selected to be a case study in this project was that an ITS system has to have been generating and archiving data.

ITS projects in two metropolitan areas were examined - Atlanta and Los Angeles. The rationale for selecting these two locations was because of their data archiving activities and the level of collaboration among local agencies and jurisdictions. However, this by no means suggests that no other areas are archiving and sharing ITS-generated data as extensively as these two areas. In fact, an increasing number of agencies and researchers have been using archived ITS-generated freeway data in the past two years to monitor their system performance.

4.2.1 Georgia Department of Transportation's NaviGAtor in Atlanta

NaviGAtor is designed to gather information from a variety of sources: a video monitoring and detection system, Highway Emergency Response Operators (HEROs) and the public. NaviGAtor links the Transportation Management Center (TMC) to the Transportation Control Centers (TCCs) of five surrounding counties (Cobb, Gwinnett, Clayton, Fulton and Dekalb), the City of Atlanta, and the Metropolitan Atlanta Rapid Transit Authority (MARTA), creating an intelligent transportation network spanning more than 220 miles.

System Description

The current level of coverage is about 220 miles of instrumented roadway including freeway and arterial streets monitored by the central TMC and satellite TCCs. The central TMC currently has 42 miles of instrumented freeway along Interstates 75 and 85 inside the Interstate 285 beltway. Additional 14 miles of instrumentation were deployed along the northern arc of the 285 beltway in July, 2001.

Atlanta's NaviGAtor system (which is operated by Georgia DOT) is highly integrated with other agencies. The central TMC is currently linked to the Traffic Control Centers (TCC) of 5 other counties: Clayton, Cobb, DeKalb, Fulton, and Gwinnette counties, plus the City of Atlanta and the Metropolitan Atlanta Rapid Transit Authority (MARTA). These county and city TCCs are used to manage arterial road systems, while the NaviGAtor TMC manages the freeways. All monitored data are shared between the centers so that the arterial TCCs can see the traffic conditions on the freeways, and conversely, the freeway TMC can see traffic conditions on the arterial streets. The NaviGAtor TMC acts as the main warehouse for stored data. However, it is not clear whether the city and county TCCs archived any of their data.

Some of the agencies that are currently integrated into the system are:

- Georgia Emergency Management Agency (GEMA),
- Atlanta City Police Department,
- 911,
- Metropolitan Atlanta Rapid Transit Authority (MARTA), and
- Georgia State Patrol, which is located in the same compound as the TMC. (Although not currently connected to the system, it will be connected in the near future.)

NaviGAtor uses the video monitoring and detection system (i.e., a camera-based system) to provide real-time images of road conditions. It serves as an incident verification tool. Installed on Interstates 75 and 85 are more than 317 fixed black-and-white Autoscope detector cameras that are spaced 1/3 of a mile apart, and 67 pan, zoom and tilt full color surveillance cameras spaced 2/3 of a mile apart. Information on average *speed*, *traffic volume, lane occupancy* and *vehicle classification* is collected from the Autoscope cameras. Video monitoring from the surveillance cameras allows the operators at the TMC to verify incidents, thus reducing response time, speeding up removal of incidents and minimizing congestion. The newly instrumented northern arc of I-285 added 114 additional fixed black and white cameras, and 36 color cameras. This brings the total to 103 pan, zoom, and tilt full-color cameras and 431 fixed black and white cameras.

Of these two types of camera, only data generated from the fixed black and white Autoscope cameras are archived. The color surveillance cameras provide views of the traffic for the authorities as well as for the public at large via the Internet. No information from the color surveillance cameras is archived.

A gyroscopic camera mounted on a helicopter is used for aerial monitoring. This aerial camera provides live video within a 50-mile radius of Atlanta, vastly increasing NaviGAtor's area of coverage.

The County and City TCCs use primarily loop detectors for traffic signal optimization on arterial streets. There are some surveillance cameras installed in order to view incidents but no data is generated from these cameras that can be archived.

Data Archiving

The Autoscope cameras gather data on a 20 second polling period. These data are then aggregated into 15-minute logs, which are stored onto an internal server for 30 days. Each month, the data are compressed, written and archived to a CD. When uncompressed, this system generates 4.6 megabytes of data on a daily basis[4.3]. Data have been archived for the past 4 years.

The Autoscope camera images are interpreted by software at the TMC. Speed and vehicle counts are interpreted directly while the other data elements are derived using mathematical algorithms. The following is a list of data elements that are generated by the NaviGAtor freeway system for each lane of the freeway:

- Speed,
- Vehicle Counts,
- Lane Occupancy,
- Vehicle Classification
  - Auto: Less than 25 feet,
  - Light Truck: 25 to 49 feet, and
  - Tractor Trailer: $\geq$ 50 feet.
- Headway: a measurement of the average gap between vehicles,
- Flow Rate: expressed as number of vehicles per lane per hour, reflecting lane capacity,
- Level of Service: Graded A through F, where A= light traffic, and F= gridlock,
- Presence of stopped vehicles, and
- Wrong way vehicles

Georgia DOT has the ownership of the data stored at the TMC. Of these data elements, only data on traffic volume, speed and lane occupancy are archived on a fifteen-second interval. Figure 4.6

[4.3] Based on the original 42 miles of instrumentation along interstates 75 and 85.

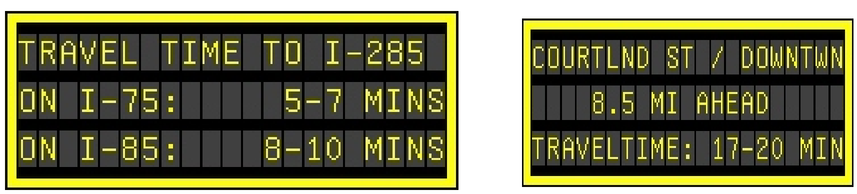
Figure 4.6 An Example of Archived Freeway Data from NaviGAtor

```
#############################################################################
# NAVIGATOR Detector Data Archive
# Date: 21 January, 1999
# Format: One sample per line, fields separated by '|'
#       field 1: Detector ID
#       field 2: Sample Start time (MM/DD/YYYY HH:MM)
#       field 3: Total Volume
#       field 4: Average Speed
#       field 5: Average Occupancy
# Note: due to unavoidable technical difficulties, the
#     NAVIGATOR system may not have been able to
#     record some detector data.  sorry.
##############################################################################
#####
287|01/21/1999 00:00|53|78.45|2.44
288|01/21/1999 00:00|94|76.08|4.84
289|01/21/1999 00:00|52|66.21|2.65
290|01/21/1999 00:00|40|61.40|2.27
301|01/21/1999 00:00|50|57.82|2.74
302|01/21/1999 00:00|85|61.98|3.93
303|01/21/1999 00:00|90|64.71|4.18
304|01/21/1999 00:00|48|61.25|2.70
347|01/21/1999 00:00|24|55.21|1.08
348|01/21/1999 00:00|105|61.50|5.26
                    •
                    •
                    •
287|01/21/1999 00:15|42|76.21|2.13
288|01/21/1999 00:15|86|72.41|5.16
289|01/21/1999 00:15|40|66.07|2.18
290|01/21/1999 00:15|23|61.78|1.48
301|01/21/1999 00:15|45|59.76|2.44
302|01/21/1999 00:15|78|62.08|3.64
303|01/21/1999 00:15|73|64.16|3.27
304|01/21/1999 00:15|35|66.23|1.50
347|01/21/1999 00:15|29|57.62|1.17
348|01/21/1999 00:15|95|61.85|4.49
```

illustrates an example of these archived data. These archived freeway data are stored in a format which facilities use for further analyses.

Although the information disseminated by Variable Message Signs (Figure 4.7) is not archived at the present time, the availability of these data in real time on the Internet suggests that it can easily be archived. The usefulness of this information, by itself, is probably of little value. However, if integrated with sensor, roadway and weather information, it could provide valuable insights in the nature of locale-specific congestion and delay, and the effectiveness of different control strategies.

Figure 4.7 Examples of Archived VMS Message



Sharing and Uses of Archived Data

Since real time data are shared among all agencies integrated into the NaviGAtor system, there has not been a need to share archived data among those agencies. However, there have been many external requests to NaviGAtor's central TMC for archived data. Some examples are:

- Planning Commissions use the archived traffic data to analyze the traffic impacts of new construction.
- Academia and the research community (e.g., Georgia Technology Institute) rely heavily on these data to develop a new generation of traffic prediction models that predict traffic delays by the month of the year and by weather conditions.

- Environmental Protection Agency (EPA) establishes relationship(s) between traffic patterns and air quality based on the archived traffic data.
- The Atlanta Regional Commission (ARC) used the archived data to create surface transportation models.
- Environmental advocacy groups attempt to halt unwanted commercial developments.
- Private citizens request the archived speed data to contest speeding tickets and other types of citations in court.

Unfortunately, there is no convenient way for sharing archived data. When archived data are requested, Georgia DOT burns a CD that contains the data in compressed .txt format. The data are uncleaned and contain time stamps and camera ID numbers, along with their associated data elements.

Accommodating data requests can be extremely time consuming, which has prompted Georgia DOT to consider several options:

- Make the data available **online** for the public to query using some sort of relational database. This idea is under serious consideration and is likely to happen in the near future.
- Another option being considered is a **data broker** who could take the entire data management responsibility off Georgia DOT. This option is still in its infancy and faces many institutional barriers such as how to use taxpayer money to contract out to a private company. One possible solution might be a mutually beneficial arrangement where control of the data management is given to a company or an organization, but no funds are passed from Georgia DOT to the data broker. The data broker can then provide value added to the data and sell it.

Barriers and Lessons Learned

Although freeway data are archived and shared with the planning communities, Georgia DOT speculates that the archived data have not been fully utilized because of incompatible data format and data aggregation.

Initially, there was much concern and debate over the development of an integrated system with shared control of equipment, especially the pan, tilt, zoom, color surveillance cameras. Many were concerned that sharing the control of cameras might conflict with the different objectives of different agencies. In reality, this concern has not been substantiated. Nonetheless, a camera control hierarchy has been developed.

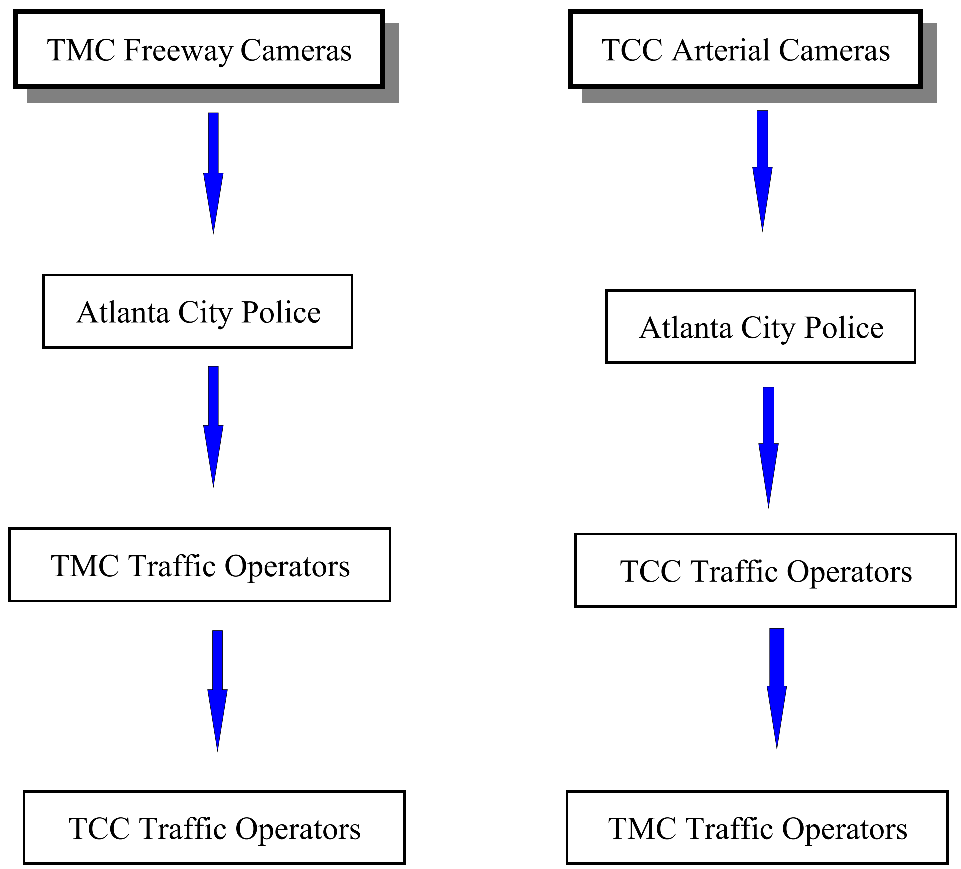
Although the surveillance cameras can be controlled by many different groups in the NaviGAtor system, Atlanta City Police have priority control of these cameras. This policy intends that if there are other users on the system trying to adjust the same camera simultaneously, the system defers priority control to the City Police. Otherwise, anyone in the NaviGAtor network with a set of controls can adjust the cameras. After the City Police, the NaviGAtor TMC has priority over their freeway cameras, and the various TCCs have priority over their arterial cameras. The diagram depicting the control hierarchy is illustrated in Figure 4.8.

Data archiving and sharing of the archived data transpire despite the fact that ADUS has yet to be part of the NaviGAtor's system architecture. At the time of the interview, a plan was underway to use NaviGAtor data to meet reporting needs required by the Highway Performance Monitoring System (HPMS).

4.2.2 Traffic ITS Deployments in the Los Angeles Metropolitan Area

Traffic operations and transportation planning in the Los Angeles metropolitan area are

Figure 4.8 Color Camera Priority Control Hierarchy
Atlanta's NaviGAtor System



the responsibility of many different jurisdictions. Experience and plans in archiving ITS-generated data and using the archived data in three agencies were analyzed: (1) the City of Los Angeles' Department of Transportation (LADOT); (2) Los Angeles Metropolitan Transportation Agency (LAMTA), and (3) California Department of Transportation (CalTrans). The rationales to include these agencies in our case study are that: (1) they each have different perspectives on data archiving and sharing data, and (2) there is an ongoing plan to eventually integrate almost all

ITS systems in the southern California areas into an integrated system. The extent of archiving data and use of archived data varies from one agency to the next. Nonetheless, there was consensus among all agencies visited that ADUS has significant benefits.

The City of Los Angeles Department of Transportation (LADOT) has centralized authority over the planning and operation of the City's street system - which consists of 6,400 street miles, 1,400 major and secondary miles, 5,000 collector and local miles, 40,000 intersections and 160 freeway miles. Among its many other responsibilities, LADOT is responsible for the installation and maintenance of traffic signals, and other traffic control devices; and administers the City's transit programs. LADOT develops and uses the Automated Traffic Surveillance and Control (ATSAC) System to optimize the capacity of its existing highway system by reducing delay and minimizing traffic congestion. It is estimated that ATSAC reduces travel time of recurrent traffic by 12%, intersection delay by 32%, and intersection stops by 30%[4.4].

The Los Angeles County Metropolitan Transportation Authority (MTA) is unique among the nation's transportation planning agencies in that it serves as transportation planner and coordinator, designer, builder and operator of LA County's transportation system. MTA was identified as a case study for its role in the Southern California Priority Corridor Showcase project, and its role as a potential ADUS user.

CalTrans District 7 is the state transportation department that constructs and maintains the California state highway and freeway system in Los Angeles and Ventura Counties (Figure 4.9). Specifically, it manages 909 freeway and highway miles in LA County, and 273 freeway and highway miles in Ventura County. On a typical day, these miles carry an average of 90

[4.4] http://www.lacity.org/LADOT/

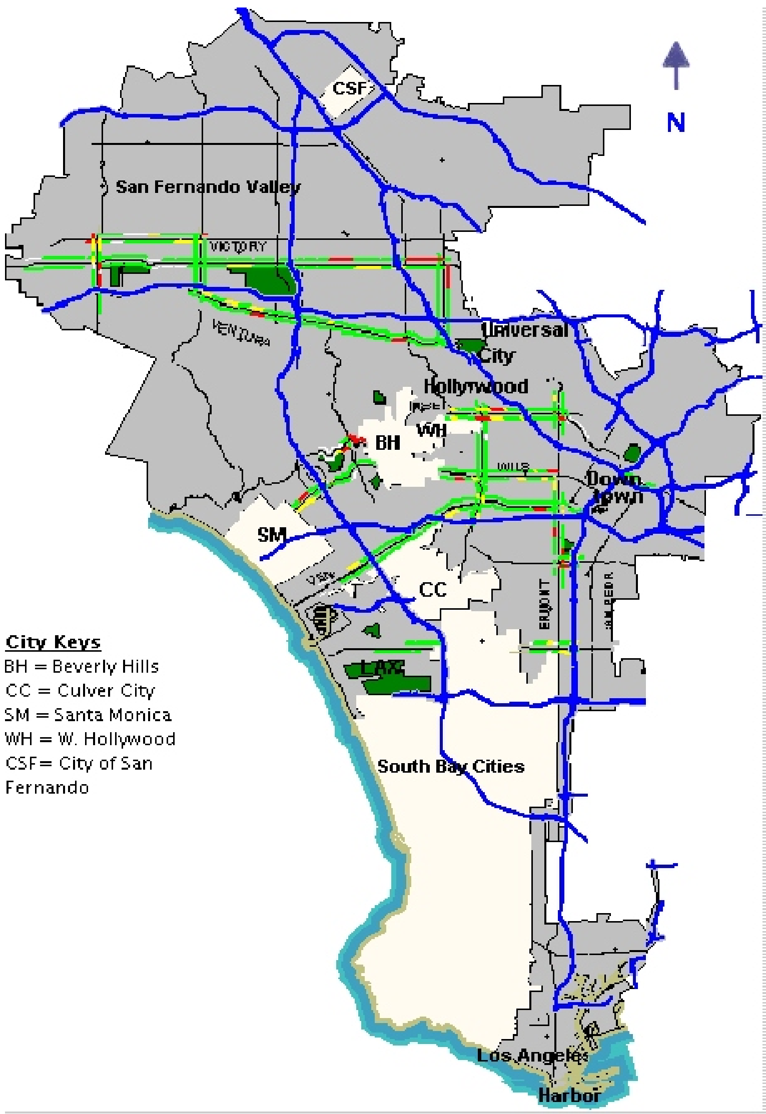
Figure 4.9 Area Coverage of CalTrans' District 7

million vehicle miles traveled (VMT) per day.

Automated Traffic Surveillance and Control (ATSAC) system

The Automated Traffic Surveillance and Control (ATSAC) system, a computer-based traffic signal control system, is used by the City of LA to optimize the capacity of its existing arterial systems (Figure 4.10). ATSAC monitors traffic conditions and system performance. Loop detectors imbedded in the arterial roads detect the passage of vehicles, vehicle speed, and the level of congestion. If required, the signal timing is either automatically changed by the ATSAC computers or manually changed by the operator to achieve better traffic flow.

Figure 4.10 LADOT's ATSAC Coverage



To date, ATSAC operates 11,000 loop detectors and has been deployed in 2,449 of the 4,285 signalized intersections. Funding has been committed to instrument additional intersections, leaving only 25% of the city's intersections without instrumentation. To supplement the information from loop detectors, closed-circuit television (CCTV) surveillance equipment has been installed at critical locations throughout the city. At the time of the site visit (February 2000), there are 150 CCTV cameras installed.

ATSAC-Generated Data

Loop detectors generate data on vehicle counts, speed, and lane occupancy. Real-time traffic conditions are posted on the web[4.5]. Congestion level is determined by speed thresholds. For example, congestion is considered "heavy" when the average vehicle speed falls below 10 miles per hour (mph), "moderate" between 10 and 20 mph, and "none" above 20 mph. No data are generated from the CCTV cameras. Although no incident information is generated from ATSAC, the California Highway Patrol (CHP) posts incident information on its' Traffic Incident Information Page[4.6]. This page contains all incidents to which CHP responded. Hot spots, the most serious incidents, are identified on real-time basis. Information generated for each incident includes: the area, type (e.g. "Traffic Collision-Ambulance Responding"), location, time, additional details, and CHP's responses of the incident. Figure 4.11 illustrates a few examples of the incident report. These incidents are geo-coded on a GIS platform (Figure 4.12). Although incident data are not archived at the present time, it could easily be done especially with the "text" format of the data.

[4.5] http://trafficinfo.lacity.org/

[4.6] http://cad.chp.ca.gov/

Figure 4.11 Examples of Incident Report Posted on the Web

Type	Traffic Hazard
Location	**E HOLT AV ONR E at to I10**, Baldwin Park (Los Angeles County), California
Description	7:27AM PLS ROLL FSP FOR A GRN FORD SW BO ENG 7:27AM CHP Unit On Scene
Advise	Drive carefully
Reported by	CHP on October 08, 2001 07:27AM PDT
Expires	October 08, 2001 07:53AM PDT

Type	Traffic Hazard
Location	**I10 E at just west of BALDWIN AV**, East Los Angeles (Los Angeles County), California
Description	
Advise	Drive carefully
Reported by	CHP on October 08, 2001 07:25AM PDT
Expires	October 08, 2001 07:53AM PDT

Type	Structure or Grass Fire
Location	**I210 W at at LOWELL AV**, Altadena (Los Angeles County), California
Description	7:29AM INFO FOR CALTRANS - THERE IS A WATER PIPE WITH A LARGE LEAK IN IT HERE - LOWELL ONR TO WB 210 7:24AM POSS BRUSH FD, SMOKE COMING FRM RIGHT SIDE, 1039 GLENDALE FD 7:27AM CHP Unit On Scene
Advise	Drive carefully
Reported by	CHP on October 08, 2001 07:21AM PDT
Expires	October 08, 2001 07:53AM PDT

Archiving, Sharing and Uses of Archived ATSAC Data

Traffic data generated from ATSAC are archived only for one week. The system

Figure 4.12 An Example of CHP Traffic Incident Web Page

Source: http://cad.chp.ca.gov/

automatically over-writes the old data after a week. Requests on archived data are addressed on an individual basis. For example, Southern California Association of Governments (SCAG) uses ATSAC's traffic volume information to validate results from its travel forecast models. A contract was put in place for LADOT to archive and reformat the traffic data.

In addition to outside users (e.g., SCAG), LADOT uses the archived ATSAC data to identify traffic "signatures." Traffic surveillance data collected from surface streets impose a challenge different from those brought about by the freeway traffic data. Unlike freeway systems, no loop detectors are placed on curve lanes, thereby underestimating traffic volume. Although not a barrier to archiving traffic data, this is definitely a challenge for the proper use of the data.

Barriers, Lessons Learned, and Potential of Archived ATSAC-Generated Data

ATSAC officials believe that any long-term data archiving needs first to overcome storage limitations. To date, ATSAC data amount to 76MB per day. Their second concern about data archiving is the challenge to make data accessible in a reasonable time frame. To make ATSAC more useful for planning purposes, ATSAC data should be integrated with data from other sources (e.g., weather).

Although little is occurring right now at ATSAC on data archiving and data sharing, the potential of the archived data is considerable. For example, the LADOT, in collaboration with the Los Angeles County Metropolitan Transportation Authority (MTA), is implementing an advanced transit project - the Transit Priority System (TPS)[4.7]. This project is designed to improve the on-time performance of metro buses by adjusting the signal timing at intersections for buses as they approach the intersection. A transponder mounted underneath a bus communicates with the ATSAC loop detectors imbedded in the roadway. Traffic signal priority is provided to a particular bus only if the bus is running behind schedule. If data generated from this project are archived, they can provide the information needed to develop plans for transit operations without impacting street traffic.

CalTrans

CalTrans District 7 monitors more than 500 miles of freeway in LA area. Loop detectors are installed every ½ mile. Data on V(olume), O(ccupancy), and S(peed) are generated. The 30-second data are archived for thirteen months. In addition to the loop detectors, more than 20,000 CCTVs are installed. However, no video data are archived.

4.7 Hu, K., Skehan, S., and Gephart, R. "Implementing a Smart Transit Priority System for Metro Rapid Bus in Los Angeles." Presented at the 80th Annual Transportation Research Board Meeting. Washington, D.C. January 2001.

Archiving, Sharing and Uses of Archived ATSAC Data

Lane-specific VOS data that are archived on a stand-alone server are accessible by University of California, Berkeley to perform the California Transportation System Performance Measures Project (PeMs).[4.8] This project assists Caltrans Traffic Operations and Traffic Operational Centers to manage traffic operations. Caltrans' primary goal in using these archived data is to measure the performance of the freeway system and to identify recurrent congestion. Parameters such as Vehicle Miles Traveled (VMT) and Vehicle Hours Traveled (VHT) are measured at each loop location in real time and are archived for up to one year.

Furthermore, CalTrans uses archived traffic volume data for special event planning, and archived speed profiles for incident detection. The latter is still somewhat ad hoc. CalTrans staff recommend the use of Common Object Request Broker Architecture (CORBA) to facilitate data sharing. No video images are archived due to the privacy concern. Archived ITS-generated data could be more widely used and many parts of the agency could benefit from ADUS.

4.2.3 Houston Roadway Weather Monitoring[4.9]

The Houston area is confronted with frequent weather conditions that affect traffic. In order to study the effects of weather conditions on traffic, 27 weather stations were deployed in the Fall of 2000. These stations provide real-time data on:

- Roadway water depth. This measurement is achieved by using a pressure transducer imbedded in the base of a curb which provides readings based on the pressure of water at a given depth. They hope to use this technology to establish a baseline water depth for road closures.

4.8 Headed by Professor Pravin Varaiya, UC Berkeley.

4.9 Benz, R. "*Monitoring Mobility: Utilizing Environmental, Weather, and Traffic Data.*" Texas Transportation Institute.

- Rainfall rate,
- Humidity,
- Wind speed. Houston has many tall bridges which are exposed to high wind velocities and wind gusts. These weather conditions pose a serious rollover threat to trucks and vehicles around the trucks. Variable Message Signs can be used to alert truck drivers of hazardous wind conditions.
- Wind direction. These data will be used to assess the vulnerability of bridges to cross winds that could pose a threat to tall box-style trucks.
- Air temperature,
- Pavement temperature, which is measured by a thermocouple imbedded in the concrete of a bridge deck.
- Pavement moisture. A thermocouple imbedded in the concrete of a bridge deck perform a conductivity test in order to detect moisture. Increased moisture on the pavement increases the conductivity readings.
- Stream velocity. In Houston, a lot of ships and barges go under roadway bridges. If stream velocity rises to a dangerous level, water vessels may lose control and damage roadway structures with possible environmental consequences. This is particular true when the vessel is carrying petroleum or other hazardous materials. The attempt is to establish thresholds of stream velocity so that the Coast Guard can stop water traffic when the velocity reaches beyond the thresholds.

Figure 4.13 illustrates an example of the archived weather data. Although these data are archived in a flat text file format at **http://www.hcoem.org/road/txdot_choose_date.asp**, they are not widely disseminated. The system will be fully tested before the data can be more widely available. In December of year 2000, the plan was to store their data at the TranStar

Figure 4.13 Sample Data File of Archived Houston Weather Data

DataWise Tabular Report

Group Name	Date	Time
HARTMAN WEATHER	11/07/01	09:55:32

DeviceID	3100	3101	3102	3096	3098	3107
Date/Time	11/07	11/07	11/07	11/07	11/07	11/07
Value of	0344	0954	0906	0936	0936	0949
Last Rpt.	351	278	246	0	56	173
StatType	dif	last	last	last	last	last
DataType	precip	humid	airtemp	windspd	winddir	peakwin
Units	in	rh%	degF	20	deg	mph
11/07/101						
0955	0.00	67.9	68.2	0.0	56	6.74
0855	0.00	69.9	66.0	16.0	101	6.99
0755	0.00	71.1	63.8	12.0	203	7.18
0655	0.00	74.7	63.8	11.0	11	5.03
0555	0.00	66.4	66.0	8.0	287	5.52
0455	0.00	65.2	66.0	7.0	0	3.32
0355	0.00	77.9	66.0	5.0	174	1.61
0255	0.00	76.9	65.5	5.0	174	4.25
0155	0.00	59.6	67.7	3.0	180	3.86
0055	0.00	59.6	67.7	3.0	180	4.59
11/06/101						
2355	0.00	51.3	69.9	1.0	225	5.03
2255	0.00	47.4	69.9	15.0	326	6.89
2155	0.00	41.8	69.9	8.0	152	9.18
2055	0.00	49.6	69.9	0.0	349	10.21

traffic management center where the data will be stored along with the traffic data in an ORACLE database. The combined data base of weather conditions and traffic data will allow the examination of impacts of weather conditions on traffic.

4.3 BARRIERS AND SOLUTIONS

The institutional and other barriers associated with implementing ADUS are largely the same among the different ITS applications. These common barriers such as cost, proprietary rights, data issues, politics, and a lack of understanding or knowledge about ADUS are covered in further detail in Chapter 2.

Beyond these common barriers, roadway/traffic and the Metropolitan planning process encounter a different kind of obstacle. People working in traffic management centers are forced to think in terms of hours and minutes, while metropolitan planners think in terms of months and years. This difference in perspective can cause a strain between these two groups when trying to implement ADUS. One possible solution to bridge this gap is to demonstrate the value of using archived data to improve operations. For example, an analysis of historical traffic patterns and signal timing can help develop proactive signal timing strategies that are sensitive to the temporal patterns of the traffic.

4.4 OPPORTUNITIES

Opportunities for using ITS-generated data to improve operations are virtually limitless. Rather than try to identify all possible opportunities, this section identifies those that are practically feasible, can be quickly deployed, and are most likely to produce immediate benefits/results. The rationale for identifying these “low-hanging fruits” is that the sooner that quantifiable benefits of using ITS-generated data for operations improvement are demonstrated and disseminated, the sooner additional deployments will be stimulated. Any of these opportunities identified below can be developed into a Field Operational Test (FOT) with public and private partnership.

4.4.1 ADUS for Assessing Security Vulnerability of Highway Network

The terrorist attacks on September 11, 2001 were the first time that terrorists used transportation vehicles as weapons of mass destruction against the United States. Uncorroborated information suggests the possibility of additional terrorist attacks against our nation's transportation infrastructure such as the Golden Gate Bridge and the Bay Bridge in the San Francisco area, the Vincent Thomas Bridge at the Port of Los Angeles, and the Coronado Bridge in San Diego.

To prepare for these and other threats, it is critical to assess the vulnerability of our transportation infrastructure, identify the weak links, and develop strategies to minimize the vulnerability.

A digital multi-modal transportation network that is populated with archived data on traffic flow and speed, facility capability information, other traffic operation characteristics, and non-ITS traffic monitoring data can provide essential information to assess the vulnerability of the nation's transportation system and to identify the weak links. With suitable algorithms and software (many of which already exist), the *vulnerability*, *resilience*, and *redundancy* of our transportation system can then be assessed. Furthermore, this integrated database can be used to develop **beforehand** alternative strategies, and to evaluate the consequences and feasibility of these alternatives. For example, if a bridge(s) and a link(s) were to be closed or destroyed, do alternative, parallel routes exist to accommodate the lost service? How long will it be before these alternative routes reach their capacities? What will then be the alternatives to these alternative routes?

It should be emphasized that ADUS alone can not satisfy all of the information needs for an assessment of our transportation security vulnerability. However, when integrated with other data sources (e.g., highway monitoring data, remotely sensed data) and tools, ADUS can provide an indispensable base to do so.

4.4.2 ADUS for Performance Measures

The interest in the development and use of performance measures and performance-based planning and program development has increased dramatically to meet customer needs under different conditions. Performance measures have been used at several levels, ranging from day-to-day operations to long-term capital planning that enhances system operations. Link travel times, duration of congestion, reliability, level of service, seasonal road closures, recurring and non-recurring delays are some of the typical performance measures used to improve highway operation performance. As pointed out in a NCHRP report[4.10], "...*evaluating and improving system operations through performance measures can be challenging. Data collection and analysis demands can be overwhelming*...." Archived ITS-generated data on traffic, speed, incidents, weather, and work zone schedules offer unique opportunities to fill this data collection concern. However, it should be emphasized that ADUS can best be used in developing *facility-specific* performance measures due to the current limited number of traffic surveillance deployments.

4.4.3 ADUS to Manage Traffic Delay

According to recent research on traffic delay[4.11], it is estimated that about 2.3 billion vehicle-hours of delay per year on U.S. freeways and principal arterials are due to work zones, crashes, breakdowns, adverse weather, and sub-optimal signal timing. This estimate is reasonably close to an estimate of non-recurring traffic delay that was produced by the Texas Transportation Institute[4.12] which includes data from the 68 most congested cities. These results reveal the magnitude of the societal impact due to traffic delay. TTI further concluded that total

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4.10 Synthesis of Highway Practice 32-07. *Performance Measures of Operational Effectiveness for Highway Segments and Systems.* Terrel Shaw, Post Buckley Schuh & Jernigan, Tallahassee, FL. Completion date: November 2002.

4.11 Chin, S.M., Franzese, O., Greene, D.L., and H. L. Hwang. *Temporary Losses of Capacity Study.* ORNL/TM-2002/3. Oak Ridge National Laboratory, Oak Ridge, Tennessee. January, 2002.

4.12 Shrank, D., and T. Lomax. 2001. *The 2001 Urban Mobility Study.* Texas Transportation Institute, College Station, Texas. May 2001.

non-recurring traffic delay is greater than recurring delay.

A study of various archived ITS-generated data on traffic conditions, the duration and nature of the incidents, speed contours by time of day, and weather and road conditions will significantly increase knowledge about *facility-specific* inter-relationships between traffic patterns, speed profiles and the propensity of traffic delay. This information can help develop *proactive* and *adaptive* facility-specific strategies to reduce traffic delay. Further, this information can help inform the traveling public of the *anticipated* reliability status of the system at different times of the day.

4.4.4 ADUS for Planning and Managing Special Events

Planned and unplanned events are an important and frequent part of transportation system operations. In Los Angeles area alone, it is estimated that there are 1,500 special events annually. To optimize the performance of the transportation system during special events, transportation agencies plan and coordinate the delivery of transportation services and operations in advance.

As implemented by Caltran, archived freeway traffic data have been used, on an ad hoc basis, to manage and plan special events. One of the greatest benefits of archived data is the development of facility-specific traffic patterns (or “signatures”). If archived traffic data are used in conjunction with real-time traffic data and dynamic traffic routing tools, then plans and alternatives can be instantaneously developed to accommodate anticipated and non-anticipated losses of roadway capacity.

4.4.5 ADUS for Planning and Managing Unplanned Events

Unplanned events include the tragic events on September 11, 2001, natural disasters, and other catastrophes. In the development of evacuation plans, archived ITS-generated traffic data provide perhaps the most accurate information on typical traffic flow and on the probability of recurring and non-recurring traffic delays by time of day, not only on the evacuation routes but also on alterative routes. With this kind of information, it is then possible to examine beforehand the impacts and feasibility of alternative evacuation scenarios by conducting "what-if" analyses.

4.4.6 ADUS for 511 Information Validation

The success of any 511 deployments depends substantially on the validity and credibility of the information provided by 511. Information validation has largely relied on subjective engineering judgements, or on "borrowed" information. Moreover, even if data are collected, data quality is sometimes questionable. ADUS provides valuable historical data to develop trends, patterns, and acceptable data ranges which will in turn facilitate identification of questionable data before they are disseminated to the traveling public.

Furthermore, ADUS allows credible estimation of potential traffic delays under varying conditions. An additional benefit of ADUS is that these estimates can be enhanced on a continuous basis because of the fact that ADUS data are continuously added to the database from which the estimates are derived. Credible information on potential traffic delays gives the traveling public adequate lead way to effectively pre-plan or alter their travel.

4.4.7 ADUS for Adaptive Signal Timing Strategies

Centralized controlled signal timing on arterial roads can significantly improve the efficiency of traffic operations. Archived ITS-generated traffic data from arterials, in conjunction with existing signal timing, can be used to evaluate the impacts of various timing plans under varying conditions. Furthermore, archived ITS-generated traffic data permit the development of timing plans that are adaptive to the site-specific traffic patterns, and analysis of alternative timing scenarios.

As previously mentioned, any of these opportunities can be developed into an FOT with the goals of:

(a) identifying technical and institutional barriers to archiving, using, and sharing ITS-generated data;

(b) developing solutions to overcome these barriers;

(c) identifying issues pertinent to standards development;

(d) examining the feasibility of integrating ITS-generated data with data collected from traditional and emerging technologies (e.g., highway monitoring data, remotely sensed data);

(e) identifying and **quantifying** costs and benefits;

(f) disseminating lessons learned, and

(g) sharing the developed procedures and software in an open-source environment. Some examples of these procedures and software are: those developed to convert raw ITS-generated data into formats acceptable to existing and/or off-the-shelf data management or analysis software, check the quality of the data, impute missing data, correct questionable data, abstract information suitable for data analysis from “text” files, estimate potential recurring and non-recurring traffic delays, and other applications. The benefit of sharing these procedures and software in an open-source environment is that it reduces the “re-inventing the wheel” thus enabling more efficient use of resources.

5. PLANNING APPLICATIONS

The essence of the transportation planning process is the development of a comprehensive blueprint for the development and improvement of mass transit, highway, airport, seaport, railroad, bicycle and pedestrian facilities. Specifically, state and metropolitan planning organizations develop their blueprints by assessing their current conditions, system performance, and potential impacts of development/improvement alternatives. The assessments are based on the predicted future implications of these alternatives with regard to system capacity, travel demand, system condition, safety, economic conditions, population, and land use.

Therefore, accurate, timely and representative data are crucial to estimating current travel demand (passenger and freight movements combined), forecasting future demand, evaluating and projecting the societal and environmental consequences of various developments and projects, and monitoring the performance of the system(s). Roadway and traffic data are the focus of this Chapter from the perspectives of archiving and using archived ITS-generated data.

5.1 STATE-OF-THE-PRACTICE REVIEW

5.1.1 Archiving and Sharing ITS-Generated Roadway/Traffic Data

ITS-generated traffic and roadway data that are pertinent to transportation planning applications are: traffic volume, speed, and vehicle classification. Specifically, the data collected from the traffic surveillance component of Freeway Management Systems and Arterial Management Systems. Also, data used for electronic screening in the Commercial Vehicle Information Systems and Networks (CVISN) can supplement traffic surveillance data to better estimate vehicle classification data.

One hundred and six agencies responded to the Freeway Management Survey in both 1999 and 2000. Almost one in three responding agencies in 1999 did not collect any freeway data while this percentage increased to almost 40% in 2000 (Table 5.1). Data collected from this

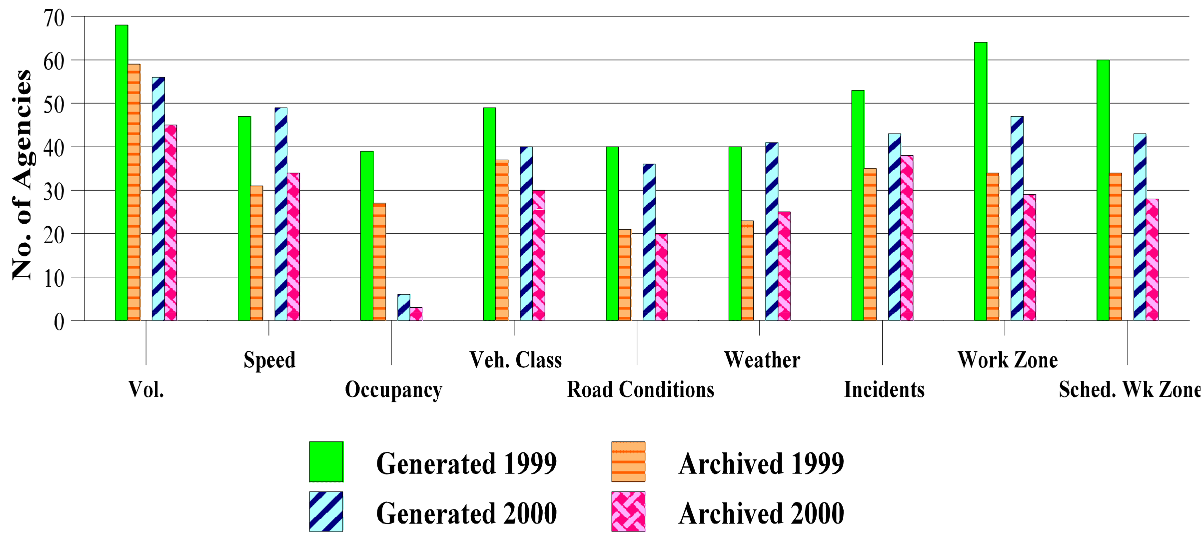
Table 5.1 Number of Agencies that Generated and/or Archived Traffic Data 1999 and 2000 ITS Deployment Tracking Surveys

Type of Data	1999		2000	
	Generated	Archived	Generated	Archived
Traffic volumes	68	59	56	45
Traffic speeds	47	31	49	34
Lane occupancy	39	27	32	26
Vehicle classification	49	37	40	30
Probe vehicles	5	3	N/A**	N/A**
Ramp queues	10	3	8	2
Ramp meter preemptions	1	1	2	0
Metering rate	12	6	12	6
Road conditions	40	21	36	20
Route designations	20	14	14	8
Weather conditions	40	23	41	25
Incidents	52	35	43	38
Current work zones	64	34	47	29
Scheduled work zones	60	34	43	28
Intermodal connections	3	3	2	2
Emergency/evacuation routes and procedures	29	22	19	16
Highway operations coordination information	30	18	22	16
Vehicle occupancy	N/A*	N/A*	6	3
Violation Rates for HOV lanes	N/A*	N/A*	2	2
Other	4	2	0	0
Agencies with none	32		40	

*These questions were not asked in 1999
**These questions were not asked in 2000

Freeway Management survey range from traffic volume, to information related to intermodal connections. By far the most commonly collected freeway data are: traffic volume, and information on scheduled work zones (Figure 5.1). The most common technique used to collect traffic data is loop detectors, followed by video imaging detectors. Figure 5.2 depicts the prominence of different techniques used to collect traffic data. It is obvious from this figure that

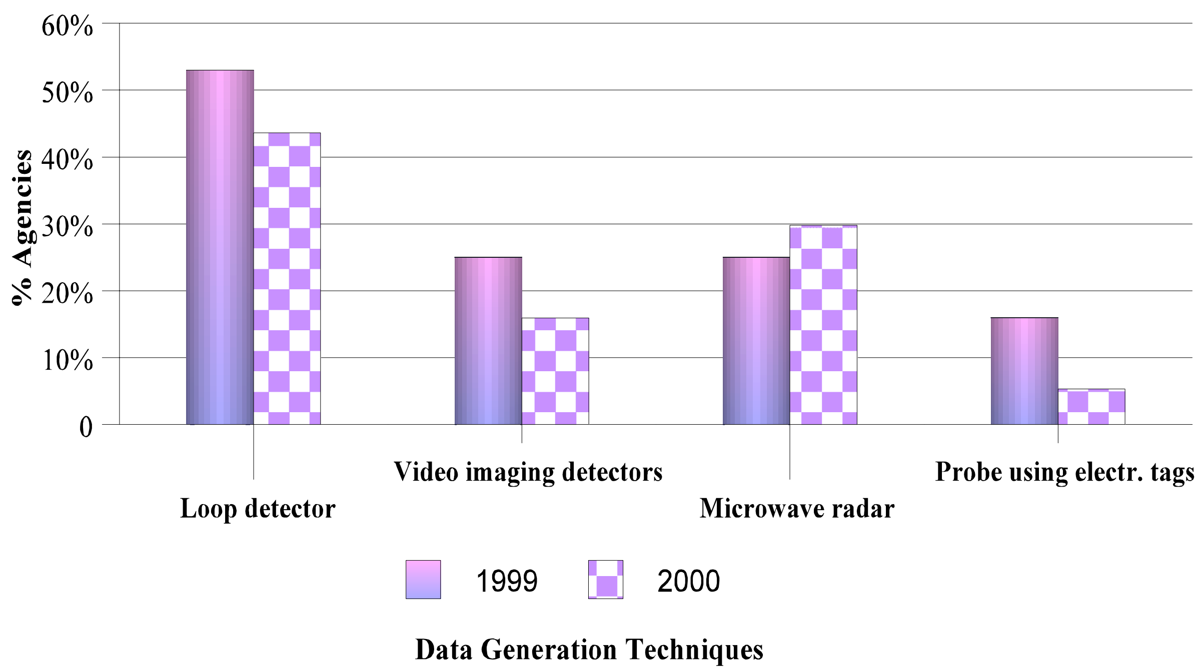
Figure 5.1 Data Generated and Archived from Freeway Management Systems
(Out of 74 Agencies Reported Data Generation and Archiving in 1999
Out of 66 Agencies Reported Data Generation and Archiving in 2000)



less intrusive technologies are becoming popular in collecting traffic data. Traffic volume and vehicle classification data are the two data elements that are most likely to be archived. Eighty-seven percent of the agencies in 1999 that collected traffic volume data also archive them. And, seventy-six percent of the agencies that collect vehicle classification data also archive them (Table 5.1). The most noteworthy observation is the fewer number of agencies that generate and archive lane occupancy data, declining from 39 agencies in the year 1999 to 6 in year 2000. We speculate that data reporting errors led to the downward trend from 1999 to 2000 in terms of fewer data elements being generated and/or archived.

Tables 5.2 and 5.3 show the propensity for data archiving in 1999 and 2000, with a significant downward trend. No agencies collect all seventeen data elements identified on the survey questionnaire. In 1999, one agency collected 14 of out the 17 data elements and it archived every data element collected. Overall, 31 of the 78 agencies in 1999 archived **all** of the

Figure 5.2 Techniques to Generate Traffic Data
1999 and 2000 ITS Deployment Tracking Surveys



traffic data collected (cells on the diagonal line) while the corresponding numbers are 19 out of 66 agencies in year 2000. Ten agencies in 1999 reportedly collected traffic data but did not archive any (the ì 0ì column).

Table 5.2 Distribution of Agencies by Number of Data Elements Generated and Number of Data Elements Archived
1999 ITS Deployment Tracking Survey

Number of Data Elements Generated	**Freeway Management Survey (74 Responses)**																	
	Number of Data Elements Archived																	
	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
17																		
16																		
15																		
14				**1**														
13					**1**	1									1			
12						**4**											1	
11								1	2			2	1				1	1
10								**4**							1		1	
9									**1**	1		1	1			2		
8										**5**		1	1			1		2
7											**2**	3		1		1	1	2
6														1	1	1		1
5													**7**		2	1		2
4														**1**				
3															**1**		1	1
2																**2**		1
1																	**2**	

Table 5.3 Distribution of Agencies* by Number of Data Elements Generated and Number of Data Elements Archived
2000 ITS Deployment Tracking Survey

Number of Data Elements Generated	**Freeway Management Survey (66 Responses)**																	
	Number of Data Elements Archived																	
	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
17																		
16																		
15															1			
14						1					1							
13					**1**													
12						**1**												
11								1	2	1	3	1	1					
10								**3**		1								
9										1		1				1		1
8										**3**	1		1		1			1
7											**3**	1		1		1		1
6													3	1		2	1	2
5															2	1	1	2
4															1		1	
3															**3**			
2																**2**		
1																	**0**	1
0																		

* Excludes agencies that archived more data elements than they actually collected.

5.1.2 Usage and Users of the Archived Freeway Data

Based on the tracking survey results, the media is the largest archived data requester/user, followed by state Departments of Transportation (Figure 5.3). The archived traffic data are primarily used for traffic analysis and planning (Figure 5.4). However, the specific applications of the analysis are unclear from the surveys. It is also unclear which of the users use which of the archived data and for what purpose.

Figure 5.3 Number of Agencies Responded to Freeway Data Request by Requesting Institute
1999 and 2000 ITS Deployment Tracking Survey

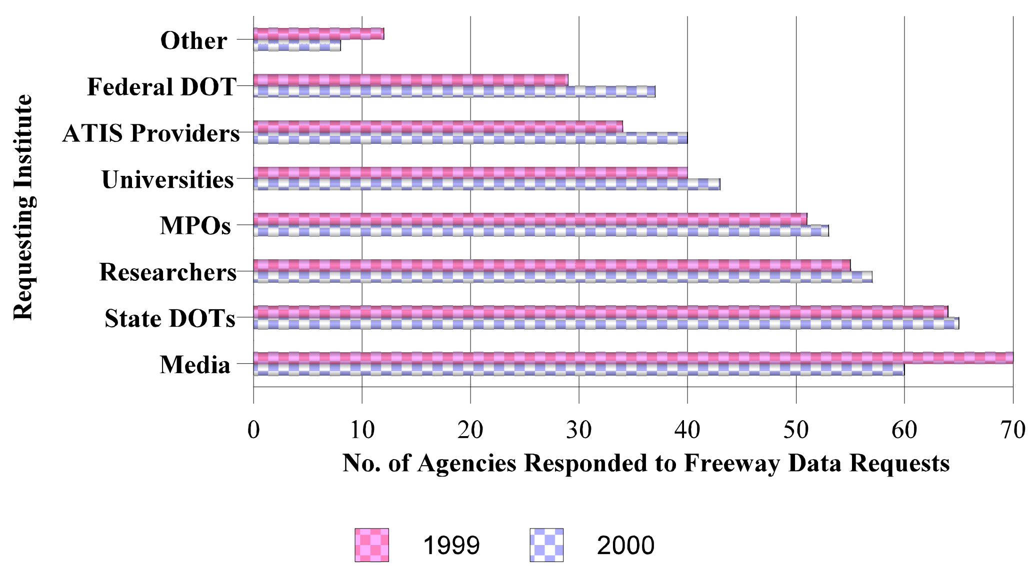
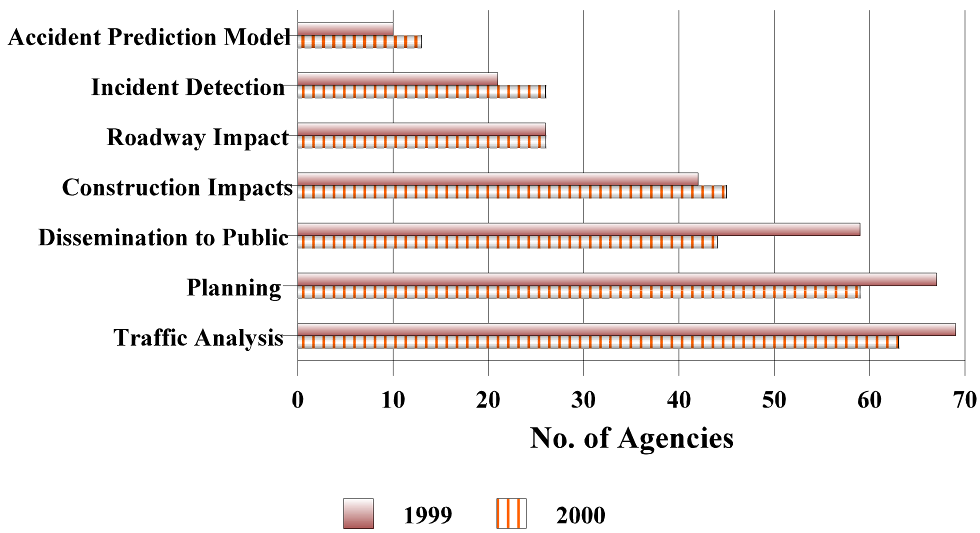


Figure 5.4 Archived Freeway Data Usage
1999 and 2000 ITS Deployment Tracking Surveys



5.1.3 Barriers to Data Archiving

To avoid reporting burden, only a limited number of agencies were contacted for questions more specifically related to data archiving. For those agencies that did not archive any data collected, the reasons given were: (1) lack of need to archive, and (2) lack of necessary hardware, storage capacity, and resources (either human or monetary) to archive. Lack of articulated needs was the overarching reason for those agencies that archived part, but not all, of the data elements.

5.2 CASE STUDIES OF PLANNING APPLICATIONS

The purpose of the case studies was to:

! gain better insight into why archived ITS-generated data are, and are *not*, used in terms of technological and institutional situations and barriers,

- identify additional opportunities for archiving and using ITS-generated data, and
- identify successful practices in archiving ITS data for transportation decision-making.

Specifically, the case studies addressed the following questions:

1. What data do ITS deployments generate?
2. How are data generated and archived?
3. Are the ITS-generated data shared?
4. If so, how, with whom and for what purposes?
5. Were there barriers to archiving and sharing the data? If so, what were they and how were they overcome?

It should be re-emphasized that this assessment only focuses on ITS deployments that have generated data that have the potential of being used in applications other than what was originally intended. This assessment has not attempted to identify ITS deployments that have not, but that could have, generated and archived data such as the I-95 Corridor FleetForward project, and the in-vehicle signing system for school buses at railroad-highway grade crossings. Specifically, the prerequisite for being selected to be a case study in this project was that an ITS system has to have been generating and archiving data.

ITS projects in two metropolitan areas were examined - Atlanta and Los Angeles. The rationale for selecting these two locations was because of their data archiving activities and the level of collaboration among local agencies and jurisdictions. However, this by no means suggests that no other areas are archiving and sharing ITS-generated data as extensively as these two areas. In fact, an increasing number of agencies and researchers have been using archived ITS-generated freeway data in the past two years to monitor their system performance.

5.2.1 Georgia Department of Transportation's NaviGAtor in Atlanta

NaviGAtor is designed to gather information from a variety of sources: a video monitoring and detection system, Highway Emergency Response Operators (HEROs) and the public. NaviGAtor links the Transportation Management Center (TMC) to the Transportation Control Centers (TCCs) of five surrounding counties (Cobb, Gwinnett, Clayton, Fulton and Dekalb), the City of Atlanta, and the Metropolitan Atlanta Rapid Transit Authority (MARTA), creating an intelligent transportation network spanning more than 220 miles.

5.2.1.1 System Description

The current level of coverage is about 220 miles of instrumented roadway including freeway and arterial streets monitored by the central TMC and satellite TCCs. The central TMC currently has 42 miles of instrumented freeway along Interstates 75 and 85 inside the Interstate 285 beltway. Additional 14 miles of instrumentation were deployed along the northern arc of the 285 beltway in July, 2001.

Atlanta's NaviGAtor system (which is operated by Georgia DOT) is highly integrated with other agencies. The central TMC is currently linked to the Traffic Control Centers (TCC) of 5 other counties: Clayton, Cobb, DeKalb, Fulton, and Gwinnette counties, plus the City of Atlanta and the Metropolitan Atlanta Rapid Transit Authority (MARTA). These county and city TCCs are used to manage arterial road systems, while the NaviGAtor TMC manages the freeways. All monitored data are shared between the centers so that the arterial TCCs can see the traffic conditions on the freeways, and conversely, the freeway TMC can see traffic conditions on the arterial streets. The NaviGAtor TMC acts as the main warehouse for stored data. However, it is not clear whether the city and county TCCs archived any of their data.

Some of the agencies that are currently integrated into the system are:

- Georgia Emergency Management Agency,
- Atlanta City Police Department,
- 911,
- Metropolitan Atlanta Rapid Transit Authority, and
- Georgia State Patrol, which is located in the same compound as the TMC. (Although not currently connected to the system, it will be connected in the near future.)

NaviGAtor uses the video monitoring and detection system (i.e., a camera-based system) to provide real-time images of road conditions. It serves as an incident verification tool. Installed on Interstates 75 and 85 are more than 317 fixed black-and-white Autoscope detector cameras that are spaced 1/3 of a mile apart, and 67 pan, zoom and tilt full color surveillance cameras spaced 2/3 of a mile apart. Information on average *speed*, *traffic volume, lane occupancy* and *vehicle classification* is collected from the Autoscope cameras. Video monitoring from the surveillance cameras allows the operators at the TMC to verify incidents, thus reducing response time, speeding up removal of incidents and minimizing congestion. The newly instrumented northern arc of I-285 added 114 additional fixed black and white cameras, and 36 color cameras. This brings the total to 103 pan, zoom, and tilt full-color cameras and 431 fixed black and white cameras.

Of these two types of camera, only data generated from the fixed black and white Autoscope cameras are archived. The color surveillance cameras provide views of the traffic for the authorities as well as for the public at large via the Internet. No information from the color surveillance cameras is archived.

A gyroscopic camera mounted on a helicopter is used for aerial monitoring. This aerial camera provides live video within a 50-mile radius of Atlanta, vastly increasing NaviGAtor's area of coverage.

The County and City TCCs use primarily loop detectors for traffic signal optimization on arterial streets. There are some surveillance cameras installed in order to view incidents but no data is generated from these cameras that can be archived.

5.2.1.2 Data Archiving

The Autoscope cameras gather data on a 20 second polling period. These data are then aggregated into 15-minute logs, which are stored onto an internal server for 30 days. Each month, the data are compressed, written and archived to a CD. When uncompressed, this system generates 4.6 megabytes of data on a daily basis[5.1]. Data have been archived for the past 4 years.

The Autoscope camera images are interpreted by software at the TMC. Speed and vehicle counts are interpreted directly while the other data elements are derived using mathematical algorithms. The following is a list of data elements that are generated by the NaviGAtor freeway system for each lane of the freeway:

- Speed,
- Vehicle Counts,
- Lane Occupancy,
- Vehicle Classification
  - Auto – Less than 25 feet,
  - Light Truck – 25 to 49 feet, and
  - Tractor Trailer - ≥ 50 feet.

5.1 Based on the original 42 miles of instrumentation along interstates 75 and 85.

- Headway: a measurement of the average gap between vehicles,
- Flow Rate: expressed as number of vehicles per lane per hour, reflecting lane capacity,
- Level of Service: Graded A through F, where A= light traffic, and F= gridlock,
- Presence of stopped vehicles, and
- Wrong way vehicles

Georgia DOT has the ownership of the data stored at the TMC. Of these data elements, only data on traffic volume, speed and lane occupancy are archived on a fifteen-second interval. Figure 5.5 illustrates an example of these archived data. These archived freeway data are stored in a format which facilities use for further analyses.

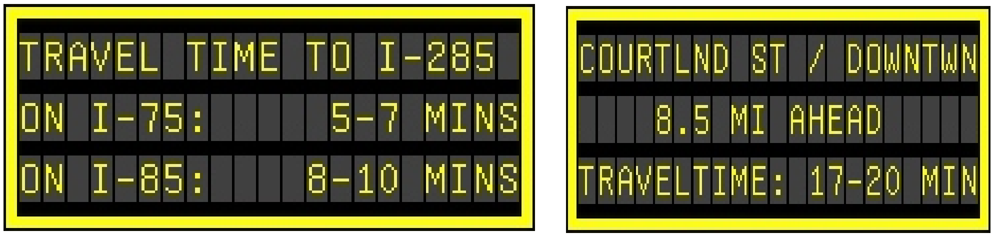
Although the information disseminated by Variable Message Signs (Figure 5.6) is not archived at the present time, the availability of these data in real time on the Internet suggests that it can easily be archived. The usefulness of this information, by itself, is probably of little value. However, if integrated with sensor, roadway and weather information, it could provide valuable insights in the nature of locale-specific congestion and delay, and the effectiveness of different control strategies.

Unfortunately, there is no convenient way for sharing archived data. When archived data are requested, Georgia DOT burns a CD that contains the data in compressed .txt format. The data are uncleaned and contain time stamps and camera ID numbers, along with their associated data elements.

Figure 5.5 An Example of Archived Freeway Data from NaviGAtor

```
#########################################################################
# NAVIGATOR Detector Data Archive
# Date: 21 January, 1999
# Format: One sample per line, fields separated by '|'
#       field 1: Detector ID
#       field 2: Sample Start time (MM/DD/YYYY HH:MM)
#       field 3: Total Volume
#       field 4: Average Speed
#       field 5: Average Occupancy
# Note: due to unavoidable technical difficulties, the
#     NAVIGATOR system may not have been able to
#     record some detector data.  sorry.
##########################################################################
#####
287|01/21/1999 00:00|53|78.45|2.44
288|01/21/1999 00:00|94|76.08|4.84
289|01/21/1999 00:00|52|66.21|2.65
290|01/21/1999 00:00|40|61.40|2.27
301|01/21/1999 00:00|50|57.82|2.74
302|01/21/1999 00:00|85|61.98|3.93
303|01/21/1999 00:00|90|64.71|4.18
304|01/21/1999 00:00|48|61.25|2.70
347|01/21/1999 00:00|24|55.21|1.08
348|01/21/1999 00:00|105|61.50|5.26
                    •
                    •
                    •
287|01/21/1999 00:15|42|76.21|2.13
288|01/21/1999 00:15|86|72.41|5.16
289|01/21/1999 00:15|40|66.07|2.18
290|01/21/1999 00:15|23|61.78|1.48
301|01/21/1999 00:15|45|59.76|2.44
302|01/21/1999 00:15|78|62.08|3.64
303|01/21/1999 00:15|73|64.16|3.27
304|01/21/1999 00:15|35|66.23|1.50
347|01/21/1999 00:15|29|57.62|1.17
348|01/21/1999 00:15|95|61.85|4.49
```

Figure 5.6 Examples of Archived VMS Message



Accommodating data requests can be extremely time consuming, which has prompted Georgia DOT to consider several options:

- Make the data available **online** for the public to query using some sort of relational database. This idea is under serious consideration and is likely to happen in the near future.
- Another option being considered is a **data broker** who could take the entire data management responsibility off Georgia DOT. This option is still in its infancy and faces many institutional barriers such as how to use taxpayer money to contract out to a private company. One possible solution might be a mutually beneficial arrangement where control of the data management is given to a company or an organization, but no funds are passed from Georgia DOT to the data broker. The data broker can then provide value added to the data and sell it.

5.2.1.4 Barriers and Lessons Learned

Although freeway data are archived and shared with the planning communities, Georgia DOT speculates that the archived data have not been fully utilized because of incompatible data format and data aggregation.

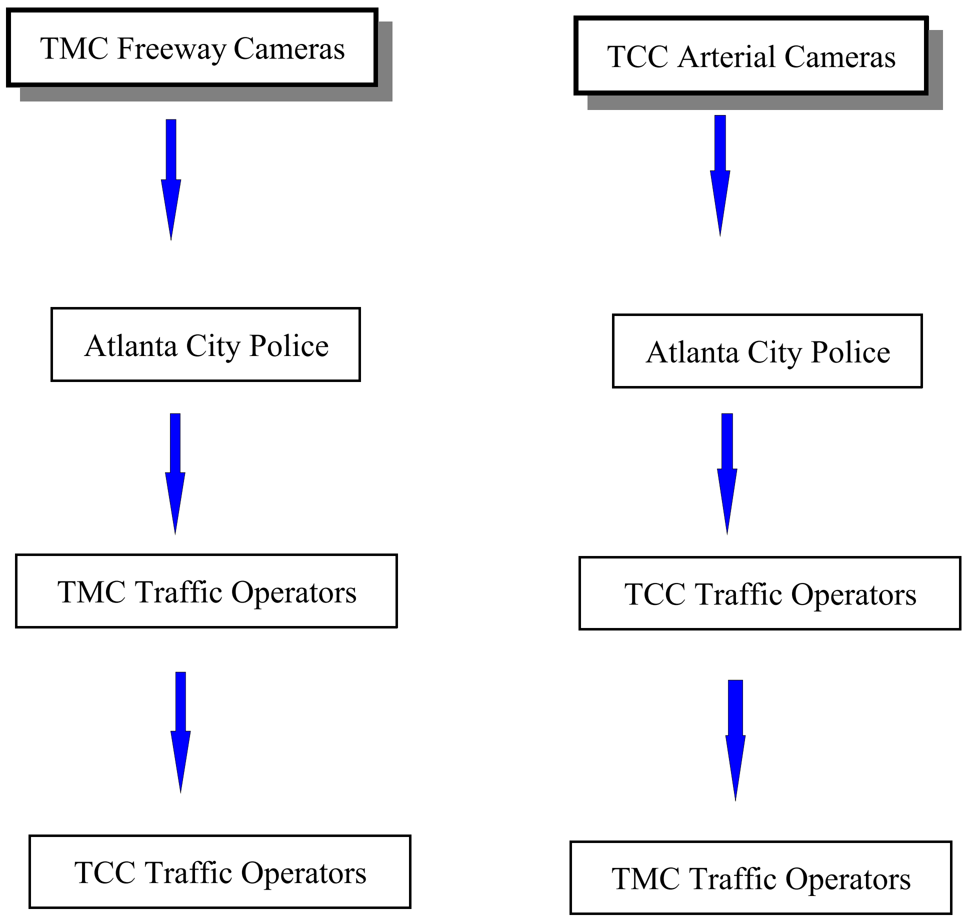
Initially, there was much concern and debate over the development of an integrated system with shared control of equipment, especially the pan, tilt, zoom, color surveillance cameras. Many were concerned that sharing the control of cameras might conflict with the different objectives of different agencies. In reality, this concern has not been substantiated. Nonetheless, a camera control hierarchy has been developed.

Although the surveillance cameras can be controlled by many different groups in the NaviGAtor system, Atlanta City Police have priority control of these cameras. This policy intends that if there are other users on the system trying to adjust the same camera simultaneously, the system defers priority control to the City Police. Otherwise, anyone in the NaviGAtor network with a set of controls can adjust the cameras. After the City Police, the NaviGAtor TMC has priority over their freeway cameras, and the various TCCs have priority over their arterial cameras. The diagram depicting the control hierarchy is illustrated in Figure 5.7.

Data archiving and sharing of the archived data transpire despite the fact that ADUS has yet to be part of the NaviGAtor's system architecture. At the time of the interview, a plan was underway to use NaviGAtor data to meet reporting needs required by the Highway Performance Monitoring System (HPMS).

The following case studies focus on traffic operations and transportation planning in the Los Angeles metropolitan area. Experience and plans in archiving ITS-generated data and using the archived data in three agencies were analyzed: (1) the City of Los Angeles' Department of Transportation (LADOT); (2) Los Angeles Metropolitan Transportation Agency (LAMTA), and (3) California Department of Transportation (CalTrans). The rationales to include these agencies in our case study are that: (1) they each appear to have different perspectives on data archiving and sharing

Figure 5.7 Color Camera Priority Control Hierarchy
Atlanta's NaviGAtor System



data, and (2) there is, or appears to be, an ongoing plan to eventually integrate almost all ITS systems in the southern California areas into an integrated system. The extent of archiving data and use of archived data varies from one agency to the next. For example, although there were plans to implement ADUS, little ADUS was actually implemented in LAMTA[5.2]. Nonetheless, there was consensus among all agencies visited that ADUS has significant benefits.

5.2.2 Automated Traffic Surveillance and Control (ATSAC) System

5.2.2.1 System Description

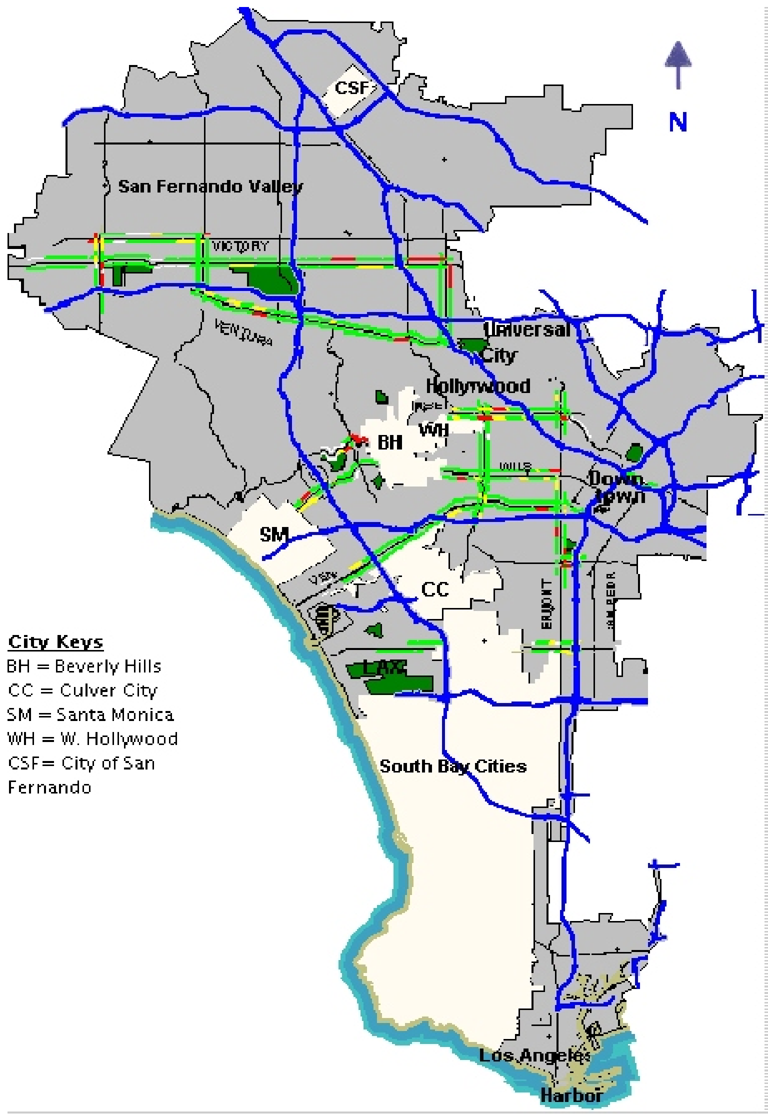
The City of Los Angeles Department of Transportation (LADOT) has centralized authority over the planning and operation of the City's street system - which consists of 6,400 street miles, 1,400 major and secondary miles, 5,000 collector and local miles, 40,000 intersections and 160 freeway miles. Among its many other responsibilities, LADOT is responsible for the installation and maintenance of traffic signals, and other traffic control devices; and administers the City's transit programs. LADOT develops and uses the Automated Traffic Surveillance and Control (ATSAC) System to optimize the capacity of its existing highway system by reducing delay and minimizing traffic congestion. It is estimated that ATSAC reduces travel time of recurrent traffic by 12%, intersection delay by 32%, and intersection stops by 30%[5.3].

The Automated Traffic Surveillance and Control (ATSAC) system, a computer-based traffic signal control system, is used by the City of LA to optimize the capacity of its existing arterial systems (Figure5.8). ATSAC monitors traffic conditions and system performance. Loop detectors imbedded in the arterial roads detect the passage of vehicles, vehicle speed, and the level of congestion. If required, the signal timing is either automatically changed by the ATSAC computers or manually changed by the operator to achieve better traffic flow.

5.2 The Los Angeles County Metropolitan Transportation Authority (MTA) is unique among the nation’s transportation planning agencies in that it serves as transportation planner and coordinator, designer, builder and operator of LA County’s transportation system. MTA was identified as a case study for its role in the Southern California Priority Corridor Showcase project, and its role as a potential ADUS user.

5.3 http://www.lacity.org/LADOT/

Figure 5.8 LADOT's ATSAC Coverage



To date, ATSAC operates 11,000 loop detectors and has been deployed in 2,449 of the 4,285 signalized intersections. Funding has been committed to instrument additional intersections, leaving only 25% of the city's intersections without instrumentation. To supplement the information from loop detectors, closed-circuit television (CCTV) surveillance equipment has been installed at critical locations throughout the city. At the time of the site visit (February 2000), there were 150 CCTV installed.

ATSAC-Generated Data

Loop detectors generate data on vehicle counts, speed, and lane occupancy. Real-time traffic conditions are posted on the web[5.4]. Congestion level is determined by speed thresholds. For example, congestion is considered "heavy" when the average vehicle speed fails below 10 miles per hour (mph), "moderate" between 10 and 20 mph, and "none" above 20 mph. No data are generated from the CCTVs. Although no incident information is generated from ATSAC, the California Highway Patrol (CHP) posts incident information on its' Traffic Incident Information Page[5.5]. This page contains all incidents to which CHP responded. Hot spots, the most serious incidents, are identified on real-time basis. Information generated for each incident includes: the area, type (e.g. "Traffic Collision-Ambulance Responding"), location, time, additional details, and CHP's responses of the incident. Figure 5.9 illustrates a few examples of the incident report. These incidents are geo-coded on a GIS platform (Figure 5.10). Although incident data are not archived at the present time, it could easily be done especially with the "text" format of the data.

5.2.2.2 Archiving, Sharing and Uses of Archived ATSAC Data

Traffic data generated from ATSAC are archived only for one week. The system automatically over-writes the old data after a week. Requests on archived data are addressed on

5.4 http://trafficinfo.lacity.org/

5.5 http://cad.chp.ca.gov/

Figure 5.9 Examples of Incident Report Posted on the Web

Type	Traffic Hazard
Location	**E HOLT AV ONR E at to I10**, Baldwin Park (Los Angeles County), California
Description	7:27AM PLS ROLL FSP FOR A GRN FORD SW BO ENG 7:27AM CHP Unit On Scene
Advise	Drive carefully
Reported by	CHP on October 08, 2001 07:27AM PDT
Expires	October 08, 2001 07:53AM PDT

Type	Traffic Hazard
Location	**I10 E at just west of BALDWIN AV**, East Los Angeles (Los Angeles County), California
Description	
Advise	Drive carefully
Reported by	CHP on October 08, 2001 07:25AM PDT
Expires	October 08, 2001 07:53AM PDT

Type	Structure or Grass Fire
Location	**I210 W at at LOWELL AV**, Altadena (Los Angeles County), California
Description	7:29AM INFO FOR CALTRANS - THERE IS A WATER PIPE WITH A LARGE LEAK IN IT HERE - LOWELL ONR TO WB 210 7:24AM POSS BRUSH FD, SMOKE COMING FRM RIGHT SIDE, 1039 GLENDALE FD 7:27AM CHP Unit On Scene
Advise	Drive carefully
Reported by	CHP on October 08, 2001 07:21AM PDT
Expires	October 08, 2001 07:53AM PDT

an individual basis. For example, Southern California Association of Governments (SCAG) uses ATSAC's traffic volume information to validate results from its travel forecast models. A contract was put in place for LADOT to archive and reformat the traffic data.

Figure 5.10 An Example of CHP Traffic Incident Web Page

Source: http://cad.chp.ca.gov/

In addition to outside users (e.g., SCAG), LADOT uses the archived ATSAC data to identify typical traffic patterns ("signatures"). Traffic surveillance data collected from surface streets impose a challenge different from those brought about by the freeway traffic data. Unlike freeway systems, no loop detectors are placed on curve lanes, thereby underestimating traffic volume. Although not a barrier to archiving traffic data, this is definitely a challenge for the proper use of the data.

5.2.2.3 Barriers, Lessons Learned, and Potential of Archived ATSAC-Generated Data

ATSAC officials believe that any long-term data archiving needs first to overcome storage limitations. To date, ATSAC data amount to 76MB per day. Their second concern about data archiving is the challenge to make data accessible in a reasonable time frame. To make ATSAC more useful for planning purposes, ATSAC data should be integrated with data from other sources (e.g., weather).

Although little is occurring right now at ATSAC on data archiving and data sharing, the potential of the archived data is considerable. For example, the LADOT, in collaboration with the Los Angeles County Metropolitan Transportation Authority (MTA), is implementing an advanced transit project - the Transit Priority System (TPS)[5.6]. This project is designed to improve the on-time performance of metro buses by adjusting the signal timing at intersections for buses as they approach the intersection. A transponder mounted underneath a bus communicates with the ATSAC loop detectors imbedded in the roadway. Traffic signal priority is provided to a particular bus only if the bus is running behind schedule. If data generated from this project are archived, they can provide the information needed to develop plans for transit operations without impacting street traffic.

5.2.3 CalTrans District 7

5.2.3.1 System Description

CalTrans District 7 is the state transportation department that constructs and maintains the California state highway and freeway system in Los Angeles and Ventura Counties (Figure 5.11). Specifically, it manages 909 freeway and highway miles in LA County, and 273 freeway and highway miles in Ventura County. On a typical day, these miles carry an average of 90 million vehicle miles traveled (VMT) per day.

Loop detectors are installed every ½ mile. Data on V(olume), O(ccupancy), and S(peed) are generated. The 30-second data are archived for thirteen months. In addition to the loop detectors, more than 20,000 CCTVs are installed. However, no video data are archived.

5.6 Hu, K., Skehan, S., and Gephart, R. "Implementing a Smart Transit Priority System for Metro Rapid Bus in Los Angeles." Presented at the 80th Annual Transportation Research Board Meeting. Washington, D.C. January 2001.

Figure 5.11 Area Coverage of CalTrans' District 7

5.2.3.2 Archiving, Sharing and Uses of Archived Data

Lane-specific VOS data that are archived on a stand-alone server are accessible by University of California, Berkeley to perform the California Transportation System Performance Measures Project (PeMs).[5.7] This project assists Caltrans Traffic Operations and Traffic Operational Centers to manage traffic operations. Caltrans' primary goal in using these archived data is to measure the performance of the freeway system and to identify recurrent congestion. Parameters such as Vehicle Miles Traveled (VMT) and Vehicle Hours Traveled (VHT) are calculated based on data collected from each loop detector. These are archived in PATH's website.

Furthermore, CalTrans uses archived traffic volume data for special event planning, and

[5.7] Headed by Professor Pravin Varaiya, UC Berkeley.

archived speed profiles for incident detection. The latter is still somewhat ad hoc. CalTrans staff recommend the use of Common Object Request Broker Architecture (CORBA) to facilitate data sharing. No video images are archived due to the privacy concern. Archived ITS-generated data could be more widely used and many parts of the agency could benefit from ADUS.

5.2.4 Michigan ITS Center and Michigan Department of Transportation

5.2.4.1 System Description

The Michigan Intelligent Transportation Systems Center (MITS Center) oversees a traffic monitoring system that covers 180 miles of Detroit area freeways. The daily traffic volumes on this system range from 80,000 to 190,000 vehicles on 6 to 12 lane facilities. These conditions make mainline traffic counting nearly impossible.

This system includes 24 television monitors, 155 CCTV cameras, 57 changeable message signs, 60 ramp metering locations, 2,600 inductive vehicle detectors, and a communications system consisting of fiber optics, microwave, spread spectrum radio, and coaxial cable.

5.2.4.2 Data Archived

About half of the vehicle detectors are at one-third mile spacing with one detector for each lane. The remaining detectors were installed with 2 detectors for each lane with a two-mile spacing. Data collected these detectors include: traffic volume, speed, lane occupancy percentages, and equipment failure rates. These data are collected in minute increments for each lane and archived by the Center. Lane-specific volume data are then summarized into hourly totals. This information for each location is then consolidated into a daily spreadsheet file which is electronically transmitted to Transportation Planning Bureau on a monthly basis.

5.2.4.3 Use of Archived Data

The Transportation Planning Bureau uses the archived volume data to produce Average

Annual Daily Traffic (AADT) estimates for the Detroit area. Data are also used to analyze trends for future planning.

5.2.5 Other ADUS Applications

In addition to the aforementioned case studies, there are currently a significant number of ADUS planning applications. For example, archived traffic volume data are generated by Maryland's Department of Public Works and Transportation. These data are then archived and used by Maryland's Department of Park and Planning for traffic modeling to forecast future traffic volumes. Furthermore, these data are also being used to produce network volume maps, model calibration databases, and alternative network testing. Another example is the Mitretek work that extracts real-time traffic condition data from various websites every five minutes. It uses these data to assess the on-time reliability impacts of Advanced Traveler Information Services (ATIS). Finally, researchers at the Washington State Transportation Center use data archived from multiple sources (e.g., CVISN truck tags, GPS devices, freeway loops, other traffic counters, and transit vehicle information) to create a complete picture of congestion and of its effects on trucking movements in the Seattle metropolitan area. It should be emphasized that these examples are not by any means an exhaustive list. .

5.3 BARRIERS AND SOLUTIONS

The institutional and other barriers associated with implementing ADUS are largely the same among the different ITS applications. These common barriers such as cost, proprietary rights, data issues, politics, and a lack of understanding or knowledge about ADUS are covered in further detail in Chapter 2.

Beyond these common barriers, the archiving of roadway and traffic data is being held back by a difference in perspective between data producers (in this case, the TMCs) and data users (in this case, the planners). People working in traffic management centers are forced to think in terms of hours and minutes, while metropolitan planners think in terms of months and years. This difference in perspective makes it more difficult to implement ADUS planning applications. One possible solution to bridge this gap is to demonstrate the value of using archived data to improve operations. For example, an analysis of historical traffic patterns and signal timing can help develop proactive signal timing strategies that are sensitive to the temporal patterns of the traffic (detailed in Section 4.4). A number of new initiatives by the Federal Highway Administration have recognized the need for additional data to improve operations.

5.4 POTENTIAL OF ARCHIVED DATA

The potential is immense for using archived data to meet planning data needs. However, it has been emphasized in the literature that the greatest benefit of ITS-generated data is perhaps when they are integrated with traditional data, for example, to broaden geographic coverage and to increase information reliability. An example of such data integration is the Washington State Transportation Center's study on measuring truck performance. That said, the question of how to integrate archived data and traditional data becomes considerably more imperative than the questions of how to archive data and how to use the archived data. Our attempt to identify potential uses for archived data does not deal with the challenges of data integration. As such, our assessments could appear to be overly optimistic and premature at this point (Table 5.4). Also included in Table 5.4 are the potential of archived data to meet federal reporting requirements.

In addition to the general potential opportunities outlined in Table 5.4, more specific ones are identified. These opportunities are, or appear to be, practically feasible, can be quickly deployed, and are most likely to produce immediate benefits/results. The rationale for identifying these "low-hanging fruits" is that the sooner that quantifiable benefits of using ITS-generated data for operations improvement are demonstrated and disseminated, the sooner additional deployments will be stimulated.

Table 5.4 Potential of Archived Freeway and Arterial Traffic Data

For Data Elements Outlined in *Freeway Management* Survey and *Arterial Management* Survey		
	If data are collected and archived, it could help address the following issues:	**If data are collected & archived, it could potentially help meet the following federal data reporting requirements:**
Traffic volumes	• Estimate construction impacts • Develop traffic forecast for planning purposes • Provide input to dynamic traffic assignment • Evaluate effectiveness of different traffic management strategies • Quantify benefits of ITS deployments • Monitor performance measures (i.e., travel time, hours of vehicle delay) when coupled with other ITS-generated data	HPMS: • Complement Automatic Traffic Recorder data to better AADT estimates • Complement ATR data to develop more accurate adjustment factors FARS: • Provide actual traffic conditions at the time of crash

For Data Elements Outlined in *Freeway Management* Survey and *Arterial Management* Survey		
	If data are collected and archived, it could help address the following issues:	**If data are collected & archived, it could potentially help meet the following federal data reporting requirements:**
Traffic speeds	• Monitor performance measures (i.e., travel time, , hours of vehicle delay) when coupled with other ITS-generated data • Evaluate traffic-flow control strategies • Evaluate speed impact on incidents • Evaluate speed impact on emissions	FARS: • Provide traffic speeds at the time of crash
Lane occupancy	• Estimate construction impacts	
Vehicle classification	• Provide limited classification data. • When coupled with volume, speed data and time of day information, vehicle classification data enhance emission estimates.	HPMS: • Validate Automatic Traffic Classification (ATC) data. • When coupled with traffic load data, ITS-generated vehicle classification data can be used to evaluate pavement designs.
Probe vehicles	• Validate ITS-generated data.	

For Data Elements Outlined in *Freeway Management* Survey and *Arterial Management* Survey		
	If data are collected and archived, it could help address the following issues:	**If data are collected & archived, it could potentially help meet the following federal data reporting requirements:**
Turning movements	• When coupled with phasing and cycling lengths, turning movement data can be used to evaluate different strategies of traffic signal on congestion.	
Phasing/Cycling lengths	• When integrated with turning movement data, phasing and cycling lengths can be used to evaluate different strategies for traffic signal on congestion.	
Queues	• Quantify queuing impact on congestion so as to better develop different traffic controls.	
Ramp queues	• Quantify ramp queuing impact on congestion so as to better develop ramp metering strategies.	
Ramp meter preemptions	• Evaluate the effectiveness of ramp metering strategies and the impacts of these strategies on arterial traffic	

For Data Elements Outlined in *Freeway Management* Survey and *Arterial Management* Survey		
	If data are collected and archived, it could help address the following issues:	**If data are collected & archived, it could potentially help meet the following federal data reporting requirements:**
Metering rate	• Evaluate benefits of different metering rates on congestion management controls.	
Road conditions	• Provide foundation for better and more comprehensive understanding of how road conditions influence traffic flow.	FARS: • Provide actual conditions of the road at the time of the crashes.
Weather conditions	• Provide foundation for better and more comprehensive understanding of how weather conditions influence road conditions, and consequently, traffic conditions, congestion and occurrence of incidents.	FARS: • Provide actual weather conditions at the time of the crashes.
Incidents	• Evaluate benefits of traffic control strategies (including ITS programs) on incident prevention.	
Current work zones	• Identify the most effective measure to avoid work zone congestion.	
Scheduled work zones	• Better plan to avoid work zone hazards and congestions.	

For Data Elements Outlined in *Freeway Management* Survey and *Arterial Management* Survey		
	If data are collected and archived, it could help address the following issues:	**If data are collected & archived, it could potentially help meet the following federal data reporting requirements:**
Intermodal (air, rail, water) connections	• Provide data to identify intermodal bottlenecks. • Help develop solutions for intermodal bottlenecks.	
Emergency/evacuation routes & procedures	• Develop *dynamic* evacuation routes/procedures when coupled with traffic volume, emergency vehicles signal preemptions, road conditions and current weather conditions.	
Emergency vehicles signal preemption	• Develop *dynamic* evacuation routes/procedures when coupled with traffic volume, emergency route designations, road conditions and current weather conditions.	
Highway operations coordination information	• Evaluate the benefits of information coordination on improving operations	
Transit vehicle signal priority	• Develop congestion management and incident management strategies that are sensitive to the impact of transit vehicles.	

5.4.1 ADUS for Urban Travel

Monitoring urban travel has been an immense challenge. Our previous study has demonstrated two specific benefits of using the archived ITS-generated traffic data in helping address this challenge[5.8]. First, ITS data can supplement the traditional data so that more reliable traffic estimates can be developed. Second, ITS data can be used to calculate adjustment factors that are more reliable than those calculated based on a limited number of continuous counters. Based on these findings, it is conceivable that the ITS-generated traffic counts data can significantly improve the traffic monitoring programs in urban areas.

5.4.2 ADUS for Data Reporting

Many of the planning organizations have the responsibility of meeting mandatory data reporting requirements. The task could be extremely tedious and sometime suffers from the lack of sufficient data. The ability of ADUS in helping meet these requirements seems obvious. However, the success of accomplishing this task depends on the integration of ITS generated data and non-ITS generated data, the extraction of needed information from ITS deployments, and the conversion of this extracted information to conform to existing software and reporting formats.

5.4.3 ADUS for Spatial Movements of Travel Demand

The assignment of both passenger and freight movements to transportation networks is an essential element of the transportation planning process. It helps evaluate the social, environmental, and economic impacts of various policies and programs. Information on the trip origins and destinations has been extremely difficult to collect. Data from the on-board GPS units in conjunction with the archived traffic surveillance data and electronic toll data have the potential to meet this data need. That said, a feasibility study is imperative.

[5.8] Hu, P., Goeltz, R., Schmoyer, R. Proof of Concept of ITS as An Alternative Data Resource: A Demonstration Project of Florida and New York Data. Prepared for the Federal Highway Administration. Oak Ridge National Laboratory. September 2001.

5.4.4 ADUS for Performance Measures

The interest in the development and use of performance measures and performance-based planning and program development has increased dramatically to meet customer needs under different conditions. Performance measures have been used at several levels, ranging from day-to-day operations to long-term capital planning that enhances system operations. Link travel times, duration of congestion, reliability, level of service (LOS), seasonal road closures, recurring and non-recurring delays are some of the typical performance measures used to improve highway operation performance. As part of the rationales for a NCHRP report[5.9], "*...evaluating and improving system operations through performance measures can be challenging. Data collection and analysis demands can be overwhelming....*" Archived ITS-generated data on traffic, speed, incidents, weather, and work zone schedules offer unique opportunities to fill this data collection concern. However, it should be emphasized that ADUS can best be used in developing *facility-specific* performance measures due to the current limited number of traffic surveillance deployments.

5.9 Synthesis of Highway Practice 32-07. *Performance Measures of Operational Effectiveness for Highway Segments and Systems.* Terrel Shaw, Post Buckley Schuh & Jernigan, Tallahassee, FL. Completion date: November 2002.

6. HIGHWAY SAFETY APPLICATIONS

This Chapter focuses on highway-safety discussions primarily on highway-rail grade crossings, pedestrian and bicycle safety, intersection safety, speed management, and work zone safety. As such, the opportunities for ADUS highway safety applications discussion in this report are those that can contribute to addressing issues facing the aforementioned safety areas. The opportunities for ADUS public safety applications and transit safety and securing application are discussed in chapters 4 and 7, respectively.

Highway safety is perhaps the area that is targeted the least in terms of data archiving. Nonetheless, because highway safety is a complex interaction among vehicles, roadways, environments and drivers, highway safety is also the area that will benefit the most from data archiving. Since highway safety transcends geographic boundaries (metropolitan vs. rural), data archived from almost any of the ITS infrastructure components (e.g., traffic surveillance) can be used to meet some of the data requirements in highway safety applications. For example, volume data collected from an ITS traffic surveillance project can be used to estimate accident exposure by time of day and day of the week. Another example is archived speed data which, in conjunction with information on highway geometry and weather, can be used to estimate the propensity of incidents or accidents. That said, data integration becomes ever more imperative in highway safety applications.

6.1 STATE-OF-THE-PRACTICE REVIEW

Almost all of the data elements collected by the Freeway and Arterial Management Surveys can be used to fill data gaps in highway safety, particularly the exposure aspects of highway safety. From the highway safety perspective, exposure information categorized by different vehicle types is equally important to information on overall vehicle exposure.

Based on the information collected from the ITS Deployment Tracking Surveys, by far the most commonly collected freeway data are: traffic volume, and information on scheduled work zones (Figure 6.1). The most common technique used to collect traffic data is loop detectors, followed by video imaging detectors. Figure 6.2 depicts the prominence of different techniques used to collect traffic data. It is obvious from this figure that less intrusive technologies are becoming popular in collecting traffic data. Traffic volume and vehicle classification data which are essential in deriving vehicle-type specific exposure data are the two data elements that are most likely to be archived. Eighty-seven percent of the agencies in 1999 that collected traffic volume data also archive them. And, seventy-six percent of the agencies that collect vehicle classification data also archive them (Table 6.1).

Other data elements specifically pertinent to highway safety are:

- Information on current and scheduled work zones. Almost three quarters of the agencies that collected this information archive it.
- Weather and roadway conditions. Weather conditions and road conditions are archived by at least half of the agencies that collect/report weather and road conditions as part of their Freeway Management Systems as well as their Arterial Management Systems.
- Information on ramp metering strategies help understand the propensity of side swipes and rear-end collisions on ramps.
- Data archived on emergency responses and emergency vehicle signal preemption provide a foundation to evaluate the effectiveness of emergency management controls in saving lives.
- Information on traffic signal controls (turning movements, phasing and cycle lengths and queues) advances knowledge about the causes of intersection accidents.
- Pedestrian and bicycle traffic at intersections.

Figure 6.1 Freeway Data Generation and Archiving
(Out of 74 Agencies Reported Data Generation and Archiving in 1999
Out of 66 Agencies Reported Data Generation and Archiving in 2000)

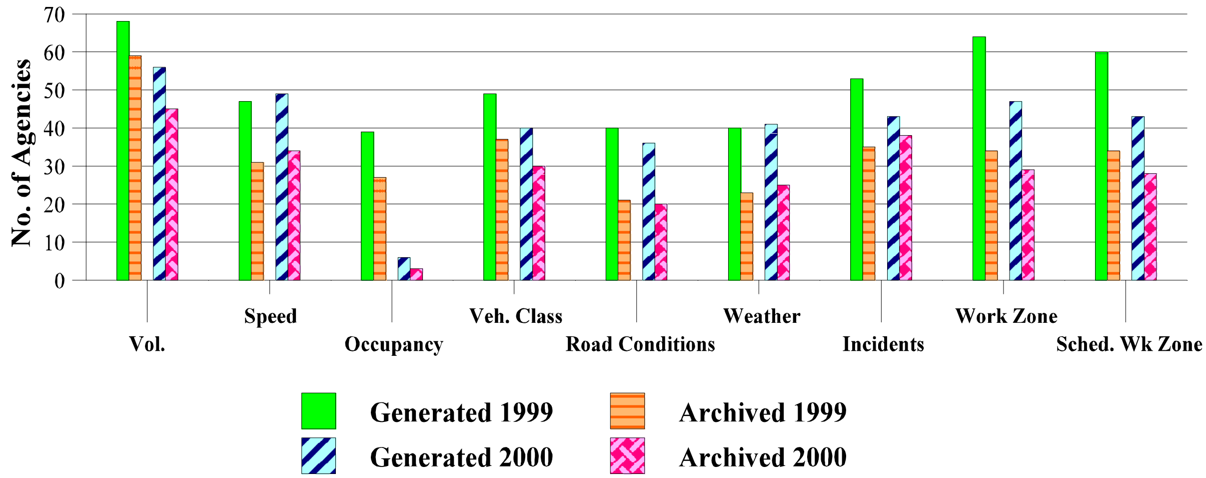


Figure 6.2 Techniques to Generate Traffic Data
1999 and 2000 ITS Deployment Tracking Surveys

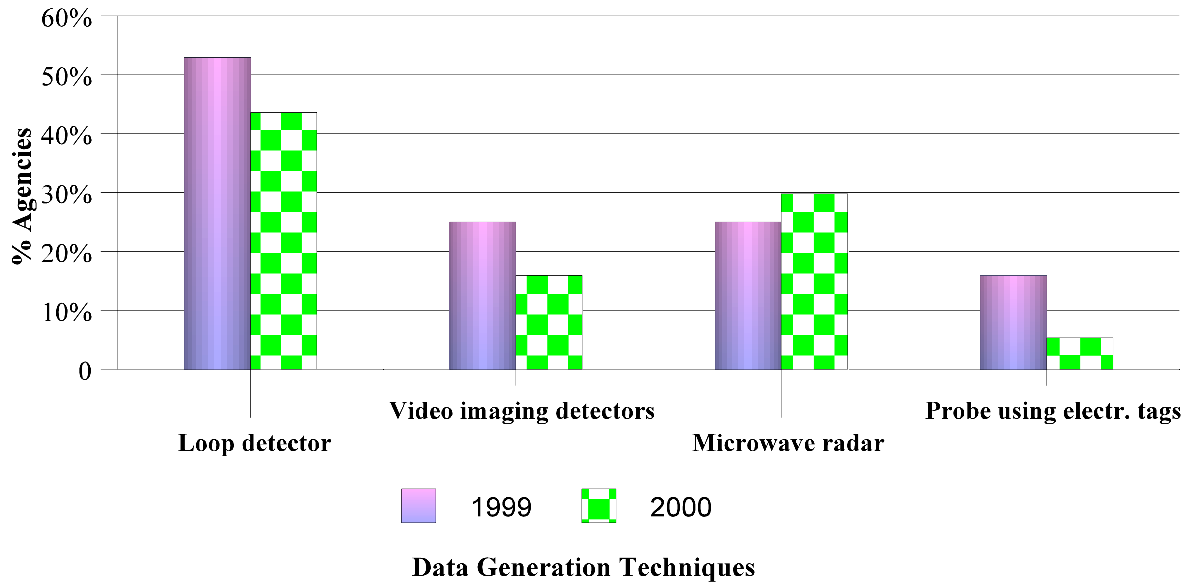


Table 6.1 Number of Agencies that Generate and/or Archive Freeway Traffic Data Pertinent to Highway Safety 1999 and 2000 ITS Deployment Tracking Surveys

Type of Data	1999		2000	
	Generated	**Archived**	**Generated**	**Archived**
Traffic volumes	68	59	56	45
Traffic speeds	47	31	49	34
Vehicle classification	49	37	40	30
Probe vehicles	5	3	N/A*	N/A*
Ramp queues	10	3	8	2
Ramp meter preemptions	1	1	2	0
Road conditions	40	21	36	20
Route designations	20	14	14	8
Weather conditions	40	23	41	25
Current work zones	64	34	47	29
Scheduled work zones	60	34	43	28
Agencies with none	32		40	

* These questions were not asked in 2000

Tables 6.2 and 6.3 show the propensity for data archiving in 1999 and 2000, with a significant downward trend. No agencies collect all seventeen data elements identified on the survey questionnaire. In 1999 one agency collected 14 out of the 17 data elements and it archived every data element collected. Overall, 31 of the 78 agencies in 1999 archived **all** of the traffic data collected (cells on the diagonal line) while the corresponding numbers are 19 out of 66 agencies in year 2000. Ten agencies in 1999 and eight agencies in 2000 reportedly collected traffic data but did not archive any (the “0“ column).

Table 6.2 Distribution of Agencies by Number of Data Elements Generated and Number of Data Elements Archived
***1999* ITS Deployment Tracking Survey**

Number of Data Elements Generated	Freeway Management Survey (74 Responses)																	
	Number of Data Elements Archived																	
	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
17																		
16																		
15																		
14				**1**														
13					**1**	1									1			
12						**4**											1	
11								1	2			2	1				1	1
10								**4**							1		1	
9									**1**	1		1	1			2		
8										**5**		1	1			1		2
7											**2**	3		1		1	1	2
6														1	1	1		1
5													**7**		2	1		2
4														**1**				
3															**1**		1	1
2																**2**		1
1																	**2**	

Table 6.3 Distribution of Agencies* by Number of Data Elements Generated and Number of Data Elements Archived
***2000* ITS Deployment Tracking Survey**

Number of Data Elements Generated	Freeway Management Survey (66 Responses)																	
	Number of Data Elements Archived																	
	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
17																		
16																		
15															1			
14						1					1							
13					**1**													
12						**1**												
11								1	2	1	3	1	1					
10								**3**		1								
9										1		1				1		1
8										**3**	1		1		1			1
7											**3**	1		1		1		1
6													3	1		2	1	2
5															2	1	1	2
4															1		1	
3															**3**			
2																**2**		
1																	**0**	1
0																		

* Excludes agencies that archived more data elements than they actually collected.

Usage and Users of the Archived Freeway Data

Based on the tracking survey results, the media is the largest archived data requester/user, followed by state Departments of Transportation (Figure 6.3). The archived traffic data are primarily used for traffic analysis and planning (Figure 6.4). Sixteen agencies reported that archived arterial data were used for accident prediction models. Unfortunately, the specific applications of the analysis are unclear from the surveys. It could not be determined which of the users use which of the archived data and for what purpose. An enhancement to this survey would be to add ìsafety analysisî as a ìprimary useî of the archived data.

Three hundred eighty-eight agencies responded to the 1999 Arterial Management Survey. One hundred eighty-one of these agencies reportedly collected arterial data. Of those that reported data collection activities, more than two-thirds collected data on traffic signal controls (Figure 6.5). The percentage of agencies that archived their traffic signal data is very high (Figure 6.5).

Figure 6.3 Number of Agencies Responded to Freeway Data Requests by Requesting Institute

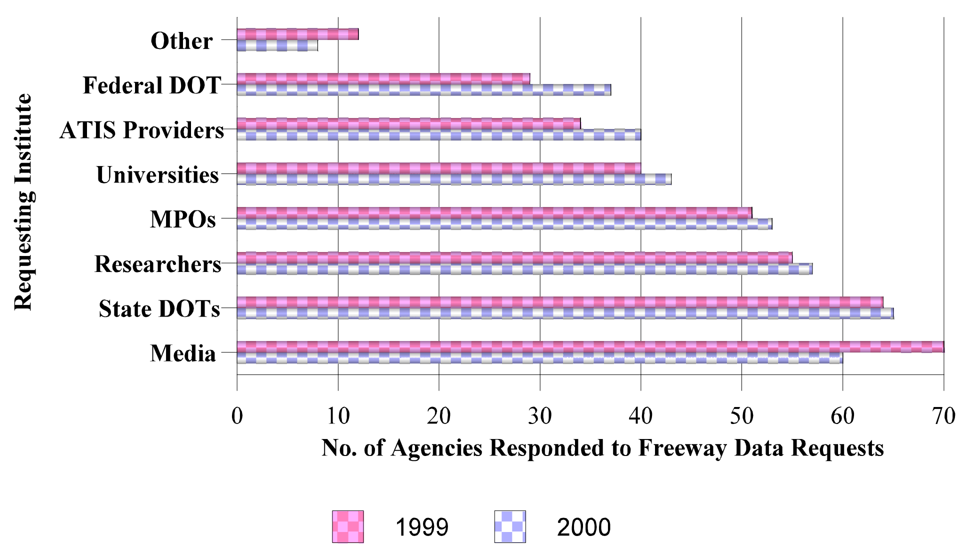
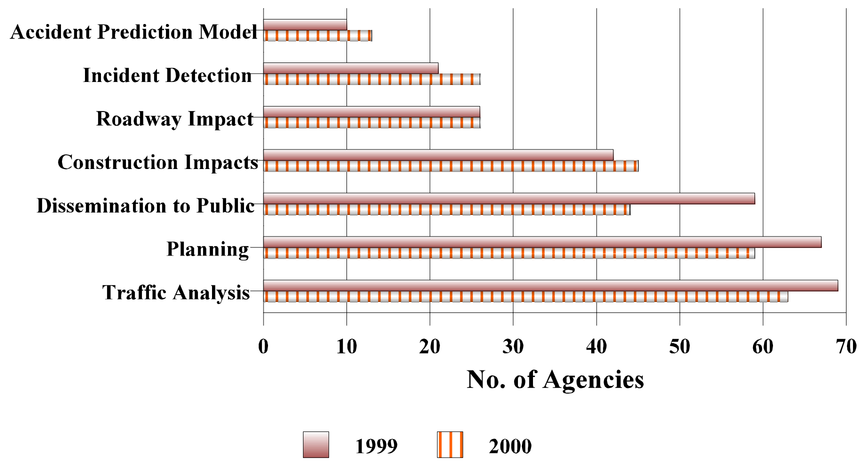


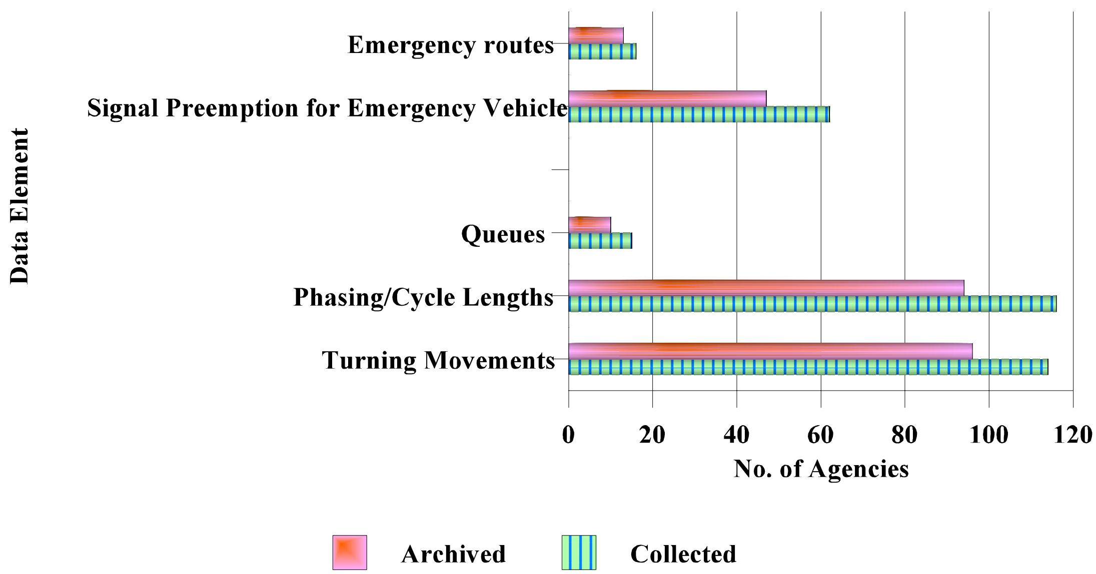
Figure 6.4 Archived Freeway Data Usage
1999 and 2000 ITS Deployment Tracking Survey



In addition to data collected/archived in Freeway and Arterial Management Systems, data that could be archived from Commercial Vehicle Operations and rural ITS infrastructure can support analyses of motor carrier safety and of highway railroad crossing accidents. For example, motor carrier safety can be enhanced through more efficient and timely information exchange. In-vehicle devices (such as those equipped in the ITS/CVO Technology Truck, see http://www.ornl.gov/dp111/index.htm) can minimize truck rollover and collisions, and an in-vehicle signing system can alert school bus drivers of potentially dangerous railroad crossing situations[6.1]. Data archived from these in-vehicle systems can improve our knowledge of pre-crash events, thereby improving the development of preventive counter-measures.

[6.1] In-vehicle Signing for School Buses at Railroad-highway Grade Crossings: Evaluation Report. Prepared by SRF Consulting Group, Inc. for Minnesota Department of Transportation. August 1998. http://www.itsdocs.fhwa.dot.gov/jpodocs/repts_te/49801!.pdf

Figure 6.5 Data on Traffic Signal and on Emergency Management
(from 388 Agencies Responding to the 1999 Arterial Management Survey)

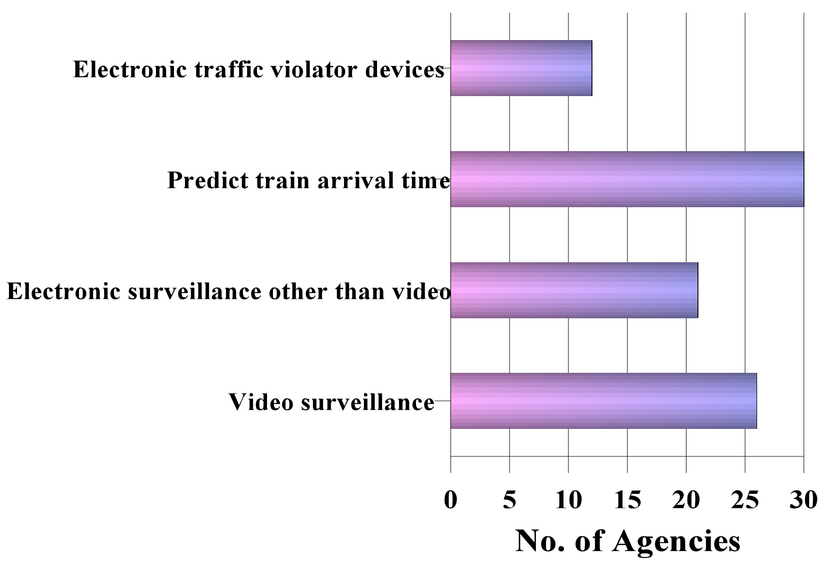


Technologies and control strategies are available that can coordinate traffic signals and notify vehicles of approaching trains at intersections. There are a few pilot projects: (1) Vehicle Proximity Alert System at Colorado, and (2) Smart Railroad Highway Crossing project at Long Island, New York. The Vehicle Proximity Alert System used an in-vehicle warning (audio/visual) to warn drivers of priority vehicles (e.g., emergency vehicles, school buses, and hazardous material haulers) of approaching trains at highway-rail grade crossings. The second project, the Smart Railroad Highway Crossing project at Long Island, New York, is to develop and test a prototype integrated warning system. None of these projects considered the idea of archiving operational data.

A limited amount of information on highway-rail intersections was asked in the Arterial

Management survey. Three hundred and eighty-eight agencies were asked whether they deployed or plan to deploy by 2005 any technology at highway-rail intersections. Three-quarters of them reported "yes." However, only 10% of these agencies actually had safety-improving technologies deployed, while the remaining 90% are planning to do so by the year 2005. Among the existing deployments, the ability to predict train arrival times electronically is the greatest requirement (Figure 6.6).

Figure 6.6 Capabilities/Technologies Deployed at Highway Rail Intersections in 1999
(Based on Arterial Management Survey)



Almost all of those who responded indicated that they convey information on highway-rail crossings to travelers via roadside media. Ninety-five percent of those who responded receive blockage information at highway-rail intersections to manage incident response. No questions were asked in the Arterial Management Survey regarding whether information on highway-rail intersections is collected or archived. Our impression at this point is that no data were archived.

6.2 CASE STUDIES OF HIGHWAY SAFETY APPLICATIONS

Highway safety involves complex interactions among vehicles, roadways, environments, and drivers. As such, highway safety is probably the area that will benefit most from data archiving. For example, almost all of the data elements collected by traffic surveillance ITS deployments (e.g., traffic volume, speeds, and traffic mix) are pertinent to highway safety, particularly in measuring *exposure* to highway crashes/incidents. The data provide both spatial and temporal information (the latter by time of day and day of the week). When integrated with archived weather and roadway condition data, hourly traffic volumes and crash data were used to develop a model that predicts the mobility and safety impacts of winter storm events in a freeway environment[6.2].

Another reason why highway safety will benefit considerably from data archiving is that it is not limited by geographic boundaries (metropolitan vs. rural). Data archived from rural ITS deployments can be used to meet some of the data requirements in highway safety applications.

Because highway safety is so complex, data requirements for highway safety are much more demanding and complicated than for other applications (i.e., transit, CVO, roadway, and rural). Consequently, the use of archived data to meeting highway safety information needs faces two challenges that are unique compared to those faced by other applications. First, since data on four different areas (i.e., drivers, vehicles, roadways, and environments) are needed, **data integration** is the key to successful ADUS safety applications. Second, data from these four areas are subject to different degrees of data confidentiality concerns. These concerns affect the nature and extent of data archiving and data sharing. For example, information on weather conditions has been archived and widely disseminated probably since the inception of the world wide web, while archiving and sharing information on drivers and vehicles demand great caution

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[6.2] Knapp, K. "Mobility and Safety Impacts of Winter Storm Events in a Freeway Environments." Iowa State University, Ames, Iowa. February, 2000. Research was funded by the Iowa Department of Transportation in terms of **liability** and **privacy** issues.

Recognizing the importance of data integration and data sharing, transportation and public safety communities use electronic and wireless technologies to integrate and share information. Two of the leading efforts are highlighted in this report: the **National Model for the Statewide Application of Data Collection & Management Technology to Improve Highway Safety** project in Iowa, and the **Capital Wireless Integrated Network (CapWIN)** project in the Washington metropolitan area. A wealth of detailed information on innovative automated data collection technologies used by law enforcement and transportation communities can be found on the International Association of Chiefs of Police (IACP) website.[6.3]

6.2.1 National Model for the Statewide Application of Data Collection & Management Technology to Improve Highway Safety Project

The goal of the National Model is to demonstrate, in a statewide operational environment, how new technologies and techniques can be cost-effectively used to improve the collection and management processes of highway safety data. Specifically, the Model is to:

- improve data acquisition related to roadway incidents,
- use technology to assist law enforcement,
- streamline the communication of safety information to key stakeholders, and
- extend the use of this information by safety and law enforcement programs.

When this model is deployed nationwide, it is anticipated that the quality of the nation's safety data will be improved through software, communications, and technologies.

6.3 IACP's Technology Clearinghouse Automated Data Collection Survey gathered detailed information on technology used. Thirty-five states responded to the survey. http://iacptechnology.org/Programs/INDEXbySTATENAME.htm

The project partners believe that these technologies can reduce data collection time, thereby minimizing disruption to traffic and improving data quality. The partners also believe that this project will contribute to better informed highway safety decisions and improved safety of the highway system.

The National Model is managed as a consortium effort. The project partners include the Motor Vehicle Division of the Iowa Department of Transportation, Iowa Department of Public Safety/Iowa State Patrol, FHWA Iowa Division, and sheriffs and police departments across the state.

At the heart of this Model is the Traffic and Criminal Software (TraCS). TraCS consists of a mobile client Microsoft Windows® based application that allows law enforcement officers to collect, validate, print, and receive information in their vehicle using either a notebook or pen-based computer (Figure 6.7). Information gathered with TraCS Mobile can be transferred to the TraCS Office and TraCS Enterprise database applications for reporting, analysis and retrieval.

Figure 6.7 TraCS Mobile Unit

Source: http://www.dot.state.ia.us/natmodel/index.htm

TraCS consists of five components. These are:

- the Mobile Accident Reporting System (MARS),
- the Vehicle Safety Inspection System (VSIS),
- the Electronic Citation Component

(ECCO),
- the Mobile Operating While Intoxicated (MOWI), and
- Complaint/Incident Report Form (CIRF).

Built around a pen-based computer, the MARS component of TraCS allows the officer to enter crash data at the scene using a combination of point-and-click lists and free form data. ECCO allows the officer to use a point-and-click list of violations and fines. Fines for the specific violation can be computed automatically, and the tickets are transmitted directly to the courts. Consequently, the courts will electronically send the conviction notices directly to the Iowa DOT.

VSIS is the vehicle inspection form that is used to inspect commercial vehicles and is issued by Iowa DOT Motor Vehicle Enforcement Officers. The MOWI component allows for electronic transmission of the state's OWI form to the DOT. An officer enters or captures an individual's information which is shared with the other components of TraCS as needed.

At the time of the writing of the report, this project uses 375 laptop computers, 225 pen-based computers, and numerous digital imaging bar code readers. The software, TraCS, is used in 100 local agencies statewide, and by all state patrols. During the last five years, the project has resulted in some outstanding improvements:

- Reduction in the amount of time that incident information is electronically available to the state to as little as one day,
- Elimination of duplicate data entry by law enforcement agency staff,
- Significant reduction of errors on accident reports, and
- Reduction in time spent completing accident reports.

Vital incident information collected from TraCS include: demographic information on the persons involved, the attributes of the vehicles involved, the severity of the incident, road and weather conditions, and the location of the incident. These data are stored indefinitely in the TraCS enterprise database and are accessible by partnering agencies. The data have been used to make informed decisions, and to identify and address emerging safety trends such as aggressive driving. Specifically, archived TranCS have been used to:

- Conduct before-and-after analyses to determine the safety improvement of construction projects,
- Conduct analysis of railroad crossing crash data to determine if changes in traffic controls are necessary,
- Determine the effectiveness and adequacy of traffic controls at intersections,
- Develop and prioritize pavement resurfacing projects for safety enhancement,
- Evaluate the safety effectiveness and performance of traffic control signing, channelization, and marking at work zones; and make appropriate changes immediately after problems arise. The Traffic Management Center in Des Moines is configured to use the archived TraCS data to ensure the safety and mobility during the 6-year reconstruction of I-235.

6.2.2 Capital Wireless Integrated Network (CapWIN) Project

The public's concern for safety in the Washington Metropolitan area has generated a need for improved coordination and information sharing among public safety and transportation agencies in Maryland, Virginia, and the District of Columbia. To meet this need, public safety and transportation agencies are using technologies to share more timely and accurate information among agencies serving the Capital Beltway and surrounding Washington areas.

CapWIN was created to build a bridge between transportation and public safety communities and is a partnership between the States of Maryland and Virginia, and the District of Columbia. This project is developing an integrated transportation and criminal justice information wireless network by integrating transportation and public safety data and voice communication systems. This project is the first multi-state transportation and public safety integrated wireless network in the United States. The CapWIN Project is sponsored by the following agencies:

- Maryland State Highway Administration,
- Virginia Department of Transportation,
- U.S. Department of Transportation (FHWA)[6.4],
- National Institute of Justice, Office of Science and Technology, and
- Public Safety Wireless Network .

A pilot test will be initiated during the strategic planning phase of the project. The pilot will include a minimum of six, and up to fourteen, in-vehicle systems that will allow messaging between police vehicles in Maryland, Virginia and Washington, D.C.; transportation vehicles in Maryland and Virginia; and local fire vehicles. Although less well developed than the National Model, the CapWIN can shed light on issues related to information integration and information sharing among multi-state agencies.

6.2.3 Other Automated Data Recording Technologies

There are a number of devices specifically deployed to improve highway safety such as on-board personal computers, on-board event data recorders, and red light running cameras. Although little or none of the data collected from these devices are archived and shared due to concerns about privacy violation and liability, the potential of these technologies and their archived data are being actively discussed.

Information on the vehicles that are involved in highway crashes can be currently

[6.4] J. Paniati of FHWA serves on the Project Executive Group.

extracted from different sources such as the police's crash reports and the event data recorders (black boxes) installed in vehicles. In fact, data collected from event data recorders not only provide vehicle information but also information on the driver's reaction, from pre-crash to post-crash periods.

Event Data Recorders (EDR)

The National Transportation Safety Board (NTSB) encouraged automobile manufacturers and the National Highway Traffic Safety Administration (NHTSA) to work together to collect crash data using on-board collision sensing and recording devices. General Motors (GM) began using event data recorders with the introduction of the air-bag in 1974, which collected information on the air-bag status and crash severity. Since that time, the event data recorders used by GM have evolved and allowed the recording of a greater number of data elements. GM's 1999 event data recorder or Sensing & Diagnostic Module (SDM) is capable of recording the following information:

- State of the warning indicator when the event occurred (ON/OFF),
- Length of time the warning lamp was illuminated,
- Crash-sensing activation times or sensing criteria met,
- Time from vehicle impact to deployment,
- Diagnostic trouble codes present at the time of the event,
- Ignition cycle count at event time,
- Maximum delta V (change in longitudinal vehicle velocity) for near-deployment,
- Delta V vs. time for front air-bag deployment event,
- Time from vehicle impact to time of maximum delta V,
- State of driver's seat belt switch,
- Time between near-deploy and deploy event (if within 5 seconds),
- Passenger's air-bag enabled or disabled state,
- Engine speed (5 seconds before impact in 1 second intervals),

- Vehicle speed (5 seconds before impact in 1 second intervals),
- Brake status (5 seconds before impact in 1 second intervals), and
- Throttle position (5 seconds before impact in 1 second intervals).

Once an air-bag deployment is recorded, this information is permanently stored and cannot be altered, erased or cleared by service or crash investigation personnel.

General Motors installs some type of EDR in most of its vehicles, and is the only manufacturer that shares its crash data with the research community. Other OEMs (e.g., Ford, Honda, etc.) also began to install event data recorder modules in some of their 2000 model year vehicles, although Ford collects fewer data elements. According to a report titled: "Recording Automotive Crash Event Data," NHTSA has begun to build a database of crashed GM vehicles by retrieving data from the event data recorders of the wrecked cars.[6.5]

It is anticipated that crash data provided by the onboard event data recorders could provide NHTSA and automotive engineers with a wealth of real-world crash data (crash pulses) which can never be obtained in a laboratory setting. These data would allow manufacturers to produce more crash-worthy vehicles, reducing the total number of injuries and fatalities. In 1992, GM installed crash data recorders on 70 Indianapolis 500 race cars. The data collected provided a better understanding of impact tolerances of human beings, which in turn resulted in design changes of the race cars. These design changes are believed to have substantially reduced the number of serious driver injuries during the 1998 racing season.

It is also anticipated that, aside from improving the crash worthiness of vehicles, the data

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[6.5] "Recording Automotive Crash Event Data." Chidester, A. and Hinch, J., National Highway Traffic Safety Administration; Mercer, T. C. and Schultz, K. S., General Motors Corporation. Presented at the International Symposium on Transportation Recorders, May 1999. http://www.nhtsa.dot.gov/cars/problems/studies/record/chidester.htm collected can benefit the design of highway infrastructure. Materials as well as the design of guardrails and crash barriers can be improved to better absorb vehicle impacts while other roadside components such as light poles and road signs can be improved to minimize injury in the event of an impact.

Using archived data from the event data recorders to achieve the greatest safety benefits, one has to first address the issues of data ownership, privacy and liability. GM maintains that any data recorded by on-board sensing devices belong to the vehicle owner and is private information. It has been suggested that experts in the aviation community be consulted when data ownership concerns arise.

Aside from the data ownership concern, it was reported that EDR data alone does not provide third party researchers with enough information to make it particularly useful[6.6]. Other crash information such as accident reports and photographs are essential to give the data needed context and meaning. But, the format of this information is not compatible with the EDR data. It was recommended by this National Cooperative Highway Research Program (NCHRP) effort that NHTSA considers the feasibility of summarizing EDR data in such a way that they would be useful to third party researchers.

National Highway Traffic Safety Administration is embarking on a research project in year 2001 where specially designed data recorders will be installed in a large fleet of "participating" vehicles to collect a wealth of information on vehicle movements, the type of roadway on which the vehicle is traveling, velocity, seat belt use, time stamp, etc.[6.7] This

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6.6 "Use of Event Data Recorder (EDR) Technology for Roadside Crash Data Analysis." National Cooperative Highway Research Program (NCHRP) Project 17-24, FY 2002.

6.7 Richard Compton, National Highway Traffic Safety Administration, personal communication, April 2001.

information will be integrated with traffic data collected from TMCs to better understand crash propensity in actual traffic stream such as the crash impact of lane weaving under different traffic conditions.

Red Light Running Cameras

Each year, more than 1.8 million intersection crashes occur. In 1998, red-light-running (RLR) crashes accounted for 89,000 crashes, 80,000 injuries and nearly 1,000 deaths. Public costs exceed 7 billion.[6.8] To raise awareness of the dangers of red light running and to reduce fatalities, FHWA created the Stop Red Light Running Program in 1995.

New technologies are used to help enforce RLR violations. Typically, a photo detection system is installed at an intersection. When the traffic signal turns red, the system becomes active and the camera takes pictures when vehicles enter the intersection. The camera records the date, time of day, time elapsed since beginning of the red traffic signal, and the speed of the vehicle. Camera films are loaded, unloaded and processed on a regular basis.

A 1999 FHWA report synthesizes the results of a number of RLR demonstrations around the country.[6.9] Data collected from the photo enforcement cameras were used to evaluate the effectiveness of this approach. Almost all demonstration sites experienced significant reduction in the number of traffic violations. The FHWA report concluded that at least a 20% and as much as a 60% reduction in RLR violations could result from the implementation of an electronic enforcement program. Although Howard County, Maryland reported a reduction in the number of crashes at the instrumented intersections, this conclusion was not based on data archived/stored in the cameras.

[6.8] http://safety.fhwa.dot.gov/fourthlevel/pro_res_srlr_faq.htm

[6.9] "Synthesis and Evaluation of Red Light Running Automated Enforcement Programs in the United States." FHWA-IF-00-004. Federal Highway Administration. September 1999.

6.3 BARRIERS TO ARCHIVE, SHARE AND ANALYZE DATA PERTINENT TO HIGHWAY SAFETY

6.3.1 Privacy Issues and Barriers

Video surveillance cameras can improve response time of emergency vehicles to the scene of an accident and, Red Light Running (RLR) camera systems can significantly reduce the number of accidents occurring at intersections with video-enforced traffic lights[6.10]. Although these technologies are supported by courts when used by traffic management centers or law enforcement, it is unclear what attitudes will be regarding the sharing of this data with unrelated third parties.

The perceived benefits of, and barriers to, sharing video data were surveyed among stakeholders of TransGuide in San Antonio[6.11]. The issue of sharing was about the possible use of TransGuide's ATMS video data by public agencies and stakeholders in San Antonio other than the Texas Department of Transportation (TxDOT) which has proprietary control of the data. The biggest public sector beneficiary of video sharing is the San Antonio Police Department (SAPD). Using video, the SAPD can verify an incident report without dispatching a patrol unit, and can respond to incidents within two minutes of detection. TransGuide video data are typically **not recorded and archived** unless it is explicitly requested The "sharing" component of TransGuide largely involves the distribution of ATMS-related data over the Internet, television, and FM radio. In TransGuide, sharing also implies informal arrangements between TxDOT and other public agencies such as the San Antonio Fire Department and Emergency Management Service. The agreement allows stakeholders to have access to live video feeds and

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6.10 Federal highway Administration. "Synthesis and Evaluation of Red Light Running Automated Enforcement Programs in the United States," FHWA-IF-00-004, September 1999.

6.11 "A Case Study: Benefits Associated with the Sharing of ATMS-Related Video Data in San Antonio, TX." Dave Novak, Center for Transportation Research, Virginia Technology Institute. August 1998.

traffic data, and in some cases allows limited control over the camera equipment.

Based on the results from the ITS Deployment Tracking Surveys, the obstacles to sharing data are: concerns about having a bureaucratic process, and privacy issues. Privacy issues center on police access to video data, and concerns over how the data would be used, especially for law enforcement purposes. The SAPD's response to these concerns is that it does not use TransGuide video data for law enforcement, and has no plans to do so.

Although the privacy concern varies from one agency to the next, there is a clear need to investigate the use of privacy protection technologies, such as cryptographic technologies, to remove these concerns. A balance between the right to information and the protection of personal data should be struck when implementing these technologies. Finally, any ADUS activity should adhere to guidelines that may limit government access to communications and stored digital information. Examples of such rulings include the Electronic Rights for the 21st Century Act, and the European Union's Data Protection Directive. Approaches to overcome liability and privacy concerns are beyond the scope of this work and will not be discussed in detail.

Although cell phones may not strictly qualify as an ITS technology, they are designed to be mobile and are often used during transportation. There are about 83,000 wireless calls to 911 per day. In addition to their obvious safety use for calling 911, cell phones also produce electronic data[6.12]. Although cell phones are designed for direct vocal communication, the electronic data they produce can also have an indirect, positive influence on safety. They emit signals that can be located in the event of an emergency call either by triangulation or via a GPS chip embedded in the phone. However, using a cell phone as a locator device comes with

6.12 U.S. News & World Report. "Help, 911! Where Am I? Cell-phone Companies Scramble to Locate Users in Trouble," June 22, 1998, http://www.usnews.com/usnews/issue/980622/22cell.htm .

privacy concerns. Although it should be noted that privacy is a concern here, it does not appear to be a barrier in the context of 911 emergencies. Ordinary land line telephones provide 911 operators with location information; therefore, it would be hard to make the argument that determining the location of a 911 call from a wireless phone for emergency purposes constitutes an unreasonable invasion of privacy. Furthermore, in April 1998, the Federal Communications Commission ordered cell phone providers to provide 911 operators with the address of the cell phone tower sending the distress call.

Event data recorders placed in automobiles are another type of recording device that raises concerns about privacy and liability. “Some people argue that black boxes in cars are a violation of privacy, but the American Coalition for Traffic Safety disagrees. It says the systems are derived from sensors and computer modules, do NOT include voice or video recorders, and thus are not a violation of privacy.”[6.13] This does not ensure that the use of event data recorders are or will be free from litigation, only that invasion of privacy will probably not be the most serious barrier to the use of this technology.

Data ownership, however, could prove to be a delicate and complex issue for the use of event data recorders. Does the owner of the car also own the data contained in the data recorder, or does the manufacturer? Do law enforcement officials have a right to that data or do they need permission or a warrant? There are also many groups who are interested in crash data such as insurance companies, courts, NHTSA, the media, manufacturers of safety equipment and maybe even those with less than noble intentions. Clear guidelines about access and ownership of in-vehicle event-data recorders will have to be established before this type of data can be widely used. Similar guidelines can be established for sharing other ITS data such as data collected from red-light running cameras or incident recorders at the intersections.

[6.13] McElroy, John. *Autoline*, June 20, 2000.

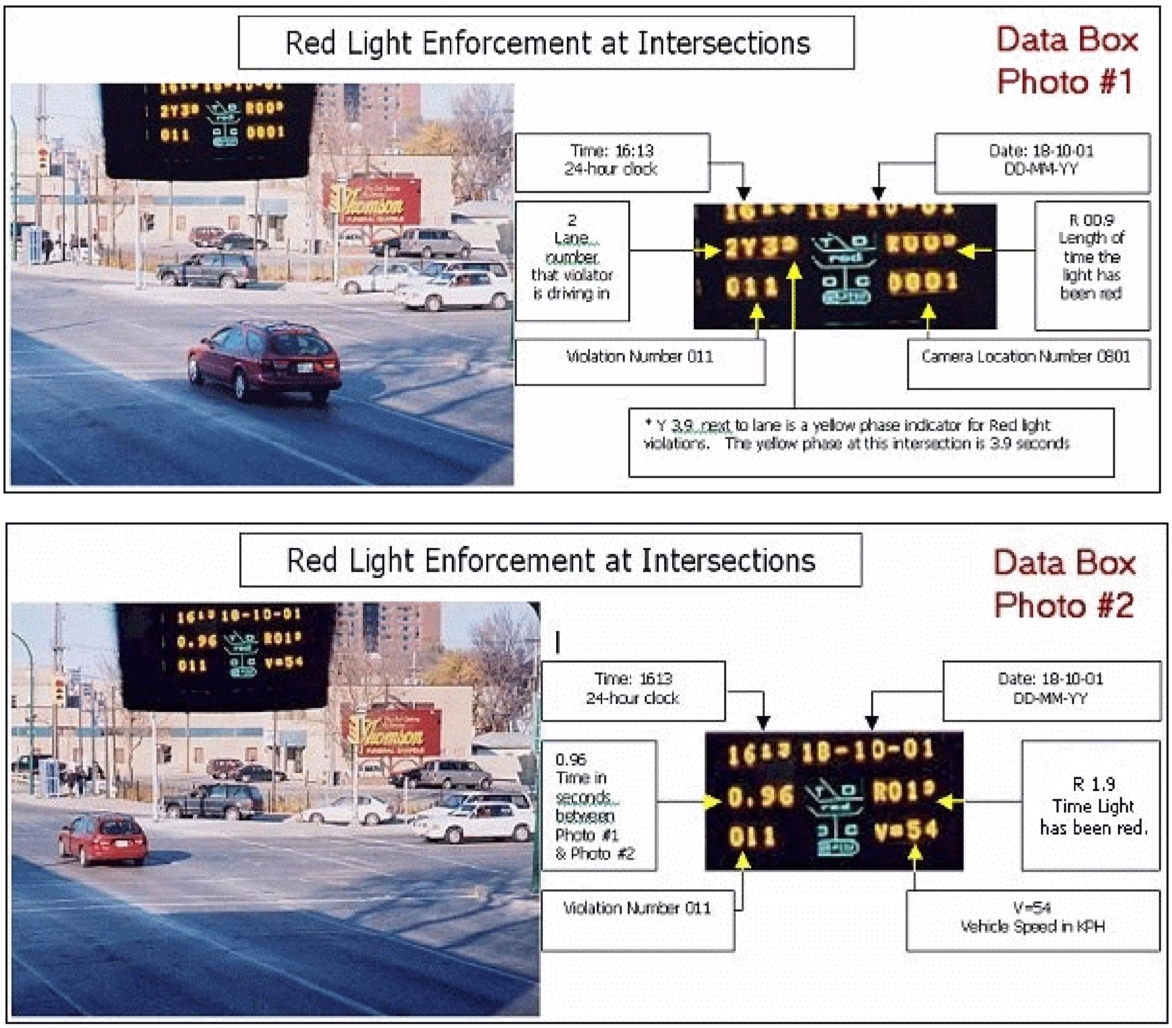
6.3.2 Technical and Technological Issues and Barriers

Technology is a significant barrier for highway safety applications of ADUS data. Event data recorders are still relatively new in automobiles and must accurately record automotive systems under the extreme conditions of an impact. Data reliability of event data recorders will have to be studied before this data can be used with confidence in courts and by other disciplines where accuracy is absolutely essential. Additionally, different manufacturers are using different types of event data recorders which can result in problems for data integration.

Although collection of location data from cell phones has been mandated for 911 calls, it is not yet completely implemented. By October 2001, cellular carriers were required to be able to locate callers with much greater accuracy. There may be several different ways to comply with this new regulation which may provide data with varying degrees of accuracy or in varying formats which would complicate the use of such data.

That said, the biggest challenge in using ADUS for highway safety applications is probably the extraction of information from the archived images in a form that is suitable for analysis. Much of the information that is currently archived, and that can be used to address intersection safety and speed management, is in image format. For example, images that are, or could be, archived from red-light enforcement cameras at intersections are typically stored in image formats (Figure 6.8). Manual processing of these images can be extremely labor intensive and resource demanding. The transformation of such images, into machine-readable form for analyses, is a monumental challenge to the user of this information. Feature detection and/or optical character recognition (OCR) have the potential to address these challenges. However, the feasibility of these technologies needs to be adequately tested and their relative costs and benefits assessed.

Figure 6.8 Archived Images from Red Light Enforcement Camera
Source: http://www.city.winnipeg.mb.ca/police/Traffic /Photo%20Enforcement/redlightexample.htm



6.3.3 Institutional Issues and Other Barriers

The institutional and other barriers associated with implementing ADUS are largely the same among the different ADUS applications. These common barriers such as cost, proprietary rights, politics, and a lack of understanding or knowledge about ADUS are covered in further detail in Chapter 2. Aside from these common barriers, the implementation of ADUS, as it relates to highway safety, faces another problem. Of all the data elements collected by ITS deployments, none of them collect data that are strictly about safety. Traffic management centers collect data in order to keep traffic flowing smoothly, which may benefit safety, but safety remains tangential to their work. Those who are interested in safety have to find their own ways to relate ITS-generated data to the topic of highway safety.

Another safety issue is the heightened concern over protecting the identity of incident victims. This heightened sensitivity can slow down or limit the flow of certain types of data. Apart from the barriers common to data archiving in general, archiving highway safety data is confronted by a very different challenge. Part of the traffic information on freeways and arterial roads is collected by cameras. In particular, video cameras are used to identify the exact locations and circumstances where something affects traffic on the freeway system. That type of information is enormously valuable in advancing our understanding of crash causation so that effective countermeasures can be deployed. Notwithstanding, access to that information has been extremely controversial. Undoubtedly, the biggest barriers to archiving data that could have some bearing on safety applications are privacy and liability issues. Recognizing these concerns, many agencies limit their data archiving or withhold safety information and camera images. On limited occasions, images are recorded for traffic studies (such as vehicle counts, weaving movements), training purposes, and exceptional circumstances (such as in criminal investigations)[6.14].

6.4 POTENTIAL FOR HIGHWAY SAFETY APPLICATIONS

ITS technologies such as event data recorders in vehicles and RLR cameras at signalized intersections have a direct influence on highway safety. Archived data from event data recorders provide accurate crash data leading to better vehicle and highway infrastructure designs and

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6.14 Arizona Department of Transportation's Freeway Management System (AZFMS). http://www.azfms.com/faq.html.

regulations while RLR cameras encourage motorists to respect red lights to avoid traffic citations and points on their driving record thus reducing the number of traffic accidents and fatalities.

Other technologies that are more on the fringe of ITS such as onboard police computer systems and cell phones can also impact safety though in a more indirect way. While onboard police computer systems are primarily designed to improve the efficiency of police reporting and limit the introduction of errors while handling evidence, they provide a secondary benefit that improves safety. By reducing the amount of manual paperwork required of officers and allowing them to work directly from their police cruisers, the officers are able to spend more of their time on patrol, where they can respond to incidents more quickly or serve as a deterrent to criminal or reckless activity.

The Criminal Investigative and Traffic Safety Incident Information Management System, or IIMS, is a program that is being implemented in Pennsylvania in order to give the Pennsylvania State Police an edge in the enforcement of crime and traffic safety. This system seeks to make every police cruiser in Pennsylvania a mobile office, providing the officers with all the information they need through onboard computer access to state and federal databases. It is estimated that this system will reduce the time officers spend on paperwork by more than half, which would have the effect of doubling the size of the police force on the street. This system is expected to be fully operational within 3 years and will include the following elements:

- Onboard computer allowing access to state and federal databases.
- Interface allowing officers to enter their report information directly into the system at the scene of the incident.
- Onboard GIS system to help officers locate an incident more quickly.
- Bar code evidence handling system.
- Portable fingerprint device linked to state and federal records for rapid identification.
- Information entered into the system by the police will be shared with other

agencies.[6.15]

The most effective data collection undertaking is driven by information needs. Without any specific application, any attempt to highlight the potential of archived data to address highway safety concerns is complicated by the complexity of crash occurrences. Nonetheless, we examined individual ITS infrastructure components separately and identified how data, if collected and archived, could be used to address safety concerns. Table 6.4 offers a list of potential uses of data archived from roadway systems, which might have some bearing on highway safety applications. From the perspective of the Intelligent Vehicle Initiative (IVI) Program, there are four Generation of Field Operational Tests (FOT) that hold promise in data archiving. These FOTs involve the use of crash avoidance technologies to improve highway safety. They are:

- testing the operational effectiveness of the Rollover Stability Advisor (RSA), Rollover Stability Controller (RSC), and Lane Tracker (LT).
- testing the operational effectiveness of the Infrastructure-Assisted Hazard Warning (IAHW) system and Automatic Collision Notification (ACN).
- testing the operational effectiveness of the bundled advanced safety system of Electronically Controlled Brake Systems (EBS), Collision Warning Systems (CWS), and Adaptive Cruise Control (ACC).
- testing driver assisting technologies that include magnetic roadway tapes, DGPS, GIS Mapping, 360 degree obstacle detection devices, forward Collision Avoidance Systems (CAS), Head-Up Displays (HUD), auditory warnings, external light warning systems, in-vehicle proximity warning systems, and Micro-Data Acquisition Systems (Micro-DAS). Although the primary focus has been on snow plow vehicles thus far, ambulances and police vehicles will also be included.

6.15 Lockheed Martin-IIMS Incident Information Management System. http://www.pspiims.com .

The integration in FOTs of data archived from these in-vehicle technologies, geometric data on roadways, and data on vehicle characteristics and functions and weather conditions will accelerate the understanding of the complex interrelationships between vehicles, roadways and environments on the occurrence of truck crashes.

Safety analysis and planning have been afflicted by incomplete, inconsistent and not-so-timely information. One system that attempts to overcome this impediment is particularly noteworthy. The Advanced Law Enforcement & Response Technology (ALERT) initiative has equipped about 10 police vehicles (a few at the College Station Police Department in Texas and a few for the Secret Police around the White House) with on-board and hand-held computers and other devices. One feature of the system is to streamline data collection and sharing, and improve communication between law enforcement and the first-response community. Unfortunately, ALERT will no longer be implemented largely due to the lack of funding resources.

In order to meet the safety objective in U.S. Department of Transportation's strategic plan, the safety considerations are to be integrated in the transportation planning processes at all levels of government, specifically in the Statewide Transportation Improvement Programs and the Transportation Improvement Programs developed by state DOTs and MPOs, respectively[6.16]. In a recent workshop hosted by the National Association of Governor's Highway Safety Representatives, good quality data and robust analysis were identified amongst the strategies important to successfully integrating safety into the transportation planning process. ITS-generated data hold promise in identifying and defining high-risk areas, and predicting the probability of crash and incident occurrences, and providing the information needed for developing and implementing effective measures for improving safety.

[6.16] *Safety Conscious Planning – Establishing A Partnership for Safe Transportation Networks.* Transportation Research Board Circular. Transportation Research Board and National Research Council. September 2000.

Table 6.4 Potential of Archived Data for Highway Safety Applications

For Data collected in *Freeway Management* Survey and *Arterial Management* Survey		
	If data are collected and archived, it could help address the following issues:	**If data are collected and archived, it could potentially help meet the following federal data reporting requirements:**
Traffic volumes	• Establish the relationship between traffic volume and the occurrence of road accidents, and between traffic volume and the occurrence of road incidents.	FARS: • Provide actual traffic conditions at the time of the crash.
Traffic speeds	• Establish the relationship between traffic speed and the occurrence of road accidents, and between traffic volume and the occurrence of road incidents.	FARS: • Provide traffic speeds at the time of the crash.
Lane occupancy		
Vehicle classification	• Quantify the impact of traffic mix on the occurrence of road accidents and incidents. • Provide reliable truck crash statistics.	FARS: • Provide actual traffic mix at the time of the crash
Probe vehicles		

Table 6.4 Potential of Archived Data for Highway Safety Applications

For Data collected in *Freeway Management* Survey and *Arterial Management* Survey		
	If data are collected and archived, it could help address the following issues:	**If data are collected and archived, it could potentially help meet the following federal data reporting requirements:**
Turning movements	• Determine the impacts of phasing/cycling lengths, turning movements, and queuing on incidents and accidents. This type of understanding lays the foundation for more effective traffic control strategies. • Establish the relationship between turning movements and the occurrence of road accidents.	• Validate the reconstruction of the accident reported in the police report.
Phasing/Cycling lengths	• Determine the impacts of phasing/cycling lengths, turning movements, and queueing on incidents and accidents. This type of understanding lays the foundation for more effective traffic control strategies.	
Queues	• Determine the impacts of phasing/cycling lengths, turning movements, and queuing on incidents and accidents. This type of understanding lays the foundation for more effective traffic control strategies.	

Table 6.4 Potential of Archived Data for Highway Safety Applications

For Data collected in *Freeway Management* Survey and *Arterial Management* Survey		
	If data are collected and archived, it could help address the following issues:	**If data are collected and archived, it could potentially help meet the following federal data reporting requirements:**
Ramp queues	• Establish the impact of various ramp queuing measures on safety.	
Ramp meter preemptions		
Metering rate		
Road conditions	• Data linking roadway accidents and road and weather conditions improves the understanding of the relationship, leading to more effective development and planning of countermeasures..	FARS: • Provide actual conditions of the road at the time of the crashes.
Route designations		
Weather conditions	• Data linking roadway accidents and road and weather conditions improves the understanding of the relationship, leading to more effective development and planning of countermeasures.	FARS: • Provide actual weather conditions at the time of the crashes.
Incidents	• Understand the impact of incidents on crashes.	

Table 6.4 Potential of Archived Data for Highway Safety Applications

For Data collected in *Freeway Management* Survey and *Arterial Management* Survey		
	If data are collected and archived, it could help address the following issues:	**If data are collected and archived, it could potentially help meet the following federal data reporting requirements:**
Current work zones	• Provide adequate and appropriate countermeasures (including re-routing) to ensure work zone safety. • Evaluate the effectiveness of countermeasures.	
Scheduled work zones	• Anticipate the needs for adequate and appropriate countermeasures to ensure work zone safety.	
Intermodal (air, rail, water) connections	• Identify safety issues pertinent to intermodal connectors. • Estimate the size of the safety problem pertinent to intermodal connectors.	
Emergency/evacuation routes & procedures		
Emergency vehicles signal preemption	• Gauge the effectiveness of different meter preemptions in emergency responses.	
Highway operations coordination information		
Transit vehicle signal priority		

Table 6.4 Potential of Archived Data for Highway Safety Applications

For Data collected in *Freeway Management* Survey and *Arterial Management* Survey		
	If data are collected and archived, it could help address the following issues:	**If data are collected and archived, it could potentially help meet the following federal data reporting requirements:**
For Data collected in *Transit Management* Survey		
Vehicle time and location		
Passenger count		
Trip itinerary planning records		
Passenger information		
Road conditions	• Data linking roadway accidents and road and weather conditions improves the understanding of the relationship, leading to more effective development and planning of countermeasures.	
Emergency vehicles signal preemption		
Transit vehicle signal priority		
Route designations		

Table 6.4 Potential of Archived Data for Highway Safety Applications

For Data collected in *Freeway Management* Survey and *Arterial Management* Survey		
	If data are collected and archived, it could help address the following issues:	**If data are collected and archived, it could potentially help meet the following federal data reporting requirements:**
Weather conditions	• Data linking roadway accidents and road and weather conditions improves the understanding of the relationship, leading to more effective development and planning of countermeasures.	
Incidents	• Fill the void in bus incident data.	
Current roadway work zones for transit	• Design countermeasures that accommodate transit vehicles, particularly passenger buses.	
Scheduled roadway work zones for transit	• Provide adequate and appropriate countermeasures (including re-routing of transit vehicles) to ensure work zone safety.	
Intermodal (air, rail, water) connections		
Emergency/evacuation routes & procedures		
Transit operations coordination information		

Table 6.4 Potential of Archived Data for Highway Safety Applications

For Data collected in *Freeway Management* Survey and *Arterial Management* Survey		
	If data are collected and archived, it could help address the following issues:	**If data are collected and archived, it could potentially help meet the following federal data reporting requirements:**
Highway operations coordination information		

6.5 OPPORTUNITIES

There are many ways that archived ITS data could improve highway safety. Rather than try to identify all possible opportunities, this section identifies those that appear to be feasible, can be quickly deployed, and are most likely to produce immediate benefits/results. The rationale for identifying these "low-hanging fruits" is that the sooner that quantifiable benefits of using ITS-generated data for safety improvement are demonstrated and disseminated, the sooner additional deployments will be stimulated. Any of these opportunities identified below can be developed into a FOT with public and private partnership.

6.5.1 ADUS for Intersection Safety

More than 2.8 million crashes occur annually at intersections, killing 10,000 people and injuring another 1.5 million people. These crashes account for 45% of all reported crashes. As a result, the Federal Highway Administration has identified intersection safety as one of the four high-risk areas; and the American Association of State Highway and Transportation Officials highlighted the need to improve the design and operation of our highway intersections in its Strategic Highway Safety Plan.

Participants in a recent workshop[6.17] recognized the need to implement proven, effective intersection safety technologies (e.g., red light running enforcement camera, signal timing), and to develop data and tools to analyze safety at intersections. One of the actions needed to meet these priorities is the improvement of databases on traffic, roadway, signal timing, and crash.

Images collected from enforcement cameras, and archived data on weather and roadway conditions, traffic volume, and vehicle turning movements can facilitate the identification of the reasons for the most common and severe types of crashes at intersections, and an understanding of the inter-relationships among these factors. The integration of these data can also be used to evaluate the effectiveness of different intersection safety technologies.

With the infrequency of crash occurrence, one of the challenges in crash analysis has always been small sample sizes. To overcome this challenge, any efforts to use these archived data for intersection crash analysis needs to include data collected/archived from enforcement cameras around the country. A carefully designed plan to harvest the archived data/images is the essential first-step.

6.5.2 ADUS for Work Zone Safety

Work zones in U.S. highways have become increasingly dangerous for both workers and travelers. An estimate for the year 2000 was that there were about two deaths per day from work-zone related accidents[6.18]. Overall, approximately 800 people are killed, and forty thousand people are injured every year as a result of motor vehicle crashes in work zones. The safe and efficient flow of traffic through work zones has been, and continues to be, a major concern to the transportation community.

6.17 *Synopsis of Intersection Safety Workshop.* Milwaukee, WI, November 14-16, 2001

6.18 http://www.tfhrc.gov/focus/jan00/workzone.htm.

Decision-making tools can be effective in improving work zone safety through planning, traffic management, traveler information, and traffic control. Motorists can be alerted to traffic congestion by portable message boards and a highway advisory radio system. An effort is underway by the FHWA to develop user friendly PC-based decision making tools that will accurately analyze and reliably predict work zone impacts. These tools will allow practitioners involved in the project pre-planning, planning, development, construction and maintenance phases to weigh alternative strategies to mitigate the mobility and safety impacts of work zones. ADUS should be an integrated and an essential component of these tools.

Decision making tools become useful only when decisions are made based on realistic and current data. Oftentimes, decisions are made based solely on subjective judgements or "similar" data. If archived data are used to develop trends and patterns, decisions can be made that are more accurate for a specific locale or facility.

Furthermore, archived information from variable electronic message boards, that inform motorists with real-time traffic delay and alternative routes, can be integrated with archived data on traffic and speed that were recorded <u>before</u> and <u>after</u> the message was broadcasted. This confirmation of data can help evaluate the safety impacts of alternative traffic management plans.

6.5.3 ADUS for Speed Management

According to the Fatal Accident Reporting System, almost 1 of every 3 traffic fatalities is related to speeding. These crashes also cost the American economy approximately $27.7 billion each year.

With the repeal of the National Maximum Speed Limit, there is renewed interest in how best to set speed limits. Speed management is a complex issue involving engineering, driver behavior, education and enforcement. Research is underway to develop and test strategies and technologies to manage speeds and encourage wider adoption of speeds appropriate for the particular class of road, roadway design, and travel conditions.

Travel speed has been the most commonly collected and archived data element from the Freeway and Arterial Management Systems. These data are most appropriate for establishing the relationship between travel conditions and speeds, analyzing the safety implications of different speeds, and examining the feasibility of speed limits that are adapted to current travel and roadway conditions.

6.5.4 ADUS for Pedestrian and Bicycle Safety

Six thousand pedestrians are killed and another ninety thousand pedestrians are injured every year in this country. It is estimated that pedestrian injuries and fatalities have resulted in $20 billion in societal costs every year.[6.19]

Analysis of pedestrian and bicycle safety has been hindered by the lack of data. Images from cameras installed at signalized intersections can help decipher the events that lead up to a crash. That said, a feasibility study should be conducted before a full-scale study is implemented.

Several technologies (such as microwave pedestrian detection) are being deployed to minimize vehicle and pedestrian conflicts. The integration among these technologies, AVL in transit vehicles, and adaptive signal timing might further reduce these conflicts. This notion is similar to the current use of signal over-ride for transit vehicles and emergency vehicles on arterials. The feasibility of this idea can be examined by analyzing the archived data from cameras installed at pedestrian crossings, and archived data from signal timing plans. Again, a carefully designed plan to harvest the archived data/images is the essential first-step.

[6.19] http://www.tfhrc.gov/safety/pedbike/pedbike.htm

6.6.5 ADUS for Highway Safety Public Awareness and Training

Archived images from surveillance cameras installed in construction and maintenance areas or at intersections can be used to increase public safety awareness. However, a comprehensive testing of privacy-protection technologies should be the first step.

As previously mentioned, any of these opportunities can be developed into an FOT with the goals of:

- identifying technical and institutional barriers to archiving, using, and sharing ITS-generated data;
- developing solutions to overcome these barriers;
- identifying issues pertinent to standards development;
- examining the feasibility of integrating ITS-generated data with data collected from traditional and emerging technologies (e.g., highway monitoring data, remotely sensed data);
- identifying and **quantifying** costs and benefits;
- disseminating lessons learned, and
- sharing the developed procedures and software in an open-source environment. Some examples of these procedures and software are: those developed to convert raw ITS-generated data into formats acceptable to existing and/or off-the-shelf data management or analysis software, check the quality of the data, impute missing data, correct questionable data, abstract information suitable for data analysis from “text” files, estimate potential recurring and non-recurring traffic delays, and other applications. The benefit of sharing these procedures and software in an open-source environment is that it reduces the “re-inventing the wheel” thus enabling more efficient use of resources.

7. TRANSIT APPLICATIONS

7.1 STATE-OF-THE-PRACTICE REVIEW

Transit ITS has three components: (1) metropolitan, (2) rural, and (3) the Intelligent Vehicle Initiative. The metropolitan component focuses on urban and suburban transportation in the areas of Traveler Information, Transit Management, and Electronic Payment. The rural Transit ITS component addresses these same areas but emphasizes rural area applications. The Intelligent Vehicle Initiative pertains to automating transit vehicle control and safety systems.

A state-of-the-practice was conducted to determine the use of data archived from transit ITS technologies. A growing number of transit service providers are using Automatic Vehicle Location (AVL) and/or computer aided dispatch (CAD) systems to better manage their bus operations. These systems help to circumvent traffic congestion and to meet passengers' demand for more reliable service. Beyond the area of operations control, AVL technology holds great promise for improving service planning, scheduling, and performance analysis practices. In particular, AVL systems can collect substantial amounts of operating data at the spatial and temporal scales that are required for performance analysis. In addition, Automatic Passenger Counters (APCs) can collect and archive passenger activity data that are compatible with AVL operating data.

7.1.1 ITS-Generated Transit Data

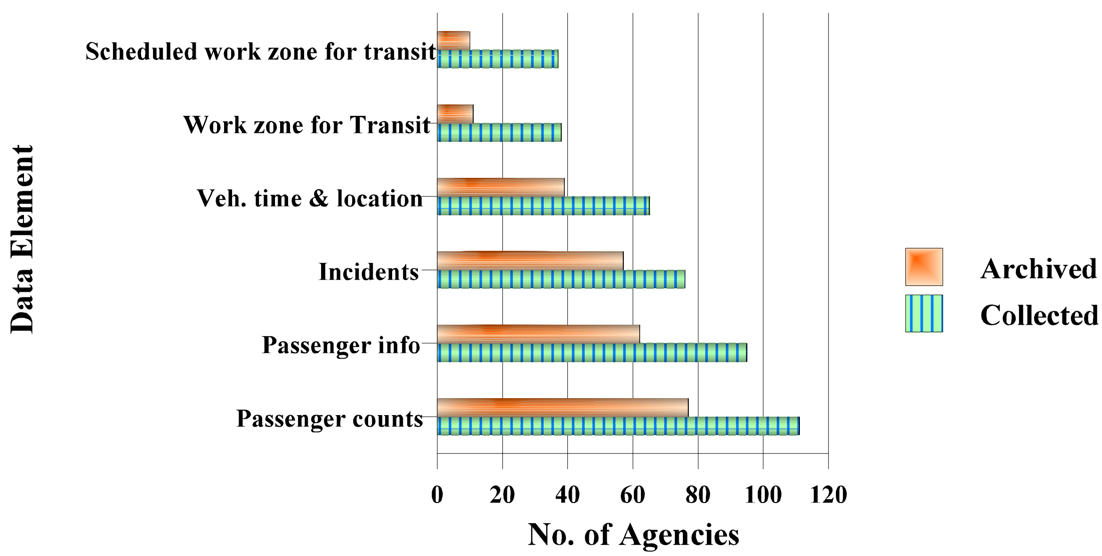
One hundred and ninety-six transit agencies responded to the 1999 Transit Management Survey. Table 7.1 demonstrates the propensity of data archiving by transit agencies. One in every three transit agencies did not archive any data collected (the "0" column), while more than one in every three archived all data collected (cells on the diagonal line).

Table 7.1 Distribution of Transit Agencies by Number of Data Elements Collected and Number of Data Elements Archived
1999 ITS Deployment Survey

Number of Data Elements Collected	**Transit Management Survey (138 agencies responded to questions pertinent to data archiving)**																	
	Number of Data Elements Archived																	
	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
17																		
16																		
15																		1
14																		
13																		
12						**1**					1	1						
11										1								1
10												1	2		1			1
9											1	2		1	3			
8										**2**			1		1			3
7											**2**	1	1	3	2			2
6												**7**	1		1			4
5													**5**	3	2			4
4													1	**11**	3		1	5
3															**11**	3	1	5
2																**6**	2	6
1																	**5**	12
0																	**3**	

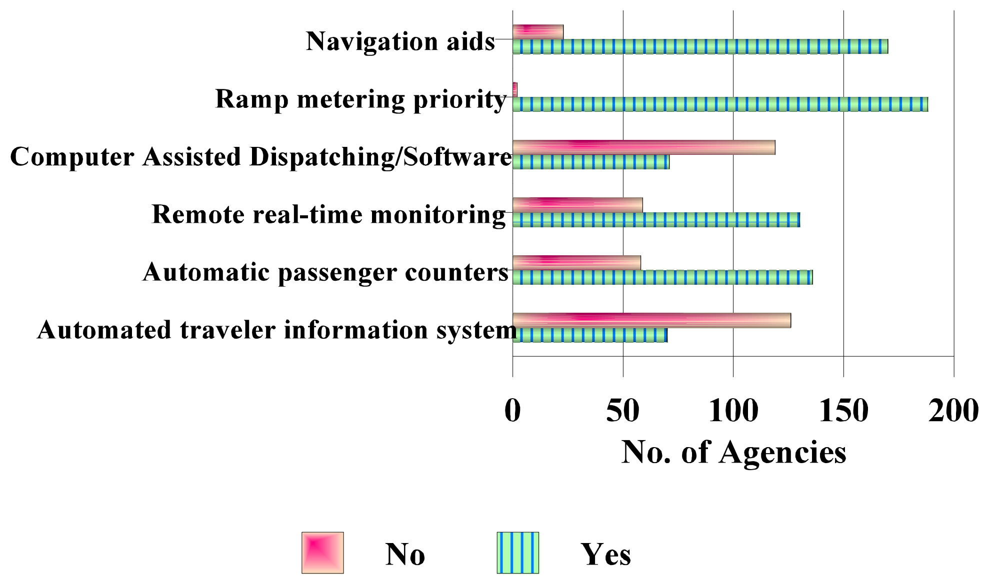
The most commonly collected transit data are: passenger counts and passenger information (Figure 7.1). Many transit service providers are increasingly equipped with ITS Advanced Public Transportation System (APTS) technologies. These include the Automatic Vehicle Location (AVL), Computer-Aided Dispatch (CAD), Fleet Management System (FMS), Automatic Passenger Counter (APC), and Automatic Fare Payment System (FPS) technologies.

Figure 7.1 Selected Transit Data Collected and Archived
(of 196 transit agencies in 1999 and 220 in 2000 responding to transit management survey)



The likelihood to install advanced technologies varies by the type of the technology. Almost all of the responding agencies indicated that they have or plan to have their vehicles equipped with ramp metering priority capability (Figure 7.2). Three quarters of them have (or plan to have) their operators/dispatchers report traffic incidents. This has safety implications by, for example, potentially facilitating the integration of the safety component into the transportation planning process. About forty percent of transit agencies that responded to the 1999 transit survey had

Figure 7.2 Agencies That Have (or Plan to Have) Equipment Installed
(of 196 responding transit agencies in 1999)



information on transit work zones and one of every four such agencies archived that information.

7.1.2 Archiving of ITS-Generated Transit Data

One in every three transit agencies did not archive any data collected, while more than one in every three archived all data collected. Based on discussions with a very limited number of transit agencies, the overarching reason for archiving data is to satisfy mandatory federal reporting requirements such as input to the National Transit Data Base (NTDB). A secondary reason for data archiving is for service planning, scheduling, and performance analysis.

7.1.3 Use of Archived ITS-Generated Transit Data

A growing number of transit service providers use AVL and/or CAD systems to help circumvent traffic congestion by better managing their bus operations. Also pertinent to operations and maintenance applications is the archived information on work zones and scheduled work zones for transit.

Archived transit data have the potential to provide more representative, comprehensive, and timely information on service scheduling, vehicle maintenance, transit management systems, evaluation, and capital planning. These advantages of archived data can fulfill some of the NTDB limitations identified in a recent evaluation[7.1]: data timeliness, and data accuracy. In addition, archived data hold substantial promise for providing accurate and timely input to a number of funding apportionment formulae such as the Urbanized Area Formula Program funds, the Elderly and Persons with Disabilities Program funds, and the Metropolitan Planning Program funds.

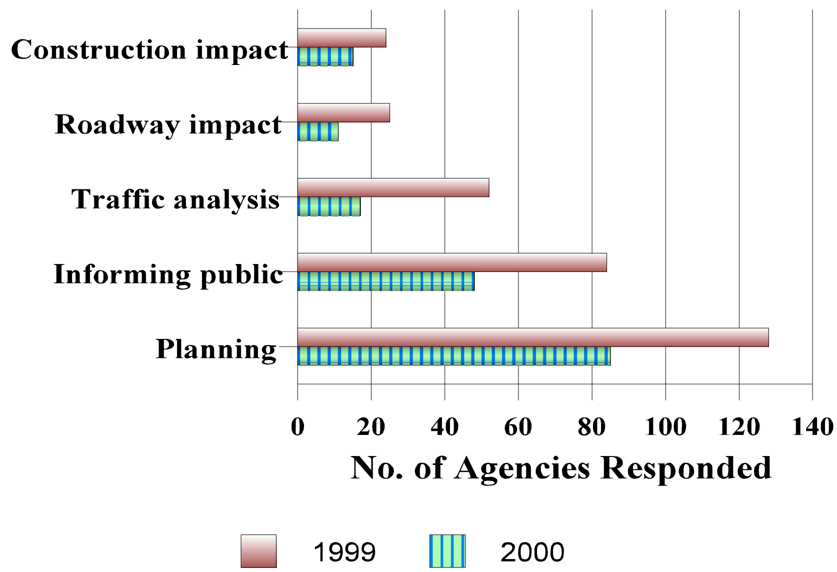
Staff at all levels of the public sector use ITS-generated transit data more frequently than those from the private sector, the media, or academia. This suggests that ITS-generated transit data are used to serve both the regional and local needs. Similar to the use of freeway and arterial data, archived transit data are most likely to be used for planning purposes, followed in frequency by dissemination to the public (Figure 7.3).

7.2 CASE STUDIES OF TRANSIT APPLICATIONS

Three ADUS transit applications are discussed here: the smart card and the transit signal priority projects in King County Metro of Washington State, the automated transit fare system in New York City, and the operations improvement in the Tri-Met Transit System.

[7.1] "Review of the National Transit Database: Report to Congress." Federal Transit Administration, U.S. Department of Transportation. May 2000.

Figure 7.3. Uses of ITS-Generated Transit Data
(of 138 agencies responded in 1999 survey and 106 in 2000 survey)



7.2.1 King County Metro

7.2.1.1 System Description

The King County Department of Transportation Metro Transit Division, commonly called the King County Metro (KCM), is located in Washington State. The KCM, with an annual ridership of over 75 million, operates in a 2,128 square mile area that includes Seattle. The KCM Transit service area is shown in Figure 7.4 in the central portion of the map. The KCM has a fleet of about 1,300 vehicles, including coaches, trolleys, buses, and streetcars.[7.2]

7.2 " King County, Washington, Metro Transit at a Glance," http://transit.metrokc.gov/programs_info/metrotransit.html.

There are about 1,000 peak-hour (i.e., rush hour in the morning and evening) buses. About 500 buses are in operation at noon. There is not a lot of coordination of the transit schedules with counties to the north and south; however, KCM tries to have a bus available when the ferry docks.[7.3] KCM and other transportation agencies work together to the extent possible to provide efficient transportation options to the public. For example, KCM feeds data to Smart Trek, a real-time traffic information on-line service for the Puget Sound region.[7.4] In addition, KCM provides options for internet users to view congestion, construction, and road condition information.[7.5] In 1999, KCM began collaboration with six other transportation agencies, including transit, ferries, and rail, to implement a regional Smart Card system. Under this system, the seven agencies provide riders with the option to use one fare card in four Puget Sound counties. Fare collection is done using the Smart Card to allow linked trips between the different agencies.[7.6]

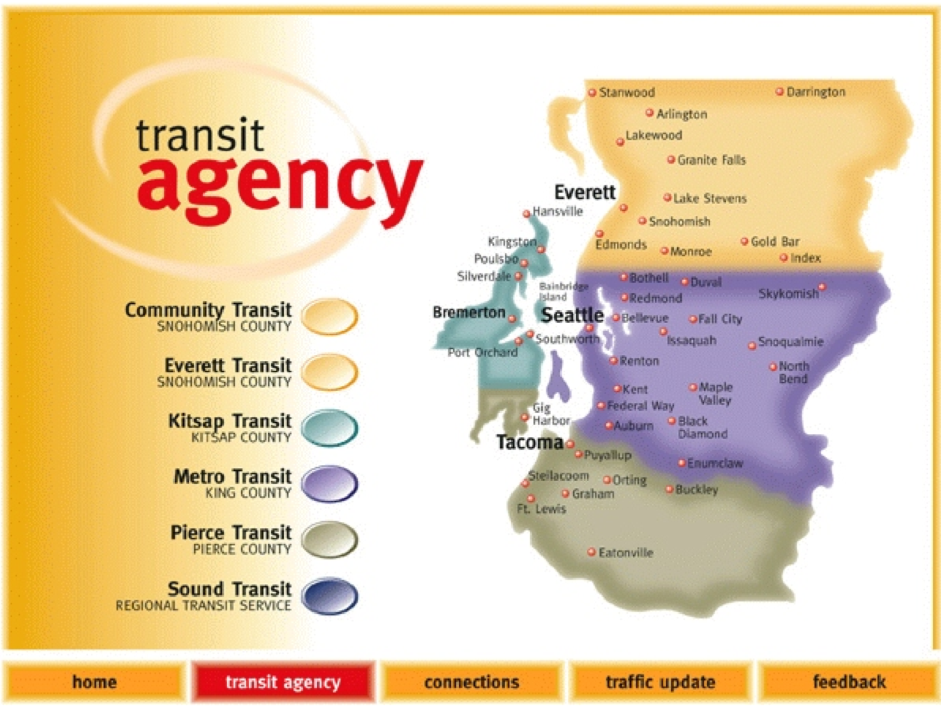
7.3 Tom Friedman, King County Metro, Personal Communication, April 24, 2001.

7.4 "Smart Trek: Your Traffic Information Source for the Puget Sound," http://www.smarttrek.org/ .

7.5 "King County, Washington, Traffic Update," http://transit.metrokc.gov/traffic_update/trafficupdate.html.

7.6 King County, Washington, Smart Card Project," http://transit.metrokc.gov/programs_info/smartcard/smartcard.html .

Figure 7.4. Coverage Area of the King County Metro and Comparison with Other Transit Agencies in the Same Area of Washington State



(Source: http://www.riderlink.gen.wa.us/rl_agency.html).

The KCM is currently working with traffic engineers in partner cities (e.g., Seattle, Shoreline) to test Transit Signal Priority (TSP). TSP allows specially equipped buses to communicate with traffic signals to hold a green light until the bus passes through the intersection. This is similar to the system implemented in LADOT. The purpose of this system is to increase the efficiency of the buses and to provide a smoother ride for the transit passengers.[7.7] It is not known whether data will be archived from this project.

The KCM transit system currently collects and archives two types of ITS-generated data and one non-ITS-related type of data. The ITS-generated data AVL data and APC.

7.2.1.2 Data Collection and Data Archiving

AVL data record the actual time that a transit vehicle is at a specific point. About two years of detailed data have been archived, and there is storage space for about five more years of data. Only the detailed AVL data are stored; any summaries are produced as needed. Data are stored in flat files.[7.8] Real-time AVL data are centrally monitored. About four to five staff people are required to monitor buses during peak periods. If buses are off schedule, the drivers may be contacted via radio. Monitoring also serves to ensure safety and to identify incidents.

APC data include on/off counts at all stops. The equipment includes a pair of pressure-sensitive mats placed on the steps of the bus. The count for whether a passenger is boarding or leaving the bus is determined by the order in which the mats are pressed when the passenger steps on them. The KCM has sufficient mats for about 15% of the buses; the mats are alternated among buses to collect counts for all routes. Data are manually downloaded once each week. KCM has been collecting APL data for about 15 years. Both detailed and summary data are stored. Archived data are retained in compact disc (CD) format.[7.9] These files represent the detailed (i.e., not aggregated across multiple dates) data level.

Non-ITS data are incident data as reported by drivers or collected from police reports.

7.7 King County, Washington, Transit Signal Priority," http://transit.metrokc.gov/programs_info/tsp/tsp.html .

7.8 Tom Friedman, King County Metro, Personal Communication, April 24, 2001.

7.9 Tom Friedman, King County Metro, Personal Communication, April 24, 2001.

Although these data are non-ITS in nature with respect to collection methodology, they are stored for potential future use.[7.10]

In addition, although there are currently no cameras on the buses, the KCM plans to add 200 Digital Video Recording Systems on transit buses in a few months. The systems will include storage devices; however it is not known how any of the camera-based images will be stored or used in the future.[7.11]

7.2.1.3 Data Sharing

The KCM owns the data stored from the transit data collection effort. Several potential opportunities exist for storing and sharing ITS-generated data from the KCM. For example, the DVRS data could be used for safety purposes, and TSP data could be used by traffic engineers for strategic planning and analysis.

Currently, AVL and APC data are archived and used for multiple purposes. The AVL data are used by transit schedulers. One of the primary uses of the data are by KCM to check for schedule adherence. In addition, historical AVL data are run through a scheduling package called HASTUS[7.12] to analyze, and possibly revise, schedules to cover 80% or 90% (or whatever is desirable) of the riders.

The AVL data are used to provide real-time arrival/departure times at two transit stops – a feature called TransitWatch. Actual arrival/departure times are also posted on the internet at two sites – “BusView” (http://transit.metrokc.gov/bus/busview.html) and “MyBus”

[7.10] Tom Friedman, King County Metro, Personal Communication, April 24, 2001.

[7.11] King County, Washington, Digital Video Recording System Project, http://transit.metroke.gov/programs_info/dvr/dvr.html.

[7.12] A product of GIRO, described at http://www.giro.ca/hastusa.htm.

(http://www.its.washington.edu/mybus/). The web sites allow slightly different methods for potential passengers to preplan their trips. This website information was programmed by and is currently managed by the University of Washington using real-time (i.e., not archived) KCM data. The University of Washington also used these archived data to develop an algorithm that predicts the arrival time of transit vehicles[7.13].

The AVL archived data are combined with vehicle count data collected by the Puget Sound Regional Council to perform a congestion management analysis. This analysis is required by the Federal government and is also used by the Seattle Metropolitan Planning Commission (MPO).[7.14]

The APC are used by transit managers and planners to perform route productivity analyses, and to determine new routes and schedules.

The incident data are recorded for future safety analysis. There is no interface with commercial vehicle operations. Table 7.2 shows areas of current usage.

In general, the archived data are shared with anyone who makes a request. However, it was decided early on that the raw data will generally not be shared. Computer programs were developed so that appropriate data can be extracted for sharing.

7.13 Dailey, D.J.; Wall, Z.R.; Maclean, S.D.; Cathey, F.W. "*An Algorithm and Implementation to Predict the Arrival of Transit Vehicles.*" Department of Electrical Engineering, University of Washington.

7.14 Tom Friedman, King County Metro, Personal Communication, April 24, 2001.

Table 7.2 King County Metro (KCM) Archived Transit Data Usage (AVL, APL, and Incident Information)

Archived data	Long-range planning	Operations planning	Adv. traveler information system	Performance monitoring	Other stakeholders
AVL	To identify new features and new routes. *User: KCM*	To perform routes and schedules analysis *User: KCM*	To develop route planning (via web site) *User: Riders*	To meet Federal reporting requirements *User: Public agencies*	To develop strategies to improve air quality through signal timing changes and congestion monitoring *User: Puget Sound Regional Council and the Seattle Metropolitan Planning Commission (MPO)*
APC	Improve efficiency and productivity (supply and demand scheduling) *User: KCM*	Develop traffic signal timing strageties *User: County traffic engineers*	Provide public advisory information (via web site) *User: Riders*	Evaluate transit performance, incidents, congestion, etc. *User: Public agencies*	
Incident data	Develop incident countermeasures *User: KCM*				Research *User: Academia*

7.2.2 New York City Transit Automated Fare Collection (AFC) System

7.2.2.1. Location and General Description

The New York City Transit in New York is one of the largest and most complex public transportation systems in the world and has been in operation since 1904. The bus and subway services operate twenty-four hours a day throughout the city. The high point in ridership numbers was in 1946-1947 when there were about 8 million passengers per day. Ridership declined in the 1950's through 1970's but in recent years has been increasing. Currently, an average of over 6 million riders use the New York transit system daily. The New York City Transit includes 468 subway stations. Over 47,600 employees are needed to manage, operate, and maintain the many components of the system.[7.15]

The New York City Subway has an automated fare collection (AFC) system using fare cards. These MetroCards can be used on either the subway or the bus system. There are several types of MetroCards (e.g., unlimited rides, pay-per-ride, student, senior citizen). Purchasers can find out how much time or money is left on their fare card at MetroCard Readers, located at any Metro Station. Currently, about 80% of all subway riders use MetroCard.

MetroCards are individually identifiable by a serial number. Data can be collected on card usage every time the card is inserted into a fare reader. For example, when a MetroCard is inserted into the meter at the entrance to the subway, the serial number, date and time of entry, subway booth number, type of card, type of transaction, and other details are recorded. No information is recorded when the rider exits the subway, because it is not necessary to insert the card into a reader when exiting.

Three months of "active" transaction data are kept on line. After that time, the data are archived indefinitely and are retrievable if needed. The MetroCard system has been in operation for about four years. The transaction data have been extracted and studied extensively for about a year.[7.16]

7.15 "About New York City Transit: Introduction," http://www.mta.nyc.ny.us/nyct.facts/ffintro.htm.

7.16 James Berry, New York City Transit Authority, personal communication, April 30, 2001.

7.2.2.2 Uses of Archived Data

The New York City Subway system needed to conduct an origin-destination (O-D) study to determine up-to-date ridership habits and future usage requirements. Rather than conduct a traditional O-D study, which is both expensive and time-consuming, transit authorities decided to use existing data available from the fare card transactions.

Although entrance (i.e., origin) information is obtained by the fare card at the time it is inserted into the meter, exit (i.e., destination) information for a rider is not collected. Therefore, two key assumptions were made concerning how to determine exit locations:

- "people usually return to the exit station of their previous trip to begin their next trip," and
- "a person's last trip of the day very often ends at the station where his/her first trip of the day began."[7.17]

The assumptions were validated through use of a travel diary survey conducted by the New York Metropolitan Transportation Council that record actual origins and destinations of transit trips. The survey data showed that use of the MetroCard transactions to determine an O-D pair with the assumptions listed above would yield about 80 to 90% accuracy in determining O-D pairs.

Two major results occurred from this shared usage of archived ITS data. First, the analysis provided detailed O-D tables by time of day to planners who are responsible for determining modifications to the existing service or for planning new and/or expanded services. Second, the analysis provided peak hour trip data for use with the travel demand forecasting

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7.17 James Berry, "Origin and Destination Estimation in New York City Using Automated Fare Collection System Data." Presented at the 8th TRB Conference on the Application of Transportation Planning Methods, April 2001, Corpus Christi, Texas.

model and other major investment studies. That is, the data could be used to calibrate the model, to look at demand on a zone level, and to supplement journey-to-work data for the Census Bureau.

It is expected that this concept of shared data usage will be expanded to include bus, as well as subway, data. The results of these studies can be used for many purposes – for example, to identify separate trips, infer the end location of a trip, and allocate station and bus stop groups to O-D zones. In addition, special MetroCard types (e.g., student cards or senior citizen cards) could be studied to learn travel patterns of these special citizen groups. Research results will be beneficial for use by the following:

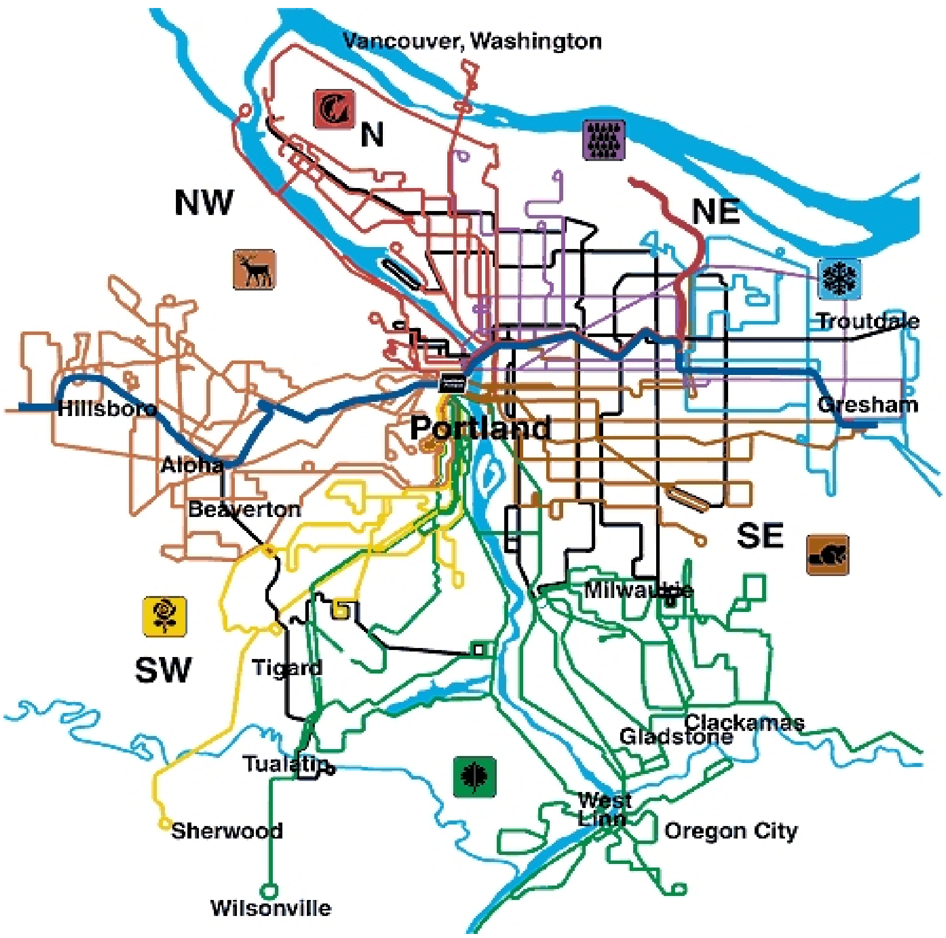
- New York City Transit authorities to determine routes and schedules,
- the New York Metropolitan Planning Council when examining congestion and traffic management tactics, and
- public-private-educational agencies when desiring up-to-date travel information for various research needs.

7.2.3 Tri-Met Bus Dispatch System Data for Operations, Planning and Scheduling

7.2.3.1 System Description

Tri-Met provides transit services to the Portland, Oregon, metropolitan area (Figure 7.5). It operates 105 bus lines, 2 light-rail lines, more than 800 vehicles and 9,000 bus stops. In a typical weekday, there are more than 270,000 boardings. Bus Dispatch System (BDS) was activated in October, 1996 with a few test vehicles. The main functions of the BDS are to: (1) improve dispatch capabilities, (2) enhance security, (3) provide real-time information to other systems, and (4) collect operating data.

Figure 7.5 Tri-Met Service Area



This system was implemented as a regular system in June, 1997. All of the vehicles are equipped with a satellite GPS-based AVL system, and half of the vehicles are equipped with light-beam APC. All of the vehicles have a CAD system with a CAD/AVL console. An on-board interface unit reports schedule deviation.

7.2.3.2 Data Collection and Archiving

Every morning a driver inserts a PCMCIA Data Card into the on-board computer. The card contains schedule information such as routes and stops for the day. In addition, it records (in hexadecimal format) all of the *stop* data and *event* data. *Stop* data include those data elements that are automatically recorded at every bus stop and every door opening, and are listed below:

Route	Ons (Boardings)	Offs (Alightings)
Direction	Passenger Load	Door Opening
Trip	Lift Operation	Dwell Time
Date	Maximum Speed	Latitude
Vehicle ID	Operator ID	Longitude
Stop Location	Actual Arrive Time	Actual Leave Time
Scheduled Leave Time		

There are 500,000 stop records generated daily.

Event data include data elements that are collected at the discretion of the operator such as:

Pass Up/Overload	Traffic Delay	Bridge/Train Delay
Deadhead Delay	Route Blocked	Fare Evasion
Securement Refused	Silent Alarm	Medical Emergency
Accident	Mechanical: Blocking	Mechanical: Lift Problem
Bill/Coin Jam	Restroom Break	Operator Ill

There are about 25,000 event records recorded every day.

At the end of the day, the driver downloads the data. These data are then matched against the schedule data and stored in ORACLE tables which can be queried for additional analyses. Raw *stop* data are kept online for 6 months. However, they are not accessible to the public without special arrangement. After the data are downloaded, the PCMCIA card is completely wiped clean and a new route-schedule is stored in the card for the next day.

7.2.3.4 Using Archived Data

A metadata file (Figure 7.6) that "describes" the data elements in the archived files (a portion of the BDS_Data in Figure 7.7) facilitates the use of the data. The agency uses these data extensively for: scheduling, service planning, operations (for training, fare inspection, and special service planning), project development (including signal priority), streamline, real-time customer information evaluation, facilities maintenance, customer service, and legal matters.

Furthermore, data are used to monitor on-time performance (Figure 7.8). Between 1997 and 2001, Tri-Met's overall on-time performance improved from 78% to 83%. The agency attributes this improvement to the use of the archived BDS data[7.18]. Specifically, the agency lists the benefits of using archived data as:

1. Reduced and eliminated manual counts,
2. Improved data reliability,
3. Reduced staff time and cost,
4. Complete and timely operational data,
5. Improved statistical evaluation,
6. Better incident tracking,
7. Data available for field personnel,
8. Rapid schedule modification,
9. Improved schedule reliability, and
10. Informed service reallocation.

[7.18] Steve Callas. Tri-Met Coordinator for Service and Performance Analysis. Portland, Oregon.

Figure 7.6 Example of Tri-Met Metadata File

Columns in the BDS_DATA Table

Service_Date
The calendar date associated with the service. Typically this is the date the vehicle leaves the garage. When the vehicle is on the road at midnight, the service provided after midnight is associated with the previous day. Such late service is usually completed by 3:00 AM.

Vehicle_Number
The Vehicle Number of the bus recording the data. This is the number that is painted on both the interior and exterior of the bus. In the data, the Vehicle Number is stored as a five-character field with leading zeros. For example, the Vehicle Number for bus 512 is represented as '00512'.

Train
The Train or Block number stored as a number. Scheduled trips are blocked together into trains for assignment to vehicles. The number of the train assigned to a vehicle is usually displayed at the bottom of the front right window of the bus.

Badge
The Operator ID stored as a number.

Route_Number
The internal numeric designation of the Route. For Example, Route 1 has the Route_Number of 1 for the Greeley Line and 101 for the Vermont Line.

Direction
A one digit numeric field indicating the direction of travel for the scheduled trip. The field contains either the character Zero or One, where 1 specifies inbound and 0 specifies outbound. On cross-town routes 0 often specifies Northbound and 1 specifies Southbound.

Service_Key
A designation for the different types of service that are provided on different calendar dates. Common Service Keys, such as 'W', 'S', and 'U', specify regular Weekday, Saturday, and Sunday service. In these cases the different types of service are reflected in the published schedule. However, Tri-Met usually operates with about 15 additional Day Types that reflect additional service that does not follow a weekly pattern. Examples of these types include designations for additional service for Blazer games, the Portland Meadows Racetrack, and the Gateway/Airport Holiday Shuttle. When the schedule for such additional service is changed, the Day Type designation may also be changed. As a result, the type of extra service identified by a Day Type may be valid for only a short period of time.

Trip_Number
A number that provides the most specific identification of a scheduled trip. The combination of Route_Number, Direction, Service_Key, and Trip_Number provide a unique identifier for every scheduled trip in the current schedule.

Figure 7.7 A Small Portion of the Archived BDS Data

SERVICE_DATE	VEHICLE NUMBER	LEAVE_ TIME	TRAIN	BADGE	ROUTE_ NUMBER	DIRECTION	SERVICE_KEY	TRIP_NUMBER
01OCT2001:00:00:00	601	18748	705	2703	0	0		0
01OCT2001:00:00:00	601	20556	705	2703	0	0		0
01OCT2001:00:00:00	601	22432	705	2703	0	0		0
01OCT2001:00:00:00	601	22524	705	2703	0	0		0
01OCT2001:00:00:00	601	22582	705	2703	0	0		0
01OCT2001:00:00:00	601	22654	705	2703	0	0		0
01OCT2001:00:00:00	601	22892	705	2703	0	0		0
01OCT2001:00:00:00	601	23008	705	2703	0	0		0

Figure 7.8 A Sample of On-Time Performance Report from Tri-Met BDS

Summary Load Data and On Time Performance by Trip For a Specific Location

14 - Hawthorne | Outbound to Foster & 94th | Weekday

Hawthorne & 12th

TRAIN	TRIP #	SCHED TIME	AVG MIN LATE	MAX LOAD	ON TIME	LATE	EARLY
1401	1720	5:01 PM	02:49	33	73%	24%	3%
1418	1740	5:05 PM	02:13	33	85%	11%	3%
1419	1770	5:10 PM	01:40	34	77%	11%	11%
1421	1772	5:14 PM	01:38	33	89%	5%	6%
1414	1780	5:19 PM	04:09	47	71%	26%	3%
1411	1810	5:24 PM	04:09	40	62%	30%	8%
1408	1820	5:29 PM	05:02	43	52%	45%	3%
1409	1822	5:34 PM	03:33	43	76%	17%	6%
1405	1825	5:39 PM	03:43	39	79%	18%	3%
1410	1827	5:45 PM	03:01	37	77%	20%	3%
1412	1830	5:50 PM	00:58	34	89%	8%	3%
1406	1835	5:55 PM	03:26	43	84%	14%	2%
1407	1840	6:01 PM	00:57	33	95%	3%	2%

There has not been much interest expressed from outside parties seeking access to the data with the exception of researchers from the University of Washington. In this case, data access was granted.

7.2.3.4 Barriers to Using Archived Data

Tri-Met archives its raw bus data and schedule-matched data to tapes (in a Jazz drive). Recovering old data is easy. However, using these data is non-trivial because with the constant changes in bus schedules, stops, and routes, time references have to be established that correspond to the data. Even with the correct time references, any analyses involving a span of time can be very challenging because the changed schedules and routes do not allow for data continuity[7.19]. This example confirms the challenge of integrating data archived from different sources.

7.3 BARRIERS AND SOLUTIONS

7.3.1 Privacy Issues and Barriers

The most commonly collected transit data are passenger counts and passenger information, followed by incident information, vehicle time and location, and work zones for transit. One third of transit agencies archive all data elements that they collect, while another third archive none of the data elements collected. The remaining one third of transit agencies archive only some of the data elements they collect. This final group of transit agencies who archive only some of their data elements are of particular interest because they clearly have the capability to archive data, but choose not to. When a number of these agencies were contacted, most of them explained that they had no long term need for the data elements that they chose not to archive[7.20].

Archived transit data are most likely to be used for planning and scheduling purposes and for performance analysis. Traveler information is another common use of ITS-generated transit data; however, this dissemination of information to the public for this purpose is most often real-time data rather than archived data.

Two specific transit applications were examined – New York City Transit and King

7.19 Steve Callas, Tri-Met. Portland, Oregon.

7.20 Based on data from the Metropolitan Intelligent Transportation Systems Infrastructure Deployment Tracking Database. http://www.itsdeployment.its.dot.gov/

County Metro (Washington State). The ITS data collection feature, selected from the New York City Transit, was use of archived data from the fare card payment system. Although the cards are identifiable by serial numbers, the serial numbers are not identifiable to a particular individual. Therefore, they are not considered a privacy violation.

King County Metro collaborates with partner cities and agencies with a joint fare card system and to provide real-time traffic information to the public. The King County archived ITS-generated data include automatic vehicle location (AVL) data and automatic passenger counts (APC). Currently these archived data sets are analyzed for trends which are then used by transit managers and planners to perform route productivity analyses in order to optimize transit utilization. They are also used by the Metropolitan Planning Organization to perform a congestion management analysis. The data are shared with anyone who makes a request.

There are no apparent privacy barriers to sharing the transit data currently collected and archived by the King County Metro. In the future, however, plans call for installation of digital video recording systems (DVRS) on transit buses. The purpose will be to monitor the bus as a safety feature.

Several cities' public transit systems, both bus and rail, have used surveillance cameras for a number of years in an attempt to prevent incidents of fraudulent claims, passenger harassment, and vandalism. Nieto notes that video recording devices are generally accepted as being successful in preventing crimes and helpful in prosecuting persons caught on film while committing a crime[7.21].

Although surveillance cameras are generally accepted by the public when used by transit officials to ensure public safety, it remains to be seen what attitudes will be regarding the sharing

[7.21] Nieto. CRB-97-005, June 1997.

and use of transit data outside of the official transit environment.

7.3.2 Technical and Technological Issues and Barriers

ITS-generated data are used by planners, managers, and schedulers to produce mandatory reports and to improve service and productivity within the transit business community. The greatest barrier to the use of transit data for these purposes is the failure of transit providers to archive the data. Only a third of all transit data collected is archived.

Another barrier to the use of stored transit data is that other users have not seen the value of the transit data. For example, transit data could be used to coordinate emergency management and evacuation plans – for example in rural areas, nursing homes, and other emergency services. Transit data have not been widely used by academia for research, possibly because research projects using transit data have not been defined.

Finally, video-based data, as already noted, have large storage requirements and content searches are, at this time, not automated.

7.3.3 Institutional Issues and Other Barriers

The institutional and other barriers associated with implementing ADUS are largely the same among the different focus areas of ITS. These common barriers such as cost, proprietary rights, politics, and a lack of understanding or knowledge about ADUS are covered in further detail in Chapter 2. Transit faces an additional barrier if competing agencies are unwilling to cooperate in data sharing for fear of losing a "market share" of ridership. The example provided by KCM and adjoining transit providers is a positive example of how sharing benefits customers as well as original data collectors.

7.4 OPPORTUNITIES

As depicted in Figure 7.3, archived transit data are used more frequently by public agency staff than by the private sector, the media, or academia. ITS-generated transit data are used primarily for planning, route scheduling, vehicle maintenance, informing the ridership, traffic and analysis. All of these uses are valuable to the transit community.

Case studies and results from our literature review suggest that the transit community has extensively been, and continues to be extremely active in, archiving and using archived ITS-generated data to meet its information needs. That said, opportunities for using ITS-generated data to improve transit operations, maintenance and planning are still plentiful (Table 7.3).

Rather than try to identify all possible opportunities, this section identifies those that are (or appear to be) feasible, can be quickly deployed, and are most likely to produce immediate benefits/results. The rationale for identifying these "low-hanging fruits" is that the sooner that quantifiable benefits of using ITS-generated data for transit operations improvement are demonstrated and disseminated, the sooner additional deployments will be stimulated. Any of these opportunities identified below can be developed into an FOT with public and private partnership.

Table 7.3 Potential of Archived ITS-Generated Transit Data

For Data collected in *Transit Management* Survey		
	If data are collected and archived, it could help address the following issues:	**If data are collected and archived, it could potentially help to meet federal data reporting requirements (NTDB):**
Vehicle time and location	• Fleet management • Route scheduling (fixed route, or demand responsive route) • Evaluate routing strategies with respect to reliable services	
Passenger count	• Revenue count • Performance evaluation • Service planning and vehicle maintenance planning • Fleet management	• Meet data reporting requirements of NTDB. • Can be used to estimate passenger miles which is the primary input to the capital formula program.
Trip itinerary planning records	• Evaluate supply and demand relationship	
Passenger information	• Revenue count • Performance evaluation • Service planning and vehicle maintenance planning • Fleet management	• Meet data reporting requirements of NTDB. • Can be used to estimate passenger miles which is the primary input to the capital formula program.
Road conditions	• Allow the development of anticipatory scheduled services	

For Data collected in *Transit Management* Survey		
	If data are collected and archived, it could help address the following issues:	**If data are collected and archived, it could potentially help to meet federal data reporting requirements (NTDB):**
Emergency vehicles signal preemption	• Evaluate the effectiveness of different signal preemption strategies in emergency management	
Transit vehicle signal priority	• Evaluate the effectiveness of different signal strategies in meeting transit demand, especially during rush hours	
Route designations	• Develop plans for emergency evacuation	
Weather conditions	• Allow the development of anticipatory scheduled services	
Incidents	• Identify the most effective countermeasures for incidents onboard	• Enhance NTDB Safety and Security Data Reporting
Current roadway work zones for transit	• Adjust schedule and routing accordingly	
Scheduled roadway work zones for transit	• Adjust schedule and routing accordingly	
Intermodal (air, rail, water) connections	• Coordinate rail/bus interconnection	

For Data collected in *Transit Management* Survey		
	If data are collected and archived, it could help address the following issues:	**If data are collected and archived, it could potentially help to meet federal data reporting requirements (NTDB):**
Emergency/evacuation routes & procedures	• Develop emergency management and rural disaster management, especially for nursing homes and other emergency services	
Transit operations coordination information	• Coordinate central dispatchers and drivers • Provide services for special events	
Highway operations coordination information	• Coordinate emergency evacuation plans	

7.4.1 ADUS for Assessing Security Vulnerability of Transit Systems

The terrorist attacks on September 11, 2001 deepened the security concern that transit agencies and transit management have faced since the development of modern public transportation in the mid-1800s. To prepare for future threats, it is critical to assess the vulnerability of our transit infrastructure, identify the weak links, and develop strategies to reduce the vulnerability.

A digital multi-modal transportation network that is populated with archived data from AVL and APC systems, trip origins and destinations, non-transit traffic flow, facility capability information, and other transit operation characteristics can provide valuable information to assess the vulnerability of the nation's transportation system and to identify the weak links. With suitable algorithms and software (many of which ready exist), the *vulnerability*, *resilience*, and *redundancy* of our nation's transit systems can then be assessed.

It should be emphasized that ADUS alone can not satisfy all of the information needs for an assessment of our transit security vulnerability. However, when integrated with other data sources (e.g., highway monitoring data, remotely sensed data) and tools, ADUS can provide an indispensable base to do so.

7.4.2 ADUS for Emergency Management and Preparedness of Transit Systems

In order to reduce the vulnerability of transit infrastructure to the consequences of intentional harm to the system, its employees and its users, all transit systems are encouraged to develop and implement a *proactive* system security plan. Furthmore, all transit systems are encouraged to develop this plan that also ensures that the community's transportation needs continue to be met <u>during</u> and <u>after</u> the emergency. Therefore, it is crucial to develop this proactive security and emergency preparedness plan based on realistic, system-specific data. ADUS data can help meet this information need.

The aforementioned digital multi-modal transportation network can also be used to evaluate the consequences and feasibility of alternative strategies on evacuation and re-routing. For example, if a link(s) were to be closed or destroyed, do alternative, parallel routes exist to accommodate the lost service? Are there adequate equipment and operators to accommodate the lost service? How should these equipment be routed and the drivers be scheduled to ensure that mobility needs are met? How long will it be before these alternative routes reach their capacities? What will then be the alternatives to these alternative routes?

During transit emergencies, personnel from many agencies must come together to manage the incident, performing such tasks as rescuing or evacuating passengers, extinguishing fires, controlling crowds, repairing track and wayside structures, and restoring service. Under these circumstances, a seamless integration among these agencies is crucial. Archived information from integrated ITS deployments such as ramp metering preemption, signal priority and route guidance for emergency vehicles and transit vehicles can help evaluate how well the local law enforcement, fire departments, medical emergency services and transit services work together to respond to emergencies.

7.4.3 ADUS for Transit System Operations and Maintenance

Planning for transit operations and maintenance can progress from a *reactive* mode to a *proactive* one by continually adapting and learning from historical patterns and trends. For example, the variance between the actual and scheduled locations of transit vehicles can support decisions to improve schedule adherence. Traffic and signal timing data, in conjunction with other available transit priority and locational data, can help develop preferential signal timing and routing strategies, and evaluate the effectiveness of these strategies.

7.4.4 ADUS for Paratransit for Special-Needs Groups

Almost one quarter of the transit vehicles operated by the 78 most congested areas have the capability to provide demand responsive flexible routing and scheduling[7.22]. Archived data from AVL can support the development of *proactive* demand-responsive computer-aided routing and scheduling algorithms that can optimize vehicle assignment and routing to meet non-recurring public transportation demand. Archived transit data can further assist in determining priority programs (e.g., the elderly, students, handicapped, or rural passengers).

As previously mentioned, any of these opportunities can be developed into an FOT with the goals of:

- identifying technical and institutional barriers to archiving, using, and sharing ITS-generated data;
- developing solutions to overcome these barriers;
- identifying issues pertinent to standards development;
- examining the feasibility of integrating ITS-generated data with data collected from traditional and emerging technologies (e.g., highway monitoring data, remotely sensed data);
- identifying and **quantifying** costs and benefits;
- disseminating lessons learned, and
- sharing the developed procedures and software in an open-source environment. Some examples of these procedures and software are: those developed to convert raw ITS-generated data into formats acceptable to existing and/or off-the-shelf data management or analysis software, check the quality of the data, impute missing data, correct questionable data, abstract information suitable for data analysis from "text" files, estimate potential recurring and non-recurring traffic

[7.22] Surveyed by the ITS Deployment Tracking Survey.

delays, and other applications. The benefit of sharing these procedures and software in an open-source environment is that it reduces the “re-inventing the wheel” thus enabling more efficient use of resources.

8. CONCLUDING SUMMARY

Intelligent Transportation Systems (ITS) are an alternative data source that could conceivably lead to win-win situations. ITS-generated data will not only benefit the transportation operations and planning communities by allowing them to access more and better data. It will also enhance the appeal of ITS deployment by significantly broadening its originally intended benefits. The notion of using ITS-generated data as an alternative data resource is reflected in the Archived Data User Services (ADUS) in the National ITS Architecture.

Usually, an agency will evaluate the costs and the benefits of ADUS before it decides whether to deploy ADUS. The cost of archiving and using ITS-generated data is typically measured in terms of the effort needed to archive and re-format the data, re-vamp the software, and address data quality and data integration issues. The benefits, on the other hand, are measured in terms of the value added by the ITS-generated data. Although at this point the costs are high to use ITS-generated data for purposes other than the originally intended use, our previous research[8.1] has proven the concept that ITS-generated data can indeed improve transportation decisions by, in this particular case, improving traffic estimates.

8.1 BENEFITS OF ADUS

In the past, transportation planning, operations and preservation were constrained by information that was typically out-of-date and limited in scope. That situation arose because data collection is expensive, and information compilation and dissemination take time. Data limitations have been widely and duly recognized, and addressing this limitation is one of the

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[8.1] Hu, P., Goeltz, R. T., and Schmoyer, R. L. "*Proof of Concept of ITS as An Alternative Data Resource: A Demonstration Project of Florida and New York Data*." ORNL/TM-2001/247. Oak Ridge National Laboratory, Oak Ridge, Tennessee. September 2001.

themes in the forthcoming reauthorization legislation.

With the recent advent of intelligent transportation systems, these systems provide another source of data. Archived ITS-generated data are distinct from traditional data sources in three aspects: (1) ITS-generated data are temporally intensive (e.g., collected in very short intervals), (2) ITS-generated data meet some major data gaps that could not be met in the past due to resource limitations, and (3) all ITS-generated data are on electronic media, thereby expediting data analysis and information dissemination.

These attributes of archived ITS-generated data provide unprecedented opportunities that traditional ways of compiling information can not offer. Making information accessible almost on a real-time basis allows transportation planners and operators to anticipate emerging issues, thereby allowing them to progress from a *reactive* mode to a *proactive* mode. Furthermore, more detailed and insightful understanding of the problems (safety, planning, operations, or maintenance) is now possible because of the expanded scope and increased frequency of data collection.

The specific benefits of using ITS-generated data vary from one application to the next, and are difficult to enumerate. However, the general benefits of using archived ITS-generated data can be gauged in at least three ways. First, can ITS data replace traditional data? If so, this benefit can be measured in monetary terms. Second, can ITS-generated data supplement traditional data so that more reliable estimates can be developed? Third, can ITS-generated data meet data gaps that are expensive or impossible to meet with traditional data sources? Results from our previous research confirm that ITS-generated data can both replace and supplement data collected through traditional ways[8.2].

[8.2] Hu, P. S., Goetz, R., Schmoyer, R. "Costs and Benefits of Using ITS as An Alternative Data Source: A Case Study." Forthcoming. Transportation Research Records. 2002

As more and more ITS is deployed in the future, ITS-generated data can replace many of the current data collection processes. However, before then, the greatest contribution that ITS data can offer is probably when they are integrated with, or used to supplement, traditional non-ITS data to address gaps in these data.

8.2 BARRIERS TO ADUS

ADUS can be viewed as a progression in three phases with increasingly challenging activities: archiving data, using the archived data, and sharing the archived data. Consequently, the barriers to ADUS are characterized into three categories: (1) barriers to *archiving* data, (2) barriers to *using* archived data, and (3) barriers to *sharing* archived data. Although similarities exist, the barriers and benefits of each of these phases can be considerably different from those in other phases,. The decision to archive and use ITS-generated data typically hinges on the trade-off between the costs of removing the barriers and the benefits from using the archived data.

The nature of these three types of barriers can be characterized as decreasingly technical and increasingly institutional. For example, the barriers to archiving data are typically more technical in nature, while the barriers to sharing archived data are largely institutional. Ideally, when barriers in all three phases are removed, ADUS would reach its greatest potential. Nonetheless, the benefits are still substantial even when barriers in only a single phase are overcome.

Overall, ADUS barriers include institutional inertia, concerns over privacy, proprietary concerns, liability, data ownership, data liability, data integrity and quality, data compatibility, and other technical and technological issues. They can be categorized into five areas:

- Institutional impediments,
- Data issues,

- Lack of standardization,
- Privacy and liability, and
- Other technological barriers.

In addition to the direct costs, the costs include efforts needed to:

- Articulate and communicate the needs for archived data,
- Save the data,
- Re-format the archived data into a user-friendly format,
- Re-vamp the existing software to accommodate archived data,
- Address data quality issues,
- Make archived data accessible in a timely manner,
- Integrate the archived data with non-ITS data to meet broader data needs,
- Reconcile data incompatibilities among different data sources, and
- Forge mutually beneficial partnerships among data-producing agencies and data users.

8.2.1 Barriers to Archiving Data

Results from the ITS Deployment Surveys, case studies and the literature review suggest that the level of data archiving and use varies from one application to the next, and from one locale to another. Transit applications are significantly more advanced and widespread than the other three applications. The prevalence of the transit community in using ITS-generated data seems to stem from the nature of its organizational structure. The data "producers" are oftentimes the data "users." This structure greatly reduces the institutional barriers that challenge the other three user communities.

The planning community is not progressing as rapidly as the transit community on ADUS. This is primarily due to two reasons. First, the entities that produce the desirable planning data (e.g, the TMCs) are organizationally separate from the data users (e.g., the planners). Second, many data producers do not currently see the need to archive their data. When more data producers experience the benefits of the archived operational data, more planning applications will likely be implemented.

Highway safety is perhaps the area that has been targeted the least in terms of data archiving. There are two contributing factors. First, the implementation of ADUS, as it relates to highway safety, faces an unique problem. Of all the data elements collected by ITS deployments, none of them collect data that are strictly about safety. Traffic management centers collect data in order to keep traffic flowing smoothly, which may benefit safety, but safety remains tangential to their work. Those who are interested in safety have to find their own ways to relate ITS-generated data to the topic of highway safety.

Another safety issue is the heightened concern over protecting the identity of incident victims. This heightened sensitivity can slow down or limit the flow of certain types of data. Apart from the barriers common to data archiving in general, archiving data pertinent to highway safety is confronted by a very different challenge. Part of the traffic information on freeways and arterial roads is collected by cameras. In particular, video cameras are used to identify the exact locations and circumstances where something affects traffic on the freeway system. That type of information is enormously valuable in advancing our understanding of crash causation so that effective countermeasures can be deployed. Notwithstanding these potential benefits, access to that information has been extremely controversial. Undoubtedly, the biggest barriers to archiving data that could have some bearing on highway safety applications are privacy and liability issues. Recognizing these concerns, many agencies limit their data archiving or withhold safety information and camera images. On limited occasions, images are recorded for traffic studies (such as vehicle counts, weaving movements), training purposes, and exceptional circumstances (such as in criminal investigations)[8.3].

The second contributing factor, that limits the application of ITS-generated data to improve safety, is the complexity of highway safety applications. Safety is a complex interaction among vehicles, roadways, environments, and drivers. By the same token, highway safety could be the area that will benefit the most from data archiving. Since highway safety transcends geographic boundaries (metropolitan vs. rural), data archived from almost any of the ITS infrastructure components can be used to meet some of the data requirements in highway safety applications. For example, volume data collected from an ITS traffic surveillance project can be used to estimate accident exposure by time of day and day of the week. Another example is archived speed data which, in conjunction with information on highway geometry and weather, can be used to estimate the propensity of incidents or accidents. That said, data integration becomes ever more imperative in highway safety applications.

Across all of the applications, another major barrier to archiving data is the question of who should bear the cost of data archiving--data providers such as Transportation Management Centers (TMCs) or data users? In an increasing number of cases, this cost has been borne by the data user. For example, data are made available by data brokers on the internet and are accessible by the user through subscriptions. Or, agencies who recognize the cost effectiveness of using the archived data (i.e., data user) provide funding to the data producers (e.g., TMCs) so that ITS-generated data can be archived, and sometimes reformatted, to meet the data user's specific needs. Alternatively, the data "users" contract to a third party to archive and analyze the ITS-generated data.

[8.3] Arizona Department of Transportation's Freeway Management System (AZFMS). http://www.azfms.com/faq.html.

8.2.2 Barrier to Sharing Archived Data

Our findings also suggest that different applications face different concerns in sharing archived data. Data sharing becomes almost impossible when it risks violating individuals' privacy rights. Although the privacy concern varies from one agency to the next, there is a clear need to investigate the use of privacy protection technologies, such as cryptographic technologies, to remove these concerns.

Other than the resistance within an agency to change or to adapt to new data systems, the traditional stove-pipe organizational structure also discourages data sharing among agencies. Furthermore, this disinclination to share data among agencies involves a number of non-institutional issues. For example, the possibility of sharing data with sister agencies raises concerns about one's data quality –"*Are we comfortable enough to share our data with others?*" and "*Who is responsible for data quality assurance?*" This concern about data quality is an unexpected "barrier" to information sharing. On the other hand, it might be an unintended benefit of ADUS deployments because agencies might be spurred to improve the quality of their data before they share them. Before ADUS can be widely adopted, this data stewardship/ownership issue needs to be addressed. Incompatibility of data formats, data models, and analysis software also hinders data sharing among agencies.

The lack of communication or the lack of awareness adds another barrier to sharing and using ITS-generated data. In many cases, potential users of archived data are unaware of the existence of these data collections. For example, officials in City X are aware of the data collected in their own area, but they may not be aware of the data collected in City Y. A transportation engineer in City Z might be unaware of either collection of data. This lack of awareness about the availability of archived data is a very real barrier.

Proprietary rights to value-added data (as such in the cases of freight and CVO applications) can be another barrier to sharing the data. A lack of institutional cooperation among various data users might mean that disparate users duplicate data collection rather than jointly share in the costs of collections, ownership, and use.

8.2.3 Barriers to Using Archived Data

Data collection is an extremely expensive undertaking. As such, the purposes of any data collection efforts are usually clearly defined and understood before the data collection begins. Even more desirable would be a comprehensive plan, before data collection, of how the data should be analyzed after they have been collected so that the purposes of the data collection effort will be fully addressed. This is the typical principle of any data collection effort. Examples of such data collections include household travel surveys, commodity flow survey, highway monitoring programs, the Highway Performance Monitoring System (HPMS), and the General Estimates System (GES).

Limited resources sometimes lead to the alternative of leveraging on data recorded/reported for administrative purposes. Examples include the International Registration Plan (IRP), International Fuel Tax Agreement (IFTA), drivers' licenses, vehicle registrations, police accident reports, etc. Attempting to use data to meet data needs for which data are not originally intended is significantly more challenging than using data for purposes for which the data are originally intended. Since the notion of ADUS is to use ITS-generated data in applications other than what is originally intended, ADUS data are in this category.

The difficulty to use archived data is confirmed by a common reaction from data producers and data users: "*...the benefits of using archived data to meet my data gaps are obvious, but it is not at all clear how I can use these data and for what.*" This barrier could be overcome by generating and disseminating lessons learned, developing "how-to" guidebooks, deploying field tests, and developing easy-to-use tools on calculating the expected range of costs and benefits of different ADUS applications.

8.3 OPPORTUNITIES

Findings from the case studies in this project suggest that the advantages of archiving and sharing archived ITS-generated data are *recognized* and *capitalized* on by almost all stakeholders. That said, some stakeholders remain somewhat skeptical in that the benefits of ADUS have to be clearly demonstrated in terms of *costs* and *benefits* before any consideration will be given to ADUS applications. The most common hurdles are: "*It [ADUS] sounds really nice, but there is not adequate staff and time to figure out what problems can be addressed by the archived data.*" or "*What is in it for me?*" To overcome these barriers, the benefits of ADUS have to be clearly articulated through field testing that must be carefully crafted to address very specific issues.

Rather than try to identify all possible opportunities, this project identifies those that are practically feasible, can be quickly deployed, and are most likely to produce immediate benefits/results. The rationale for identifying these "low-hanging fruits" is that the sooner that quantifiable benefits of using ITS-generated data for operations or planning improvement are demonstrated and disseminated, the sooner additional deployments will be stimulated. These opportunities are summarized in Table 8.1. Background information and objectives on each of these opportunities are discussed in the respective chapters. Note that a few of them are cross-cutting in that they are pertinent to multiple applications. For example, work zone safety can be a collaborative effort between the operations and the safety communities.

Opportunities that are practically feasible, can be quickly deployed, and are most likely to produce immediate benefits/results are those that are able to:

- identify specific technical and institutional barriers to archiving, using, and sharing ITS-generated data;

Table 8.1 Proposed Opportunities by Application
Operations Applications
1. *Assessment of Security Vulnerability of Highway Network* (Page 4.1)
2. *Monitoring of Performance Measures* (Page 4.2)
3. *Management of Traffic Delay* (Page 4.3)
4. *Planning and Managing Special Events* (Page 4.4)
5. *Planning and Managing Unplanned Events* (Page 4.5)
6. *511 Information Validation* (Page 4.6)
7. *Adaptive Signal Timing Strategies* (Page 4.7)
Planning Applications
1. *Urban Travel* (Page 5.41)
2. *Data Reporting* (Page 5.42)
3. *Spatial Movements of Travel Demand* (Page 5.43)
4. *Monitoring of Performance Measures* (Page 5.47)
Highway Safety Applications
1. *Intersection Safety* (Page 6.51)
2. *Work Zone Safety* (Page 6.52)
3. *Evaluation of Alternative Strategies for Speed Management* (Page 6.53)
4. *Pedestrian and Bicycle Safety* (Page 6.54)
5. *Highway Safety Public Awareness and Training* (Page 6.65)
Transit Applications
1. *Assessment of Security Vulnerability of Transit Systems* (Page 7.41)
2. *Emergency Management and Preparedness of Transit Systems* (Page 7.42)
3. *Transit System Operations and Maintenance* (Page 7.43)
4. *Paratransit for Special-Needs Groups* (Page 7.44)

- develop feasible solutions to overcome these barriers;
- identify issues pertinent to standards development;
- examine the feasibility of integrating ITS-generated data with data collected from

traditional and emerging technologies (e.g., highway monitoring data, remotely sensed data);

- identify and **quantify** costs and benefits;
- disseminate lessons learned, and
- share the developed procedures and software in an open-source environment. Some examples of these procedures and software are: those developed to convert raw ITS-generated data into formats acceptable to existing and/or off-the-shelf data management or analysis software, check the quality of the data, impute missing data, correct questionable data, abstract information suitable for data analysis from "text" files, estimate potential recurring and non-recurring traffic delays, and other applications. The benefit of sharing these procedures and software in an open-source environment is that it reduces the "re-inventing the wheel" thus enabling more efficient use of resources.

Although the costs are high at this point to use ITS-generated data for purposes other than the originally intended use, many ADUS applications have demonstrated that ITS-generated data can indeed improve transportation decisions by improving the quality of the existing data or by meeting unmet data needs. As more and more ITS is deployed in the future, ITS-generated data can no doubt replace many of the current data collection processes. However, before then, the greatest contribution that ITS data can offer is probably when they are integrated with, or used to supplement, traditional non-ITS data to address gaps in these data.

Despite the promise of ITS-generated data, it is imperative to caution that ITS-generated data should not be viewed as a "silver bullet" for addressing data gaps. Furthermore, it can be extremely misleading to assume that ITS data are "ready-to-use." Extensive and thorough data quality checks which can be extremely demanding are essential before ITS-generated data can be used.

It is also important to point out that the costs of using ITS-generated data should decrease considerably as more uses are stimulated. At that point, the costs could very well become inconsequential compared to the benefits. Additional research and analysis would be useful to *quantify* these costs and benefits, to help standardize the data archiving, to develop standards, to improve methods to “prepare” and use ITS-generated data, and to develop simplified user-friendly analysis tools.