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Data Fusion For Delivering Advanced Traveler Information Services

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16. Abstract

Many transportation professionals have suggested that improved ATIS data fusion techniques and processing will improve the overall quality, timeliness, and usefulness of traveler information.

The purpose of this study was four fold. First, conduct a literature review of the ATIS and data fusion fields in order to summarize current ATIS data fusion practices. The review also included an examination of relevant field case studies and discussions with selected ATIS practitioners to determine the extent and direction of their data fusion interests and applications. Second, develop an appropriate ATIS data fusion model and guidelines to enable a multitude of source data to be fused to create ATIS products and services, consistent with the National ITS Architecture. Third, identify appropriate metrics that describe quantitatively and qualitatively how data quality can be verified, modeled, and processed so that traveler information products can be considered more reliable and useful. Fourth, provide general guidelines on the development of an ATIS data fusion system.

This report is intended for surface transportation professionals who have an interest in the planning and deployment of ATIS data fusion systems.

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Executive Summary

Advanced Traveler Information System (ATIS) is one of several Intelligent Transportation System (ITS) technologies that offers users integrated traveler information before and during travel, thereby providing a wider range of choices about how, when, and where to travel based on individual interests and needs. One of the major reasons ATIS services has garnered public and professional interest is the concern created by the continuing disparity between the growth in surface transportation travel demand and the relatively minor addition of travel capacity. This combination has resulted in increased regional roadway congestion, greater uncertainty in travel time estimates, and higher real or perceived costs in safety and productivity. Increasing transportation capacity by building roads and other related infrastructure is not a feasible solution in many urban areas due to the high costs as well as environmental and associated societal concerns. Alternative solutions are necessary.

To be effective, ATIS systems must work with a broad set of source data and information, combine and qualify the information to yield better traveler information, and disseminate the information when needed by travelers. One component of this complex process is data fusion.

The purpose of ATIS data fusion is to combine data (in the broadest sense of the term) to estimate or predict the state of some aspect of the surface transportation world. These estimates may include statements about current or future vehicular speeds, mean speeds, vehicular classifications and volumes on selected roadway segments, environmental information, transit system performance, and similar topics of interest to travelers.

The overall effectiveness of data fusion needs to be evaluated in a systems context, taking into consideration the overarching system mission and purpose, architectures, data processing capabilities, data validation and verification, human-system interface, and institutional arrangements. A study was completed, examining these issues, the findings of which can be found in this report. The process of the study was three fold. First, a literature review was conducted of the ATIS and data fusion fields to examine current practices. The review also included an examination of relevant field case studies and discussions with selected ATIS practitioners to determine the extent and direction of their data fusion interests and applications. Second, an appropriate ATIS data fusion model was developed, along with guidelines to enable a multitude of source data to be fused to create ATIS products and services. The model describes ATIS data fusion using five distinct levels of functional activities. Third, appropriate metrics were identified that describe quantitatively and qualitatively how data quality can be verified, modeled, and

processed so that traveler information products can be considered more reliable and useful.

The major findings that arose from this study include:

- A general awareness of ATIS data fusion and its purpose exists.
- The general public, and travelers in particular, are predisposed to use better travel information, although it is unclear under what business model and range of products and services.
- Data fusion conducted at transportation and environmental public agencies involves basic fusion functions such as spatial or temporal alignment of input data. Assessments of ATIS services at selected Metropolitan Model Deployment Initiative sites and Field Operational Test sites indicate positive support and public benefits.
- Third-party ISPs perform additional data fusion activities, but the specific techniques, accuracy, and usefulness are not readily discernable due to proprietary restrictions.
- Two general perspectives exist for ATIS data fusion: a data-centric view and a model-centric view. These perspectives are not mutually exclusive.
- Agencies are migrating to the use of the NTCIP and associated data element and message set standards, but will likely initiate their use based on industry acceptance and agency confidence in their utility and longevity.
- Data quality policies and procedures are not comprehensive. Practices are limited primarily to "find and fix" tactics on the more egregious data elements.

The findings point out the need for a more comprehensive ATIS data fusion methodology that would allow for increased cross-disciplinary communication and research sharing. A proposed ATIS data fusion model, based on the JDL process model, was offered to help bridge this gap. Moreover, specific data fusion techniques, appropriate for the ATIS context were identified and qualitatively assessed using multiple criteria such as ease of implementation and potential usefulness.

General guidelines for data fusion architectures are presented in the report. The wide variety and combination of ATIS fusion applications and associated architectural components do not allow for a prescriptive, detailed definition of architectural components and fusion techniques. This prescription is best handled through a more structured, system engineering (SE) process involving all stakeholders and design experts. Key elements of the SE process are outlined.

Input data quality continues to be a hindrance to the offering of more advanced ATIS services. Current practices focus on "fix and find" methods without long-term, systemic attention to data quality issues. One of the key issues is the different perspective held by stakeholders on the level of satisfaction with the existing data quality and the associated remedies and costs to make improvements. Greater awareness and understanding of the issues are needed before prescribing remedial action, if any. Resolution of data quality issues will require partnerships among the data owners and users to reach a shared solution.

The report concludes with proposed future actions for enhancing ATIS data fusion practices, summarized into three categories: technological, institutional, and economic opportunities.

Table of Contents

List of Figures

Glossary

ATIS	Advanced Traveler Information System
AVI	Automatic Vehicle Identification
AVL	Automatic Vehicle Location
CATV	Cable Television
CVO	Commercial Vehicle Operations/Operator
CORBA	Common Object Request Broker Architecture
DATEX-ASN.1	DATa Exchange in Abstract Syntax Notation One
DMS	Dynamic Message Signs
FHWA	Federal Highway Administration, USDOT
FOT	Field Operational Test
FTP	File Transfer Protocol
GPS	Global Positioning System
HAR	Highway Advisory Radio
HTML	HyperText Markup Language
IEEE	Institute of Electrical and Electronics Engineers
IM	Incident Management
ISP	Internet Service Provider
ITS	Intelligent Transportation Systems
IVR	Interactive Voice Recognition
JDL	Joint Directors of Laboratories (U.S. government laboratories)
MMDI	Metropolitan Model Deployment Initiative
NTCIP	National Transportation Communications for Intelligent Transportation System Protocols
PDA	Personal Digital Assistant
RAID	Redundant Array of Inexpensive Disks
RFID	Radio Frequency Identification
SDO	Standard Development Organization
SE	Systems Engineering
SNMP	Simple Network Management Protocol
SQL	Structured Query language
STMP	Simple Transportation Management Protocol
TFTP	Trivial File Transfer Protocol
TMC	Traffic Management Center
USDOT	United States Department of Transportation
VMS	Variable Message Signs
W3C	World Wide Web Consortium
WIM	Weigh In Motion
WWW	World Wide Web
XML	Extensible Markup Language

Section 1 Introduction

Many issues will affect the performance of the 21st century surface transportation systems, particularly highways and transit systems, in the United States and in similar industrialized nations. A paramount concern is the growing congestion on highways and roads created in part by increased travel demand coupled with a modest increase in travel capacity. The effects of this disparity are captured in a number of measures and perceptions, including visible and consistent roadway congestion, the loss of personal and professional time, environmental degradation, and general traveler frustration. An often-cited report of this phenomenon is the Texas Transportation Institute's report on urban mobility, which estimated the total cost due to roadway congestion at $78 billion for the 68 largest urban areas in 1999[1]. A recent national satisfaction survey conducted by the Federal Highway Administration notes 65 percent of those surveyed are satisfied with the major highways they travel most often. However there is greater dissatisfaction due to heavier traffic flows and delays, especially circumstances caused by workzones and roadway incidents[2]. Substantial debate has occurred about the proper course of action to address these concerns and trends.

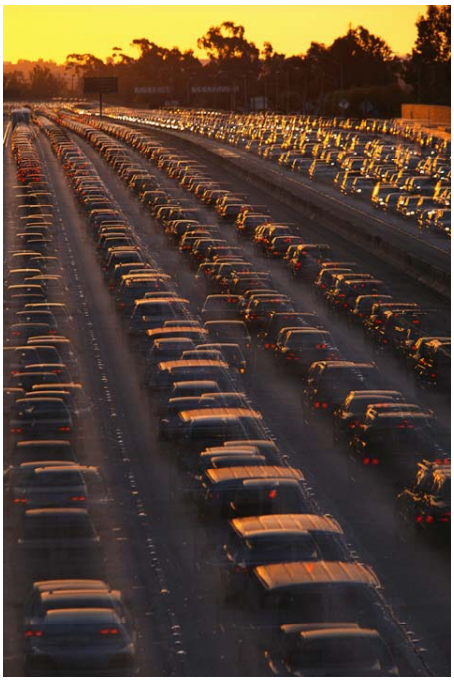

Figure 1-1 Greater Roadway Congestion Has Generated Increased Interest in Advanced Traveler Information Systems (ATIS)

Advanced Traveler Information Systems (ATIS) is one of the many components of Intelligent Transportation Systems (ITS). The purpose of ATIS is to provide practical and timely help to travelers in an integrated, multi-modal environment using the goals, principles, and practices of the National ITS Architecture[a]. Effective traveler information would support the needs of many travelers. The information would assist users in selecting their mode of travel (car, train, bus, etc.), route, and departure time, as well as provide supplemental information about the weather, congestion indicators, and other issues affecting their travel.

[a] There are many definitions of architecture, usually closely tied with the context of usage. In this context, architecture refers to a structure of components, their relationships, and the principles and guidelines governing their design and evolution over time (IEEE source).

1.1 ATIS Concepts

Effective traveler information services support many types of information[b] requests and categories of travelers, and combine multi-modal information in an effective and timely manner. Information may be provided in a number of ways, including pre-trip (static) information and real-time information. Static information comes from such sources as transit schedules, planned workzones, and known road closures. Dynamic information comes from a variety of sources including roadway-based sensors, surveillance equipment, and driver information. The information assists travelers in selecting their mode of travel, route, and departure times. Figure 1-2 illustrates the range of data sources, processing and uses of ATIS information. The figure depicts the various sources of data (left-hand side) that are collected and centrally processed (central part of figure) to yield integrated information about the current and future travel conditions, such as roadway congestion and transit schedules. This information is broadcasted or disseminated to travelers, allowing them to make informed choices about when, where and how to travel.

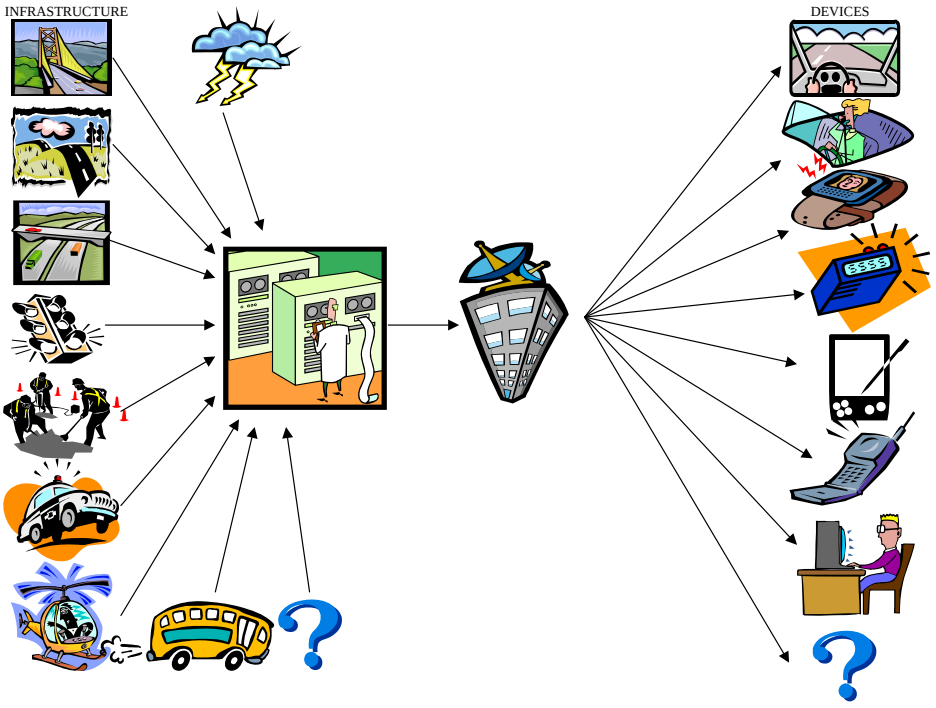

Figure 1-2 Informal Illustration of Sources and Uses of ATIS Information[3]

The National ITS Architecture has identified nine market packages that incorporate ATIS user services[4]. These packages can be further broken down into static or dynamic

[b] For this report, information is considered to be data which has been processed for some purposeful use.

services. For the purposes of this report, the six dynamic related services will be emphasized.

Dynamic, Traffic Related Market Packages	Definition and Key Points
Broadcast Traveler Information	▪ Disseminates near real time traffic information over a wide area through existing infrastructures and low-cost user equipment such as radio or cellular phones ▪ Information flow is one way
Interactive Traveler Information	▪ Responds to a user's request with tailored information, using wide range wireless and wireline communication systems
Dynamic Route Guidance	▪ Provides advanced route planning and guidance that is responsive to current conditions ▪ Relies on a digital receiver, map databases and a variety of in-vehicle computational systems and devices
ISP-Based Route Guidance	▪ Similar to Dynamic Route Guidance, but it moves the route planning function from the user device to a service provider ▪ The user has the option of equipping their vehicle with the map databases and location determination capability
Integrated Transportation Management/ Route Guidance	▪ Used by both public consumers and traffic management centers ▪ Traffic management centers use it to optimize traffic control ▪ Consumers benefit from advanced route planning and guidance based on current conditions
In-Vehicle Signing/Message Exchange	▪ Based on communication between roadside equipment and in-vehicle devices ▪ Roadside equipment communicates with the traffic management subsystem in order to provide traffic and travel advisory information to the in-vehicle device

Figure 1-3 The Range of Dynamic Traveler Information Services

In addition, the National ITS Architecture can be categorized by two types of basic services: i) traffic and road condition information; and ii) location, navigation, and route guidance information.

1.1.1 General ATIS Model

A number of individuals, organizations, technologies, and processes must be assembled to develop, implement, and sustain effective and valued ATIS services. Appropriate sensing and surveillance equipment is required. Public-private partnerships are needed to gather and disseminate timely, useful traveler information based on public and private data sources and data processing. Multiple vendors and technologies necessitate the use of accepted standards and protocols to enable interoperability and functionality.

The following diagram offers a generalized functional model of ATIS. Read from left-to-right, Figure 1-4 indicates the wide range of available information sources, the data fusion activity, the opportunity for value-added services from public or private agencies, and the dissemination of traveler information through multiple means and mediums. Data collection has traditionally been conducted by public agencies (e.g., highway and transit agencies) primarily to meet their agency objectives for management and operation within their service areas and responsibilities. Recently, private agencies have supplemented public agency data to provide more complete coverage of a region or subcorridor. Data fusion, in general, refers to the process of combining information from a variety of sensors and processing the data to yield better estimates describing the state of the transportation system. The value-added function may include a variety of activities, such as repackaging basic traveler information for consumers in a form more available (e.g., cellular phone, websites, or mass media) or understandable (e.g., graphical displays or site-specific congestion metrics). Moreover, additional content may be added (or fused in the earlier stage) to enhance basic traveler information, such as confirmation of incidents, better microscale weather information, geo-location of events, and recommendations on alternative routes or departure times. The resulting information can be distributed to consumers through a variety of media, with the opportunity for specialized equipment and software allowing the receiver to customize the traveler information.

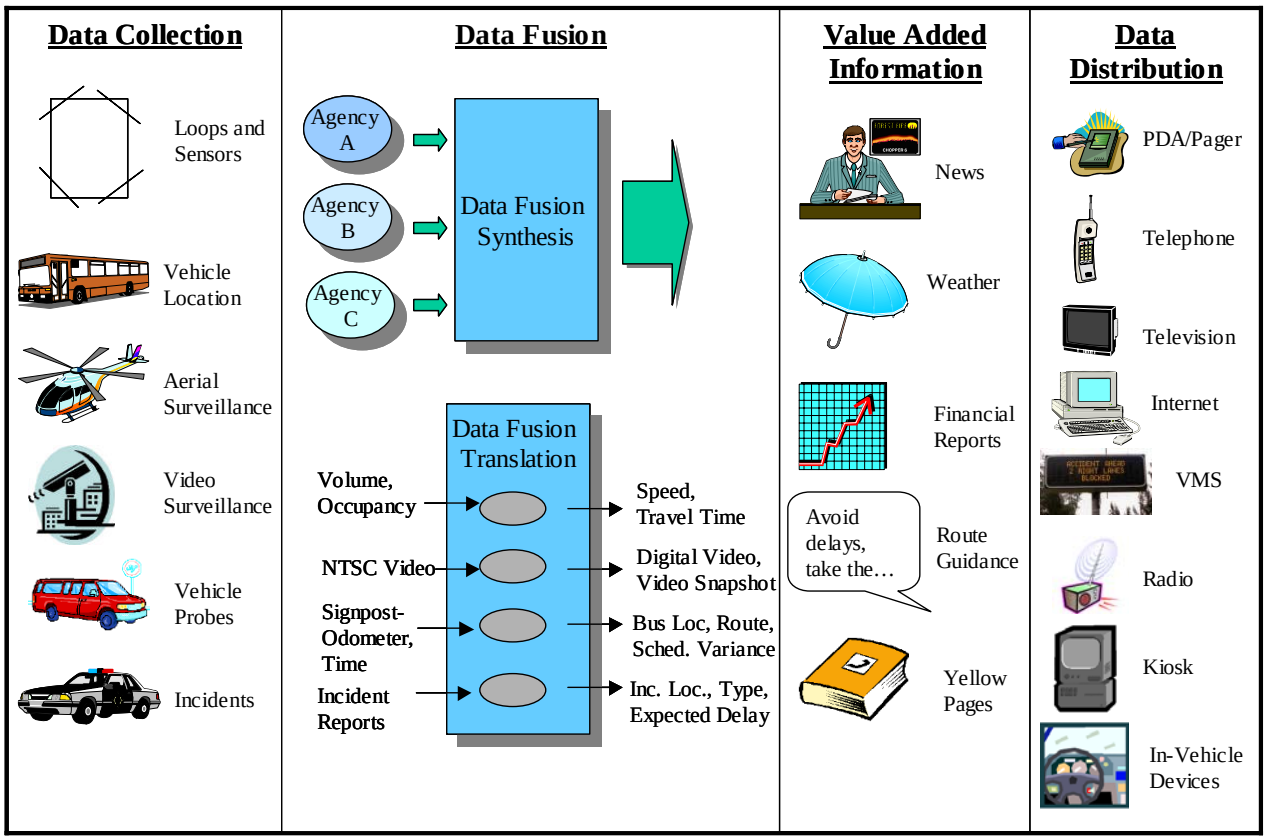

Figure 1-4 A Generalized Model of ATIS Functions and Services[4]

The simplicity of this ATIS model is complicated by a variety of factors, including institutional and regulatory issues, legal concerns, partnership agreements (among all combinations of public and private organizations), consumer expectations, contracts for the types and quality of traveler information delivered, and the changing technology base underpinning this service delivery[c].

1.2 General Concepts of Data Fusion

In general, the purpose of ATIS data fusion is to combine data (in the broadest sense of the term) to estimate or predict the state of some aspect of the surface transportation world. These estimates may include statements about current or future vehicular speeds, mean speeds, vehicular classifications and volumes on selected roadway segments, environmental information, transit system performance, and similar topics of interest to travelers.

[c] Additional insights into this wide-ranging field can be found at www.its.dot.gov.

Within the graphic depiction of the data fusion function illustrated in Figure 1-4, a complex set of activities is occurring and will be elaborated upon in subsequent report sections. Major data fusion functions include:

Raw Data Collection	Transmitting and receiving error-free[d] data from field sensors or other locations
Data Identification	Matching the sensed data with the source or adjusting for missing data values
Data Alignment	Configuring identified sensor data to a common spatial and temporal reference/origin, as well as transforming data into compatible representations and/or languages (e.g., XML[e])
Data Combination	Performing various association analyses (e.g., statistical correlations, pattern recognition, etc.) to improve detection, classification, and tracking of entities of interest (e.g., cars, surface temperature readings, etc.)
State Estimation	Predicting the kinematic (time and/or spatial) performance of an entity of interest
Performance Assessment	Applying techniques to assess fused data quality and fusion processes.

The overall effectiveness of data fusion needs to be evaluated in a systems context, taking into consideration the overarching system mission and purpose, architectures, data processing capabilities, data validation and verification, human-system interface, and institutional arrangements. These issues will be examined in this document.

1.3 Opportunities and Challenges of ATIS Data Fusion

ATIS data fusion is an emerging and evolving field. Some of the basic benefits of ATIS have been garnered through the savvy, cost effective design of regional ITS architectures and the value-added application of market-proven techniques to meet customers' needs. However, there are opportunities for greater ATIS data fusion applications. Prospects include the increased collection of usable data from sources other than the installed sensor and surveillance networks owned and operated primarily by public agencies. Wireless technologies, coupled with the increased acceptance of data standards and protocols, will offer the potential for easier reporting and access to customized ATIS

[d] The specification and quantification of "error-free" data transmission and reception is an overall systems requirement and primarily a function of the telecommunication subsystem design and operation.

[e] XML is an emerging representation language used by Internet browsers (and other applications). HTML is the current defector standard.

information. Technological and data processing advances in affiliated scientific and engineering disciplines, such as database management and web-based commerce, coupled with cost reductions in computer and telecommunication equipment, can provide a foundation for greater ATIS data fusion applications and value-added services. Moreover, public agencies can contribute substantially to ATIS through their internal systems for monitoring and improving the performance of the transportation system, such as traffic signal control, incident management, bus fleet performance or the analysis of ADUS[f] information. However, several challenges may hinder the accelerated use of data fusion for ATIS. These obstacles include the improvement of institutional/organizational collaboration, the timely establishment and use of standards and protocols that serve the widest set of potential ATIS customers, concerns about data quality, and establishing a delivery model that provides real-time, quality ATIS services in an environment when basic traveler information is free.

1.4 Section 1 References

1 Urban Mobility Study 2001, Texas Transportation Institute, College Station, Texas, 2001.

2 Moving Ahead: The American Public Speaks on Roadway and Transportation in Communities, Federal Highway Administration, FHWA-OP-01-017, 2001.

3 ATIS Data Collection Guidelines Workshop: Workshop Summary, ITS America Publication, February 2000.

4 Developing Traveler Information Systems Using the National ITS Architecture, FHWA – ITS JPO, August 1998.

[f] ADUS – Archived Data User Services represents the systematic storage of real-time data collected through deployed ITS subsystems. ADUS is the mechanism for managing ITS data beyond real-time control. See www.its.gov/TravelManagement/adus.html.

Section 2 Study Approach

2.1 Study Objectives

It has been suggested that improved ATIS data fusion techniques and processing will improve the overall quality, timeliness, and usefulness of traveler information. In particular, with increased use of multiple sources of data, properly combined, fused, and quality-controlled, a more reliable, real-time set of traveler information can be produced, which will be valued more than the information services currently available to the traveler. Increased attention to data fusion will also better inform agency planning and guide ITS architecture development and deployment.

The purpose of this study was four fold. First, conduct a literature review of the ATIS and data fusion fields in order to summarize current ATIS data fusion practices. The review also included an examination of relevant field case studies and discussions with selected ATIS practitioners to determine the extent and direction of their data fusion interests and applications. Second, develop an appropriate ATIS data fusion model[a] and guidelines to enable a multitude of source data to be fused to create ATIS products and services. The model should be able to account for the challenges of multiple sources of data, varying types of quality, institutional impediments, and evolving standards and practices associated with the National ITS architecture. Third, identify appropriate metrics that describe quantitatively and qualitatively how data quality can be verified, modeled, and processed so that traveler information products can be considered more reliable and useful. Fourth, provide general guidelines on the development of an ATIS data fusion system.

As a result of the study, a phased model and guidelines is available to assist agencies with ATIS data fusion considerations. These considerations include the development of specific ATIS data fusion goals and subsystems in the context of an overall ITS mission and supporting architecture. Moreover, agencies will likely gain an increased awareness of ATIS data fusion capabilities, limitations, and resources for further inquiry.

This study was conducted during December 2000 until August 2002. During this period substantial changes were occurring nationally and internationally in three fields closely related to ATIS data fusion, namely telecommunications, computing, and web-based

[a] "Model" is a term with many uses. In this study, model refers to a description of the ATIS data fusion activities using a five-part functional representation, which is the focus of Section 4.

commerce. These factors are mentioned since the annotated literature listed in the appendix presents a potentially divergent picture of growth, opportunity, challenges, and retreat, which may confuse the reader without an explicit mention of the study period.

2.2 Study Approach

Data collection was the first study task and involved a literature review, examination of case studies, and discussion with ATIS experts. The literature review was conducted using web-based searches, reference list back-chaining, a search of relevant transportation databases, and discussions with knowledgeable individuals to identify key documents and source materials. The information was screened for relevance and then organized and sorted based on assigned keywords, such as data fusion, data quality, etc. A summary of the major findings is presented in Section 3. The appendix contains an annotated bibliography of the sources.

Case studies, primarily from the Metropolitan Model Deployment Initiative (MMDI) evaluation program, were reviewed for ATIS features and applications. The cases were examined for state-of-the-practice and specific data fusion activities performed by either public agencies or private firms. In the case of private sector firms, little or no information was available regarding data fusion techniques, as these were considered highly proprietary and competitor-sensitive.

Structured interviews were conducted with representatives or individuals knowledgeable about ATIS deployments. The interviews were designed and the data collected not to be generalizable, but instead to document the practices and attitudes of some of the major public sector ATIS practitioners. The interviewer elicited a description of ATIS services provided by the agency/organization, identification of fusion techniques (as appropriate), metrics on data quality, difficulties in implementing ATIS services, the extent of conformance or use of ITS standards, and remarks on future activities, especially for data fusion. Interviews were conducted with individuals from Seattle (Washington), San Francisco (California), Los Angeles (California), Houston (Texas), I-95 Corridor Coalition (Virginia/Maryland representatives), Hampton Roads-Smart Travel Center/I-81 (Virginia), and Transcom (New York, New Jersey, and Connecticut). The aggregate findings are reported in Section 3.

A proposed ATIS data fusion model was developed to meet the second purpose of the study. The model is based on the literature and other background information gathered during the first study objective. A functional model was identified as the most promising for meeting the needs of the ATIS community. Details of the data fusion model and

corresponding guidelines for fusion techniques and architectural considerations for implementation are the primary subject of Section 4.

The third purpose of the study, data quality, is addressed from the perspective of overall customer needs and system performance specification. The systemic complexity of data quality necessitates a structured approach to data quality awareness, assessing data element quality and data importance, and the implementation of appropriate techniques to improve data quality, namely finding/fixing errors and preventing errors. The second portion of Section 4 discusses the ATIS data quality issues.

The fourth purpose of the study, guidelines for developing an ATIS data fusion system, is discussed in Section 5. A generalized approach is presented for defining the specific algorithms and subsystem elements for an ATIS data fusion model, with attention to data quality. Finally, Section 6 provides a brief summary of the study findings and conclusions with suggested directions for advancing ATIS data fusion.

Section 3 ATIS Concepts, Trends, and Directions Affecting Data Fusion

Section 1 introduced the concepts of ATIS. This section provides a deeper foundation for developing a data fusion model and guidelines by presenting the major findings from the literature review and the insights gained from discussions with representatives at selected public ATIS sites. The section concludes with key findings and implications for ATIS data fusion. The appendix of the report contains an annotated bibliography of materials that supported the development of this section.

3.1 Summary of Literature Review and Selected Interviews

ATIS services have been studied or analyzed from several perspectives, which cluster into three groupings: institutional/organizational, operational, and technological. A brief overview of these groupings is presented, with the majority of this section devoted to the more technical issues of data sources, data processing, and data/information uses necessary to support ATIS data fusion systems.

The institutional/organizational perspective represents some of the major challenges to successful ATIS data fusion, especially real-time systems. In general, the institutional issues pertain to planning and cooperation in the design and implementation of systems in order to collect and share data appropriate for traveler information. A key topic, currently under discussion at many public agencies, is the scale and scope of the public sector's role and obligations in providing traveler information. Obviously, the purpose of a data fusion activity, the associated architecture, data collection and sharing requirements, multi-organizational/institutional issues, and similar design consideration all affect the performance and usefulness of an ATIS data fusion system. These institutional issues may be the greatest within a single agency or organization and likely involve intra-agency relationships, resource allocation, and policies that introduce new relationships and responsibilities between function groups (such as planning, design, and maintenance/operations) and support groups such as Information Technology, records management, and similar repositories or stewards of data. Institutional issues for advancing ATIS data fusion also occur across organizations in which geographic and jurisdictional boundaries create interface and data sharing challenges. Current practices to manage these interfaces include Memorandums of Agreement, performance-based specifications, and delineation of interface protocols and requirements. While these interface issues may have been achieved in such traditional areas as asset management and transit service providers, new challenges emerge when considering issues of data coverage and quality, ownership rights, and data fusion performance-based criteria.

These institutional issues are discussed in this section within the context of developing a data fusion model.

Operational issues have been captured best through case studies and evaluations of ATIS. The evaluations have provided insights into a range of challenges, including institutional, technical, standards development, resource allocation, and implementation of new systems and partnerships. The operational issues are highlighted in Section 3.1.5.

The technical issues associated with developing ATIS data fusion systems can best be represented by a simplified, three-part, structured analysis. This format is widely used in this type of study to define system inputs, processes, and outputs. It also provides a simplified introduction to data fusion, in preparation for the more detailed functional representation found in Section 4.

Inputs for data fusion are from one or more sources that are collected and subsequently processed to meet specific end users' needs or output requirements. The following figure illustrates this three-part process. The three parts of the process serve as the major discussion topics reviewed in this section.

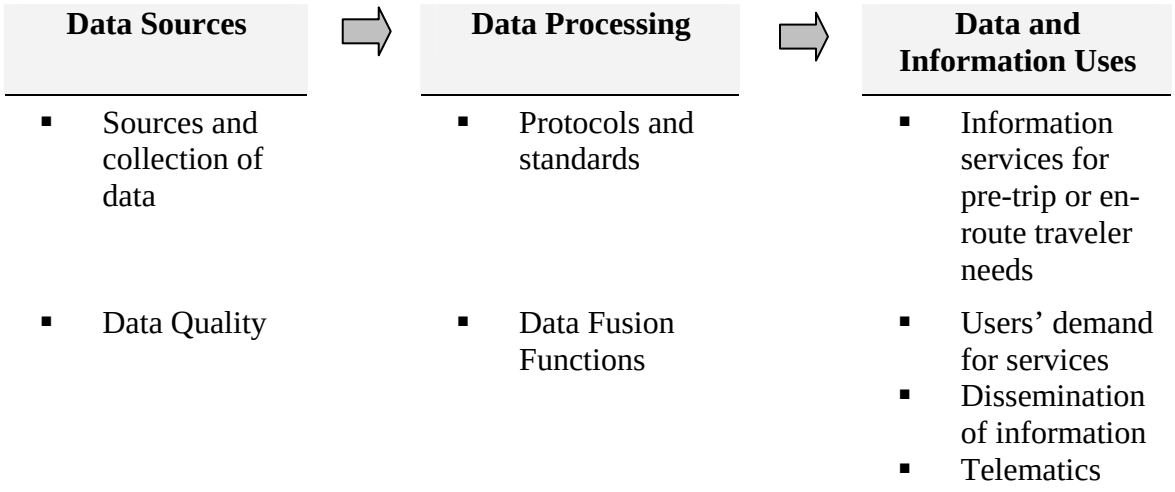

Figure 3-1 A Simplified Structured Analysis Model of ATIS Data Fusion

Many of the institutional, operational, and technical perspectives overlap in this simplified model since they contribute in one or more ways to the overall functions and performance of an ATIS data fusion system. The separation shown in the figure, however, does allow a convenient means of highlighting the major data-centric findings that contribute to the opportunities and challenges for ATIS data fusion.

The following discussions focus primarily on real-time freeway and major arterial systems. However, archived data, data from speed studies, and other traffic or transit studies also constitute valuable sources of ATIS data. The challenges of using these data sources will be ones of compatible frames of reference (geospatial and temporal), data verification, and data formats. These current issues and practices are discussed in the following subsections and addressed in Sections 4 and 5 of this report.

3.1.1 ATIS Data Sources

Two topics dominate the literature associated with ATIS data sources: (1) a description and discussion of the many sources of data and information that can contribute to ATIS services, and (2) input data quality.

3.1.1.1 Sources and Collection of Data

The largest source of ATIS data is the loop detector system, usually owned, operated, and maintained by the public highway agency. Loop detection data requires some level of localized signal processing after which the modified signal is communicated to a more centralized location, usually based on a polling request. Loop detector data can be processed to estimate, among other things, speeds, occupancy, and congestion. Typically loop detectors are placed approximately one-half mile apart on highways in metropolitan areas and may be placed around interchanges or intersections to collect data about traffic flows[1]. Major arterials may have loop detectors, but usually only at key intersections or near highway connections. Key determinants in placing detectors on arterials include consideration of studies of traffic counts, safety reports, availability to communication networks, and usability of the collected data. As data collection coverage needs increase, arterials are becoming more instrumented.

Loop detection reliability[a] has been estimated to be between 10 and 50 percent, depending on agency maintenance practices, time of the year, and age/type of the loop detector. Some loop detectors are more than 30 years old, which affects performance, accuracy, and the type of information they are able to collect. Communication links between field collection points and a centralized location may be affected by a variety of factors including telecommunications engineering (speed, bandwidth, communications protocol, polling frequency, transmission errors and reprocessing of data streams, noise, etc.) and maintenance issues (cable cuts, power outages, etc.).

[a] Reliability refers to the availability of the sensor to supply at any given time a signal matching the sensor performance requirements.

Once collected, field data is usually stored on a large capacity, non-proprietary database system. These database systems may collect as much as 2GB of daily information, depending on the size of the network, the sampling rates, and data compression, if used. ATIS systems make use of real-time as well as historic data. Consequently, data management, data messages, and data access issues can affect overall ATIS system performance. Efficient and cost effective storage of video data is still an evolving field of study[2].

Loop detectors only measure aggregate traffic at particular freeway locations, rather than the movement of individual vehicles in a specific space. Consequently, ATIS route guidance services are severely hampered by the lack of information about trip distributions. To augment loop data, additional sources of data and information are being used. Video technology has been developed and applied for more than 30 years as a substitute for inductive loop detectors. Within the past 3-5 years, CCTVs have migrated from analogue to digital formats, resulting in greater resolution and lower costs. Three major developments have enhanced the use of CCTV for ATIS services. First, the digital conversion allows for more efficient signal processing and field-to-center transmission, including the use of compression methods such as the de facto MPEG-2 standard. Higher resolution images could enable such activities as improved incident management or vehicle tracking at sensor locations, thus contributing to discerning trip distribution. Second, digital video recorders are being produced in sufficient quantity to make them cost-effective means of storing video images, especially when coupled to video motion detection methods that do not engage the recorder when no significant activity is detected, thereby saving storage space. Third, low cost, efficient transmission protocols have emerged in metropolitan areas to enable more reliable and wider network coverage. These protocols are based on such technologies as enhanced fiber optic networks (Dense Wave Division Multiplexing- DWDM), Digital Subscriber Line (DSL) protocols, Multi Protocol Labeling System (MPLS), and others.

The effectiveness of CCTV for ATIS use is a function of image resolution, communications bandwidth, uses of the image (human interpretation versus pattern recognition methods), and overall life cycle benefit-cost. Video cameras are used to detect and verify roadway or network conditions and confirm incidents within the range and capabilities of the equipment and telecommunications system. Video information is centrally collected and manually scanned for unusual traffic patterns. Some traffic management centers have the capability for simultaneously displaying more than 50 field locations, requiring additional personnel or less frequent reviews of the video images and assessment of the traffic networks. Camera network coverage and deployment is typically constrained by the cost effective access to higher-bandwidth communication links. Moreover, the quality of the video does not readily lend itself to pattern

recognition or feature extraction (e.g., license plate) processing due to low resolution and frame refresh specifications.

Another source of roadway information comes from travelers who report events or incidents. These reports provide a varying range of usable data about the event. Many times drivers are unable to accurately locate where the event occurred, although GPS chips in cellular devices may allow for greater accuracy. Moreover, this information is conveyed to a human operator, who must be skilled at eliciting the information needed to verify and characterize the event in order to provide sufficient traveler information. However, with the "human-in-the-loop," there will be restrictions on the number of calls that can be processed, regardless of the operators' abilities.

Another source of traveler information comes from vehicular "tags" (RFID devices) that can be read by roadside readers on public roadways for the purpose of charging a user fee (toll tag), identifying vehicles (CVO registration or transit vehicles) or verifying credentials (WIM specifications). This information is usually available only to the public agency responsible for collecting a fee or processing traveler information. The information would be valuable for developing an improved understanding of trip distributions, but currently there are no institutional arrangements that allow for sharing this user information with ATIS service providers, public or private. Other sources of traveler information come from GPS-based systems, including certain types of Automatic Vehicle Location (AVL) systems employed in certain transit systems and GPS-enabled probe vehicles.

Once the data is collected, it is usually stored in a database waiting further processing.

3.1.1.2 ATIS Data Quality And Performance Issues

In general, ATIS data quality can be defined as fitness for use by information consumers, public or private. Determining the fitness for use is a complex issue to assess since the data quality can originate in the data source, data processing, and application or use of the data. At any point in this process, data quality can be enhanced or diminished.

Several sources of poor ATIS performance have been noted in studies[3,10,14], including:

- Scope and scale of data coverage (geographic and temporal)
- Software errors (development and maintenance phases)
- Hardware or facility failures (including security breaches)
- Poor input data quality

Data coverage is one of the more important sources of poor ATIS performance primarily because sensors and other sources of data collection do not adequately cover the network to be associated and supported by data fusion. Moreover, the roadway networks that are covered tend to be freeways rather than major arterials and key intersections. Transit systems coverage is similarly hampered by the availability of temporal and geospatial vehicle information. Enhanced software methods for improved code development are being applied in the ATIS field, including the use of structured design methods, application of costing/performance models, and use of more rigorous contract specifications to ensure performance, standards, and warranty issues are addressed. Hardware failure, especially at the distributed sensor level (such as inductive loop detectors), is an individual agency issue. Some agencies have indicated that as much as 30 percent (on average) of their network of loop detectors may be unavailable or provide inaccurate data on a daily basis. Failures at centralized facility or operation centers are less of a problem since private-sector recovery practices have been applied in public agencies. These practices include facility designs with disaster recovery features and hardware configurations to provide frequent backup of computer and communication systems (RAID, frequent imaging at locations unaffected by local disturbances, communication system redundancy, etc.). Field facilities usually employ environmentally hardened equipment and power supply configurations to minimize outages. When field failures do occur, automated alert systems usually become activated or else central facility operators detect a malfunction or outage. Poor input data quality has been identified as the most common source of information system failure. While there are no estimates available from the ATIS community, business organizations that have reported data quality issues estimate the data error rates ranging from one-half to 30 percent[3].

The literature contains numerous ways and specific techniques to improve data quality. These techniques can be classified into two broad categories:

- Finding and fixing data errors (clean-up)
- Preventing errors

The ATIS service providers interviewed for this project indicated they only focused on the first category, although many would like to have the more systemic approach of preventing errors. After determining that poor input data quality was the source of concern, their typical response to poor input data quality was a three-part process:

(1) determine the upstream sources of the erred data (sensors, communication links, etc.) and resolve as appropriate;

(2) conduct large or small database clean-ups as part of everyday maintenance operations (correcting obvious errors such as outliers, false alarms, no signal, no value, etc.); and

(3) deal with the impacts of the erred data, such as manually correcting ATIS information using historical estimates (if appropriate), posting notifications of information unavailability, searching for the erred data source (if not already found, isolated, or qualified).

The effectiveness of this three-part process has not been assessed systematically in the ATIS community. However, experience from other organizations offers some insights. The sensor or communications link data quality issues are becoming relatively easier to resolve as improved equipment with self-diagnosing methods is deployed. In addition, maintenance and operations functions in public agencies are becoming more tightly coupled as performance-based management systems are being implemented. These organizational process improvements allow ATIS information providers to be more aware of operational issues associated with network and equipment performance. The database clean-up strategy works in the short-run, but is less effective in the long-term. While certain automated tools exist to correct the obvious errors, more errors are usually created due to newly calculated data elements based on uncorrected, erred data. Depending on the frequency of the use of the data (e.g., monthly reports on ATIS usage versus hourly indicators of signal system timing), the data may become permeated with errors. This leads to a never-ending, time-consuming cycle of periodic clean-ups, at increasing expense. Short-term database clean-ups are done on time-sensitive or system-sensitive data, but also face the same long-term issues. Moreover, this database clean-up approach does not provide a long-term, scalable answer[4].

3.1.2 ATIS Data Processing

ATIS data processing is based primarily on systems and applications developed in other disciplines or industries. One of the most important issues in ITS, transportation, and traffic communities is the lack of widely recognized and accepted communications and data standards. As a consequence, challenges of interoperability and interchangeability among agencies, across jurisdictions, and among users have hampered data sharing[b], data processing, and more widespread use of ATIS services. Increased standards and protocols definition and adoption has been discussed extensively in the literature and seen by some as an evolutionary means to help reduce institutional and organizational barriers in planning and implementing data fusion systems. After data and communication

[b] This includes “free” data or “for fee” data, the cost of which is relative to the overall system objectives and importance of the data for achieving the objectives.

standards, data processing methods and approaches emerges as a key topic in the advancement of data fusion systems. Each of these topics is reviewed in the following subsections.

3.1.2.1 Standards and Protocols

Data about travel conditions are the foundation for ATIS services. The data is sensed, collected, transmitted, and processed by multiple agencies at different locations using different types of equipment. The resulting information is used to support traveler information services, but also traffic management operations, maintenance activities, emergency response, as well as agency planning and budgeting functions. Typical systems have several integration and interoperability issues such as:

- Different types of devices unable to operate on the same communications channel
- Software system updates as new devices are added
- Proprietary protocols or device configuration information
- The inability to effectively exchange information among public and private agencies supporting ATIS and other transportation functions

To ensure these needs are met and all subsystems are integrated and interoperable, as much as possible, standards are being developed. There are three primary categories of ATIS standards being researched and developed: (1) communication standards; (2) data dictionary elements (objects); and (3) message sets. The purpose of the standards development process is to:

- Increase design flexibility and choices for operating transportation agencies
- Enhance interoperability and coordination
- Remove proprietary barriers
- Allow different types of devices and enabling software from different vendors to be mixed within the same system at minimal integration life cycle costs

For the most part, agencies and industry participants have embraced this approach and are contributing to its success.

The overall standards process is a multi-part endeavor:

(1) Identifying the standards to be defined
(2) Defining the standards
(3) Testing/verifying the standards
(4) Maintaining the standards

(5) Training in the standards
(6) Communicating/outreach on the standards

Most of the effort to date has focused on the needs and definition of standards. More than 100 standards have been identified and developed to varying degrees of completion. For traveler information, a variety of standards have been defined and are under development, including the following key elements:

- Vehicle Location Referencing Standards
- In-Vehicle Message Priority Sets
- The message set for Traveler Information Systems
- Data Dictionary Standards
- The Traffic Management Data Dictionary
- NTCIP-Compliant Dynamic Message Signs
- Many others[c]

Comprehensive testing of the standards is a process that is just beginning.

3.1.2.1.1 Communication Standards

The National Transportation Communications for Intelligent Transportation System (ITS) Protocol (NTCIP) is a family of standards that provides both the rules for communicating (called protocols) and the vocabulary (called objects) necessary to allow electronic transportation control equipment from different manufacturers to operate with each other as a system[c]. These are open, industry-based standards that make it possible for ATIS and other ITS services from multiple vendors to exchange information using a common communications interface. The NTCIP is a five-layer model developed, in part, on the Open Systems Interconnection (OSI) 7-layer concept[d]. There are a variety of NTCIP standards pertaining to the level and interface within or across levels. The NTCIP is the first set of standards for the transportation industry that allows transportation management and control systems to be built using a "mix and match" approach with equipment from different manufacturers. Therefore, NTCIP standards reduce the need for reliance on specific equipment vendors, customized one-of-a-kind software, and costly interface management. NTCIP is a joint product of the National Electronics

[c] See www.its-standards.net for additional information.
[d] The five layers are: Information, applications, transport, sub-networks, and plant level. Most transportation-specific standards are at the information level in which standards, data, and objects are under development. The other layers draw heavily on protocols and standards developed in the telecommunications, computing, electrical, and electronic industries.

Manufacturers Association (NEMA), the American Association of State Highway and Transportation Officials (AASHTO), and the Institute of Transportation Engineers (ITE).

The NTCIP defines two major types of communications, both of which are important to ATIS:

- Communications between a management center and field devices (Center-to-Field – C2F)
- Communications between two or more management centers (Center-to-Center – C2C) as well as units within the same agency[e]

C2F communications may involve commands to field devices or the receipt of data from field devices, such as polled roadway loop sensors or CCTV images. C2C communications enables information exchange about signal status, incident/event notification, image sharing (CCTVs), and regional traffic control (major event traffic diversion control and implementation).

3.1.2.1.2 Data Object and Message Set Standards

Of particular concern to ATIS are the information-level and applications-level standards that address center-to center communications, since traveler information usually does not reside at one center (or database) location (e.g., roadway, transit, weather). A variety of standardized data elements (objects) and message sets supporting ATIS have been developed. Message sets are common terms and definitions for ATIS data used to disseminate ATIS information. In a simple analogy, message sets are the sentences whereas the data elements are the individual words. The standards supporting ATIS functions and services include:

- ATIS Data Dictionary, which provides the definition and syntax of individual data elements that make up the specific message content of a message. SAE J2353, Advanced Traveler Information Systems (ATIS) Data Dictionary, defines the data elements for ATIS messages and was approved in August 2000.
- ATIS Message Sets, which provides the messages that are exchanged among information providers, traffic management centers, and other ITS centers. SAE J2354, Advanced Traveler Information Systems (ATIS) Message Sets was approved in October 2000.

[e] While traveler information exchange is focused at the traffic management center, other units of an agency are or may be involved with C2C functions. For example, the structures unit of a state Department of Transportation typically keeps design information in databases, which may be needed by a traveler information system and data fusion algorithm to verify weight limits on a roadway segment.

- Traffic Management Data Dictionary developed by ITE, which supports C2C information exchanges, is under review and comment.
- Message Sets for External Traffic Management Center Communications (MS/ETMCC).
- Incident Management standards, which are being co-developed by NEMA and IEEE, are being developed.
- Roadway Weather Information System (RWIS) data and message sets are being developed for siting and calibration needs, as well as communications[5].

At the applications level, six protocols have been proposed and standardized by NTCIP. These include Common Object Request Broker Architecture (CORBA[f]), DATa Exchange in Abstract Syntax Notation One (DATEX-ASN.1), Simple Network Management Protocol (SNMP), Simple Transportation Management Protocol (STMP), File Transfer Protocol (FTP), and Trivial File Transfer Protocol (TFTP). CORBA and DATEX-ASN.1[g] are suitable for C2C communications whereas SNMP and STMP are more appropriate for C2F. FTP and TFTP can be used to retrieve server files when a client receives a file transfer request. With the exception of STMP and DATEX-ASN.1, all application protocols exist and are widely accepted industrial standards for the application layer.

3.1.2.1.3 Metadata Standards

In an increasingly distributed computing and communication environment, it will be necessary to define content description standards or metadata standards of complex, multi-layered, time-depending data streams. A metadata model specifies an application's object, structure and content and conveys information about the application's elements thereby enabling reasoning about the data and the metadata. A variety of approaches are emerging on metadata definitions including the Resource Description Framework (RDF) Schema. Extensible Markup Language (XML)[h], Document-type Definitions (DTDs),

[f] CORBA is a product of more than 12 years of collaboration among approximately 300 industry representatives, known as the Object Management Group. The intent of the collaboration was to foster interoperability and interchangeability for data base management systems. See www.OMG.org.

[g] NTCIP 2304 "Application Profile for Data Exchange ASN.1" (DATEX-ASN.1) and NTCIP 2305 "Common Object Request Broker Architecture" (CORBA) are the two defining standards.

[h] XML is a representation language that contributes to the development of the "Semantic Web," in which automated agents effectively search the Internet and find the right information that a user is seeking. HTML is a simple and easy-to-use presentation format intended for a human audience, not for processing by an "intelligent" application. XML was created to add clues or markers in the data that would enable an application to better "understand" what the data is about. XML is used primarily for two purposes: as a representation language to create documents (especially those with self-defined style sheets and document definitions) and as a dynamic object, facilitating data exchange or dynamic representation. In the latter application of XML, the W3C is developing a Document Object Model (DOM) to allow programs and scripts to dynamically interface and access the content, structure, and style of documents, independent of

Document Content Description (DCD), MPEG-7, and Schema for Object-Oriented XML (SOX). The ATIS developments in Seattle have been employing self-describing data (SDD) techniques since the mid-1990s[6].

3.1.2.2 Data Fusion Methods and Approaches

The data fusion field has been in existence for about 20 years. Consequently, some of the methods and techniques applied in data fusion work draw heavily from other disciplines and fields of study and application. The arena of data fusion is best captured in the following figure. As illustrated in Figure 3-2, a number of disciplines, areas of study, and techniques contribute to the data fusion.

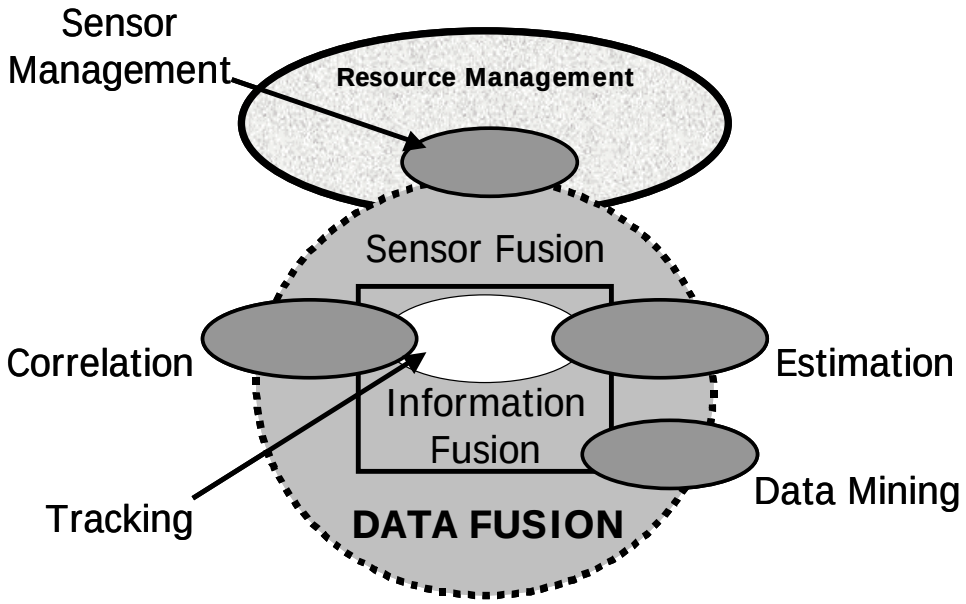

Figure 3-2 Data Fusion Draws From And Contributes To A Number of Overlapping Disciplines[7]

- Data mining is the nontrivial discovery of meaningful new correlations, patterns, and trends and the extraction of implicit, previously unknown, and potentially useful information from large amounts of data. By applying sophisticated software tools, an analyst is able to infer rules from among data objects that can be used to predict future states or guide decision-making. Data mining methods represent one of several techniques for developing some of the parameters needed

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the platform and language employed. DOM uses a current three-level model to delineate standards and functions of the DOM. Additional information is available at "www.w3.org/DOM."

by more advanced data fusion algorithms, such as knowledge-based systems or intelligent agent functions, which are discussed below.

- Estimation refers to the use of methods to infer information or define parameters about a general population based on a limited set of observations about the population. Estimation methods usually are based on principles of sampling theory and include metrics for the accuracy of estimation.
- Sensor Management refers to the range of activities to ensure sensor data is formatted and processed in a timely and accurate manner as needed by the data fusion subsystems, as well as possibly controlling the sensor operations[i] and adjusting the data processing in order to improve estimation and prediction of selected objects.
- Correlation refers to the degree of relationship among two or more variables.
- Tracking refers to the temporal and geospatial location of objects. The tracking of objects involves a number of factors including uncertainty in position location, management of multiple measurements for the same object, database organization, and scalability.

ATIS data fusion development can be categorized between data-centric activities and model-centric activities. Data-centric systems typically analyze large pools of data found in the host agencies databases and may be augmented by external data sources. The analysis and fusing of the data is typically a well-structured problem and involves the timely collection, processing, storing of information at proper locations (e.g., data warehouses), and disseminating ("pushing") the information based on the ATIS system design or subscriber services. Data elements can be part of an object-oriented or relational database management system. Model-centric systems are heavily based on algorithms that employ some form of reasoning to assess a current situation and to provide forecasts or estimates. A model-centric system may draw on the data-centric information to make informed estimates of patterns, trends, and "what if" types of situations. For ATIS applications, these estimates may include a variety of topics, including a forecast of network clearance times given the current depiction of an event or the estimated changes in historic mean speeds on highways when rain is occurring at a certain pace and time of day. Figure 3-3 illustrates the general distinction between data-centric and model-centric ATIS data fusion functions. Current ATIS systems tend to be data-centric.

[i] The issue of sensor control by the non-owner is a key concern and highlights some of the multi-jurisdictional challenges of a more fully integrated ATIS data fusion system. Current data dictionaries and protocols for C2C operations do allow for "remote" control (e.g., a management center controlling a CCTV sensor outside their jurisdiction), however, whether these control functions will be enabled is an institutional planning and implementation issue. At this point, no general guidance or pattern of practice has emerged.

The technology and methodologies used in data fusion are rapidly evolving in a variety of fields, including military applications, medical diagnosis, and industrial process controls/operations. With distributed database systems and the rapid generation of data that may support ATIS functions, renewed interest in data fusion methods has emerged. Current research is focusing on the development of new or improved algorithms and the assembly of techniques into an overarching framework and architecture that addresses a data fusion project's needs. An overarching framework also assists in comparing findings from related fields (e.g., correlation and tracking analysis, while extending studies into unresolved areas).

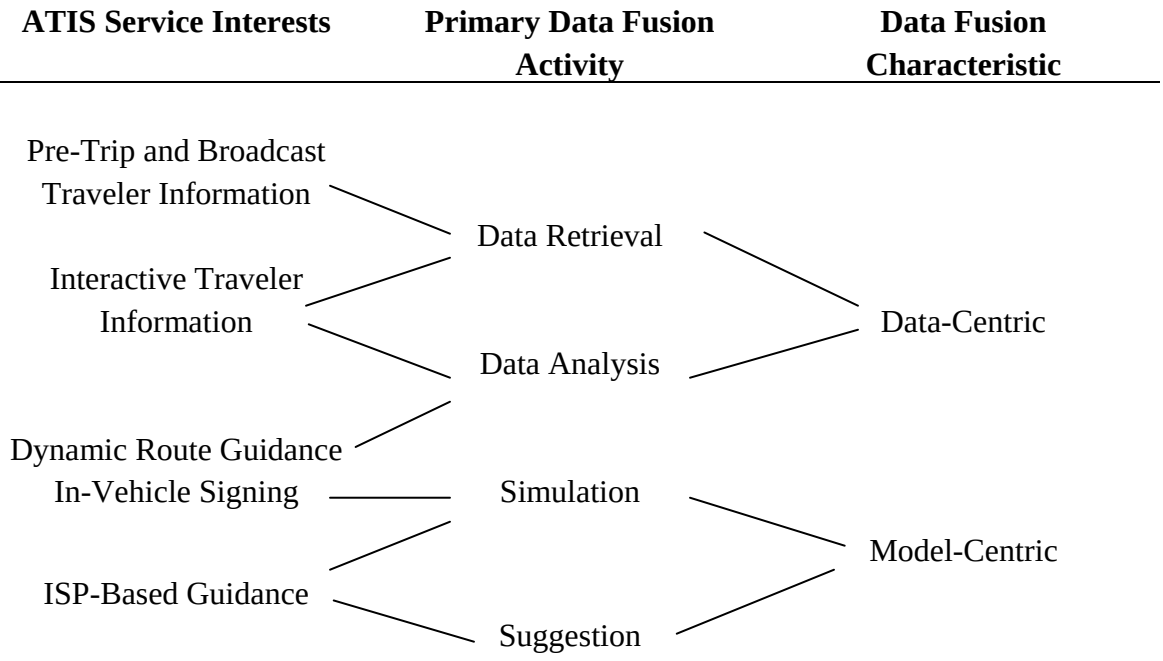

Figure 3-3 Data Centric and Model-Centric ATIS Data Fusion Activities

3.1.3 ATIS Information Uses

The uses of ATIS information have received the most attention and discussion. Early studies focused on the range of information services that may appeal to users for both pre-trip and en-route circumstances. Later attention focused on the various means for distributing the information. As experience with ATIS deployments continued, subsequent studies and reports examined the various business models and users' demand for ATIS services. Convergence in communication systems and in-vehicle technologies

brought renewed focus to the telematics field, which offers insights into IVN performance, system design and implementation, as well as estimates of market demand and price points for various services.

3.1.3.1 Information Services for Pre-Trip Needs

Most pre-trip information systems are demonstrations of individual technologies or configurations of technologies that provide pre-trip information to a wide-range of users, based on their requests and actions. Given the relatively static nature of pre-trip information, agencies or service providers are able to organize the traveler information using Commercial-Of-The-Shelf (COTS) software (with minor modifications) and distribution methods, e.g., an agency's web page, e-mail address, telephonic voice message tree, and PDAs. The pre-trip information is assembled into useful information services ("packages") based on expert judgments, feedback from users, and the evolutionary refinement of the business models, e.g., adding desired features based on budget cycles, service demands, the cost/value ratio of implementation. The primary challenges for pre-trip ATIS are the need to keep timely and accurate information in databases (especially timely information across jurisdictions), the operation and maintenance of the dissemination technologies (e.g., modem-connections to devices, updates to voice messages and/or recognition software to offer schedule information, web-page updates). During the initial trials of deploying traveler information websites, some agencies were not able to handle the volume of requests and consequently, potential users were turned away due to unacceptable delays in response time. These issues have been largely overcome with enhanced network sizing, planning, rapidly declining equipment costs, and improved processing speeds for web servers.

3.1.3.2 Information Services for En-Route Needs

En-route information services typically provide travelers with a variety of real-time traffic conditions, incidents, construction, weather, and transit schedules/operations.

Currently, many state agencies collect and process data to yield some form of traffic conditions, usually average speeds or camera images associated with selected highway segments. Typically this information is centrally assembled and analyzed at a data warehouse or traffic management center, where co-location with law enforcement and/or agency maintenance personnel may also enhance the information regarding the scope, location, accuracy, and timeliness of the highway or network conditions. The co-location of these supporting services usually allows for more rapid detecting, tracking, and promulgating of time-sensitive information about incidents, roadway construction, or

closures to ATIS users[j]. Some of the primary issues for en-route information services are the extent of the network coverage (sensor spacing/location as well as type of roadway -- highways, but not usually adjacent or key arterials), accuracy and availability of the data within and across jurisdictions, and timeliness of the data[8].

Value-added information about roadway conditions may also be generated by a third-party Information Service Provider (ISP) who further refines and augments basic network conditions by providing enhanced estimates of travel times or delays, suggested routes or navigation information based on forecasted roadway conditions, pre-trip advice/planning based on current network conditions, and other services. Third-party information providers may use additional data collection methods, such as aerial surveillance and probe vehicles[k] or capture information from travelers, passively through ancillary location detection via cellular phone calls[l] or actively through direct reports of events to a TMC, emergency number, or local radio station. This enhanced information may be provided for little or no cost through commercial radio broadcasts or on a fee-for-service basis.

Turn-by-turn route guidance, usually with voice or tone prompts, is another form of ATIS that has received generally favorable support and use. These systems are undergoing additional enhancements through the use of better display maps, faster in-vehicle processing and response time, GPS equipment offering better accuracy and signal reception, and experimental voice-activated commands to meet "hands-free" driver requirements. These product improvements are driven by a combination of cost-effective technological enhancements drawn from other industries and favorable value/cost ratios based on user feedback and preferences. The rental car industry is one of the primary providers of these ATIS services, starting with the initial Travtek project[9].

En-route transit services are beginning to offer expanded information on transfers and bus/rail connections, arrival and departure times at designated stops, and space availability at "park-n-ride" lots. These enhancements are typically the result of combining market proven technologies into a new "package" of ATIS services. For example, with the recent California certification of BART's automatic vehicle control system, even greater precision in the geo-location of vehicles through dedicated wireless

[j] The effects and effectiveness of agency/service co-location on increased performance are usually offered anecdotally.

[k] The number and frequency of use of one or more probe vehicles are a planning and design decision based on the desired information, accuracy, and frequency of update.

[l] Using multi-path phenomena, a variety of cellular phone companies were experimenting with using signals to locate and estimate vehicular speed/direction (assuming cellular service activation in a vehicle). These projects and studies of this effect have since been suspended or discontinued due to the substantial downturn in the U.S. telecommunications industry during the past 6-18 months.

networks will be possible, enhancing general operations and specifically the accuracy, reliability, data quality, and timeliness of arrival and departure information.

3.1.3.3 Users' Demand for ATIS

Almost all ATIS users appear to be employed commuters with the highest usage during peak commuting hours[10]. Users generally react favorably to having the choice of receiving accurate, real-time traveler information. In general, four factors influence the level of use or demand for ATIS services:

- Regional traffic context. The primary users for ATIS come from highly congested regions with limited build-out options, constrained route possibilities, and frequent traffic events due to incidents, weather, unexpected roadways repairs, etc. Accurate, regionally oriented, timely message formulations for ATIS users are critical.
- Quality of the ATIS service. Users are interested in the accuracy, reliability, timeliness, portability, and value/cost ratio of the ATIS information. These factors influence the level of confidence and how frequently an ATIS service would be consulted.
- Individual travel or trip characteristics. Trip length, particular routes or choices, departure time flexibility, and alternative mode choices influence the demand for ATIS.
- Characteristics of the traveler. Factors such as user awareness of available ATIS services, potential use patterns, responses to services provided, human-machine interface design, and valuation influence to varying degrees the demand for and types of services needed or requested.

Focused research on ATIS users' needs has been building for the past 8-10 years and is still on going. While these four factors indicate the extent to which users will consume ATIS services, much more work is needed to understand such quantitative and qualitative factors as desired products/services, users' needs for timeliness, accuracy or reliability, and the user's "willingness to pay" or price breakpoints. These users' needs, in turn, help system developers establish technical requirements and their relative priorities in the ATIS system and among subsystems.

3.1.3.4 Dissemination of ATIS Information

The primary means of disseminating traveler information has been through audio (telephone, radio broadcasts, etc.) or video means (CCTV, CATV, broadcast TV, web-based services, etc.). The specific means and methods have largely been imported from developments in other industries.

Websites have been one of the most common means used by ATIS service providers of disseminating traveler information. Most of the website development is done under agency direction using their preferred web development standards. Consequently, there are no standard formats, metadata, or descriptors established for the websites[m]. While languages such as HTML and XML provide for document definition techniques, the implementation of the websites do not necessarily follow a standard format or set of techniques. Consequently, web-based data mining and data parsing is usually conducted on a case-by-case basis. As webpage formats change, adjustment in parsing, mining, and capturing techniques are usually required. Recent advances have employed machine learning approaches to effectively parse and output in XML formats the content of a web site[11].

3.1.3.5 Telematics

Telematics refers to automotive-grade electronics and communications systems to make vehicles operate smarter, safer, simpler and more synchronized with their environment. Telematics can assist with location-based services, entertainment, navigation, concierge services, and emergency needs. Telematic components include a variety of technologies and processes, including GPS technology, radio frequency communication subsystems, embedded computing to monitor vehicle performance (mechanical, electrical, driving behavior, road conditions), on-board devices for display (flat panel displays, audio systems) and capturing information (hands-free operations, voice-activated commands). The telematics industry offers a variety of services, including identification/location, navigation, entertainment, personal safety and security. A subset of these services may use ATIS data sources and information.

Telematics is an evolving industry. There are an estimated two million vehicles with some level of ATIS telematics capability installed, however these estimates are difficult to verify since automobile manufacturers rarely publish information about their telematic sales and after-sale service agreements[12]. Companies are experimenting with a variety of business models to determine consumer preferences. Technically, telematics evolution will progress based on the establishment of industry standards and the use of cost-effective hardware and software components appropriate for automobile/truck/bus use[13]. Some standards for in-vehicle communications protocols have been established (e.g., in-vehicle data bus (IDB) standards), however others are still working through the standards development organizations, such as common incident message sets and roadside-to-vehicle protocols.

[m] Beyond those standards identified by the National ITS Architecture mentioned earlier.

3.1.4 Legal/Institutional Issues

Many agencies use their own data to provide basic traveler information (e.g., average roadway speeds, roadway images for local broadcast television, transit schedules). The initial legal concerns about tort liability (distributed information that is false, inaccurate, or unreliable resulting in an accident or damages) have been addressed by developing disclaimers of liability and the use of warranty conditions. Liability also has been addressed through the use of third-party state universities who collect and distribute the information under research-based agreements, which minimize the potential for claims.

Recent research work has focused on data sharing, specifically how the public and private sectors deal with data ownership and sharing, and examines policies aimed at facilitating data sharing and ultimately improving the quality and quantity of information that reaches travelers[14]. Even though their motives are typically different, public agencies and private sector organizations are both active participants in the use of traveler information as a transportation management tool. A major finding was that agencies that have data to share protect their interests by placing restrictions on access to data, but firms generally do not find these conditions to be onerous. Almost all agencies provide information directly to the public with VMS, HAR, kiosks, and interactive voice response telephones. Although agency data are a fundamental source, private providers generally need to enhance public data before they are marketable. The most common types of augmented information include traffic and road conditions, incident information, and planned construction information. Transit data are generally less useful to private providers, and only a third of them report transit delay information. When new equipment and operating expenses were required, the primary beneficiary incurred the expenses[n]. Finally, two or more conditions on data access were observed, the most frequent condition being an acknowledgement of the agency as the source of the data when distributed to the public (e.g., a logo on an image or a statement such as "this information brought to you courtesy of 'agency' …").

3.1.5 Site-Specific Evaluations

A number of evaluations of ATIS services have been conducted, either as stand-alone systems or as part of a larger evaluation effort. Two major sources of evaluation are the Field Operational Tests (FOT) evaluations of ATIS and the Metropolitan Model Deployment Initiatives (MMDI) assessments. Verifiable private sector assessments were not available. Three representative ATIS studies are summarized since they provide insights into operational issues that affect ATIS data fusion system design and operation.

[n] A common example is the need to have a full-motion video feed from a Traffic Management Center (TMC) to a broadcast studio. The costs for the communications link and interface equipment at/near the public TMC are paid by the broadcast affiliate.

An FOT cross-cutting evaluation of ATIS was conducted in 1998[15]. The primary conclusion was the users value traveler information, but usage will depend on a variety of factors such as awareness of service, information reliability, timeliness, accuracy, and user cost. At the time of the FOT study, key issues concerned legal liability, improved business models for partnering, expectations for agency-partner performance, quality in a quasi-private business enterprise, and market research into users' preferences. Some of these concerns have been investigated further or since resolved.

The MMDI evaluations were multi-purpose evaluations to assess the deployment and efficacy of ITS. Certain studies focused on ATIS, such as those in Seattle and San Antonio. In Seattle, the evaluation focused on traveler use of the Washington State Department of Transportation (WSDOT) traveler information web site in Seattle and the greater Puget Sound area[16]. The objective of this web-use analysis was to better understand preferences for traveler information, the usage levels at the MMDI site areas for information provided through the Internet, the potential for reaching the traveling public via the Internet, and the patterning of use of traveler information. Findings indicated the WSDOT traffic conditions web page is very popular with travelers in the Seattle area and is one of the most heavily used traffic information web sites in the nation. Unusually congested traffic, caused by severe weather or incidents, prompts significant "spikes" in usage of the web site, indicating substantial latent demand for real-time traffic information. The CCTV image pages were heavily frequented. The daily patterns of use clearly indicate heaviest usage during the afternoon commute peak period.

In San Antonio, the MMDI evaluation of the Transguide system reported the most effective stand-alone ATIS implementation was the incident management component[17]. The ATIS system utilized kiosks and a web site as the primary means for disseminating information. The kiosks had several functional problems and location/placement concerns, thus they were less unlikely to be used by travelers. The web site evaluation indicated substantial use of the site, especially for the real-time weather and traffic/roadway conditions. Overall, the pre-trip and real-time ATIS services indicated they could help reduce delay, crash risk, and fuel consumption.

Discussion with operators and planners at six public ATIS sites were conducted. The sites included Seattle, San Francisco, Los Angeles, Houston, the I-95 Corridor Coalition (Virginia/Maryland representatives), Hampton Roads—Smart Travel Center/I-81 area, and Transcom.

General observations from these discussions include the following:

- The primary sources of real-time data are the loop detection system, CCTVs, video imaging detectors, tollgates, reports from law enforcement or agency

patrols, weather-sensing stations, other operations centers (transit, bridge-tunnel authorities) or travelers. In general, data is collected in the following categories: traffic (speed, volume, congestion, lane occupancy, road conditions, weather, parking); incidents and emergency management (accidents, special event, road closure, construction schedule); transit (metro schedule, fares, intermodal connection); and other more customized special services including ride-sharing, location and navigation information.

- Data is almost always gathered at a central location, processed, and then distributed. Any data fusion activity is centrally based.

- Data fusion activities are either manually performed by layering data over maps or combining information through human judgments (e.g., a human operator verifies a reported incident and defines subsequent actions). The resulting assessment and actions are usually monitored or confirmed by an operations "chief" and posted for dissemination as a verbal report, web-site update, or DMS display. Only when using a self-contained system, such as with a GIS or CAD system, was a more automated data fusion approach possible, primarily through relatively simple geo-spatial and temporal alignment algorithms. Most GIS and CAD systems manipulate proprietary data sets and so interoperability and exchangeability of data is complicated[18]. One agency has five different GIS systems used throughout the agency, each of which would be valuable to ATIS services. However, automated cross-referencing in a cost effective and timely manner across the five systems is not possible.

- The most frequently cited reason for insufficient data quality is inadequate geographical coverage. This arises mainly from incomplete data collection in metropolitan areas with multiple jurisdictions with incompatible data sources, ITS, or ATIS system within each area.

- The extent of archived data to be used, especially for travel time estimates, has not been well defined. Both real-time and archived data are important for travel time estimation. Techniques for using this information have been left to research universities or other interested individuals. While most agencies are not out of data storage space, the cost of archiving may eventually impose limitations on archival and timely retrieval capabilities.

- An increasing number of ATIS services have incorporated GPS functions. There has been an emerging common practice of using Location References Management System (LRMS) to incorporate GPS functions into ATIS services.

In terms of incorporating GIS functions, achieving interoperability (interchangeability) is more complicated, because there are already many GIS products in various formats and existing practices.

- Data quality is assessed primarily by informal or heuristic judgment methods. The extent of the assessment is in reaction to the identification of outliers or obvious errors. Some quality check functions are embedded in the process (hardware/software), but there is still no common approach or organizational discipline to establish data quality rules. Data collected through some loop systems did provide metadata, which offer the means of assessing rudimentary single loop performance (e.g., recent calibration, false signal alarms, equipment self-reports).

- Data is shared through third-party partners or lead agencies that have the consent of the other partners. No fee is usually charged, but acknowledgement of the source is required.

- Agencies are migrating to the use of the NTCIP and associated standards, but will likely phase in their use based on industry acceptance and agency confidence in their usefulness and longevity.

- Many 511 systems are beginning operations. Insufficient data was available to make an informed systemic assessment.

As mentioned earlier, these sites were selected primarily because of their advanced planning and operation of ATIS services. Not all observations pertain to all sites and so it would be inappropriate to attempt to generalize these findings.

3.2 Key Findings and Implications for ATIS Data Fusion Development

There is a general awareness in the ATIS community of data fusion function and purpose. The awareness is due to the promulgation of National ITS architecture materials and specific ATIS presentations. Within the ATIS community there are multiple interpretations of data fusion and what can be achieved. One perspective is a relatively simplistic view and follows the data-centric model, e.g., primarily data alignment processing through templates or common referencing methods, with limited data analysis. Another perspective is a more sophisticated, model-centric view of the opportunities to

combine data from a wide-range of data sources and then apply association and estimation techniques to meet a large set of ATIS user needs.

Data fusion is used primarily at public agencies to perform spatial or temporal alignment of input data. The data alignment and transformation issues can be addressed through proper system design and application of proven techniques. Third-party ISPs typically augment the public data, provide some form of value-added service, and offer it through a variety of mediums to fee-paying ATIS subscribers. The value-added services include greater network coverage, more frequent updates of network conditions, cross-platform compatibility and functionality for sending or receiving traveler information, and enhanced cross-referencing of complementary data/information sources, such as better maps and weather information. Some public ATIS service providers are interested in the development of data fusion methods, but do not perceive them as critical for their role in ATIS service delivery at this time. Moreover, public agencies would prefer a system-level proof of concept from another agency (reliable, durable, accurate, value/cost assessment) before embarking on more extensive data fusion projects.

Some of the challenges for ATIS data fusion development include:

- For ISPs, uncertainty in the ATIS business models and potential benefits, including:
  - Data access issues, which three to five years ago were issues between public agencies and third parties, have been largely resolved.
  - Sensor coverage (primarily inductive loops, CCTVs) and reliability does not allow for more sophisticated travel time predictions or network status, which potential customers may desire;
- Certain algorithms require probabilistic or other sophisticated parameters or estimates, which would need to be calculated or estimated by humans. The alternative is to keep a "person-in-the-loop" at key decision points in the overall processing of traveler information;
- Uncertainty in the subsystems and system-wide performance based on the emerging standards–NTCIP, data objects and message set development status (ATIS, TMDD, RWIS, etc.);
- Data fusion techniques exist but need adaptation to the ATIS field and sharing of performance across with the community;
- Model-centric data fusion relies on higher-order problem solving forms (reasoning with uncertainty types of problems) which are highly context-dependent, potentially unstable, and not easily generalizable; and
- ATIS systems are not typically developed as stand-alone systems and therefore co-exist and are influenced by other system architecture design and goals such as

a freeway management system. Consequently, ATIS issues involve the relative priorities placed by agencies on ATIS goals vis-à-vis other ITS subsystem goals, the need for real-time processing capabilities to meet ATIS outcomes, the extent of the network sensor coverage required to achieve ATIS performance goals versus other ITS subsystem goals, and the means of defining, calibrating, and improving data quality in a systematic manner.

3.3 Section 3 References

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Section 4 Data Fusion Framework for ATIS Analysis and Implementation

The purpose of establishing a data fusion framework is to provide a functional model for use by a diverse set of individuals or communities interested in ATIS. Working from a common framework, interested individuals would be more inclined to coordinate and collaborate across disciplines and expertise. A functional ATIS data fusion model also facilitates user understanding and communication, permits comparison and integration across disciplines, promotes expandability, modularity, and reusability, and offers cost-effective systems engineering and systems development insights.

This section presents an adaptation of a Defense Department data fusion model to the ATIS context. The first part defines the key functions and multi-level (or phased) features of the model as well as methods and processing techniques appropriate to each level[a]. The discussion presents a combination of data-centric and model-centric methods for advancing ATIS data fusion. The second part presents a review of possible fusion architectures with an emphasis on ATIS communication configurations and qualitative performance tradeoffs. The final section focuses on data quality assessment and management, although data quality implications are noted throughout this section.

4.1 Key Functions To Be Performed In An ATIS Data Fusion System

Section 3 introduced a simplified, three-part model to enable a general review of ATIS studies and discuss the supporting role of data fusion. That model depicted data sources, data processing, and data/information uses (outputs) as the three key functions. To advance the applicability of ATIS data fusion, an expanded model of these functions is desirable. It was noted that ATIS data fusion is evolving from a data-centric practice to more model-centric features in order to meet users' needs. The model-centric features will require a broad range of data fusion functions, which when properly combined, can help meet the users' needs. Moreover, new and emerging technologies will provide alternative and unforeseen means of supporting data fusion. A more generalized model can assist in incorporating these innovations. Finally, an industry-defined set of data fusion functions allows planners and developers to draw on the experience and ideas from affiliated data fusion applications.

[a] This discussion draws on the work of Hall and Llinas[3], Hall[4], and Klein[5].

The major data fusion functions, in support of ATIS, can be established as[2]:

- Alignment of sensor data to a common reference of time and space (or reference frame).
- Association between measurements or observable data collected from different sensors and tracks[b] to determine candidates for correlation processes.
- Correlation of tracks and the measurement data to improve detection, classification, and tracking of objects of interest. Objects of interest may include vehicles, temperature, incident images, transit vehicle locations, and similar objects which, when combined, will provide a more complete representation of the transportation system.
- Classification of the track data sets to determine object type, situation/network description, and impact assessments.
- Estimation or prediction of an object's future position or representation.
- Regulation and synchronization of data processing functions to manage the feedback of threshold levels, perform periodic self-diagnostics, coordinate integrated timing, and monitor data communications.

While listed individually, these key functions work in a concerted manner to support the goals and purpose of a data fusion system. For example, regulation and synchronization of data processing functions is a continuous, crosscutting activity. Other functions pertain only to specific data collection or object identification requirements. A functional model can be used to place these key functions into a hierarchical arrangement that support the basic purpose of data fusion, namely to combine data to estimate or predict the state of some aspect of the surface transportation world.

4.2 Data Fusion Model Applicable to ATIS

The model developed by the JDL[1] (Joint Directors of Laboratories) has been selected for adaptation and refinement for the ATIS community for two reasons. First its functional representation is consistent with National and Regional ITS Architecture principles, guidance, and practices. Second, it is the most widely used model in the data fusion research and development communities. The JDL model is a multi-level, general framework allowing for attention and refinement of key system elements, such as objects, situations, and processes. Figure 4-1 depicts the ATIS data fusion model, with the following discussion highlighting general definitions and functions pertinent to ATIS.

[b] In the general parlance of the data fusion field, a track refers to the best (database) record of objects and state estimations developed from the previously observed and measured data sources.

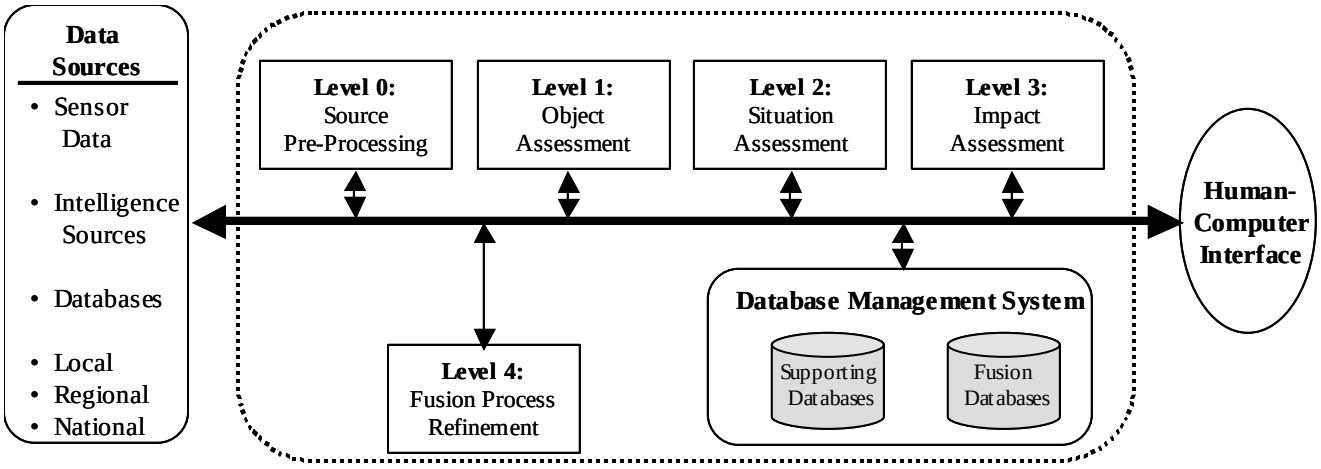

Figure 4-1 A Data Fusion Model Applicable to ATIS

On the left, the model depicts input data received from multiple sources and/or sensors. Typical sources include roadway sensors (loops, cameras, infrared or microwave detectors, etc.), network intelligence sources such as probe vehicles (transit system AVLs or other private/public sources, as available), and traffic control system data and historic databases. Supportive ATIS information may include environmental conditions (weather, topological data, etc.), roadway information (as-built construction drawings, geometrics, etc.), historical data about the ATIS users' preferences and system performance, other system notifications (utility company information about nearby roadway repairs via web-enabled intelligent agents), and condition reports or inferences obtained from travelers through telephone calls, PDAs, e-mail communications, etc. The scale or scope of this information may be drawn from local, regional, national, or worldwide sources, depending on the particular function and traveler information sought.

In general terms, the five levels in the model depict the major data fusion activities, which are:

Level 0 **Source Pre-Processing**: alignment and estimation of signal-observable or object observable states (changes in frequencies at a loop detector, pixel changes on a CCTV data set, etc.) at the signal-level or pixel-data characterization.

Level 1 **Object Assessment**: estimation and prediction of entity states (vehicle, building, pedestrian, temperature, wind speed, etc.) on the basis of *observations* and source data from Level 0 and supporting databases. Missing data are also addressed at this point, once proper editing and alignment have occurred.

Level 2: **Situation Assessment**: estimation and prediction of an ensemble state on the basis of *inferred relationships* among the objects defined in Level 1.

Level 3: **Impact Assessment**: estimation and prediction of effects based on situations of planned or predicted actions by others.

Level 4: **Process Refinement**: adaptive data acquisition, processing, and management consistent with the overall purpose of the data fusion system.

On the right, external interfaces allow for human-computer interface (HCI) and the dissemination of data fusion results. The dissemination of results may occur through public address systems, mass media, Internet-based broadcasts, Internet Service Providers (ISPs), in-vehicle communication subsystems, and/or various handheld (wireless) devices such as telephones, PDAs, etc. The HCI also provides a means of making queries of the data fusion model as well as monitoring/evaluating the system performance through off-line observations and analysis.

Depending on the system design and objectives, the ATIS data fusion processing at a level could encompass[2]:

- Level 0 -- Processes input data from all appropriate sources, including real-time roadway sensor information, weather sensors, cellular telephone traffic, incident reports, etc. Level 0 activities include data formatting, referencing, and/or normalizing as well as managing the scheduling and process management functions to ensure all input data is available at the same time for the next level of processing. Most of the activities in this level are concerned with signal processing, transmission, data storage, and process management activities as defined by the overall system architecture and goals. The effectiveness of data sharing and data quality will depend, in part, on the use of standards and protocols at Level 0. For example, standard XML schemas (or DOM-based approaches) will enhance the ability of Level 0 processing to parse and distribute elementary source data.

- Level 1 -- Processes the refinement of the Level 0 data into object identification (what it is) and state estimation (where it is and when). Some of the Level 1 processing involves information with some uncertainty and so processes and techniques must be employed to improve on the estimation process. At other times, the certainty of the detection, classification, and estimation of the signal comes with high confidence and so a minimal amount of processing is needed to achieve an optimal identification or estimation. Level 0 and Level 1 activities converge when the data object are characterized and identified as signals or

features. Not all Level 1 activities are necessarily automated as in the case of operators making a final determination on certain pattern recognition processes.

- Level 2 -- Processes merge the results of the Level 1 processing with information from other sources, including human-system interaction or databases. These sources may include weather reports, historical traffic patterns for key segments of roadways, GIS network data, and workzone locations. Level 2 fusion results in the estimation and prediction of the system state (levels of congestion, travel times on the defined network, micro-scale roadway weather status, and similar systems state descriptors) on the basis of inferred or absolute relationships. Level 2 processing may also identify the circumstances or situation causing the observed data and events, i.e., known workzone locations.

- Level 3 -- Processes are a subset of Level 2 activities. Level 2 involves estimating and predicting all types of relational states, while Level 3 involves predicting specific relationships of interest between a specific object (vehicle or individual) and the environment. For example, Level 3 processing might assess multi-jurisdictional network traffic flow patterns and other data with respect to the likely occurrence of a quick-moving rainstorm through a particular area and the subsequent impacts on regional traffic flow. This assessment might then provide en-route guidance information to the ATIS user.

- Level 4 -- Processes are for planning and control, but not estimation. As such, Level 4 techniques involve assigning resources to tasks (operating system or database management controls), evaluating the need for additional data resources (storing and processing capacity and speeds), or modifying some of the process or system parameters.

Interrelationships among the three primary levels of data fusion processing are illustrated in Figure 4-2. In this illustration, a subgroup of sensors might represent real-time roadway loop induction sensors, while the remaining sensors might represent weather data gathered from nearby environment sensing stations. The Level 0 data processing may occur i) simultaneously or at different times and ii) centrally or in separate distributed processes and paths. For example, ambient temperature detection and Level 0 processing (sensor signal conversion to a data object/packet) may occur in the field, depending on vendor equipment and system architecture. Polling of the environmental data may occur every 60 minutes, whereas the polling of the loop sensors may occur every 30 seconds. The sensed objects are combined in a Level 1 association process to confirm object identity, as needed, and provide state estimation of the object, e.g., forecasted temperature for that sensing location and surrounding area for the next several

hours. Once the object identity and state estimations are complete, the objects are passed on for Level 2 and 3 processing.

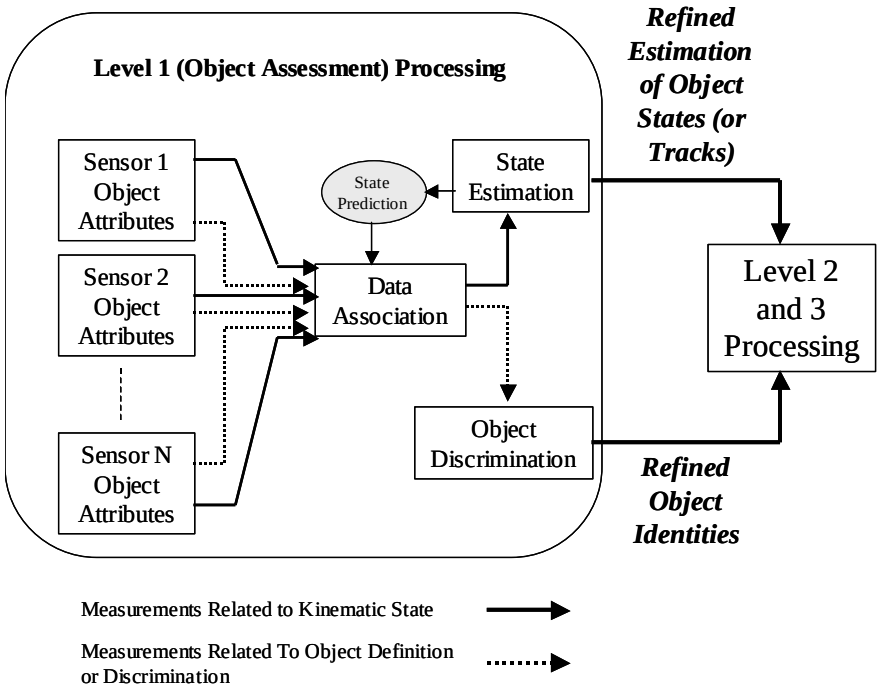

Figure 4-2 Relationships Among Data Fusion Processing at Levels 1, 2 and 3[3]

The following subsections discuss the various techniques and suggested guidelines associated with the five functional levels in the ATIS data fusion model.

4.2.1 Level 0 (Source) Processing and Techniques

The purpose of Level 0 processing is to transform data received from multiple sensors into common spatial and temporal reference frames.

Raw data from mechanical, opto/electrical, or similar sensors usually require some signal processing and refinement before using. Most vendors provide firmware that allows for a variety of functions associated with the signal processing and data alignment. Major activities include the signal collection and digitization (as needed), local storage of the digitized data, processing for levels of detection (thresholding or gating), adjusting for false alarms, scaling or other adjustments based on established calibration processes. Once the basic signal has been normalized it is usually formatted for transmission as a data element or group of data elements (including the definition of metadata), interfaced

with the communications subsystems, scheduled and/or released for transmission based on the communications protocols and polling requests. Specific data alignment functions could include coordinate transformations (e.g., topocentric non-inertial references to geocentric inertial coordinates), time transformations (e.g., mapping from reported observations to actual physical events), and unit conversions. Depending on the sensor and its application within an overall architecture, a self-assessment procedure may also be part of the Level 0 processing.

The sensor accuracy requirements or specifications are usually established by the overall ATIS service and system goals[c]. A wide range of factors can affect the measurement accuracy, including the design of the sensor, its placement in the operating environment (offsets, height, etc.), the conditions under which it operates (weather, lighting conditions, etc.), and the life-cycle maintenance and upkeep. Even if the raw data is properly processed and transmitted for subsequent use, the usefulness in applying the data is dependent on the overall system architecture and processing. For example, temperature readings from an environmental sensing station may be captured by an agency only for historical purposes and not provided except on an hourly basis. But if ambient temperature readings, coupled with the potential for roadway icing conditions in the vicinity of the sensing station, were to be properly fused, the resulting decision could affect traveler information, route selection, and safety.

Data quality is an important system performance characteristic at this level, since data fusion methods will be only as good as the raw data that is supplied. The data sensor quality is affected by a number of parameters, including sensor specification, sensor locations, operating environment, polling frequency, and signal processing. To enhance data quality, some sensor subsystems are including metadata elements to aid in qualifying the raw data quality. For example, in certain inductive loop detectors, a set of metadata descriptors are provided by the sensor that indicate not only the data format of the transmitted data, but error checking information (indicating if the sensor working, if it has been calibrated, etc.). This information can be further processed during Level 1 and Level 4 activities to improve estimations. ATIS data definitions and NTCIP standards provide technical guidance on Level 0 data quality, primarily from the transmission and communication perspective.

The strategy for handling missing data should be established during the design and calibration of the data fusion model since these are the points at which an overview of all

[c] Systems requirements as well as system constraints may be inherited from legacy systems or preceding ITS deployments. Tradeoff studies are usually conducted at the ATIS system scoping and system definition phase to determine if an ATIS data fusion system can meet users' needs based on the development context.

available data sources can be made to determine the desired levels of data precision, reliability, and the best data adjustment methods to minimize distortion and maximize the usefulness of the substituted data. The approach for handling missing data should satisfy four criteria: i) limit the biases caused by not having a complete and accurate record; ii) contain an audit trail for evaluation purposes in Level 4 activities; iii) ensure the substituted/missing data values are internally consistent with the overall design and intent of the data fusion system; and iv) be objective and efficient. A range of missing data techniques is available, such as substituting the last known value (from a time series, for example), estimating the missing value with a parametric model defined during the data fusion system design and calibration phase, making an inquiry for the missing values through the Human-Computer Interface, tagging substituted data values, or alerting subsequent data processing functions to avoid calculations involving this (non-critical) data element until the missing data is resolved. These represent five common methods, but whichever method is selected, it must be internally consistent, efficient, traceable, and objective.

Not all data may come from field sensors, as described above. For example, an ATIS data fusion model may seek information from other websites or ATIS users about network conditions or other data needed to enhance the ATIS needs. In this case, data alignment and protocols/standards become critical requirements.

4.2.2 Level 1 (Object Assessment) Processing and Techniques

Level 1 processing is conducted to achieve two purposes: object identification and state estimation of the object or its "track" (time and changes in location or representation) The identification and state estimation may occur simultaneously, however the following discussion keeps the discussion separate for clarity. The outcome from Level 1 processing is a "situation statement" for each individual object, e.g., a vehicle object captured by a CCTV image, a digital phone record of a cellular caller's report of an incident, or a temperature reading at a specific milepost location.

Sensor outputs from Level 0 are available to various algorithms to help estimate the object identify and its track. Level 0 signal data may indicate vehicle occupancy over a loop sensor while Level 1 processing helps confirm the presence of a vehicle and possibly its classification, depending on the type of sensor. The degree of accuracy and performance of Level 1 processing is established as part of the overall ATIS system design and usually includes such design elements as the required sensor quality (expressed within certain confidence levels, such 95% or 99%), availability (overall system up-time is 95% or greater), and timeliness (key object data is reported within seconds or minutes, as appropriate).

Implications for data quality at Level 1 can be delineated in terms of a variety of metrics, such as positional accuracy, completeness, validity, consistency, and timeliness. Positional sensor accuracy is based on subsystem functioning of the sensor, the communication system, and the processing of the sensor data, a sequential process that may cause a cumulative degradation in data quality if any sub-element is defective or performing poorly. So while a sensor may be functioning at a 99% confidence interval, the processed data may only be 50% reliable due to communication system faults, for example. Data completeness refers to the percentage of Level 1 data fields that have values entered, namely for which the data collection (Level 0) and assessment processes (Level 1) successfully occurred. Data quality for completeness is usually a "yes" or "no" indicator with a threshold established for the required percent of completed data field[d]. Validity refers to the percent of data having values that fall within respective domains or allowable values. As with data completeness, data validity is assessed by means of an acceptable threshold of allowable values. Consistency refers to the stability of the Level 1 assessment process and is usually evaluated using the percent of matching values (within tolerances) across data records. Timeliness refers to the extent at which the data item is provided at the time required or specified by the data fusion system. Level 4 functions of the data fusion model is able to monitor and assess the timeliness of Levels 0 and 1 data quality through exception reporting, data or process tagging, and other process monitoring techniques.

4.2.2.1 Object Identification Methods at Level 1

For Level 1 identification purposes, objects are usually classified hierarchically into one of four categories, as shown below in Figure 4-2[e]. The purpose of the fusion processing at Level 1 – object identification – is to estimate the object category based on the sensed data.

The level and accuracy of the discrimination among the categories depends on a number of factors including the type of sensor, the resolution of the sensor, any a prior knowledge about this sensor (such as bias, Mean Time Between Failure), and the signal-to-noise ratio at the input to the sensor. Also, the object may be well defined and identified if it comes from a "trusted" data source, e.g., a set of roadway design specifications from an agency's database which have been formatted, verified, and quality controlled. In this case, detailed object identification activities are not required and the data object is forwarded in support of other data fusion algorithms and activities.

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[d] Means of handling missing values, one component of data completeness, was discussed in Level 0 processing, subsection 4.2.1.

[e] Adapted from Hall[4].

Category	Interpretation
Detection	Object is present
Orientation	Object may be described in gross geometric terms (symmetric or asymmetric, thick or thin) and orientation (up or down, high or low).
Classification	Object class is matched (voice pattern with a word, vehicle classification, bushes, etc.)
Identification	Object is defined based on the observer's knowledge (type of bush, declaration of a manufacturer/make of a vehicle, temperature reading, etc.)

Figure 4-2 Levels Of Object Identification

The major mathematical techniques to achieve object identification can be grouped into three broad groups with corresponding subgroups: physical models, feature-based models, and cognitive-based models.[4,5] Figure 4-3 illustrates the range of major techniques, with the subsequent discussion starting on the more conventional and established state-of-the practice methods, followed by newer, but feasible techniques.

Physical Models	Feature-Based Models	Cognitive-Based Models
▪ Kalman Filtering	▪ Parametric Techniques	▪ Logical Templates
▪ Maximum Likelihood estimators	▪ Non-Parametric techniques	▪ Knowledge-Based Expert Systems
▪ Least Square Approximations		▪ Fuzzy Set Techniques

Figure 4-3 The Major Techniques Appropriate For ATIS Object Identification (Level 1)

4.2.2.2 Physical Models For Object Identification[f]

Physical models take the sensor-observed data and estimate the identity based on matching algorithms that compare modeled or pre-determined/pre-stored object descriptors with the observed data. Examples could include inductive loop sensor data as a function of vehicle types, temperature, or height profile images. The estimation techniques for physical models are primarily simulation and estimation methods. Estimation processes, such as Kalman filtering, maximum likelihood estimation, and least squares approximation, are representative methods and can be considered state-of-the practice.

4.2.2.3 Feature-Based Methods For Object Identification

Feature-based inference techniques do not use physical models. Instead, correlation is performed by mapping the observed data into an identity declaration. Feature-based algorithms can be subdivided into parametric and non-parametric or what Waltz and Llinas[3] refer to as information theoretic techniques.

- **Parametric techniques**. The identification challenge is addressed by mapping (through estimation techniques) the parametric data directly into a declaration of identity. Parametric techniques require an explicit "measure of match", such as a least squares estimation. Parametric techniques include classical inference, Bayesian inference, Dempster-Shafer inference, and Generalized Evidence Processing.

    - Classical inference starts with an assumed hypothesis and then seeks to determine the probability that an observation can be identified with or attributed to an object or event. Metrics associated with these techniques include determining confidence intervals, calculating sample size for a desired margin of error, conducting test for statistical significance, etc. Decision theory can be used to select among hypotheses. The major disadvantage with classical inferences for ATIS services is the collection of representative probability density function to assist in classifying the observation into a category. As multivariate calculations are proposed, the complexities in defining joint probability density functions increase substantially.

[f] This section draws from the work of Hall and Llinas[2] and Klein[5].

- Bayesian inference addresses some of the challenges of classical inferences. Classical inference allows for the calculation of an event probability based on a hypothesis. Bayesian inference provides a means of determining the probability of a hypothesis being true given the observed data. For example, Bayesian inference could answer an important question such as 'what is the likelihood a cellular caller can accurately verify the location of an incident given the history of incidents in that area?'. Multiple hypotheses can also be assessed.[5] The drawbacks of the Bayesian inference technique include the challenge of defining prior likelihood functions and the complexities of disaggregating and estimating when there are multiple hypotheses and conditionally-dependent multiple events.

- The Dempster-Shafer (D-S) method is a generalized version of the Bayesian inference method for assessing propositions, i.e., that an object is in a category. Through its generalization, D-S can account for general uncertainty by distributing the required evidence (known as support) for a proposition between the proposition and the union of any propositions that include it. Any evidence that cannot be directly assigned to a proposition (or its opposite) is assigned to an uncertainty set. The support set and the uncertainty set make up the hypothesis space. Bayesian and D-S yield the same results when all the basic propositions are mutually exclusive and no support is assigned to the uncertainty set. The challenges of the D-S method include the formulation of the hypothesis, which can become complex with only a few variables, and the assignment of the degree of support for a proposition. Klein provides a more detailed example of the D-S application for ATIS[6].

- Generalized Evidence Processing (GEP) uses evidence collected by multiple sensors and assigns a probability mass to the evidence, much like the D-S technique. GEP differs from D-S in that the probability mass assignments and their combination are based on the a priori conditional probability of the propositions or hypotheses[5]. GEP has a similar set of implementation challenges as D-S.

- **Information theoretic (non-parametric) techniques**. The parametric techniques listed above incorporate an explicit stochastic aspect of the observed data into the calculations. Information theoretic techniques make no attempt to model stochastic features of the observed data during the process of object identification. The information theoretic techniques include parametric templates,

artificial neural networks, cluster algorithms, voting methods, and Figures of Merit, pattern recognition, and correlation measures.

- Parametric templates are one of the most straightforward means of object identification. Sensor data, collected over a pre-determined period of time, are combined with other information sources to determine if they match pre-selected conditions and thereby identify an object. Parametric templates can be used for object/event detection, general situation assessment, or single object identification.

- Artificial neural networks are combined hardware or software subsystems that emulate the thinking processes that occur in biological nervous systems. The technique involves defining the various system states, establishing processes that map input data or stimuli into intermediate or output categories/identity states, and conducting sufficient training and initialization to allow the network to become sufficiently accurate and self-sustaining.

- Cluster algorithms take data elements and groups them into natural sets based on an association metric. The association metric is used to describe the closeness or nearness of fit among the data and the clusters. Association metrics may be spatially defined or statistically defined. The meanings of the clusters are usually the result of an expert or team providing an interpretation. In general, clustering algorithms and the interpretation of the clusters are subject to variability in the final object identification due to data preparation (scaling, data cleansing, etc.), the choice of association metric and algorithm, and possibly the order or sequence of the input data or sets. Hence, application of cluster methods must be judged on their overall effectiveness, post-assessment performance, and reliability to form consistent and meaningful object identity clusters[6].

- Voting methods treat each sensor's data declaration as a vote in which majority, heuristic rules, plurality, weighted voting, or other forms of decision-tree rules may be applied to determine the final object identity. The challenges with voting methods are the training time and the declaration of the detection modes and desired confidence levels. Calibration is an iterative process in which the relation of detection and false alarm probabilities are assessed against desired identification confidence levels.

- Figures of Merit (FOM). Observations are compared with each identity category and with other observations. Because the observations can contain both parametric data (time, location, etc.) as well as non-parametric data (e.g., an identify declaration from a sensor), then a figure of merit is used to qualify the degree of association with the category. The FOM is a numerical measure of the confidence the two observations represents the same object/entity. Numerical measures are similar to the distance measures used in clustering algorithms, such as Euclidean or Mahalanobis. When working with alphanumerical data, a different approach is used, usually based on heuristic insights rather than more rigorous mathematical measures.

- Correlation measures are derived from the combinations of weighted figures of merit. Correlation measures allow for a comparison score or measure of correlation to be assessed across systems that have numerous figures of merit. Used in this fashion, the correlation measure represents the total likelihood that two objects/entities are the same.

- Pattern recognition is used for the description or classification of sensed data[7]. Three primary approaches to pattern recognition are currently in use. First is statistical pattern recognition (sometimes referred to as a decision theoretic approach) in which a set of characteristic measurements or features is extracted from the input data and use to assign the set of features to one of several pre-determined classes. This technique assumes a class is pre-defined by an underlying statistical model that represents a state of nature, set of probabilities, or probability density functions to which the features can be matched or assigned. Second is syntactic pattern recognition (also referred to as structural modeling) in which the technique focuses on the relationships or interconnections among features in order to yield identity information. The structural similarity of patterns is assessed by quantifying and extracting structural information using, for example, the syntax of a formally defined language, e.g., digraph theory. Third is the artificial neural network approach applied to pattern recognition, which was discussed previously.

4.2.2.4 Cognitive-Based Methods For Object Identification

Cognitive-based models attempt to mimic the inference processes of human analysts in recognizing object identity. The most widely used techniques include logical templates, knowledge-based expert systems, and fuzzy set theory.

- Logical templates use a comparison process in which a predetermined and stored pattern is matched against observed data to infer the identity of the object. Logical templates are also useful in assessing the Level 1 position estimation (another key function in the Level 1 processing) as well as constructing an overall situation report (Level 2 processing). Templates can be developed for both parametric and non-parametric data. Identity can be established through Boolean relations as well as through relative measures of association. Semantic logic, which is an evolving field, may also be employed to assist with classification. Fuzzy logic can be applied to the pattern matching technique to account for a range of uncertainty in either the observed data or the logical relationships used to define a pattern.

- Knowledge-based expert systems incorporate formal rules and other knowledge from experts, through a process of knowledge engineering, to automate the object identification process. Knowledge-based expert systems usually consist of five subsystems: a knowledge base that contains facts gleaned from one or more experts through carefully structured interviews and data collection processes; description of specific algorithms and a set of heuristic rules that reflect the processing steps of the expert(s) for the knowledge domain; a database; a control structure or inference engine; and a human-computer interface. The inference engine processes the data by searching the knowledge base, applying the facts, algorithms, and rules to the data, and suggesting a set of actions, usually presented at the human-computer interface. Completely automated knowledge-based systems involve decision-making among the set of actions without the use of the human-computer interface. Intelligent agents and genetic algorithms are typically considered to be subclasses of knowledge-based systems.

- Fuzzy set theory and techniques. Fuzzy logic consists of a variety of concepts and techniques for representing and inferring knowledge that is imprecise, uncertain, and unreliable. Fuzzy logic can create rules that use approximate or subjective values and incomplete or ambiguous data or relationships. Application of this technique (at Level 1) will allow for a mapping of data or observations into appropriate identity categories. To apply fuzzy logic requires three subsystems: a definition of the fuzzy sets, the membership function (fuzzification), and a set of production rules that are represented in the form of If-Then rules. The logical processing using fuzzy set is known as fuzzy logic. Fuzzy sets incorporate

vagueness into the production rules, since they can represent less precise linguistic terms (e.g., hot/cold, short/long, etc.). The production rules operate simultaneously and influence the output of association and category definition.

These techniques represent the more practical set of methods and techniques for Level 1 object identification. There are additional fields of study that are emerging, but these are still in the development stages and include multiple criteria optimization, multiple hypothesis testing using knowledge-based guidance, random set theory, conditional algebra, and relational event algebra.

4.2.2.5 State Estimation Methods at Level 1

State estimation seeks to combine parametric data from multiple sensors to obtain the most accurate estimate of an object's state and change of state. The state estimation is achieved through a combination of physical models (such as equations of motions or observational models) and statistical assumptions about the observation process to match the observed data to a state vector, a set of variables such as position and velocity that can be used to predict future states ("tracks"). The tracks are stored in a central track file for use in estimation of subsequent state values. For ATIS, the primary areas of interest for state estimation include vehicle tracking (velocity and position), situations affecting traffic flow (incidents, workzones, ramp metering performance, toll plaza/booth performance, etc.), overall roadway conditions (mainline and arterial levels of performance), and weather advisories. State estimation algorithms can be used at the level of the sensors and/or in software utilized at traffic management centers or other data collection and processing locations to make estimations.

Two broad categories of state estimation and tracking have been identified[5,6]. The first category is based on a search direction identified by the sensor (data) or object (target). The second category is based on techniques needed to associate and correlate data and state vectors.

- Direction tracking systems can be either sensor driven or object driven. In sensor-driven systems, state estimation data associated with an observed object (e.g., a vehicle) are used to initiate a search through a track database for other tracks that can be associated with the state estimation data according to some level of confidence. Object-driven systems works somewhat in reverse by first identifying a primary tracking sensor (based on the track) and then managing other sensors to acquire data or search databases that can be associated with the track. Sensor-

driven approaches are the most common ATIS data fusion method employed, since active sensor control may be difficult to achieve across institutional and operational jurisdictions.

- Association and Correlation of Measurement Data and Tracks. The association and correlation of measurement data (e.g., position, velocity, temperature, etc.) and tracks from multisensor inputs ultimately create central track files with some prescribed level of confidence. In an ATIS data fusion system, it is desirable for each track file to represent a unique physical object, which has significant implications for database management.

  To construct this set of state estimation track files, a number of specific processing steps are required: data alignment; prediction or threshold gates; association metrics; data and track association; position and kinematic estimation; and attribute estimation.

  - Additional data alignment may be required at Level 1 to make transformations through spatial and temporal reference adjustments and coordinate system to ensure a common space-time reference for state estimation. Errors introduced by measurement inaccuracies, adjustments for levels of precision during coordinate transformations, and object "noise" can be accounted for (to some degree) during data alignment.

  - Prediction or threshold gates are used to eliminate or gate certain types of associations based on known properties or estimates of the object. For example, rapid acceleration of vehicles during a sampling and observation period may not be possible and gating would eliminate such associative considerations. The magnitude of the gate reflects the calculated or expected object state errors associated with the algorithms used to make the calculation.

  - Data association metrics quantify the similarity of the observations. A variety of standard mathematical measures are available, including Euclidian and Mahalanobis, or variations of those.

  - Data association occurs by applying appropriate metrics to compare tracks and measurement data. The data and track association technique is dictated by the type and associated complexity of the tracking problem (such as vehicular speed and temperature changes) as categorized by single object–single sensor, single object–multiple sensor, and so on.

Some of the association techniques discussed in the object estimation discussion are applicable to state estimation, e.g., maximum likelihood estimation and Bayesian inference.

4.2.3 Summary of Level 1 Methods

The ATIS data fusion model is a non-trivial design challenge involving not only the selection of appropriate methods and algorithms, but careful attention and focus on the identification of the problem to be resolved through data fusion. The specification of the data requirements is but one component of this complex design process, which is discussed further in Section 5.

The techniques listed for Level 1 data fusion require a variety of data and information, all bound by the specific mission for which the data fusion model is being developed. Data fusion techniques, such as Bayesian inference or Dempster-Shafer require expert knowledge or information from the data fusion system designer to define (or have experts define) the appropriate a priori probabilities and likelihood functions, the probability masses, and desired confidence levels. Similarly, the use of fuzzy logic applications will require the designer to develop the appropriate membership functions and production rules based on a knowledge engineering and information extraction process. Other algorithms, such as classical inference, knowledge-based rule systems, and pattern recognition, also require the designer to assume probability density functions, rules, or other parameters for their operation. Implementation of these data fusion algorithms is thus dependent on the expertise and knowledge of the data fusion system designer, an understanding of the data fusion mission, a proper analysis of the overall operational situation, and the types of information provided by the sensor and other sources.

Figure 4-4 illustrates the relative qualitative merits of the Level 1 techniques.

	Relative Performance	Scalable	Computational Complexity (Time)	Maintenance	Cost to Implement
Parametric Based					
Classical Inference	Excellent	Excellent	Excellent	Excellent	Excellent
Bayesian Inference	Good	Poor	Good	Poor	Poor
Dempster-Shafer	Good	Poor	Good	Poor	Poor
GEP	Poor	Poor	Poor	Poor	Poor
Non-Parametric Based					
Parametric Templates	Poor	Good	Good	Poor	Poor
Neural Nets	Good	Good	Poor	Poor	Poor
Clustering	Good	Excellent	Good	Good	Good
Voting	Good	Excellent	Excellent	Good	Excellent
Figure of Merit	Good	Good	Good	Good	Good
Correlation Measures	Excellent	Excellent	Good	Good	Excellent
Pattern Recognition	Good	Poor	Poor	Poor	Poor
Cognitive Based					
Logical Templates	Poor	Good	Poor	Poor	Good
Knowledge-Based	Poor	Poor	Poor	Good	Poor
Fuzzy Set Techniques	Good	Good	Good	Good	Good

Figure 4-4 The Relative Merits of Level 1 Data Fusion Techniques

4.2.4 Level 2 (Situation Assessment) Processing and Techniques

The creation of the situation assessment (Level 2) is an iterative process of fusing spatial and temporal relationship among entities to group them together to form an abstracted and probable interpretation of objects associated with the travel context. Development of the situation assessment requires the production and maintenance of an appropriate, multi-level abstraction of a dynamic situation. At this point, the data fusion process could be compared to assembling a complex jigsaw puzzle for which no clear picture or only a partial picture of the completed scene exists. Level 1 analysis offers insights into vehicle identification, vehicle movements, special events or activities.

Key functions and techniques of Level 2 processing include the following[2]:

- Object aggregation involves the establishment of relationships among objects including temporal, location, and entity dependencies (functional, associative, precedent, mathematical). For example, vehicular density, average speeds, and vehicle types for a roadway segment could be the result of object aggregation. Techniques for this function include hierarchical classification methods, neural nets, nodal graphs, and spatial relationships.

- Event and activity aggregation involves the use of a priori reasoning to establish temporal relationships among entities in order to identify meaningful events or activities. For example, a collection of Level 1 environmental sensing station objects (surface and air temperatures, wind speed, wind direction, humidity) and state estimations (roadway surface temperatures and local wind patterns) can be used to define roadway segment environmental conditions.

  Techniques appropriate to event and activity aggregation come from the knowledge-reasoning field. Three classes of techniques are available: problem-solving paradigms (e.g., rules, procedures, genetic and neural algorithms, and statistically based algorithms), evidence combination strategies (e.g., Bayesian inferences, Dempster-Shafer, and fuzzy set theory), and decision-making approaches (e.g., rule instantiation and parametric algorithms).

- Contextual knowledge and interpretation involves analyzing objects and state estimations with respect to the context of the current situation assessment. For example, the presence of deciduous trees (image data) in the summer (based on date information) would allow for the deduction that the possibility of a deep snowfall in an associated roadway segment is highly unlikely. Contextual knowledge may be provided exogenously to the fusion model or be derived from other contextual non-sensor-driven data contained in supporting databases, such as terrain, historic traffic flow patterns (including seasonal and day-of-week variations), workzone locations, special events, and emergency situations.

4.2.5 Level 3 (Impact Assessment) Processing and Techniques

Level 3 assessment focuses on the possibility and probably outcomes associated with a specific event or action. As mentioned earlier, Level 3 can be considered a subset of Level 2 activities and functions. Level 3 functions are usually implemented as a specific prediction in a topical area (such as workzone traffic flow, intermodal operability/performance, network congestion) , drawing focused types of inferences from

Level 2 associations. The impact assessment outcomes may be characterized by such parameters as the impact likelihood or cost/utility measures associated with the potential outcomes of an inferred action or probable event. Techniques for Level 3 rely primarily on knowledge-based reasoning systems, mentioned in previous discussions.

4.2.6 Level 4 (Process Refinement) Processing and Techniques

Level 4 processing involves planning and control functions, not estimation. Activities include the monitoring and evaluating of the data fusion model and corrective processes to refine the algorithmic and estimation process, managing databases to ensure optimal system performance, and regulating the data acquisition to achieve optimum results, which may involve direct sensor control, data caching/batching, and selecting/de-selecting data sources. Specific functions include:

- Identifying changes or adjustments to processing functions within the data fusion domain that may result in improved performance (self-assessed or based on mission benchmarks)
- Determining and seeking specific data requirements (from specific sensors, reference data, etc.) needed to improve individual and combined level outcomes or estimates.
- Recommending allocation and direction of resources (sensors, CCTVs, variable message signs, etc.) to achieve overall mission and goals of the data fusion system
- Employing advanced database management techniques to provide monitoring, evaluation, updating, plus data processing functions such as merging, purging, retrieval, searches, substitutes, etc.
- Managing global processes, such as time and spatial synchronization across communication systems, sensor collection points, metadata compliance, and databases.

ATIS data fusion Level 4 activities currently only include the most basic database monitoring and communication check functions. Advanced sensors or smart sensors, allowing for centralized control of field equipment, have only been tested experimentally.

4.3 Data Fusion Architectures

Architecture refers to a structure of components, their relationships, and the principles and guidelines governing their design, implementation, and evolution over time. Data fusion architecture involves four fundamental components and their interrelationships: the data sources, the data fusion algorithms and database techniques, the communication networks, and the HCI interface.

As expected, the specific configuration of the data fusion architecture is a complex design process involving tradeoffs among all of these components in a cost effective manner that meets the ATIS system goals for function and performance. Because of the wide variety of ATIS fusion applications and applicable architectural components, it is not possible to provide a prescriptive, detailed definition of which architectural components and fusion techniques are best. Consequently, this discussion provides suggested guidelines for the four fundamental components of the data fusion architecture.

4.3.1 Architecture Implications -- Data Sources

Data sources may come in a variety of formats through various communication channels. Three basic architectural alternatives can be used to capture multi-sensor data sources: direct fusion processing of sensor data; representation of sensor data using feature information, with subsequent centralized processing of feature vectors/arrays; and processing of each sensor to achieve a high-level of inference/decision about an object[4].

The first configuration involves a direct fusion of data at the sensor level. This would occur when the sensor is able to perform a substantial number of the basic fusion functions, e.g., data alignment, object association, and others. Moreover, if the same set of sensors are measuring the same physical phenomena, then the sensor data can usually be combined directly. This might be the case with a series of loop detectors for a roadway segment[g]. Techniques for raw data fusion typically involve classic estimation methods such as least-squares and Kalman filtering. If the sensor data are not the same or incommensurate, then the data should be fused using feature information or at the inference-decision level.

The second configuration uses feature-level fusion. Features are an extraction of a representative feature from the sensor data, such as a set of regression coefficients or

[g] Recent examinations of loop sensors in roadway segments indicate the potential for co-linearity and hence complications in applying certain data fusion algorithms.

Fourier transform coefficients. Features are extracted from the multi-sensor observations and combined into a representative feature vector that is typically offered to a pattern recognition technique, such as clustering algorithms or template methods. Examples of this approach include the used of CCTV and acoustic sensors to identify and estimate vehicular flow data in a critical highway segment.

The third configuration combines sensor information after each sensor has made a preliminary determination of an object's identification and location. Techniques for decision-level fusion include voting techniques and parametric inference methods. More advanced CCTV devices, especially color cameras, are offering object and location referencing based on this type of architecture. Similarly, GPS-enabled cellular phones use this approach to provide precise location information (within 3-10 feet) based on the caller's device.

There is no clear-cut preference for a data source architectural alternative. In fact, most data fusion architectures will be a hybrid of one or more of these configurations. For example, a combination of CCTV and supporting image detection sensors may best be configured for a feature-level design intended to support parking management. Specific design features would need to address such issues as cameras resolution, refresh rates, and aperture field.

4.3.2 Architecture Implications -- Data Fusion Algorithms and Database Techniques

The relative merits of various data fusion techniques for the multi-level data fusion model were discussed in previous portions of this section and summarized in Figure 4-4. When viewed from an architectural perspective, the numerical and heuristic techniques used to perform data fusion will vary widely depending on the environment in which they are embedded along with the available functions and source data. As noted, the algorithms involve substantial computations to make association, correlations, estimations, and classifications of objects. To make these calculations and estimations, the data fusion algorithms perform operations on or with model parameters, sensed data, external database information, performance data, and a priori data according to a specific technique such as Bayesian inference or knowledge-based systems. These operations almost always require the use of databases for data input, storage, retrieval, archiving, and other functions. Consequently, database management is a key consideration in the overall data fusion system architecture and performance.

Most databases available for data fusion are either relational databases or object-oriented database (OOD). Relational databases are relatively efficient in well-defined basic

functions such as estimation, sorting, storing interim calculations, or assembling track files. Hence data-centric ATIS services are more likely to be implemented using relational database architectures if judged primarily by cost effectiveness and processing performance criteria. More complicated fusion functions, such as association and classification, may require computations better suited to object-based data structures since the data fusion algorithms will need to explore complex relationships among many types of data objects. Relational databases are not as effective in multi-dimensional analysis as OOD. Model-centric ATIS services would likely be implemented on an OOD configuration if processing flexibility and sophisticated fusion objectives were the primary criteria. Hybrid database products that combine the best features of relational databases and OOD concepts are also emerging, but are usually selected for narrow, application-specific needs and supported by highly skilled staff.

Another database design consideration affecting data fusion system performance is the extent of centralized versus distributed databases. Almost all ATIS data fusion architectures will be migrating into distributed database configurations for three reasons. First, a single agency or organization does not possess all of the data required to support ATIS users' needs. Second, distributed databases allow for distributed computing, more effective resource sharing, cost effective specialization, and in some cases, system redundancy. Third, the communication network connectivity and performance (speed, accuracy, security) and associated costs are favorable in relationship to the benefits derived from a distributed architecture.

Solutions to address distributed computing have spawned the basis for client/server and n-tiered architectures in which middleware provided connectivity and interface management. Enterprise-focused database practices have resulted in the development of the data warehouse concept in which all corporate/agency data resides and is accessed by a number of software applications. Data marts are subsets of the larger data warehouse and are usually created to summarize or extract information needed for a specific purpose. Data fusion operations may involve parallel interactions with multiple data marts to allow for more rapid access and processing speeds associated with fusion-specific algorithms.

As the distributed architectures and client-server configurations increased, especially across the world wide web-based networking infrastructure based on TCP/IP, data management problems have increased. For example, distributed database management for data fusion may require connectivity among distributed homogenous databases as well as distributed heterogeneous databases. Consequently, middleware techniques have expanded to include object-oriented semantics to address the interfacing issues, such as interface standards (and backward compatibility), access privileges, metadata uses, and

data quality. A wide range of techniques has emerged to address the interface issues, sometimes referred to as tightly coupled or loosely coupled. Industry groups and standards organizations have worked to develop comprehensive solutions (tightly coupled) in which interface component are well defined, hierarchically organized, and application software developed according to these specifications. Other groups have only defined the desirable structure and requirements for selected interface components[h]. While there are a variety of methods for managing distributed databases[i], two common means of handling distributed database computing for ATIS are Common Object Request Broker Architecture (CORBA) and a Distributed Common Object Model (DCOM). Both CORBA and DCOM achieve language independence by defining object interfaces in a language-independent manner[j]. Hence data fusion algorithms can use distributed objects transparently, although with higher processing overhead due to the translation and exchange requirements. Single-vendor servers, integrated with back-end databases, have helped to improve the efficiency and timeliness of OOD, however these improvements come at the expense of multi-vendor interoperability and interchangeability. The key design tradeoff for data fusion database configurations focus on the relative processing speed of the object interface and the alternative communication network protocols for exchanging the data packets.

CORBA and DCOM are examples of object-oriented techniques applied primarily to the field of distributed database management. In an analogous fashion, Document Object Model (DOM) is applied to the area of dynamically accessing and updating the content, structure, and style of web-based documents rather than databases. DOM is being developed by the W3C group with the desire to have a platform and language-neutral interface for document access and updates. Employing object-oriented techniques, DOM utilizes a multi-level model for i) navigating and manipulating documents, ii) defining style sheet models and methods to manipulate the style sheet, and iii) document loading, updating, and saving. Commercial software is emerging to support DOM applications[k].

4.3.3 Architecture Implications -- Communication Networks

As mentioned earlier, the NTCIP is the preferred communication architecture for ITS applications. Three types of communication are required for data fusion: file transfers,

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[h] Simple Object Access Protocol (SOAP) is an example of an interface component; in this case an access definition. See www.w3c.org/TR/SOAP.

[i] These include object-oriented methods utilizing language-neutral techniques, such as Java(RMI) or C/C++ (RPC). DOM has the potential for evolving into a key component of distributed database management combined with web-based representation needs.

[j] These features have resulting in a large installation base, with support personnel and resources, relative to other distributed database management practices.

[k] See for example www.oasis-open.org/cover/dom.html.

C2F, and C2C. ATIS data fusion architecture is most affected at the NTCIP information and application layers because these represent the newer components in the overall communication architecture. The lower layers (transport, sub-network, and plant) employ widely accepted and field tested industry standards, exhibiting well-known performance and insights into network design tradeoffs. The ultimate performance of the full communication network will depend on a complete definition and assembly of all components, allowing for an assessment of the system performance using such key criteria as speed, accuracy, security, availability, flexibility/scalability, standards conformance, standards maintenance, and cost to implement and maintain. Simulation tools such as OPNET are typically employed to evaluate the various communication network design options and performance tradeoffs.

The first set of NTCIP applications layer protocols pertain to file transfers, which are handled through well-established and readily-available protocols such as File Transfer Protocol (FTP) or Trivial File Transfer Protocols (TFTP). The design choice is determined by the desire for a connection or connectionless type of transport layer. Connection-oriented communication provides greater guarantees and transmission checking than connectionless-oriented configurations. The choice is dependent on the criticality of the ATIS information being exchanged, speed, and cost.

The second set of NTCIP application layer protocols pertain to C2F communications, which typically involve communication between a traffic or transit management center and field equipment. NTCIP allows for relatively straightforward communication protocols for exchanging data objects. These may be done with well-established protocols such as SNMP, which is suitable for traffic demands with high bandwidth and low volumes of messages, e.g., certain types of high-resolution CCTVs images with low polling frequency. Cellular phone systems and certain OOD systems employ SNMP as a means of managing data packet transmission and monitoring/managing selected network functions. STMP, developed by the NTCIP, reduces packet overhead with more efficient data encoding rules[1] and is most suitable for low bandwidth and high volumes of messages, e.g., traffic signal systems. STMP is restricted however to 13 message sets, but more are under development.

The third set of NTCIP application layer protocols pertain to C2C data exchange, which is managed through DATEX-ASN.1 or CORBA. DATEX-ASN.1 employs a relatively simple procedure for exchanging data and is a cost effective solution for low bandwidth, small system needs. DATEX-ASN.1 is not however an object-oriented protocol.

[1] STMP utilizes Octet Encoding Rules (OER), a means of encoding data more efficiently than 8-bit based systems.

CORBA is able to exchange data, including objects, as well as activate methods embedded in remote objects, i.e., initiate remote processing. CORBA provides a full range of features for data exchange (both data and objects) but requires increased message overhead, resulting in higher implementation resources, including technical skill levels and maintenance costs. Consequently, CORBA is selected when a management center needs high communications bandwidth, the message volumes are relatively high, and the data and data processing methods are essential or mission-critical to the center's operation.

4.3.4 Architecture Implications -- Human-Computer Interface

The HCI is an important data fusion architectural component. The most obvious HCI design considerations are with the ATIS user. The technologies and human factors features of HCI devices for ATIS applications have come from insights gained in other fields, namely industries such as PDA retailers, the wireline and wireless telephone industries, computer retailers, vehicle manufacturers promoting telematics, pattern recognition retailers, and the commercial mass media, which helps to shape content and distribution methods. ATIS user preferences and their implications for HCI interface design are still an evolving area. For example, the level of consumer acceptance of interactive voice recognition (IVR) techniques, used in the travel, banking, and the telecommunications service industries, is still an ongoing debate. Recent cellular phone products and 511 deployments have started to promote IVR as an improved, safer method of operating devices and communicating.

Other architectural aspects of the HCI involve the actual human interface with function points in the data fusion model. These involve standard computer-based interfaces which allow for system control and data update. Certain data fusion algorithms are not completely autonomous and therefore may require human judgments at certain points in their calculations and analysis. Consequently, the HCI must provide alerts and opportunities for operators to supply answers to interim estimations or inferences, propose hypothesis or tests through, for example, SQL inputs, and make annotations on the data fusion system performance.

4.4 Data Quality Management And Assessment

Data quality for ATIS data fusion is a multidimensional issue. Just as a vehicle has many quality dimensions associated with it, a data element or information product also has quality dimensions. This concept is important in developing methods to assess and improve ATIS data quality, since different levels of importance and different organizations/owners place potentially wide-ranging values on the dimensions of data quality. For example, some organizations or data contributors may be data-centric while others are model-centric. A public agency may be very satisfied with their level of data quality to estimate mean speeds. A third-party ISP may need greater resolution in sensor data in order to meet their business objectives, but may not be able to achieve it from a public agency. These differences may lead to a partnership for enhancing input data quality. However, to be successful in achieving effective data quality management, attention to all the quality dimensions is required by all data owners and users.

In general, data quality can be defined as fitness for use by information consumers[m]. The degree of fitness pertains to five main quality dimensions illustrated below in Figure 4-5. The techniques or perspectives listed on the right-hand side of the figure are defined as follows:

- Systems Planning view – Separate data classifications or classes from one another in order to support strategic, tactical, and operational assessments. Strategic and tactical views focus on the role that data has in the overall system purpose and types of decisions or information to be produced. Operational views examine the transactional data needed to carry out the routine activities of the fusion model.
- Function view – This is the most common type of perspective and represents the functions to be performed with the data, e.g., association, correlation, estimation, and classification.
- Applications System view –A focus on the entity-relationships among applications and interfaces within the context of an enterprise data model.
- Process view – A perspective that indicates how the data is consumed or transformed throughout a multi-stage, multi-level process. The process model is typically used to validate the objects and object transformations in a data model, and thus assess data quality.

[m] A variety of agencies and organizations have promulgated data quality standards and associated metrics. See for example: "http://www.thecre.com/quality/agency-database.html" (Federal Agency Data Quality Guidelines), "http://dqo.pnl.gov/software.htm" (U.S. Department of Energy and EPA) , and http://www.ombwatch.org/article/articleview/1177/ (OMB Oversight Role of Agency Data Quality Guidelines).

- Time-Dependent view – A high-level perspective of the current (As Is) and future (To Be) state of data quality, with defined improvements in data definition, architecture, applications, business processes, policies, and objectives to achieve improved data quality as characterized by the future state.

Data Quality Category	Data Quality Dimensions	Techniques or Perspectives For Assessing
Intrinsic value/quality	Accuracy, objectivity, believability, reputation	Systems Planning view Functional view
Contextual or domain quality	Relevancy, value-added, timeliness, completeness, amount of information	Application systems view Process view Time-Dependent view
Representation or presentation quality	Interpretability, ease of understanding, concise representation, consistency, ease of manipulation	Functional view
Data Models	Accuracy, granularity, comprehensiveness, robustness, consistency	Functional view Applications systems view
Information Policy	Accessibility, access security, ownership, metadata, redundancy, cost	Systems Planning view

Figure 4-5 Data Quality Categories, Dimensions, And Techniques for Assessing

Many data quality improvement techniques or programs focus on the first or second dimension, the intrinsic value/quality or domain value. Typically techniques focus on the functional view or process view to find and fix the data errors. Findings errors associated with intrinsic or domain values can be done a number of ways, but almost all generally involve identification and correction. Identification is done by locating missing data, inconsistent data or outliers, duplicates, or traceable error due to erroneous conclusions or reasoning, e.g., Type 1 or Type 2 errors. Correction of erroneous data values may be done through many techniques, but they tend to employ domain-dependent methods that use keyword or domain relevance substitution, merge/purge, or data combination/reduction[8]. These "find and fix" techniques are used when there is a high understanding of the context in which the data is to be used, the objective and subjective[n] ranges and constraints under which the data is observed and assessed. The more systematic approaches employ some form of root-cause analysis or similar trace-back

[n] Fuzzy set techniques have been used, for example, to assist with data cleansing

methods to isolate the point of dysfunction in maintaining a data quality threshold. These methods are usually time consuming, but can be aided by the use of structured programming methods, such as UML, to develop process and function checkpoints and range verification methods. Intelligent agents, coded to search for specific events or data ranges, represent another means of dynamically screening for potentially poor data quality throughout the data fusion architecture, especially data sources.

A variety of techniques exist to confirm data model quality. Approaches are usually drawn from the software development field, in particular the verification and validation techniques[9]. More than 45 different techniques are available to verify and validate models, employing such techniques as boundary value analysis, event tree analysis, critical timing/flow analysis, sensitivity analyses, fault tree analysis, debugging tools, and others. Requirements for model verification are usually part of an agency's overall information policies and procedures.

The final perspective listed in Figure 4-5 on data quality is based on an agency's or owner's information policies and practices. Some organizations do not have widespread, codified policies or procedures, only isolated references to the general use of data, acknowledgement requirements, and accessibility or security. For more progressive organizations, a minimum threshold of data quality acceptance is usually defined. This threshold has been established based on the perceived or actual business consequence of falling below the threshold, e.g., missed deadlines, legal liability, cost to operations, or unbearable customer criticism leading to the likely loss of clientele or support. The elements of the data policy and procedures are usually based on the data quality dimensions listed in Figure 4-5 and the previously mentioned evaluation and correction techniques preferred by an agency or organization. Ultimately these procedures are encapsulated in some form of continuous improvement process (CIP), such as basic TQM practices, ISO-based processes, or Software Engineering Institute (SEI) certification using the Capability Maturity Model (CMM) construct.

Ultimately, increased attention on data quality will occur after consumers and managers recognize the importance and transactional value of data quality. The availability of proven methods to correct near-term data elements and to implement long-term organizational processes and policies are not the constraints.

4.5 Section 4 References

[1] Steinberg, A.N., Bowman, C.L., and White, Jr., E.E., "Revision to the JDL Fusion Model", Proceedings of the 3rd NATO/IRIS Conference, Quebec City, Canada, 1998.

2 Hall, D. and Llinas, J., *Handbook of Multi-Sensor Data Fusion*, CRC Press, 2001.
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4 Hall, D., *Mathematical Techniques In Multisensor Data Fusion*, Norwood, MA, Artech House, 1992.
5 Klein, L., *Sensor Technologies And Data Requirements For ITS*, Boston, MA, Artech House, 2001.
6 Klein, L. and Yi, P., et. al., "Decision Support System For Advanced Traffic Management Through Data Fusion and Mining", Transportation Research Board, 81st Annual Meeting, Washington, D.C., 2002.
7 Duda, R., Hart, P., and Stork, D., *Pattern Classification*, John Wiley and Sons, New York, 2001.
8 Pyle, D., *Data Preparation for Data Mining*, Morgan Kaufman, New York, 1999.
9 Schulmeyer, C., and MacKenzie, G., *Verification and Validation of Modern Software-Intensive Systems*, Prentice Hall, 2001.

Section 5 Implementing Data Fusion for ATIS

Traveler information services are the result of a multi-stage process of data collection, fusion, value-added information, and distribution, as presented in Section 1. Consequently, the data fusion component must be developed in conjunction with and in the context of these other components in order to be effective. This development process is usually accomplished through the use of a structured, systems development process, which involves a wide range of experts and carefully sequenced process steps[a].

5.1 Development Of ATIS Data Fusion Systems

ATIS data fusion systems need to be developed in conjunction with other ITS systems. Consequently, the general process for developing any ITS system is appropriate, especially those in a regional context where ATIS is most likely to be applied. The general process of developing an ITS regional architecture has been documented in a recent USDOT report[1]. The three major steps of the process are described in Figure 5.1. The development of the final ATIS data fusion system will be based on an iterative approach in which candidate concepts and tradeoffs will be made among the various ITS system goals, resources, and interested groups.

It is desirable to have the need for ATIS services emerge as part of the first step, since this avoids retrofit or substantial redesign at a later point an overall ITS development process. Moreover, it will be important to have ATIS representatives engaged in the entire development process, since decisions on such issues as ITS architecture, communications protocols, database formats, data sharing, and HCI can all significantly affect an ATIS system performance, especially the data fusion architecture. The outcomes of such a structured development approach provide the context for defining the specific architecture, algorithms, and subsystem elements for an ATIS data fusion model.

[a] ISO 9001 and 14100 describe some of the basic quality control processes needed in the development of systems, especially manufacturing systems. Similarly, the software industry, through the Software Engineering Institute (SEI), has defined levels of performance associated with the software system development process.

Phase 1 (Scoping and Needs)	Phase 2 (Design and Build)	Phase 3 (Operate and Maintain)
▪ Identifying the overall needs and purpose ▪ Defining the coverage/region ▪ Identifying the desired outcomes from the ITS subsystems ▪ Describing a Concept of Operations ▪ Identifying and engaging Interested Parties or Groups	General planning and design of the system, detailing activities such as: ▪ Collecting the appropriate data ▪ Defining interfaces ▪ Developing multi-layer process maps and functional requirements ▪ Establishing a systems architecture ▪ Defining algorithms and activities to enable the processes ▪ Assembling the components into a system for evaluation	▪ Calibrating the system to verify system performance against specifications ▪ Modifying the relevant systems components until acceptable performance is achieved ▪ Fielding the system ▪ Maintaining and monitoring the performance of the system ▪ Providing enhancements according to the system life-cycle plan and operational experience

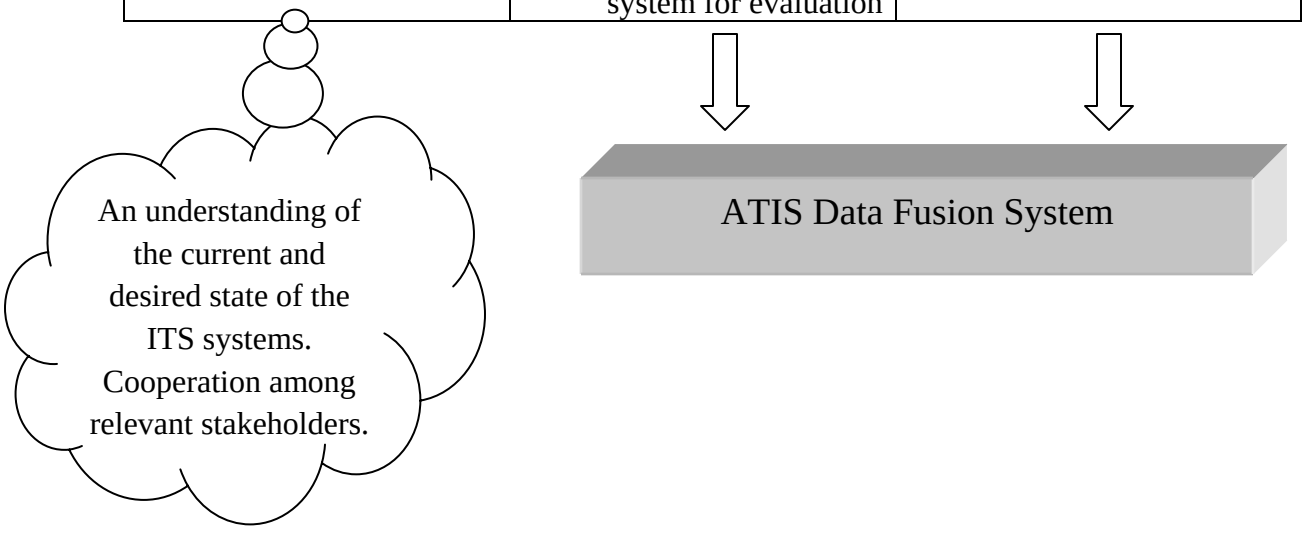

Figure 5-1 Major Process Steps For Developing An ATIS Data Fusion System[b]

[b] Adopted from Reference 1.

Once an ATIS data fusion system has been defined in the context of an overall ITS system, key individuals for the ATIS data fusion system need to be engaged early and continuously. These include[2]:

- Planners and implementers of the regional architecture who have an overarching appreciation of the regional ITS capabilities and needs, especially in the ATIS area
- ATIS users whose concerns include systems requirements, performance, constraints, and operational preferences
- Numerical/statistical specialists who are knowledgeable about the range of algorithms discussed in Section 4 and who are experienced in algorithm design and implementation
- Operators and analysts concerned with the HCI, transaction analysis, and operational concept definitions of the data fusion model
- Systems engineers who can assist with designing and assessing system performance, interoperability with other ITS subsystems, and system integrity
- Owners and implementers of the system who can address the systemic issues of cost, schedule, quality, and institutional relations.

The result of this group's deliberations on design features will likely yield a combination of automated and manual process steps for the data fusion architecture. These design decisions will be tempered by the availability of data, inter-jurisdictional issues, available resources, desired outcomes, and the state of the practice. Moreover, an ATIS system (and the data fusion system) may be implemented in stages, with the data fusion process restricted to well-known methods of data sensing and alignment (Level 0) and incorporation of selected features, such as freeway speeds and web-based displays to support (non-automated) route guidance decisions (Level 1). As data fusion systems become more sophisticated and the need for greater services arises, some of the techniques discussed in Section 4 can be introduced with minimal reconfiguration of the overarching architecture.

5.2 Data Fusion Algorithm Selection

There is no well-known "textbook" approach to data fusion development other than the generalized functional model presented in Section 4. Consequently, the selection of the appropriate estimation or prediction algorithms used in the data model will be an iterative process of matching desired outcomes with, and the subsequent integration of, the algorithm into an ATIS data fusion system. However, there are some key development steps that can help ensure a greater chance of success, as illustrated below in Figure 5-2.

Although the steps are indicated as a somewhat sequential process, substantial iteration is required. Moreover, data mining techniques can lend insights into data patterns and guide the selection of subsequent algorithms[c].

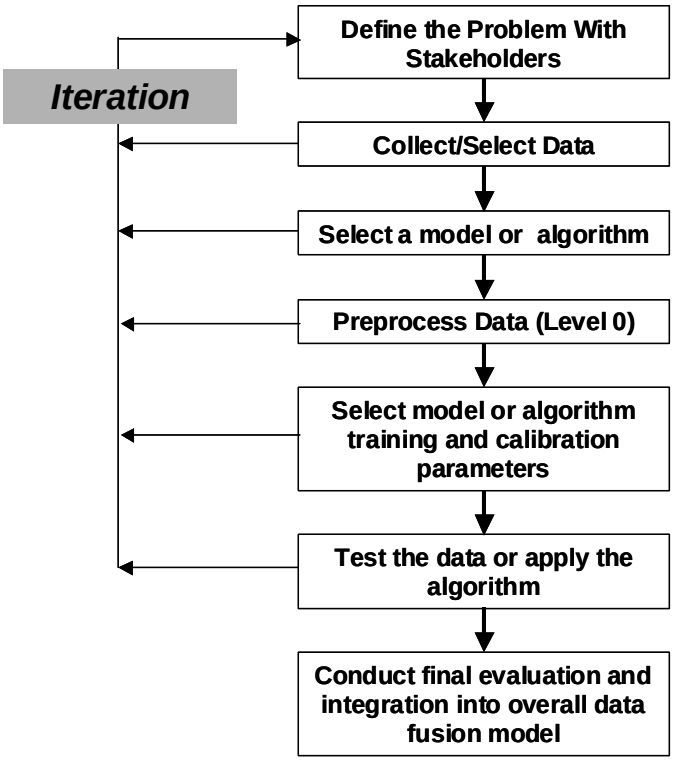

Figure 5-2 A Systematic Approach for Selection and Testing of A Data Fusion Algorithms[3]

Repeated application of the steps in Figure 5-2 for each of the major ATIS data fusion functions would be needed to develop the suite of fusion algorithms. This suite of algorithms would need to interface with the appropriate data sources (quality and availability) as well as yield results in a format for end-user consumption or for an intermediate value-added provider. Additional activities will include alignment of the database management subsystems, HCI, and constraints or requirements inherited from the overarching ITS architecture. These options would then be assessed against criteria established during the ATIS needs assessment process, as part of the first step in the ITS development architecture activity. Iteration and modification of the ATIS design elements would be needed to develop a configuration that conforms to the overall ITS architecture and meets the specific ATIS requirements. It is likely that substantial

[c] For example, see the Freeway Performance Measurement Project (PEMS) at http://pems.eecs.berkeley.edu/login.phtml. The intent of this project is to collect historical and real-time freeway data from freeways in the State of California in order to compute freeway performance measures.

simulation of the ATIS data fusion model would be needed to gather data fusion performance data and to conduct subsequent trade studies.

Once the ATIS data fusion model has been defined and tested, it is ready for integration into the overarching ITS architecture. At this point, testing and evaluation of the total ITS would be required to ensure the subsystems performed as expected and met the specifications and requirements. Once activated, monitoring and maintenance procedures would be followed to assess the performance of the ATIS model and provide insights and opportunities for further refinement and enhancements.

5.3 Section 5 References

[1] *Regional ITS Architecture Development Process Workshop*, USDOT Architecture Development Team, October 2002.

[2] Hall, D., *Mathematical Technique in Multisensor Data Fusion*, Artech, Boston, 1992.

[3] Chen, Z., *Data Mining and Uncertain Reasoning*, Wiley, New York, 2001.

Section 6 Areas For Future Study and Activities

6.1 Study Summary and Conclusions

Data fusion is a key element in advancing the state of the practice in ATIS information services. Major findings summarized in this report include:

- A general awareness of ATIS data fusion and its purpose exists.
- The general public, and travelers in particular, are predisposed to use better travel information, although it is unclear under what business model and range of products and services.
- Data fusion conducted at transportation and environmental public agencies involves basic fusion functions such as spatial or temporal alignment of input data. Assessments of ATIS services at selected MMDI and FOT indicate positive support and public benefits.
- Third-party ISPs perform additional data fusion activities, but the specific data fusion techniques, accuracy, and usefulness are not readily discernable due to proprietary restrictions.
- Two general perspectives exist for ATIS data fusion: a data-centric view and a model-centric view. These perspectives are not mutually exclusive.
- Agencies are migrating to the use of the NTCIP and associated data element and message set standards, but will likely initiate their use based on industry acceptance and agency confidence in their utility and longevity.
- Data quality policies and procedures are not comprehensive. Practices are limited primarily to "find and fix" tactics on the more egregious data elements.

These findings point out the need for a more comprehensive ATIS data fusion development methodology that would allow for increased cross-disciplinary communication and research sharing. A proposed ATIS data fusion model, based on the JDL process model, was offered to help bridge this gap. Moreover, specific data fusion techniques, appropriate for the ATIS context, were identified and qualitatively assessed using multiple criteria regarding ease of implementation and potential usefulness.

Suggested guidelines for data fusion architectures were presented and qualitative performance metrics were offered. The wide variety and combination of ATIS fusion applications and associated architectural components do not allow for a prescriptive, detailed definition of architectural components and data fusion techniques. This

prescription is best handled through a more structured, system engineering process involving all stakeholders and design experts.

Input data quality continues to be a hindrance to the offering of more advanced ATIS services. Current practices focus on "fix and find" methods without long-term, multi-dimensional, and systemic attention to data quality issues. One of the key issues is the different perspectives held by stakeholders on the level of satisfaction with the existing data quality and the associated remedies and costs to make improvements. Greater awareness and understanding of the issues are needed before prescribing remedial action, if any. Resolution of data quality issues will require partnerships among the data owners and users to reach a shared solution based on need and transactional value.

6.2 Future Opportunities and Activities

Three areas for further research and study are offered.

6.2.1 Technological

- Test ATIS-specific data fusion algorithms at university/research facilities and share the results.
- Confirm the more promising context-based algorithms (such as knowledge-based reasoning systems), associated data needs, stability, cost to implement/maintain, and reasonable methods to acquire model parameters.
- Evaluate Level 2 and Level 3 algorithms for a specific region since future ATIS users may have the greatest interest in this fused information.
- Establish a generalized DBMS capability for text, signal data, images, and symbolic information with scalability and object-oriented/component-oriented features.
- Perform additional research into fusion capability of images and non-image data.
- Conduct detailed system-level analysis and performance assessment using the proposed ATIS data fusion model at an operating site.

6.2.2 Institutional

- Completion of relevant metadata standards for ATIS (and associated) message sets.
- Management of expectations regarding data fusion benefits through additional field evaluations.
- Raise awareness and quantify the consequences of ATIS data quality issues through such techniques as root-cause or trace analysis.

- Expand participation and exchange of interest and needs by the ATIS community in the general data fusion and data mining communities.

6.2.3 Economic

- Develop examples of viable ATIS business model for private and public sectors containing quantitative and qualitative performance metrics.
- Confirm and prioritize the fused ATIS information valued by users, adjusted for regional contexts.

Appendices

The annotated bibliography is organized into four appendices:

- General ATIS References
- Data Fusion
- Data Quality
- MMDI and Field Tests Evaluation

A typical entry contains a short annotated description of the article or publication. Listings in each subsection have been sorted alphabetically. Occasionally, a document will be listed in two or more places since multiple topics were sufficiently examined to warrant a multiple listing.

General ATIS References

Abernethy, B. (Feb/Mar 2001). Road to Nowhere: The Ongoing Standards Saga. Traffic Technology International.

Article. The ITS industry faces being burdened by standard that are often untested and unwanted. ITS standards development process has serious shortcomings. The author recommends to return the standards process to that which proved successful 'pre-ITS'.

Albright, N. (1/25/01). 511 Case Studies in Kentucky.

Focuses on the Commonwealth of Kentucky and its implementation of statewide 511 services. Provides a concise, current "snapshot" of the progress being made. Includes sections on history/perspective; institutional background; plans/visions; ongoing activities; and lessons learned.

Allied Business Intelligence (4/25/01). Despite Slow Start, Satellite Digital Radio Industry Will Flourish, According to New Digital Car Study from ABI. Oyster Bay, NY.

news. Satellite-based digital audio radio services (SDARS) broadcasters, XM Satellite Radio and Sirius Satellite radio, will ultimately benefit from increased consumer uptake an large recurring service revenues. By 2006, recurring annual service revenues for SDARS will reach $350 million, according to the findings in "The Digital Car: A Strategic View of Global In-Vehicle Communications Technologies and Next-Generation Telematics Systems," a new study from Allied Business Intelligence (ABI).

Allied Business Intelligence Inc. (12/12/00). Wireless Internet to Drive Voice Recognition, According to New Allied Business Intelligence Study.

Discusses the pace of growth in the satellite navigation industry, particularly GPS, the first and only system that is fully operational with existing users. The US GPS system addresses a plethora of industries including agriculture, aviation, communications, in-vehicle, marine, recreation, science, surveying/mapping, and timing.

Almeroth, K., et al. (Jul/Aug 1999). An Alternative Paradigm for Scalable On-Demand Applications: Evaluating and Deploying the Interactive Multimedia Jukebox. IEEE Transactions on Knowledge and Data Engineering, Vol. 11, No. 4**:** 658-672.

Straightforward, one-way delivery of audio/video through television sets has existed for many decades. In the 1980s, new services like pay-per-view and video-on-demand were touted as the "killer applications" for interactive TV.

However, the hype quickly died away, leaving only hard technical problems and costly systems. As an alternative, we propose a new jukebox paradigm offering flexibility in how programs are requested and scheduled for playout. The jukebox-scheduling paradigm offers flexibility ranging from complete viewer control (true video-on-demand), to complete service provider control (traditional broadcast TV). In this paper, we first describe out proposed jukebox paradigm and relate it to other on-demand paradigms. We also describe several critical research issues, including the one-to-many delivery of content, program scheduling policies, server location, and the provision of advanced services like VCR-style interactivity and advanced reservations. In addition, we present our implementation of a jukebox-based service called the Interactive Multimedia Jukebox (IMJ). The IMJ provides scheduling via the World Wide Web (WWW) and content delivery via the Multicast Backbone (MBone). For the IMJ, we present usage statistics collected during the past couple of years. Furthermore, using this data and a simulation environment, we show that jukebox systems have the potential to scale to very large numbers of viewers.

Anderson, S. M. I. (3/5/01). 32-bit Power Drives the Intelligent Car. Austin, TX.

(news) 32-bit microcontrollers are on the fast track to winning many applications within the smart vehicle. Last year, according to Strategy Analytics Inc. (London), 32-bit processors powered 10 percent of the vehicle. By 2005, 32-bit solutions are expected to take over 25 percent of the processing power in the vehicle.

ANSI and USDOT (1999). ANSI TS 286: Commercial Vehicle Credentials.

His standard was developed and is maintained by Accredited Standards Committee (ASC) X-12, Electronic Data Interchange (EDI) of the American National Standards Institute (ANSI). The standard contains the format and established the data contents of the Commercial Vehicle Credential Transaction Set (TS 286) for use within the context of an EDI environment. Operating a commercial vehicle in the US requires many credentials. Vehicles must be titled and registered. Carriers must have adequate liability insurance and must be authorized to carry certain types of cargo. Special permits are required to operate vehicles that are over the legal weight of size. Drivers must be licensed to drive whatever size vehicles they intend to operate, and must meet medical standards. Carriers must pay fuel taxes for operating vehicles in each jurisdiction. Some states have additional credential in requirements. This bi-directional transaction set can also be used by authorizing jurisdictions to transmit electronically credential data to applicants and other authorized entities.

ARC Group (4/12/01). In-Car Telematics Fitted in 56 Million Vehicles by 2005.

According to a recent study by ARC Group, the automotive telematics market is expected to undergo an average growth rate approaching 90% a year over the next five years, bringing the total number of cars fitted with telematics systems to 56 worldwide by 2005 compared with just over one million today.

ATX Technologies Inc. Emergency Services.

(news) ATX provides emergency services including: automatic collision notification; emergency response; basic roadside assistance; enhanced roadside assistance; remote door unlock; locator service; stolen vehicle tracking; and security system notification.

ATX Technologies Inc. Information Services.

(news) ATX Technology Inc., provides information services including: messaging services, vehicle operation information; and information services (weather, financial and sports for location-enhanced information).

ATX Technologies Inc. Motorist Demand for Telematics: Increased Mobility Increases Demand for Telematics.

(news) The growing demand for telematics, or location-based emergency, navigation and information services has market analysts forecasting a subscriber base of 1 million by 2004.

ATX Technologies Inc. Navigation Services.

(news) ATX Technologies Inc., provides navigation services including: emergency navigation; connected navigation; traffic information; and dynamic road guidance.

ATX Technologies Inc. (2/21/01). ATX Technologies Company Information.

Provider of vehicle and wireless device applications (emergency services, navigation services, information services) and resource operations (response center technology, skilled response specialists, and working with police/911)

ATX Technologies Inc. (3/15/01). ATX Technologies Business Growth to Result in Call Center Expansion.

To meet the demands of a rapidly developing market for telematics, ATX announced plans to open a second voice and data interaction center in the central or southeastern US.

Baca, M. e. (1998). Metadata: Pathways to Digital Information, Getty Information Institute**:** i-iv, 1-41.

A collection of essays on metadata* (*treated as plural), particularly for the World Wide Web. Gilliland-Swetland presents an overview, outlining types, functions, attributes, and characteristics of metadata, with examples from the "real world." Her essay demonstrates the importance and role of metadata in the current information universe. Gill's essay focuses on metadata in the context of the World Wide Web, and examines three important emerging Web metadata standards. Cromwell-Kessler discusses the importance of mapping different metadata standards to facilitate interoperability, and identifies some f the concomitant issues, benefits, and necessary future steps.

Barry, C. and M. Lang (Apr/Jun 2001). A Survey of Multimedia and Web Development Techniques and Methodology Usage. IEEE, National University of Ireland, Galway, Ireland**:** 52-60.

The survey results suggest that no uniform approach exists to multimedia systems development and that practitioners aren't using the multimedia models cited in the literature. Developers need new techniques that capture requirements and integrate them within a systems development framework.

Belo Interactive, I. (4/4/01). Belo Interactive Announces Launch of 'My Traffic': Powered by Strategy.com, My Traffic Keeps Consumers Informed of the Traffic Conditions That Affect Them. Dallas and Vienna, VA.

PRNEWS. Belo Interactive, Belo's Internet subsidiary, and Strategy.com™ Incorporated, a provider of one-to-one messaging through Web, wireless and voice, announced the launch of My Traffic on March 30, 2001. My Traffic is a personalized service that provides traffic conditions for personally selected routes to the desktop, email, or to wireless devices. In addition, My Traffic immediately alerts subscribers via the Web, email or wireless devices of problematic traffic conditions and offers information on alternative routes.

BeVocal (1/17/01). BeVocal Company Information.

Created voice portal applications that can be based on a caller's location, delivered to any device, and customized via any platform. Voice Portal applications include nationwide business finder, driving directions, and traffic updates and worldwide weather.

Blackwell, D. (3/18/01). Traffic Service to be Launched.

Global Telematics, which supplies satellite-based tracking systems for vehicle fleets, will announce a service giving up-to-the-minute news on traffic congestion, roadwork, and other delays to its users.

Boll, S. and W. Klas (May/Jun 2001). Z_YX - A Multimedia Document Model for Reuse and Adaptation of Multimedia Content. IEEE Transactions on Knowledge and Data Engineering, Vol. 13, No. 3, IEEE**:** 1041-4347.

> "Advanced multimedia applications require adequate support for the modeling of multimedia content by multimedia document models. More and more this support calls for not only the adequate modeling of the temporal and spatial course of a multimedia presentation and its interactions, but also for the partial reuse of multimedia documents and adaptation to a given user content. However, our thorough investigation of existing standards of multimedia document models such as HTML, MHEG, SMIL, and HyTime leads to us the conclusion that these standard models do not provide sufficient modeling support for reuse and adaptation. Therefore, we propose a new approach for the modeling of adaptable and reusable multimedia content, the Z_YX model. The model offers primitives that provide - beyond the more or less common primitives for temporal, spatial, and interaction modeling - a variform support for reuse of structure and layout of document fragments and for the adaptation of the content and its presentation to the user context. We present the model in detail and illustrate the application and effectiveness of these concepts by samples taken from our Cardio-OP application in the domain of cardiac surgery. With the Z_YX model, we developed a comprehensive means for advanced multimedia content creation: support for template-driven authoring of multimedia context and support for flexible, dynamic composition of multimedia documents customized to the user's local context and needs. The approach significantly impacts and supports the authoring process in terms of methodology and economic aspects."

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> Summarizes and interprets results of several FOTS that have traveler information components. Analysis and results are categorized as impacts, user response, technical lessons learned, institutional challenges and resolutions, and cost to implement. Highlights successes and problems these tests have encountered while attempting to develop the technologies appropriate to establishing and implementing ATIS.

Business Wire About Cox Radio/ About Traffic.com.

Cox Radio is the fourth largest radio company in the US based upon net revenues. Cox Radio will own, operate or provide sales and marketing services for 83 stations clustered in 18 markets, including major cities such as Tampa, Miami, Orlando, Fla., Atlanta, Houston and San Antonio. Traffic.com is creating the premier traffic information franchise with its exclusive TrafficPulse digital sensor network, and

Advanced Traffic Information Services (ATIS). The network continually measures traffic flow on major highways to provide motorists with real-time actual speeds and point-to-point travel times.

Business Wire (2/28/01). Traffic.com to Provide Content for Traffic Reports on Cox Radio's Six Tampa Stations: Listeners to Benefit form More Accurate Traffic Reports. Wayne, PA.

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Canadian Corporate (2/22//01). WebTech Wireless Launches End-to-End Wireless Vehicle Location System for GSM Operators. Cannes, France.

> (news) WebTech Wireless Inc., a global vehicle tracking and location services provider, announced the launch of the Quadrant Vehicle Location System™. The Quadrant System is the industry's first end-to-end, wireless vehicle location system that delivers a suite of location services on Palm Powered™ devices, such as Palm™ and Handspring handheld computers (PDAs), through an online services portal. The Quadrant Vehicle Location System enables GSM network operators to realize new data service revenue streams with commercial fleet and vehicle location services.

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Charles River Associates Inc. (3/1/96). User Acceptance of ATIS Products and Services: A Briefing Book on the Current State of JPO Research.

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Cloyd, M. (Jan/Feb 2001). Designing User-Centered Web Applications in Web Time. IEEE Software**:** 62-69.

As designers struggle to develop Web applications "in webtime," they are under the added pressure of delivering usability. This author describes her company's successful transformation to user-driven processes for designing e-commerce applications. She also offers strategies for introducing human factors methods into a reluctant development organization.

Colley, J. (2/23/01). Trouble With Traffic: TranStar Turns to Web to Speed Commuter Drive Times. Houston, TX.

(news) Houston TranStar, organized by Harris County, the City of Houston, the Metropolitan Transit Authority and the Texas Department of Transportation, coordinates emergency management for the entire Houston area. It also targets

transportation management with such technologies as freeway surveillance cameras, message sighs an speed sensors. It funnels traffic information to media outlets for regular drive-time reports.

Cue (2/22/01). Cue Company Information.

Large radio data network, founded in 1984 by Nokia. Offers nationwide, regional, and local messaging, as well as data services, including real-time traffic information

Dailey, D., M. Haselkorn, et al. (1/1/98). A Structured Approach to Developing Real-Time Distributed Network Applications for ITS Deployment.

Framework for addressing ITS-specific networks, e.g., reliability issues, fault tolerance, etc

David, R. (3/6/01). "Smart Cars" Will Make Crash Victims Easier to Find.

Communications tools used in luxury cars to find the nearest ATM are being combined with automotive "black box"-type crash sensors in ways that researchers hope will soon save thousands of lives each year.

Delio, M. (9/6/00). Mobile Phones Redefine Cities.

(news) According to "Life in the Real-Time City: Mobile Telephones and Urban Metabolism," mobile phones are changing the world more profoundly than any other new technology. Anthony Townsend, an associate research scientist at New York University's Taub Urban Research Center, which released the report, believes that the productivity gains associated with the proliferation of mobile phones -- if measurable -- would be far greater than the gains attributed to the personal computer or the Internet.

Diaz, C. (3/27/01). Wireless World Hears Call of Voice Recognition Software. New York.

(news) The next generation of wireless infrastructure base on voice recognition will bring user-friendlier applications to every-day devices like cell phones and handheld computers on what many are already dubbing the next Internet-like revolution. SpeechWorks Inc., a maker of voice recognition software, with funding from the U.S. Defense Advanced Research Projects Agency (DARPA), responsible for the development of the principles of the Internet, has been working on the research of speech-based multimodal access to content on wireless devices.

Downie, J. (Feb. 2001). In-Vehicle Telematics - Key Market Trends, Opportunities, Issues and Challenges: Presentation to Microsoft Telematics Conference.

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Dowsett, S. (3/14/01). Trafficmaster recuperates on upbeat results.

British traffic information provider Trafficmaster clawed back some losses following upbeat results and a deal with hand-held computer giant Palm.

DSRC (1997). Web Resources for DSRC Standardization. Austin, TX.

A list of Web site with background information on key issues underlying DSRC standards

Dvorak, J. (3/12/01). Somebody Will be Watching You Eventually.

Discussion of @Road, a company that uses established telecommunications infrastructure to create systems that track and dispatch fleet vehicles, police, ambulances, school buses, cabs.

Eddington, M. S. (3/7/01). Commuter Web Site May Save Millions, Nerves. Salt Lake, UT, Salt Lake Tribune.

(newsletter) Updated State of Utah transportation Web site www.UtahCommuter_Link.com lets Salt Lake County motorists access a wealth of information that can shave dollars and minutes off their commutes. It also can cut down on pollution from idling vehicle stuck in traffic.

Edwards, J. (3/24/01). Traffic Information System to Offer 24-7 Service.

In Cincinnati, ARTIMIS will begin monitoring traffic 24 hours a day, 7 days a week. The service increase comes from an overwhelming demand for it from local fire and police agencies.

EIA and USDOT (Apr 2001). CEA/EIA-794: Data Radio Channel (DARC) System ITS Standards (Fact Sheet). ITS Standards Fact Sheet. Washington, DC.

Coversheet. EIA-794, Data Radio Channel (DARC) System specifies the technical details for a system for the delivery of data services to mobile, portable, and fixed receivers using subcarrier signals within the standard FM broadcast band. It specifies the modulation and coding schemes and content to the transmitted signal and describes the organization of the multiplex for the DARC system.

EML (10/16/00). Dolphin Telecom Tracks Down APD Communications Ltd.: INCA AVLS Product Certified for Use on TETRA Network EML Communicating Technology RE:EMR4043. Basingstoke, EML Communicating Technology.

Dolphin Telecom has formally certified the INCA AVL (Automatic Vehicle Location) system, designed by APD Communications LTD, for use on its European TETRA network. INCA is a GPS vehicle an asset tracking system allowing remote monitoring of data from a variety of inputs.

Employment Review Online (3/26/01). Telematics Industry Kicks Into High Gear.

Nearly three decades ago, the introduction of FM radio in all automobiles was a giant leap forward in the communications arena. Vehicles have come a long way since then, thanks to a rapidly growing technology as telematics. Overview of telematics industry and major players.

ENTERPRISE, DELCAN, et al. (8/12/00). ITS Internet Applications, ENTERPRISE, DELCAN, NET.

(presentation) A presentation on frameworks for developing an open architecture for information dissemination and presentation of data over the Internet; establishing guidelines for the exchange of data in graphical, tabular and textual formats; and co-ordinate and promote guidelines.

Etak (2/15/01). Etak Company Information.

Publisher of map data, real-time traffic info, and advanced mapping technologies. Has an established partnership arrangement with Metro Networks.

European Automotive Design (2/1/01). Motorola Integrates Web-based Navigation with Telematics.

news. Motorola is to deliver a server based navigation application as part of its iRadio System. It will deliver turn-by-turn route guidance using NavTech digital maps, and real-time traffic and weather information. Demonstrated at the Consumer Electronics Show in Las Vegas in Jan. 2001, the mobile navigation and driver information service should be available to US and Canadian consumers in 2002.

Europolitan (3/6/01). Europolitan and Volvo Cars to Collaborate on Telematics for Cars.

Volvo and Euopolitan (principal owner - Vodafone) plan to offer telematics services initially focused on safety -- automatic call to emergency center in case of airbag release and manual emergency signal. Other services that can be offered include: roadside assistance, navigation, travel and traffic information,

automatically recommending and booking garage appointments, sending an alarm to a mobile phone if someone tries to break into the car.

Eyeforauto Satellite Internet Access Up in the Air.

(article) Though major Internet service providers (ISP) either have plans to or already offer broadband internet access via satellite, satellite access isn't cheap, the demand is uncertain, and satellite technology is not robust. It may have seemed like a good bet at the time, but now it looks like a waste of money.

Eyeforauto Telematics Update Magazine (3/12/01). Interview with Wireless Car CEO Jan Hellaker.

Interview with CEO of WirelessCar, a company set up be AB Volvo, Telia, and Ericsson. WirelessCar intents to offer a one-supplier interface to the automotive industry for telematics services.

Eyeforauto Telematics Update Magazine (Mar. 2001). EyeForAuto Telematics Update Magazine: Wireless Intelligence for the Auto Industry. EyeForAuto Telematics Update Magazine, Issue 1.

Telematics issues include: OEM and Service provision business models, and selling safety technology.

eyefortransport.com (3/5/00). QUALCOMM Reveals Roadway Express Set to Purchase OmniExpress Mobile Communications System.

(news) QUALCOMM, a leader in mobile communications for the transportation industry, has announced that Roadway Express, Inc., the nation's largest less-than-truckload (LTL) carrier, will purchase and utilize the OmniExpress mobile communications system for use in its network of vehicles and 20 of its terminals within North America.

Feldman, S. (11/1/00). Mobile Commerce for the Masses.

Article on the advent of "mobile commerce." Topics include" if we build it, will they come; enhancing presentation; and application design and execution.

Ferre, X. and N. Juristo (Jan/Feb 2001). Usability Basics for Software Developers. IEEE Software**:** 22-29.

The tutorial examines the relationship between usability and the user interface and discusses how the usability process follows a design-evaluate-redesign cycle. It also discusses some management issues an organization must face when applying usability techniques.

FHWA (1/8/01). ITS System Architecture and Standards.

FHWA Ruling on Architecture Standards and conformance of projects to ITS Architecture Standards

FHWA (7/1/95). "Trav-Tek System Architecture Evaluation".

"TravTek was a joint public sector - private sector project to develop, test and evaluate an integrated driver information system and supporting infrastructure in metropolitan Orlando, Florida. TravTek provided motorists with navigation, real-time traffic information, route selection and guidance, and motorist information services. TravTek systems were installed in 100 1992 Oldsmobile Tornados operating in a 1900 km2 area surrounding Orlando. Seventy-five of the cars were in a car rental fleet for use by visitors to Orlando and 25 of the cars were used by local residents and for special controlled tests. The project was the largest, most comprehensive advanced driver information system project to date attempted in the United States. It officially started on March 23, 1992 and operated for 1 year. TravTek was a partnership between the private sector, represented by General Motors and the American Automobile Association, and the public sector, represented by the Federal Highway Administration, the Florida Department of Transportation, and the City of Orlando. Additional private sector participants included Motorola and Avis. The TravTek evaluation consisted of a series of connected research efforts that addressed every facet of the system. This effort was organized as a collection of major tasks. Task A was the Project Management task, and coordinated all efforts of the evaluation team, as well as provided liaison with the TravTek partners. Task B included the Rental User Study, to evaluate the drivers' impressions of TravTek, and the Local User Study, to evaluate the participation of local users in longer term experiments. Task C included the Yoked Driver Study, to evaluate the relationship between use of the TravTek functions and measures of driver/vehicle performance, the Orlando Traffic Network study, to evaluate alternative TravTek/driver interface features, and the Camera Car Study, to examine driver interactions with different versions of the TravTek in-vehicle system. Task D included the Debriefing and Interview Study, to gather qualitative information from participants, and the Questionnaire Study, to obtain user perceptions from a wider range of attributes. Task E included the TravTek Modeling Study, to model the traffic and safety performance of the TravTek system, and the Safety Study, to evaluate the safety of using in-vehicle information systems. Task F was the System Architecture Study, to evaluate all aspects of the TravTek system design."

FHWA (9/1/00). Traveler Information systems -- A Primer.

An primer on ATIS -- traveler information systems, today and tomorrow, how they work, implementation, everyday examples

FHWA and Booz Allen & Hamilton (9/1/99). Genesis Field Operational Test, Final Evaluation Report.

"This document is the Final Evaluation Report for the Genesis Advanced Traveler Information System (ATIS) Field Operational Test (FOT). This test was CO-sponsored by the Federal Highway Administration (FHWA), and the Minnesota Department of Transportation (Mn/DOT) as part of the Minnesota Guidestar program, with additional contributions from other project partners, including Loral Federal Systems, MinnComm, and Motorola. Genesis was one of the early projects sponsored by the US Department of Transportation (USDOT) Intelligent Transportation System (ITS) FOT program. The project originated from the formulation of the Minnesota Guidestar Program in 1989. Mn/DOT proposed the Genesis ATIS project, which was accepted by FHWA and incorporated into the national ITS operational test program in 1991. The primary source of information for this Final Evaluation Report comes from the five Individual Test Reports, available under separate cover, including:

- Genesis System Effectiveness Test
- Report
- Genesis Modeling Test Report
- Genesis User Perception Test Report
- Genesis Human Factors Report
- Genesis Institutional Issues Report."

FHWA and SAIC (3/1/99). Evaluation Plan for the I-95 CC ATIS (Corridor - TRAVTIPS) Program.

"The Boston-to-New York travel corridor is one of the busiest travel corridors in the country and, typical of such developed areas, is experiencing congestion and safety problems and other travel-related inefficiencies along its transportation systems. Currently, transportation agencies along the Corridor collect static and real-time transportation and travel information for their individual areas or regions. Access to this information on a corridor-wide basis is limited. As a result, the I-95 Corridor Coalition has sponsored a program, known as the I-95 CC ATIS project, to develop and maintain corridor-wide traveler information along this Corridor. The I-95 CC ATIS project (FOT #4) is a field operational test to collect, process, and disseminate traveler information to interregional travelers corridor-wide between the New York and Boston regions along the l-95 Northeast Corridor. The overall purpose of the 1-95 CC ATIS program is to enhance the quality, quantity, and availability of timely, accurate traffic, travel, schedule, and

other information among transportation operations and management agencies and authorities, to the media, and to the public. This program will permit more effective and coordinated management of transportation services throughout the Region and more informed travelers who can then make better travel decisions."

FHWA Office of Travel Management (Jan. 2001). Guidance on Including ITS Elements in Transportation Projects.

"The purpose of the document is to provide guidance for including ITS equipment/technologies as part of traditional transportation construction or maintenance projects."

Flammia, G. (Jul/Aug 1999). The Skinny on MetaData. IEEE INTELLIGENT SYSTEMS.

Background (nontechnical) on metadata concepts and applications. RDF will slowly become a widely accepted standard on the Internet, especially for large-scale catalogs that combine domain knowledge about multiple domains.

Fried, I. (3/15/01). In-car Net Access Ready to Hit the Road.

MobileAria, a company with backing from Palm and Delphi, plans to release a beta of its voice-activated Internet service for the car by midyear.

Gardner, E. (Apr. 2001). Embedded: Cars to Kitchens. UPSIDE magazine. Troy, MI.

(article) General Motors (GM) subsidiary OnStar's project on telematics -- the embedding of electronic microprocessors into automobiles -- to be a $5 billion industry in the coming years.

Georgia Institute of Technology (2/19/01). A New Kind of Information Highway Emerging in Nation's Cities.

(news) Urban transit systems would take advantage of state-of-the-art computing and communications technology, according to latest research at Georgia Tech. Software is replacing hardware such a roads, cars and rails.

Geoworks (3/20/01). Geoworks Teams with U.S. Wireless, Nuance, and Maptuit in Technology Trial.

Geoworks, U.S. Wireless, Nuance (leader in Voice Web software), and Maptuit (leading supplier of wireline and wireless Internet location-based services are teaming to conduct a technology trial to combine wireless data, position location,

and voice and mapping technologies. The technology trial will provide a voice interface on cellular devices for ATM location requests.

Goodwin, C., S. Gordon, et al. (3/31/99). Location Referencing Message Specification, Spatial Data Interoperability Protocol for ITS Project.

"This document describes the Location Referencing Message Specification (LRMS), a set of standard interfaces for the transmission of location references between different components of Intelligent Transportation Systems (ITS). The LRMS facilitates the movement of ITS data having the attribute of location -- typically, but not always, on a transportation network.

Having standard interfaces (formats and definitions of data elements) enables the communication of a location of an event or thing from one component of an ITS system to another in an unambiguous and mutually understandable way. Having more than one standard interface is necessary given the variety of ITS application domains in integrated systems for cities and regions. For example, the location of a traffic accident could be communicated from a police car to a central site, which would estimate the impact of the accident on traffic patterns. The central site could then communicate a sequence of driving directions, made up of a sequence of location references, to an automobile's navigation system in order to divert the traffic around the accident area. During this process, the location of the accident and its impacts would be expressed in different ways, since what is appropriate for a police car may not be appropriate for a central site or for a private automobile. The LRMS specifies more than one interface option so that an application can use the appropriate option for its computer systems, digital map data sets, communications media, and users."

GPS World (2/1/01). Keeping Track of RF. GPS World.

(news) Tomorrow's high speed trains will depend on data radio communications, controlled by GPS. Operating a mix high speed passenger and freight trains in the same corridor requires an innovative safety system such as Positive Train Separation (PTS).

Greimel, H. A. (3/1/01). Technology: Car Makers Seek Pole Position on Information Superhighway. Geneva.

news. At the Geneva auto show, telematics and online services automakers are rushing to develop in hopes of eking out an extra profit. While European automakers lag behind their U.S. counterparts in rolling out onboard Internet access, the new software capitalizes on Europe's expansive mobile phone coverage to bring faster, more reliable connections.

Grenier, M. (2/18/01). More People Have Access to Internet But Digital Divide Persists, Study Says.

(news) Though the Internet accessibility prevails, the oldest and poorest adults still lag behind those who are younger and wealthier, according to a study by Pew Internet and American Life Project.

Havinoviski, G. N. (1/10/00). Data Security and Privacy Task Force: Brief Overview of Activities: A Presentation to the ITS America ATIS Committee, Wilbur Smith Associates.

promoting awareness of ITS data security an privacy concerns.

Hecker, J. (3/21/01). How to Make a Simple 2.425GHz Helical Aerial for Wireless ISM Band Device**:** 14 pages.

How to construct an aerial that can be used with other equipment that requires a broad bandwidth in the 2.425GHz band such as the new 802.11 wireless network cards or video transmitters

Hicks, B. and M. Carter (12/1/00). What Have We Learned About Arterial Management.

Chapter 3 in a larger report: What Have We Learned About ITS. Presents what has been learned (levels of deployment, benefits, deployment challenges, and future steps) for four principal areas of arterial management: Adaptive Control Strategies, ATIS, automated enforcement, and integration. For ATIS, limited dissemination is in part due to lack of surveillance on arterial streets and the absence of commonly understood method of describing conditions on arterial streets. Advent of new technologies increases the likelihood that arterial information will make its way into traveler information systems.

Houck, J. B. (5/8/01). Rand McNally Handheld Trip Planner Hits the Roadwireless.

The new handhelds, TripLink and Pocket TripLink, will let users download address-to-address, turn-by-turn driving directions from the Internet and will provide information about highways and points of interest.

Howe, P. G. (3/19/01). Firm to Give Its Message a Voice: Flight Alert Service to Be Expanded.

(news) OAG Worldwide, publishers of the Official Airline Guide, has chosen Billerica-based Envoy Worldwide to add voice notification to its existing service that automatically sends messages to cell phones, Palm Pilots, and other handheld devices with flight change information.

Hu, P., E. Chang, et al. (11/30/00). "Initial ADUS Studies and Reviews: Cross-Cutting Studies and State-of-the-Practice Reviews Interim Report 1 Cross-Cutting Studies and State-of-the-Practice Reviews Interim Report 1".

> "Intelligent Transportation Systems (ITS) provide and use information about transportation conditions to improve system performance in such areas as safety, mobility, efficiency and environment. Typically, ITS generates massive amounts of data about the current situation 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, even 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 US 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 includes reports covering the data and applications for various subject areas..

The subject areas include: (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 reported in a recent report ."

Huhns, M. (Nov/Dec 2000). An Agent-Based Global Economy. IEEE Internet Computing**:** 83-84.

Agents will continue to evolve from assistants into decision-makers, and their autonomy and responsibility will increase. Ultimately, transactions among economic software agents will constitute an essential and perhaps even dominant portion of the world economy.

IEEE and USDOT (Jan. 2000). IEEE Std 1489 - 1999 Standard of Data Dictionaries for Intelligent Transportation SystemsITS Standards (Fact Sheet). ITS Standards Fact Sheet. Washington, DC.

Coversheet. IEEE Std 1489 - 1999, Standards for Data Dictionaries for Intelligent Transportation Systems established a national standard for defining data concepts. It allows transpiration systems to interoperate. This standard embraces features of existing worldwide and U.S. national interconnectivity standards on how information is defined in open systems.

IEEE and USDOT (July. 2000). IEEE SH94633 through SH94638 (Books 106) The Survey and Analysis of Extending Standards and Those Under Development Applicable to the Needs of the Intelligent Transportation System (ITS) Short-Range and Wide-Area Wireless Communications ITS Standards (Fact Sheet). ITS Standards Fact Sheet. Washington, DC.

Cover sheet. The six documents, IEEE SH 94633-94638, 'The Survey and Analysis of Existing Standards and Those Under Development Applicable to the Needs of the Intelligent Transportation System (ITS) Short-Range and Wide-Area Wireless Communications' were written in response to a request by the FEHA for a survey of communications, technologies, practices, and standard relevant to the ITS short-range and wide-area wireless and wireless communications.

InterTrak Tracking Services, L. L. C. (2/28/01). InterTrak Combines Automated GPS Tracking with Live Response Center to Deliver Affordable Automotive Security. Frisco, TX.

(PRNEWS) InterTrak Tracking Services, L.L.C., an emergent telematics equipment and service provider, launched the first emergency vehicle location service without a monthly fee. InterTrak Tracing Services has partnered with TelEvoke, Inc. and the Aeris.net MicroBurst® cellular network to deliver affordable automotive tracking and security to an expanded market of customers.

ITE (1/1/01). Operations in A Regional Transportation Organization Environment. ITE.

As a part of National Dialogue on Transportation Operations being led by Federal Highway Administration and the Institute of Transportation Engineers, the Institute plans to produce a case-study report examining several regional approaches to transpiration management.

ITS America (2/5/01). Edwards and Kelsey Takes a Bite out of the Big Apple's Traffic Congestion.

Discusses EK's FMView, a versatile software application that provides real-time, real-world information and aids traffic control operators in the early detection of traffic incidents. EK is performing all aspects of the design including systems engineering, communications and software development, and convention civil and electrical design.

ITS America (3/15/01). Wireless Industry Petitions FCC for Reconsideration of 211 and 511.

The Petitions for Reconsideration bring up issues in the following areas: procedural and administrative; competitive; implementation; number assignment; and access to information. The Petitions do not take away the assignment of 511 for traveler information, they do request that the FCC address the concerns raised in them.

ITS America (3/17/01). Telematics, Location-Based Services: What Customers Want.

As public interest in and familiarity with telematics gradually builds, recent studies find emerging trends and preferences: telematics as loyalty builder; beyond safety, research shows interest in e-mail, navigation, traffic, IVR systems; users prove telematics-based route assistance not a tool just for out-of-town trips

ITS America (3/20/01). Telematics Likely to be Driven by Warranty and Insurance Savings. Munich, ITS America.

(news) Warranty and insurance could ultimately justify the installation of a telematics control unit, irrespective of the monthly subscription model. According to Deutsche Bank's Ken Blaschke, "Telematics is likely to be driven by warranty and insurance savings...The key factors for a successful telematics industry appear to be; (1) warranty cost savings from telematics-enabled vehicles, $100-500 per vehicle, (2) insurance savings from fewer stolen vehicles, over $7 billion stolen/year, (3) amount consumers will be willing to pay for telematics in the vehicle, and (4)recovering the cost of the Telematics control unit (TCU).

ITS America (3/21/01). Nokia, Motorola, Ericsson, and Siemens to Further Advance the Development of Personal Mobile Services through XHTML.

Leaders in the mobile communications and content industries have announced that they are supporting the XHTML markup language as the format for the future evolution of mobile services. The companies also expressed their intention to develop products, content, and services based on the XHTML language.

ITS America (3/27/01). ITS America Urges Members to Respond to FCC, and Issues General Guidance to Assist. ITSNEWS. Washington, DC.

(news) Five national cellular companies and the CTIA have formally submitted to the FCC Petitions for Reconsideration of 211 & 511. ITS America believes it is important that 511 stakeholders, and all members in general, express their views to the FCC on these petitions, and therefore is distributing the guidance and a request that members submit comments opposing the arguments advanced by the wireless phone companies.

ITS Cooperative Deployment Network ITS Deployment Along the Silicon Valley Smart Corridor -- Part 1: A Discussion with Jim Helmer, Deputy Director, San Jose Department of Transportation.

newsletter (discussion). Discussion with Jim Helmer, Deputy Director of the San Jose CADOT on the "Silicon Valley Smart Corridor", the most ambitious corridor-wide ITS deployment initiatives in the country.

ITS Cooperative Deployment Network ITS Deployment Along the Silicon Valley Smart Corridor -- Part 2: A Discussion with Ron Northouse, Senior Traffic Engineer, San Jose Department of Transportation.

newsletter. Discussion with Ron Northouse, Senior Traffic Engineer of San Jose CADOT on the "Silicon Valley Smart Corridor", and its challenges of a "data-driven" traffic management system, unexpected communication system breaks, in particular.

ITS Cooperative Deployment Network Seasoning rWeather: Lessons Learned in Providing Road Weather Information to Travelers: A Discussion with Project Manager Bill Brown from Washington State DOT**:** 10 pages.

newsletter. The rWeather web site in Washington State is one of the more ambitious attempts yet to provide traveling public with timely information about roadway weather condition. The site enables travelers to access approximately 350 weather stations, traffic cameras, and pass reports across the state. ICDN Editor Jerry Werner discussed the evolution of the Web site with rWeather Project Manager Bill Brown from Washington State DOT.

ITS Cooperative Deployment Network TravInvo® II Heads Towards Deployment: A Discussion with Emily Van Wagner and Michael Berman.

(newsletter) Since the mid -1990s, the San Francisco Bay Area's TravInfo® project has been well-known traveler information projects. Over two years after the conclusion of the TravInfo field operational test (FOT), the project remains

one of the largest traveler information initiatives led by a Metropolitan Transportation Commission (MTC). While the societal value of such traveler information projects (and the public's "willingness to pay" for premium traveler information) is still largely unproven, MTC remains firmly convinced in the intrinsic value of traveler information to both commuters and the transportation infrastructure itself. ICDN Editor, Jerry Werner discussed the strategy and objectives of TravInfo II, the next phase of the operation, with co-project managers Emily Van Wagner and Michael Berman.

ITS Cooperative Deployment Network (.). ITS Deployment Experience in the 'Burbs: A Discussion with Shirley Land Transportation Manager City of Mission Viejo, CA.

Johnson, C. and E. L. Thomas (9/1/99). Developing a Regional ITS Architecture, A Cross-Cutting Study.

"A regional intelligent transportation systems (ITS) architecture provides states and localities with a framework for sharing information and a structure for integrating new ITS projects with existing systems. Sharing information helps to maximize the ability of agencies to meet specific transportation management needs. A basis for addressing these needs has been established through such initiatives as the National ITS Architecture and special incentive funding. These initiatives, along with a growing understanding of the value of sound systems engineering practices, are making a strong case for regional and statewide ITS integration.

This report highlights cross-cutting findings and perspectives gleaned from a series of case studies that examined the development processes of regional and statewide ITS architectures. In selected instances, relevant findings from the commercial vehicle cross-cutting study of electronic credentialing in Kentucky, Virginia, and Maryland also are included in this report.

Five of the six studies were conducted by the U.S. Department of Transportation's (U.S. DOT) Volpe National Transportation Systems Center, under the sponsorship of U.S. DOT's ITS Joint Program Office, and in coordination with the Federal Highway Administration and the Federal Transit Administration. The Houston study was conducted by Mitretek Systems, with support from the Volpe Center. Credit and appreciation goes to stakeholders at each site who took the time necessary to tell the story of their site's regional ITS architecture development process. Each of the cases is unique. What is compelling about them is the way in which each site dealt with the main issues inherent in the regional

ITS architecture development process. Generally, these issues can be grouped around steps toward regional ITS architecture development: laying a foundation, gathering stakeholders, organization and governance, outreach and education, resources, and implementation and maintenance. Cross-cutting findings specific to these topics are discussed in this paper."

Kantowitz, B. and J. Foley Telematics Exclusive: Driver Focus - A Crucial Part of Telematics.

News. The message-laden telematics environment may be an area ripe for new federal transportation-safety regulations (B. Kantowitz 5/4/01). The challenge for the human factors community is to help guide technology companies into practices that enhances safe operations not inhibit deployments.

Kelly, K. (2/13/01). Kelly on Autos: The Telematics War Begins at GM And Chrysler. Bridge News Commentary. Detroit, MI.

(news) Daimler Chrysler and GM have been competing on their telematics systems. Chrysler brought media to its Liberty project center in suburban Detroit to see its new I .T. Cruiser, a P.T. Cruiser loaded with telematics to compete GM's OnStar. Partners for both GM and Daimler Chrysler include Sun Microsystems.

Kenworth (1/24/01). The Truck of the Future. Australia.

News. New technology that improves the safety of truck drivers and other road users has been demonstrated by Australian truck manufacture Kenworth Trucks with the launch of the most advance heavy truck, "Truck of the Future", the company has built so far.

Kirsner, S. (May 2001). All Talk, All the Time: Can Speech Recognition System Deliver Real Business Benefits?

News. Speech recognition services are still at the premature stage. Future predictions are: the voice on a company's speech recognition system will become an important extension of that company's brand; voice verification technology will be slow to roll out; and more companies will use speech apps to support employees.

Knight, J. (3/8/01). Harman Fine-Tuning A "Telematics" Plan.

Harman International Industries is producing he telematics that BMW will include as standard equipment on the 2002 7 Series. In the center consol, what looks like a television screen will serve as both display and control panel not only for the radio, CD changer, and multi-speaker sound system, but also for the satellite

navigation system, the anti-theft alarm, the climate controls, the cellular phone, with wireless e-mail and Internet access thrown in.

Knox, R. (6/7/2000). XML Has Begun to Prove Its Usefulness, Gartner First Take.

PureEdge announced that the SEC has chosen its XML-based InternetForms product to help companies provide required information to the SEC's Edgar financial information system via the Internet. PureEdge's e-forms enable enterprises to fill out forms and submit them to the SEC securely; companies submit the filings using public key infrastructure and certificates from VeriSign. As a further layer of security, enterprises can opt to sign their submissions digitally.

Kolton, G. (4/3/01). Traffic.com to Provide Traffic Information To EMMIS Communications' Radio Stations: Service Began April 1st in New York, Los Angeles and Indianapolis. Wayne, PA.

news. Traffic.com, a provider of digital traffic and logistics information, announced that it has executed a two-year agreement with EMMIS Communications (NASDAQ:EMMS) to provide traffic information to 22 EMMIS radio stations in seven major markets. Included are on-air reports to the stations and customized updates available on the stations' respective websites.

Kulisch, E. (12/13/00). Maryland County Eases the Commute.

Provides information on two new projects in Maryland: a system that directs drivers to commuter parking lots that are not full and signs at bus stops to show riders how many minutes will pass before their bus arrives.

LA Magazine LA Magazine Cover Story: Hard Drive. Los Angeles.

article. A story about traffic jams on L.A.'s freeways

Lappin, J. (1/1/00). Advanced Traveler Information Service (ATIS): Who Are ATIS Customers?

Based on the work of the MMDI Customer Satisfaction evaluation team. Sections include: external factors influencing customer demand, using attitudes and values to segment the ATIS market, classification of MMDI customers, ATIS traffic customer characteristics, ATIS transit customer characteristics

Lappin, J. (2/9 -10/00). Advanced Traveler Information Service (ATIS): What do ATIS Customers Want? Cambridge, MA, EG&G Services/Volpe Center.

(presentation) Based on the work of the MMDI Customer Satisfaction evaluation team. Synthesizes findings from customer satisfaction research and evaluations dating back to 1996, including several field operational tests.

Lappin, J. (12/1/00). What Have We Learned about ATIS and Customer Satisfaction.

Chapter 4 in a larger report: What Have We Learned About ITS. Synthesizes customer satisfaction findings from ATIS research and evaluations dating from 1996. Finds that demand for ATIS is based on 4 factors: regional traffic context, quality of ATIS services, individual trip characteristics, and characteristics of the traveler.

Ledford, J. (3/14/01). The Lane Ranger: L.A. Commuters Go Online with Traffic Plan for Us All. Atlanta, GA.

(article) In Los Angeles, ground zero for traffic, commuters are registering to receive e-mails form a Web-based traffic service that will attempt to predict congestion up to an hour in advance.

Lipman, L. A. (2/28/01). Technology: Mathematics Proof Touted as Key to Unbreakable Codes. Boston, MA.

news. Michael Rabin, a Harvard computer science professor, claims he had developed a mathematical proof of an unbreakable code indecipherable even by the most powerful computers.

Lockheed Martin Federal Systems (Odetics Intelligent Transportation Systems Division) (Jan. 1996). ITS Standards Development Plan. Washington, DC, USDOT FHWA.

The Standards Development Plan identifies potential standards areas, reviews existing standards efforts, describes a general process to assist standards development, and suggests beneficial actions to support and encourage ITS deployment. This document is intended for use as a guide to using the architecture. It is directed toward standards development organizations, product developers, service providers, and public agencies at all levels.

Lockheed Martin Federal Systems (Odetics Intelligent Transportation Systems Division) (Dec. 1999). Executive Summaries. Washington, DC, USDOT FHWA.

ITS opportune and overview of National ITS Architecture

Lofholm, N. (3/23/01). Information Highway Hits the Road. Denver, CO, Denver Post Western Slope Bureau.

1,200 miles of fiber-optic limes will be buried along interstate roadways for Kansas to Utah and in a ring around Denver. Drivers will be able to log on to the

Internet and see road conditions recorded by roadside cameras and electronic weather devices. Along the way, more roadside electronic message boards or radio advisories will let drivers know of rockslides, avalanches, weather delays, and traffic bottlenecks. Truckers will have a few added benefits Their loads will eventually be weighed on the fly and permits issued electronically while they drive.

Luening, E. Z. (2/9/01). Cell Phone Tracker Finds Big-Name Investors.

(news) Intel and Ericsson have invested in an upstart company, Cambridge Positioning Systems (CPS) that builds technology for tracking cellular phones to a 50-meter area using a Global System for Mobile communication (GSM) methods it calls Enhanced Observed Time Difference.

Mainelli, J. (2/22/01). Radio Traffic Jam Ahead.

Describes Clear Channel's entry into the New York traffic report arena, currently served by MetroNetworks/Shadow Traffic.

Malone, B. (2/2/01). Voice Activated Technology Begins To Sound OK.

Trends and directions in the development of speech codecs and their potential applications to travel systems

Mangalindan, M. (2/15/01). Firm Tackles Timeless Query: 'Where's That Doggone Bus?' The Wall Street Journal.

article. Highlights new technology from NextBus Information Systems, Inc, a company that lets bus riders log onto the web through a cell phone, pager, or PDA to retrieve information on when the next bus will arrive on their selected route, direction, and bus stop.

May, M. (3/20/01). New 'Web Cams to Guide I-70 Commute. Delaware.

(news) The Ohio Department of Transportation (ODOT)'s new "Web Cam" system, posted at ww.I-70.org, allows motorists to access real-time traffic images along the Interstate 70/71 corridor from their home or office computer.

McDonough, B. (2/14/01). Televigation Maps the Future. Sunnyvale, CA.

(news) Televigation is preparing of third-quarter rollout of TeleNavigation.voice, a system that ups the ante for telematics direction services in two ways: First, it's voice activated, and second, it runs off your cell phone rather than an expensive device built into your vehicle.

McDonough, D. J. (5/7/01). Cell Phones to Battle Traffic Jams.

(news) Metrocall Inc. has launched a personalized traffic information service that will be delivered in real-time through its messaging and two-way wireless products -- allowing drivers to find an alternate route.

McLean, C. C. A. (2/28/01). National Public Safety Leader Encourages Location Technology. Scottsdale, AZ.

news. Thera Bradshaw, the Executive Director of City and County of San Francisco, and also the First Vice President of the Association of Public Safety Communications Officials (APCO) and a director of the ComCARE Alliance, told a conference audience on "telematics" that AOCI will "lead the charge to ensure that the rules to implement wireless location technologies are not delayed. We will also do everything we can to ensure that wireless companies that deploy this life saving technology are publicly acknowledged. Wireless is a wonderful safety technology already; this additional improvement can and should be a win/win."

MenDez-Wilson, D. (2/12/01). Plotting The Location Points.

(news) Webrasla, a Poissy, France-based global provider of personal navigation, mapping and traffic software platforms, recently secured $49 million in second-round financing and is ready on the American market.

Miller, J. (3/20/01). GM launches hands-free phone service.

GM rolls out a hands-free phone service with its OnStar package in Southeast Michigan

Mitretek Systems, I. (1/24/00). Surface Transportation Weather Decision Support Requirement: Draft (truncated*) Version 1.0 Advanced-Integrated Decision Support Using Weather Information for Surface Transportation Decisions Makers. Washington, DC, MITRETEK.

The Surface Transportation Weather Decision Support Requirements (STWDSR) document, version 1.0 provides background for stakeholder participation in the development of requirements for a concept called the Weather Information for Surface Transportation Decision Support System (WISTDSS). This STWDSRV1.0 gives baseline information on current practice and deficiencies and outlines the methodology for stakeholder participation.

Moran, T. (5/4/01). Telematics: Location, location, location.

News. Telematics is platform-indifferent, and soon, the luxury end of the market will not have the volume to support a telematics service industry on its own. It

would become valueless to the automakers, unless they rapidly change the entire retail market, but precious to those with things to sell right nowNews.

Moran, T. (5/25/01). Customer Relationship May Be Driver for OEM Telematics Services.

news. Analysis and automaker representative say OEM automakers may not share in huge telematics revenue streams, but may need to use customer relationship management through telematics to ensure future sales.

Moran, T. (5/25/01). Revenue Roadmap Still Undefined for Telematics, Panel Finds.

news. The road to revenue from telematics service is still emerging, and future income is clouded by debate over which technologies and what delivery systems will prove acceptable to motorists, panelists at the EyeforAuto Telematics Conference said.

Moran, T. (5/25/01). Standards: A Telematics Obstacle, or Necessity.

news. Standards are a double-edged sword when it comes to introducing telematics in vehicles.

Morris, J. (3/11/01). Car of the Future Will be a . . . Browser on Wheels.

Automakers are feverishly working to introduce a host of electronics into the car that promises to make the cell phone look quaint -- onboard Internet access, fax machines, real-time traffic advisories, satellite-fed audio and video.

Motorola (3/21/01). iRadio Telematics System: A Revolution for In-Car Entertainment and Communications.

Motorola announces iRadio, an end-to-end telematics solution designed to offer a wide variety of services delivered wirelessly to the car

Murray, C. (3/6/01). Auto Industry Races for Media Revolution. EE Times.

(news) The products and technology behind mobile multimedia revolution were on display at the Society of Automotive Engineers 2001 World Congress in Detroit. Article discusses the view that the revolution in automobile technology will not happen unless automakers develop standard electrical architecture that easily allow for the addition of new features.

Nagao, K., et al. (2001). Semantic Annotation and Transcoding: Making Web Content More Accessible. IEEE**:** 69-81.

A method for constructing a superstructure on the Web using XML and external annotations to Web documents is proposed. Three approaches for annotating

documents are: linguistic, commentary, and multimedia. The result is annotated documents that computers can understand and process more easily, allowing content to reach a wider audience with minimal overhead.

NEMA, ITE, et al. (Mar. 2001). NTCIP 2202 (Draft): National Transportation Communications for ITS Protocol (NTCIP) - Internet (TCP/IP and UDP/IP) Transport Profile

ITS Standards Fact Sheet. ITS Standards Fact Sheet. Washington, DC.

Coversheet. NTCIP 2202 - Internet (TCP/IP and UDP/IP) Transport Profile, defines a combination of base standards and protocols used to provide specific functions and services for layers 3 (network or routing of packets) and 4 (transport or message handling) of the Open Systems Interconnection (OSI) Reference Model (ISO/IEC 7498-1). The seven-layered model descries the basic functions and services of communication protocols.

NEMA and USDOT (Mar 2001). NTCIP 2305 (Draft): National Transportation Communications for ITS Protocol (NTCIP) Application Profile for Common Object Request Broker Architecture (CORBA). ITS Standards Fact Sheet. Washington, DC.

Coversheet. NTCIP2305 - Application Profile for Common Object Request Broker Architecture (CORBA), is one of two center-to-center protocol defined by the NTCIP, the other being NTCIP 2305, Common Object Request Broker Architecture (CORBA). It is a general-purpose protocol of object-oriented software packages that allows systems from different manufactures to exchange data and interoperate with each other, specifying how CORBA is to be used for center-to-center communications for transportation information within the United States.

NEMA and USDOT (Mar. 2001). NTCIP 2301: (Draft) National Transportation Communication for ITS Protocol (NTCIP) - Application Profile for Simple Transportation Management Framework (STMF) ITS Standards Fact Sheet. ITS Standards Fact Sheet. Washington, DC.

Coversheet. NTCIP 2301 - Application Profile for Simple Transportation Management Framework (STMF) specifies base standards and protocols that are to be used to provide specific communications functions and services. It addresses layers 5 (session layer), 6 (presentation layer), and 7 (application layer) of the Open Systems Interconnection (OSI) Reference Model (ISO/IEC 7498), a seven-layered model that describes the basic functions and services of communication protocols.

NextBus (3/13/01). Vail to Provide Real-Time Passenger Information With NextBus System.

NextBus Information Systems bring real-time information to passengers and transit managers in Vail, CO. Over 1.2 million passengers per year use Vail's public transportation system. The NextBus tracking units have been added to Vail's busiest transit route, which connects visitors to three major ski portals and the resort's pedestrian-only activity centers.

Nokia Mobile Phones (2/27/01). Nokia and Bertone-SKF Present Vision of the Future at Geneva Motor Show. Geneva.

(news) Nokia unveiled future in-car wireless communication scenario at the 71st Geneva Motor Show. The aim of Nokia's contribution to the Bertone-SKF "Filo" concept car is to evoke ideas about how future telematics may link the car with the outside world. Bertone is an automotive design house, and SKF is a supplier of bearing and sealing solutions. The audio entertainment system in the vehicle was designed and developed by Bose Corporation.

Noronha, V., M. Goodchild, et al. (4/1/99). The LRMS Linear Referencing Profile, Technical Evaluation.

The Linear Referencing Profile (LRP) is part of the Location Referencing Message Specification (LRMS), a partial solution to interoperability problems in location expression and exchange (LX) in Intelligent Transportation Systems (ITS). This report is an evaluation of the LRP, carried out by the Vehicle Intelligence and Transportation Analysis Laboratory (VITAL) at the University of California, Santa Barbara. This document assumes that the reader is familiar with the background to interoperability problems in ITS and the LRMS effort.

Orski, C. K. (1/1/01). The Traveler Information Industry Today. Traffic Technology International.

Like much of the entire ITS industry, the traveler information sector is in a state of flux. Contributing to the ferment are rapidly evolving technology, rising competition, and changing expectations concerning market demand and profitability.

Pearce, V. (12/1/00). What Have We Learned about Freeway, Incident, and Emergency Management and Electronic Toll Collection.

Chapter 2 in a larger report: What Have We Learned About ITS. Discusses that each of the ITS technologies included in this Chapter show potential benefits, but

only a few have reached widespread deployment. Reasons for limited deployment vary for each technology, but include cost, institutional barriers, uncertainty of benefits, and technological incompatibilities.

Pfeil, S. (Apr 2001). Telematics Industry Kicks into High Gear.

(article) Recent rapid decreases in both equipment and service prices are bringing telematics technology to more mid-priced automobiles. The Strategies Group, a consulting firm in Washington, D.C., reports that telematics was offered as an option or standard feature on approximately 25 percent to new cars in 2000.

Phipps, J. (2/22/01). Tracking Traffic Online Can Be 'Sticky' Proposition: Web Sites Offer Audience-Drawing Highway Info.

news. Tom Davidson, general manager for Tribune Interactive in Hampton Roads, VA., managed the company's project to put traffic on all of its newspaper and TV Web sites. Based on his evaluation, Tribune went with Etak.com. The deciding factor became utility to the user. Web sites offer audience-drawing information and newspapers are giving radio a run for its money with on-line traffic monitoring services. Description on one newspapers decision among three competitors -- Etak, SmartRoute Systems, and TrafficStation.

Poe, R. and B. 2.0) (5/1/01). Traffic Control.

Traffic.com (Wayne, Pa.), has begun rolling out a system in partnership with the U.S. DOT to make radio traffic reports more accurate. Traffic.com's Traffic Pulse currently covers Pittsburgh and part of Philadelphia, and will extend its reach to 40 U.S. cities within three years. The network gets data from sensors posted atop 20-to 30 foot poles positioned along major commuter rotes. The sensors use microwave radar to measure the speed, number, and density of vehicles. Every 60 seconds, their wireless modems send collected information to a main data center in Philadelphia over networks run by AT&T and Verizon Communications.

Pringle, D. (2/16/01). Cultures Clash Over Next Mobile Phone. The Wall Street Journal, B6. London.

(news) Describes break up of joint development project between Motorola and Psion. Project was a personal organizer that would double as a mobile phone. Motorola's focus was compact size, Psion's focus was large screen for data display. Motorola Inc. and Psion PLC were developing a personal organizer that would double as a mobile phone, but Motorola wanted a shirt-pocket size device, while Psion envisioned a bulkier gizmo with a large screen that could display plenty of data. The Motorola-Psion clash, I.e. portability-versus-power chasm,

highlights the cultural and technical differences between the mobile-phone and computer industries.

Radin, S. (2/9-10/00). Private Sector Perceptions and Public Sector Activities. Scottsdale, AZ, USDOT/Volpe Center.

"Synthesis of Metro ITS Deployment Surveys with the purpose of determining the nature and extent of the data gap: Private sector needs
Public & private sector data availability"

Radle, K. and S. Young (Jan/Feb 2001). Partnering Usability with Development: How Three Organizations Succeeded. IEEE Software**:** 38-45.

Improving product usability enhances an organization's productivity. Competitiveness, and profitability. However, integrating usability practice into an organization is challenging. These case studies examine how three organizations succeeded.

Ransom, K. (3/12/01). How OnStar and Wingcast Measure Up.

A war is currently being waged on the Telematics front, as OnStar, Wingcast and other providers duke it out for market dominance. And not only is that war far from being win, it may not even be winnable.

Raymund, P., T. L. Kunii, et al. (Jan/Feb 1999). Software Metrics Knowledge and Databases for Project Management. IEEE Transactions on Knowledge and Data Engineering, Vol. 11, No. 1, IEEE**:** 1041-4347.

"Construction and maintenance of large, high quality software projects is a complex, error-prone, and difficult process. Tools employing software database metrics can play an important role in efficient execution and management of such large projects. In this paper, we present a generic framework to address this problem. This framework incorporates database and knowledge-base tools, a formal set of software test and evaluation metrics, and suite of advanced analytic technique for extracting information and knowledge from available data. The proposed combination of critical metrics and analytic tools can enable highly efficient and cost effective management of large and complex software projects. The framework has potential for greatly reducing venture risks and enhancing the production quality in the domain of large software project management."

Reagle, J. (2/14/01). XML Encryption Activity Statement.

The XML Encryption explained

Rehor, K. (1/17/01). VoiceXML.

Background on Voice XML - non-technical.

Reuters (2/08/01). Cell-Loc, Nortel Team Up on Wireless Location Test. Toronto, Canada.

(news) Cell-Loc Inc. (Toronto) said it would contact trials of its wireless phone location technology with Nortel Network Corp in Texas, and hopes to sell the system to telecommunications carries by the end of the forth quarter.

Robinson, B. (3/19/01). Is It Too Late for Smart Cards? Chip-Card Interest Is on the Rise Again As Online Security Requirements Boost Demand.

(news) Online security requirements are expected to boost demand on smart card, and improved technology coupled with dramatic price cuts are rewriting the cost-benefit arguments that have traditionally weighed against smart cards.

Rosencrance, L. (2/7/01). Transportation Exchange FreightWise Closes.

(news) FreightWise Inc., an Internet-based freight transportation marketplace, is shutting down after only two months in business.

Rupert, B. (1/25/01). 511 Traveler Information Telephone Number. 511 Workshop, USDOT FHWA.

511 Traveler Information and USDOT activities

SAE and USDOT (Dec. 2000). SAE J2369: Standard for AITS Message Sets Delivered Over Bandwidth Restricted Media

ITS Standards Fact Sheet. ITS Standards Fact Sheet. Washington, DC.

Coversheet. SAE J2369, 'Standard for ATIS Message Sets Deviled Over Bandwidth Restricted Media' is intended primarily for systems designers who are building ATIS systems which require standardized message sets for interoperation with other message standards (such as SAE J2354, TMD External Message Set). Additionally, those who need to support multiple end use devices with a common message set over a bandwidth-limited channel will also find this standard useful.

SAE and USDOT (Dec. 2000). SAE J2540: (Draft) Messages for Handling Strings and Look-Up Tables in ATIS Standards ITS Standards Fact Sheet. ITS Standards Fact Sheet. Washington, DC.

Coversheet. SAE J2540, 'Messages for Handling Strings and Look-Up Tables in ATIS Standards' provides the formatting rules used to facilitate the conveyance of information strings between ATIS data transmitters and data receivers. It allows a range of processing options to be used from a common set of rules, and supports universal character sets found in other languages. It provides a simple, uniform

methods of reconstructing message for end users. It also allows the use of complex textual strings, incident phrases, and national tables (such as ITIS) that can be deployed without making legacy systems obsolete, thus promoting national interoperability and sustainable deployment. This standard also contains a number of national tables used in the delivery of incident descriptions over some media.

Santini, J. S.-E. D. B. (3/26/01). Utah One of First in Developing Traffic Information Line: Once Complete, System Would Allow Motorists to Call Nationwide to Find Local Traffic Conditions, StandardNET.

(news) Utah, along with four other states, was given the go-ahead to start developing three-digit traveler information number -- 511. Since the program is intended to eventually be statewide -- and nationwide -- phone number, the responsibility for developing a program that would give drivers "quick and easy answers" fell on UDOT.

Schintler, L. and M. A. Farooque (2001). Partners In Motion and Traffic Congestion in the Washington, D.C. Metropolitan Area, Center for Transportation Policy and Logistics, School of Public Policy, George Mason University.

The study uses a traffic simulation model to aid in the evaluation of Partners In Motion of its objectives: improving the quality, quantity, and availability of travel information to transportation agencies, the media, and the public in the Washington, D.C. metropolitan area. The report evaluates Partners In Motion, as it has developed over the last two years and how it may evolve over the next decade, with respect to the goal of reducing congestion.

Schreiber, G., et al. (2000). Knowledge Engineering and management: The Common KADS Methodology. US and England, The MIT Press.

Keywords: Knowledge Engineering, Knowledge-Model, Knowledge Systems Design, UML, KADS, Knowledge Model Language

Schultz, M. (2/16/01). A Brave New World of Telematics.

(news) In-vehicle computing, or telematics, is expected to play an important part in the development of tomorrow's automobiles. The Strategies Group of Washington predicts that 84 percent of new cars sol in 2004 will feature in vehicle computing systems.

Schuman, R. (1/11/01). Environmental Scan for ATIS. Washington, DC, PBS&J.

Review ATIS vision/goals from program formation, and options on activities needed to continue progress (5-10 year horizon)

Schuman, R. (2/27/01). 511 Case Studies -- Arizona.

Case study focusing on the State of Arizona and its implementation of statewide 511 services. Explains existing services and plans to reprogram switches, expand capacity, include call forwarding to reach appropriate transit agency, and deploy signage to advertise 511.

Schuman, R. and U. I. J. P. Office (Nov. 2000). 511 Case Studies Kentucky.

A case study on the Commonwealth of Kentucky. The document contains five sections: History/Perspective - Pre-511; Institutional Background in Kentucky; Plans/Vision; Ongoing Activities; and Lesson Learned

Schwartz, J. (8/21/00). Ford and QUALCOMM Jump-Start the In-Car Internet.

(news) Wingcast -- a joint venture between Ford Motor Company and QUALCOM -- promises to turn vehicles into "personalized portals to the Internet." Ford brings its telematics technology and a big piece of the auto market, while QULCOM brings its cdmaOne technology as well as the upcoming cdma2000's multimegabit bandwidth.

Siemans-Gartner (1/31/01). Information Requirements to Support Traffic Management Services on the NHS.

Approximately 50 data Requirement elements for freeways, arterials, and tunnels-bridges by approximately 11 functional areas (freeway mgt, incident mgt., etc.)

Sill, W. (2/2/01). Telematics - At A Regulatory Cross Roads?: AAA's Efforts to Enter the Lucrative Market May Be Too Little, Too Late.

(news) In filings with the Federal Communications Commission, the American Automobile Association (AAA), the provider of emergency roadside assistance, formally requested that the FCC step in and regulate the telematics industry, so that the auto industry does not create a monopoly in the telematics marketplace.

Skarpness, B. and Battelle (5/5/00). Evaluation of the FORETELL(TM) Consortium Operational Test: Weather Information for Surface Transportation, FHWA Weather and Winter Mobility Program Surface Transportation Weather Decision Support Requirements.

Slaton, J. Information Hits the Road: Drivers Can Be a Captive and Lucrative Audience for Wireless Data Services.

Car manufactures are already beginning to roll out telematics - wireless technology combined with location and remote diagnostics information in an effort to seed a whole new market for "smart cars".

SmartRoute Systems (2/21/01). SmartRoute Systems Company Information (Public Sector Partnership Division).

Focuses exclusively in traveler information data collection, fusion, and dissemination. Creates public/private partnerships with government agencies to build out the traveler info center and staff and operate the center. Public sector commitment is to provide information to the database and to purchase services.

Smith, B. (3/23/01). U.S. Drives the Telematics Show.

Forecasts of Telematics growth, with focus on OnStar, its competitors, and Telematics' entertainment component.

Sprint PCS, Sabre Holdings Corp, et al. (1/31/01). Sprint Works With Sabre and Travelocity to Provide Travel Tools for Customers via Sprint Wireless Web.

Sprint PCS customers who booked travel through a Sabre Connected travel consultant will have instant and mobile access to their Virtually There itineraries on their Sprint PCS Internet-ready phones.

Stowe, B. (3/30/01). A Technological Achievement Means More Competition and Lower costs for WSDOT. Wenatchee, WA, Washington State DOT.

"The biggest benefit is lower costs and better service in the long run." Washington State Department of Transportation North Central Assistant Regional Administrator for Maintenance, Bob Stowe talks about the successful conclusion of a five-month effort to make ITS computer programs from different manufactures compliant with new international standards.

Sun Microsystems (3/15/01). Acunia to Showcase Java Technology in BMW Car at Trade Fair.

As part of its "ConnectedDrive" strategy, BMW is demonstrating the dynamic downloading of telematics services using a Communications Administration Provider to a BMW X5 outfitted with an integrated Java communications platform. Acunia is the developer of the Open Telematics Framework, the first fully functional, end-to-end, Java-based open software design for the entire telematics pipeline.

Swissler, B. (Feb. 2001). Revolutionizing Locomotives: Nexterna, GE Transportation Systems and GE Harris Harmon Are On the Right Track With the U.S. Rail Industry.

(news) Nexterna, GE Transportation Systems and GE Harris Harmon entered a three-year partnership, announced 30, 2000, whereby GE Harris Harmon will be the exclusive distributor of Nexterna's Mobile Resource Management (MRM) technology in the North American locomotive market.

Telcordia Technologies, I. Intelligent Network Services Description: Telcordia™ ICSP Advanced Intelligent Network Services.

(news) Telcordia™ ISCP's service description including: intelligent network services; wireless intelligent network services; consultative support; home location register; Internet service Gateway; and advanced service management system.

Tellme (1/17/01). Tellme Company Information.

Developer of voice application, using VoiceXML, for the web.

Tellme (3/21/01). Tellme to Power ATT Wireless Voice-Activated Services.

Expanding services to its customers, ATT Wireless will use the Tellme network to deliver voice applications

The Daily Telegraph (3/15/01). Trafficmaster's Lights Stuck on Amber.

Trafficmaster believes it is on the right road after completing the switch from selling hardware to services and linking up with Palm to deliver traffic information via a mobile link to handheld computers.

The Engineer (2/26/01). Focusing on In-Car Telematics.

D2 Vodafone in Germany and Vodafone UK, two subsidiaries of Vodafone Group, have signed agreements to join forces with Forn of Europe to bring voice-driven telematic safety, security, and information services across Europe.

The Weather Team and Office of Safety and Traffic Operations Research and Development FHWA USDOT (5/15/98). Weather Information For Surface Transportation: A White Paper on Needs, Issues and Actions.

The White Paper focused on the needs of surface transportation decisions for better support by weather information, integrated with other information in the ITS. Findings are included from a special team workshop and feedback from conference presentations, representing wide participation by transportation and meteorological experts, in the public and private sectors. The goals of the ITS program and of the FHWA National Strategic Plan are to be met by a conceptual Weather Information for Surface Transportation (WIST) System that will be part

of the ITS for use by surface transportation operators and travelers. The goal of the WIST System is to achieve better outcomes in the surface transportation system, and weather information is a resource to decision making that can achieve this goal. Weather itself is a natural constraint on transportation, but weather information as part of better decision support can improve treatment of weather effects on surface transportation facilities, allow travelers to cope better with conditions, and expedite responses to weather-induced problems.

Thomson Financial (5/24/01). Microprocessor Cards Projected to Top Memory Cards By 2005.

news. By 2005, smart card vendors will ship more microprocessor cards used for wireless telephony, banking and network security than memory chip cards used mainly for prepaid phone cards, according to the European Smart Card Industry Association (Eurosmart).

Tiwana, A. and B. Raesh (May/Jun. 2001). Integrating Knowledge on the Web. IEEE Internet Computing, IEEE**:** 32-39.

The web provides a ubiquitous medium for seamlessly integrating distributed applications, formats, and content, making it well suited for enterprise knowledge management.

Toshiba (2/6/01.). Toshiba Announces World's First Image Recognition LSI for Intelligent Vehicle System. Tokyo, Japan.

(news) Toshiba announced the world's first image recognition LSI integrating a configurable media-processor. A version of the new LSI, customized for an intelligent vehicle system was reported at the International Solid-State Circuit Conference (ISSCC) in san Francisco.

Traffic Station (2/22/01). Traffic Station Company Information.

Provider of personalized, interactive traffic, transportation, and traveler information for the Internet, wireless, and telematics markets. Currently offers services to 28 major metro markets across North America. Has been chosen for several MMDIs: AZTech in Phoenix, Trips 123 in the New York Metro Area, and TravInfo in the San Francisco Bay Area.

Traffic.com (2/22/01). traffic.com Company Information.

Provider of real time and predictive traffic information for consumers, businesses, and government agencies. Features include: web-based delivery of information, 24/7 availability, actual vehicle speeds, current travel times between points, choice of communications platforms, personalized routing, and a historical

database. Available across multiple platforms: radio, TV, cable TV, internet, wireless, telematics.

Trafficmaster (3/14/01). Trafficmaster Develops T-nav, A Full Feature, In-car Navigation System Using Proven Mobile Telephone and GPS Technology.

T-nav combines a powerful off-board server based routing system and Trafficmaster's accurate live traffic flow data. Once the motorist has logged the chosen route with the T-nav call center, using a standard mobile phone, a route-guard service is automatically provided, watching the route ahead and sending an automatic alert should traffic problems be noted.

Transportation & Distribution (2/1/01). Internet Use Will Change Freight Patterns. Transportation & Distribution.

(news) A survey conducted by Morgan Stanley Dean Witter reveals a future e-commerce impact on freight transportation with fewer carriers and smaller, more frequent shipments.

Tribune Interactive (1/31/01). Tribune Interactive Signs Agreement with Etak to Deliver Timely Road Conditions and Traffic Information via the Web.

Announcement of agreement to give consumers access to current road conditions and traffic information via several of Tribune Interactive's newspaper Web sites

U.S. Wireless Corporation (12/13/00). U.S. Wireless Accelerates Location of Network Deployment in Washington DC.

Announcement of selection of Wireless Facilities, Inc as the prime contractor in the current build-out of Washington DC location and traffic network. This deployment phase expands U.S. Wireless' network coverage to include the entire Beltway, as well as the B-W Parkway, all of Arlington County, and portions of Tysons Corner.

U.S. Wireless Corporation (2/22/01). U.S. Wireless Company Information.

Provides instant, reliable, real-time location information, based on the RadioCamera system.

U.S. Wireless Corporation (3/26/01.). U.S. Wireless Awarded Patent for Locating and Tracking Wireless CDMA Devices, Using Location Pattern Matching Technology.

The patent describes methods for determining the location of a wireless CDMA device, based on patterns of multipath, or radio frequency reflections, as the signal bounces off of obstructions while traveling from the handset to the base

station or receiving antenna. The technology improves upon conventional line of sight location technologies

U.S. Wireless Corporation (4/10/01). National Emergency Number Association Puts U.S. Wireless' E-911Caller-Location System 'to the Test'. San Ramon, CA.

U.S. Wireless Corporation announced that it has successfully complete a series of tests for the National Emergency Number Association (NENA), confirming that the U.S Wireless Radio Camera™ caller location system satisfies the Phase II requirements of the Federal Communications Commission's (FCC) E-911 mandate. RadioCamera™ system is a network-based E-911 solution that uses Location Pattern Matching technology to locate wireless phones and other devices. NENA's test of U.S. Wireless' s E-911 caller location solution was conducted over nine days in March, in a Seattle, Washington test area.

USDOT, C. Alliance, et al. (10/23/00). Recommendations of the National Mayday Readiness Initiative.

USDOT and (FHWA) (Spring 2000). ITS Standards: Lessons Learned from Deployment/ Raising ITS Standards IQ with a Public Sector Workshop ITS Standards Lessons Learned Report #1. FHWA-0P-00-010 Doc#12643 ITS Standards Lessons Learned Report #1. Washington, DC.

Minnesota DOT held ITS Standards Workshop in November 1999. The workshop increased awareness of the development process for and the impact of ITS standards. The standards advisory group identified the following key information needed by public sector staff: 1) Who are the players in ITS standards development and deployment and what are they doing? 2) What have been the successes and failures in using ITS standards? and 3) How can standards migration planning be initiated in Minnesota?

USDOT FHWA (Dec. 2000). What Have We Learned About Intelligent Transportation Systems?

Overall evaluation of the National ITS Program. The seven areas reviewed are: Freeway, Incident, and Emergency Management, and Electronic Toll Collection; Arterial Management; Traveler Information Systems; Advanced Public Transportation Systems; Commercial Vehicle Operations; and Cross-Cutting Technical and Programmatic Issues.

USDOT ITS Joint Program Office (12/20/00). Background Discussion on Guidance: Telecommunications Installations Limited Access Highway Right-of-Way.

The document presents the key elements of the Federal Communication Commission (FCC) decision on the Minnesota agreement and then discuss the rationale for guidelines with respect to that decision to arrive at an approach than addresses both transportation statutory and regulatory issues, as well as those issues posed by the Telecommunications Act of 1996 ("TCA'). In developing these guidelines, the staffs of the Federal Highway Administration (FHWA) and the FCC Common Carrier Bureau have worked together to understand the issues of the various statutory, regulatory, and policy frameworks.

USDOT ITS Joint Program Office, FHWA, et al. (9/30/00). Department of Transportation's Intelligent Transportation Systems (ITS) Projects Book.

The document describes ITS projects, tests, and studies initiated through September 30, 2000, that partially or totally have been financed from Federal ITS funds. Completed projects plus those projects anticipated to be completed by the end of December 2000, as well as ongoing projects are included in the document.

USDOT ITS Joint Program Office and A. R. Kane (12/22/00). Guidance on Longitudinal Telecommunications December 22, 2000 Installations on Limited Access Highway Right-of-Way.

A number of States have altered their utility accommodations policies to allow longitudinal access to their limited access highway Right-of-Way (ROW) for telecommunications installations; usually fiber optic cable. Several of these installations to date have been public-private partnerships with the telecommunication industry generally referred to as AShared Resource@agreements. In December 1999, the Federal Communications Commission (FCC) issued an opinion in the Minnesota Department of Transportation (DOT) case involving such a partnership that defined the FCC's interpretation of the Telecommunications Act of 1996 (TCA) and its application to the Minnesota agreement, which has potentially broad implications for transportation agencies. As a result of the FCC's opinion, the Federal Highway Administration (FHWA) engaged in a discussion with the FCC to clarify how these partnerships and other similar telecommunications installations should be conducted to avoid conflict with the TCA and be consistent with FHWA's requirements for highway safety and ROW management."

van Eck, P., J. Engelfriet, et al. (May/June 2001). A Survey of Languages for Specifying Dynamics: A Knowledge Engineering Perspective. IEEE Transactions on Knowledge and Data Engineering, Vol. 13, No. 3, IEEE**:** 1041-4347.

"During the last years, a number of formal specification languages for knowledge-based systems has developed. Characteristics for knowledge-based systems are a

complex knowledge base and an inference engine that uses this knowledge to solve a given problem. Specification languages for knowledge-based systems have to cover both aspects. They have to provide the means to specify a complex and large amount of knowledge and they have to provide the means to specify the dynamic reasoning behavior of a knowledge-based system. This paper focuses on the second aspect. For this purpose, we survey existing approaches for specifying dynamic behavior in related areas of research. In fact, we have taken approaches for the specification of information systems (Language for Conceptual Modeling and TROLL), approaches for the specification of database updates and logic programming (Transaction Logic and Dynamic Database Logic) and the generic specification framework of Abstract State Machines."

Vartabedian, R. (3/7/01). Computerized Cars: Brave New World of Risk.

cars and trucks become more computerized, they will be more efficient, responsive, safer, and reliable. But electronic controls and their software will pose complex new problems under the hood, cause breathtaking inflation of repair costs, and raise difficult privacy issues.

Virginia Department of Transportation (April, 2000). Policy on Access to Smart Traffic Center Data and Video Imagery (DRAFT).

VDOT policy to disseminate the data and video imagery for its transportation management system as widely as possible in order to: reduce crashes and otherwise improve the safety of the surface transportation system; inform the public and enhance the quality of transportation services; facilitate route and mode choice among transportation system users; and foster the development of traveler services information by the private sector. Access to the imagery/data shall be tightly governed by VDOT to ensure the security of the systems. The number, location and method of access to the imagery/data will be determined by VDOT.

W3C (Mar. 2000). XML Protocol Comparisons. (www.w3c.org/XML/)

The purpose of the document is to compare and contrast a variety of XML protocols.

Weatherby, B., H. Rahka, et al. (10/19/98). SWIFT: Seattle Wide-area Information for Travelers Architecture Study. McLean, VA, SAIC.

The SWIFT (Seattle Wide-area Information For Travelers) Field Operational Test was intended to evaluate the performance of a large-scale urban Advanced Traveler Information System (ATIS) deployment in the Seattle area. The features of the SWIFT ATIS were the provision of information for multiple transportation

modes, the delivery of this information using three different devices, and the use of the FM sideband as the primary communication medium. The SWIFT Architecture Study is one of five component studies to the overall system evaluation. The report details the results of the SWIFT Architecture Study based on the evaluation objectives that were initially identified in the SWIFT Architecture Study test plan (1996). Specifically, four evaluation objectives are identified in the SWIFT Architecture Study test plan. The first two of these objectives relate to the system performance when the system is operating according to its functional specifications, and is essentially free of any component of failures. In contrast, the third and fourth objectives focus on what happens when part of the system becomes unavailable due to system component failures. For each of these conditions, the performance of the architecture will be examined from both the user (objectives 1 and 3) and system (objectives 2 and 4) perspective.

Wheatley, S. (5/21/01). Toad CE Explains Developing Telematics Business in Wall Street Transcript Interview.

interview Toad PLC's CE Stephen Wheatley told that the company planed to develop a market position in telematics, while continued developing its core businesses, corporate, Audio Express (wholesaling business), and its security business.

Wheatman, V. (12/7/01). New XML Framework to Enable E-Commerce Digital Signature and Data Encryption, Gartner FirstTake.

(news) A consortium of technology companies, led by Microsoft, VeriSign and webMethods, announced XKMS, which will allow software developers to integrate digital signatures and data encryption into the programming language of e-commerce applications. The consortium will submit the XKMS specification to Web standards bodies for consideration as an open Internet standard. Moreover, Microsoft intends to incorporate support for XKMS into its .NET architecture for use in business-to business and business-to-consumer environments.

Whiting, M. (11/17/97). Self-Describing Data.

Background on metadata (SDD). Definitions and examples of Self-Describing Data (SDD).

Wired Digital Inc. (2/15/01). If We Can Fly, Why Can't We Talk?

(news) Neither the FAA nor the FCC has plans to allow airplane passengers to use their cell phones and PED use, though "the issue with cell phone has less to do

with interfering with the airplane equipment" (Tim Brown, the University of Colorado in Boulder).

Witty, R. and J. Pescatore (11/20/00). XML-Based Authorization Standards Promise Path to Interoperability, Gartner FirstTake.

(news) Secruant announced that it is facilitating a working group to further the development of AuthXML, the company's XML-based product for securing e-commerce transactions. Netegrity announced that it is working with a group of companies to develop Security Services Markup Language (S2ML), its XML-based standard for securing e-commerce transactions.

Wolf, S., et al. (Oct 1991). How Will We Rate Telecommunications System Performance? IEEE Communications Magazine.

To overcome the difficulties associated with determining new digital performance standards, grater participation in the standards setting process will be required by industry and government. Participation will be required from not only end users and service providers, but also from code designers and makers of test equipment.

Wolinetx, L., A. Khattak, et al. (11/7/00). Why Will Some Individuals Pay for Travel Information When It Can be Free? Analysis of Bay Area Study.

Study was based on a "brad area" survey of San Francisco Bay Area residents collected as part of the TravInfo field test. Study analyzes respondents' willingness to pay for a hypothetical ATIS. Report discusses most desirable information content, willing ness to pay for specific content, and the possibility that future commercialization efforts focus on experimenting with various types of information content and on conducting demonstration projects that charge for information.

Wrolstad, J. (4/4/01). Alcatel Beats Wireless E911 Deadline.

news. Alcatel and MapInfo Corp. have unveiled a network-based application that provides wireless emergency 911 capability to phone service providers.

Wunderlich, K., M. Hardy, et al. (Jan, 2001.). On-Time Reliability Impacts of Advanced Traveler Information Services (ATIS): Washington DC Case Study, FHWA, MITRETEK.

Using results from a large-scale case study in Washington DC, study shows that even though over time ATIS users realize only marginal reduced in-vehicle travel time, they do realize substantial time management benefits from improved on-time reliability and trip predictability

XM Satellite Radio (3/18/01). XM Radio Successfully Launches Satellite.

Successful launch of first of three satellites -- putting in place one of the final pieces to begin broadcasting new satellite radio service in the summer of 2001.

Data Fusion References

(2/20/2002). Texas instruments introduces industry's first complete multimedia IDB-1349 and Bluetooth (TM) technologies for automotive market. Dallas, TX.

(2/23/01). ISO Publishers Technical Specification for Traffic Impediment Warning Systems. Access ITS.

(news) ISO/TS 15624:2001 - Transport information and control systems - Traffic Impediment Warning Systems (TIWS) -- System requirements has been published.

(3/1/01). 1999 ITS Deployment Tracking Results - ATIS Focus.

A survey for agencies that use any of the following technologies (telephone, Internet, E-mail, interactive TV, etc., to distribute arterial travel time, speeds, and conditions information to the public.

(4/4/01). Results of 2000 ITS Deployment Survey - ATIS Related Applications: Transit Management.

Survey results of 2000 ITS Deployment for Transit Management. 199 agencies replied.

AASHTO, ITE, et al. (Dec. 1999). The NTCIP Guide: National Transportation Communications for ITS Protocol. NTCIP 9001 v02.06 (Draft). Washington, DC, The Joint Committee on the NTCIP.

"This NTCIP Guide is an educational tool that has been created to assist decision makers, planners, specification writers, and implementers understand the various NTCIP documents and how to use them, as well as the overall motivations behind the use of NTCIP."

Adamek, J., C. (6/1/94). Fusion: Combining Data From Separate Sources.

Discusses the concept of data fusion for market research. The article also describes sources of fusion errors and media planning tool applications.

Alford, M. and P. Varshiney (1/1/99.). A Layered Architecture for Multisensor Data Fusion Systems.

Combination of data fusion processes and communication architectures

ANSI and USDOT (1999). ANSI TS285: Commercial Vehicle Safety and Credential Information Exchange
(cover sheet).

The standard was developed and is maintained by Accredited Standards Committee (ASC) X-12, Electronic Data Exchange (EDI) of the American National Standards Institute (ANSI). The standard contains the format and establishes the data contents of the Commercial Vehicle Safety and Credential Information Exchange Transaction Set (TS285) for use within the context of an Electronic Data Interchange (EDI) environment. This bi-directional standard can be used by enforcement officials, government administrators, and other authorized parties to ask electronically for information on the safety performance, regulatory compliance, and credential status of commercial motor vehicles, carriers, and drivers. It can also be used by sources that maintain such data to respond to such requests. It can also be used to submit updates to a central repository wherever new safety or credential information is received.

Antony, R. (1/1/97). Database Support to Data Fusion.

Top-down view of key algorithm and database management requirements associated with advanced data fusion methods.

Appriou, A. (6/9/97). Multisensor Data Fusion in Situation Assessment Processes.

Generic framework and algorithms to improve the selection of information from a set of possibilities (noisy input, multiple data sources, etc.)

Arena, P., S. Baglio, et al. (9/1/00). Analog Sensor Networks for Multisensor Fusion and Control.

Methodological description of processing multiple sensor sources. Separation of local and global parameters are possible.

ASTM and USDOT (January 2000). ASTM PS 111-98: Specification for Dedicated Short Range Communication (DSRC) Physical Layer using Microwave in the 902-928 MHz.

Standards for dedicated short-range communication (DSRC) are intended to meet the communications requirements between vehicles and roadside devices, as defined in the National ITS Architecture. The standard is comprised of the requirements for the physical, i.e., electrical and mechanical interfaces and the transmission medium, i.e., air, in the 902 to 928 MHz location and monitoring service (LMS) band. This standard provides information for onboard equipment based on both active and backscatter technologies and allows for interoperability between systems based on either of these technologies. The standard allows for

mixed time, frequency, and space division multiple access approaches, all similar to cellular telephone techniques allowing multiple users on a limited number of frequencies. The standard contains requirements that minimize interference between neighboring sites and between active and backscatter systems. For active legacy systems, it defines the up link and down link frequency bands and adds the possibility of operating new down link center frequencies. For backscatter systems, it defines the up link and down link frequency while using power levels consistent with the out-of-band emissions requirements. To operate at the power levels allowed in this standard and minimize interference between systems and sites, specific frequency designation are made for both active and backscatter up link and down link operations.

Ayari, I. and J.-P. Haton (1/1/95). A Framework for Multi-Sensor Data Fusion.

Description of a multi-sensor, multi-agent approach to data fusion utilizing robotic applications.

Bailey, A. and C. J. Harris (1/1/99). Using Hierarchical Classification to Exploit Context in Pattern Classification for Information Fusion.

Use of a hierarchical classification system to only select minimum information sets for fusing.

Baldonado, M., et al. (1997). The Stanford Digital Library Metadata Architecture. International Journal of Digital Libraries (1997) 1**:** 108-121.

The overall goal of the Sanford Digital Library project is to provide an infrastructure that affords interoperability among heterogeneous, autonomous digital library services. These services include both search services and remotely usable information processing facilities. In this paper, we survey and categorize the metadata required for a diverse set of Stanford Digital Library services that we have built. We then propose an extensible metadata architecture that meets these requirements. Our metadata architecture fits into our established infrastructure and promotes interoperability among existing and de-facto metadata standards. Several pieces of this architecture are implemented; other are under construction. The architecture includes attribute model proxies, attribute model translation services, metadata information facilities for search service, and local metadata repositories. In presenting and discussion the pieces of the architecture, we show how they address our motivating equipments. Together, these components provide, exchange, and describe metadata for information objects and metadata for information services. We also consider how our architecture relates to prior, relevant work on these types of metadata. Key words: Metadata architecture;

Interoperability; Attribute model; metadata repository; Proxy architecture; Heterogeneity; Metadata survey.

Barry, C. and M. Lang (Apr/Jun 2001). A Survey of Multimedia and Web Development Techniques and Methodology Usage. IEEE, National University of Ireland, Galway, Ireland**:** 52-60.

The survey results suggest that no uniform approach exists to multimedia systems development and that practitioners aren't using the multimedia models cited in the literature. Developers need new techniques that capture requirements and integrate them within a systems development framework.

Bergholz, A. (Jul/Aug 2000). Extending Your Markup: AN XML Tutorial. IEEE Internet Computing.

Tutorial on XML. Definition and capabilities of XML, which introduces a family of languages to provide a more semantic management of information than HTML

Bezdek, J. C., J. Keller, et al. (1999). Fuzzy Models and Algorithms for Pattern Recognition and Image Processing. Fuzzy Models and Algorithms for Pattern Recognition and Image Processing:. The Handbooks of Fuzzy Sets Series and Series Editors: Didier Dubois and Henri Prade. Norwell, MA, Kluwer Academic Publishers.

A book on fuzzy models and algorithms for pattern recognition and image processing. The contents include: Pattern recognition, cluster analysis for object data, cluster analysis for relational data, classifier design, and image processing and computer vision.

Biesecker, K. (October 2001). Broadband Wireless, Integrated Services, and their Application to Intelligent Transportation Systems: Phase II - Concept Prototyping. McLean, VA, Mitretek Systems.

Biezunski, M. and S. R. (Apr/Jun 2001). XML Topic Maps: Finding Aids for the Web. IEEE. P. Liu, IEEE**:** 104-108.

Topic maps superimpose an external layer that describes the nature of the knowledge represented in the information resources. There are no limitations on the kinds of information that can be characterized by topic maps. The purpose of the Extensive Markup Language topic maps (XTM) initiative is to apply the topic maps paradigm in the context of the World Wide Web.

Boll, S. and W. Klas (May/Jun 2001). Z_YX - A Multimedia Document Model for Reuse and Adaptation of Multimedia Content. IEEE Transactions on Knowledge and Data Engineering, Vol. 13, No. 3, IEEE**:** 1041-4347.

"Advanced multimedia applications require adequate support for the modeling of multimedia content by multimedia document models. More and more this support calls for not only the adequate modeling of the temporal and spatial course of a multimedia presentation and its interactions, but also for the partial reuse of multimedia documents and adaptation to a given user content. However, our thorough investigation of existing standards of multimedia document models such as HTML, MHEG, SMIL, and HyTime leads to us the conclusion that these standard models do not provide sufficient modeling support for reuse and adaptation. Therefore, we propose a new approach for the modeling of adaptable and reusable multimedia content, the Z_YX model. The model offers primitives that provide - beyond the more or less common primitives for temporal, spatial, and interaction modeling - a variform support for reuse of structure and layout of document fragments and for the adaptation of the content and its presentation to the user context. We present the model in detail and illustrate the application and effectiveness of these concepts by samples taken from our Cardio-OP application in the domain of cardiac surgery. With the Z_YX model, we developed a comprehensive means for advanced multimedia content creation: support for template-driven authoring of multimedia context and support for flexible, dynamic composition of multimedia documents customized to the user's local context and needs. The approach significantly impacts and supports the authoring process in terms of methodology and economic aspects."

Booz Allen Hamilton (9/1/98). ATIS Field Operational Test Cross-Cutting Study (ITS FOT): Advanced Traveler Information Systems. McLean, VA.

Summarizes and interprets results of several FOTS that have traveler information components. Analysis and results are categorized as impacts, user response, technical lessons learned, institutional challenges and resolutions, and cost to implement. Highlights successes and problems these tests have encountered while attempting to develop the technologies appropriate to establishing and implementing ATIS.

Bosse, E., et al. (5/26-29/96). Data Fusion Concepts Applied to a Suite of Dissimilar Sensors (Conference proceedings). Calgary, Canada**:** 692-695.

"*Conference proceedings; 1996 Canadian Conference on Electrical and Computer Engineering, May 26-29, 1996, the University of Calgary, Alberta, Canada: theme, Glimpse into the 21st century*" discusses the feasibility and usefulness of data fusion applied to a suite of dissimilar sensors.

Brandwajn, A. (10/11-141998). Fast Decomposition in Large Stochastic Models in SMC '98 conference proceedings. 1998 IEEE International Conference on Systems, Man and

Cybernetics: Intelligent systems for human in a cyber world. San Diego, CA, IEEE**:** 3073-78.

"We propose a novel approach to the decomposition of large probabilistic models. The goal of our method is to avoid the evaluation of the subnetworks obtained by decomposition for all values of the state description vector, as would be necessary with a standard aggregation and decomposition approach. Instead, we propose a fixed point interaction that requires the evaluation of the subnetwork for only a subnet of the population levels. Outside the evaluated point, simple upper and lower linear approximations are used resulting in bounds for overall system performance measures. We concentrate the evaluation of the subnetworks in the region where the difference between the lower an upper bound is most likely to impact the accuracy of the result."

Burnett, K., K. B. Ng, et al. (1999). A Comparison of the Two Traditions of Metadata Development. Journal of the American Society for Information Science 50(13)**:** 1209-1217.

Metadata has taken on a more significant role than ever before in the emerging digital library context because the effective organization of networked information clearly depends on the effective management and organization of metadata. The issue of metadata has been approached variously by different intellectual communities. The two main approaches may be characterized as: (1) the bibliographic control approach (origins and major proponents in library science); and (2) data management approach (origins and major proponents in computer science). This article examines the different conceptual foundations and orientations of the two major approaches contributing to the metadata discussion. An examination of the on-going efforts to establish metadata standards, and comparison of different metadata formats, supports a proposal for an integrated concept of metadata to facilitate the merging of the two approaches.

Cambridge Systematic, I. (5/5/00). Strategic Plan to the Development of ADUS Standards: Final.

The Strategic Plan creates the framework for the development of standards related to the implementation for the Archived Data User Service (ADUS). The Plan: establishes the need for the development of ADUS standards and their potential benefits to transportation practice; identifies the general types of standards that are required; identifies other ongoing efforts related to ADUS standards, and recommends how coordination may be archived; ascertains the policy implications of instituting ADUS standards, creates a schedule for the development of ADUS standards; and identifies institutional mechanisms for developing and implementing ADUS standards.

Cathro, W. (Aug. 1997). Metadata: An Overview. Australia.

(conference paper) Paper given at the Standards Australia Seminar, "Matching Discovery and Recovery". Definitions of metadata, and the description of the Dublin Core Standard

Chang, S.-k. and T. Znati (Jan/Feb 2001). Adlet: An Active Document Abstraction for Multimedia Information Fusion. IEEE Transactions on Knowledge and Data Engineering, Vol. 13, No. 1**:** 112-123.

A new approach is described for the fusion of multimedia information based on the concept of active documents advertising on the internet, whereby the metadata of a document travels in the network to seek out documents of interest to the pattern document and, at the same time, advertises its parent document to other interested documents. This abstraction of metadata is called an adlet, which is the core of our approach. Two important features make this approach applicable to multimedia information fusion, information retrieval, data mining, geographic information systems, and medical information systems: 1) any document, including a web page, database record, video file, audio file, image and even paper documents, can be enhanced by an adlet and become an active document, and 2) any node in a nonactive network can be enhanced by adlet-savvy software and the adlet-enhanced node can coexist with other no enhanced nodes. An experimental prototype provides a testbed for feasibility studies in a hybrid active network environment.

Charles River Associates Inc. (1/1/97). User Acceptance of ATIS Products and Services: A Report of Qualitative Research.

Summarizes lessons drawn from a series of twelve focus groups held during Fall 1996. The focus groups were conducted to appraise the potential customer acceptance for key ITS products and services directed at individual consumers. The objectives of the focus groups were to improve understanding of current consumer reactions to ATIS product concepts and help develop improved methods for subsequent quantitative customer acceptance surveys

Charles River Associates Inc. (3/1/96). User Acceptance of ATIS Products and Services: A Briefing Book on the Current State of JPO Research.

Designed as a briefing book on customer acceptance for senior management of the JPO in preparation for Congressional appropriations hearings. Sections include how people make current travel decisions, what forms of ATIS are currently available to individual travelers, what user acceptance research has been

carried out, and how new JPO-sponsored user acceptance work for ATIS should be planned.

Chi, Z., H. Yan, et al. (1996). Fuzzy Algorithms: with Applications to Image Processing and Pattern Recognition. Advances in Fuzzy Systems - Applications and Theory Vol. 10. Singapore, World Scientific. **10**.

basic concept of fuzzy algorithms, cluster-based techniques for membership function algorithms, fuzzy rule generation techniques, multi-classifier combination techniques and other concepts and ideas of fuzzy set theory.

Choi, K. and Y. Chung (January 2001). Travel time estimation algorithm using GPS probe and loop detector data fusion. Transportation Research Board, 80th Annual Meeting. Paper no. 01-0374. Washington, DC, Transportation Research Board.

Cloyd, M. (Jan/Feb 2001). Designing User-Centered Web Applications in Web Time. IEEE Software**:** 62-69.

As designers struggle to develop Web applications "in webtime," they are under the added pressure of delivering usability. This author describes her company's successful transformation to user-driven processes for designing e-commerce applications. She also offers strategies for introducing human factors methods into a reluctant development organization.

Cogburn, P., (ed). (Winter 2001). Incident Management Update. State Incident Management Committee Vol.2, Issue 3. Richmond, VA, Virginia DOT.

Richmond (VA) District Smart Traffic Center (STC) is going for operational 24 hour / 7 days a week on March 5th, 2001. The Richmond District STC is the third such center brought on-line in Virginia following successful implementation in Northern Virginia and Hampton Roads. This new office will be working closely with TEOC to keep VDOT and the motoring public informed of events/incidents on Virginia's roadways within the 14 counties and 4 cities that comprise Richmond District. A comprehensive list of Residency and Area Headquarters contact numbers is being compiled. This "data base" will provide STC controllers with information that will put them immediately in touch with the right office or person when VDOT resources are needed, or requested by other agencies.

Committee on ITS (Jun. 1999). Transportation Research Circular: Research Directions for In-Vehicle Computing: Delivering an Integrated Suite of ITS Applications for Driver Assistance and Mobile Services & Information TRB / NRC
TRB E-C009, E-circular. TRB E-C009, E-circular.

A workshop, "Research Directions for In-Vehicle Computing", hosted by the TRB on ITS (A5009) on August 25-26, 1998 met the goals of the workshop: identify research needed to appropriately advance the overall in-vehicle computing environment and related DA and MSI applications; prioritize research needs and areas where additional research attention is needed; and identify and recommend appropriate strategies and frameworks for pursuing this research. Human factors was recognized as a paramount issue throughout the workshop.

Dailey, D., et al. (Sept. 1996). Final Research Report: ITS Data Fusion (Research ProjectT9903, Task 9: ATIS/ATMS Regional IVHS Demonstration). WA-RD 410.1. Washington State, WADOT.

The ATIS/ATMS Regional ITS Demonstration project report includes: (1) literature review of data fusion technologies, (2) a detailed description of a current data amalgamation (fusion) project based at the University of Washington, and (3) the presentation of a new quantitative data fusion algorithm to estimate speed from volume and occupancy measurements. Levels 1, 2, 3 Data Fusion are delineated.

Dailey, D., M. Haselkorn, et al. (1/1/98). A Structured Approach to Developing Real-Time Distributed Network Applications for ITS Deployment.

Framework for addressing ITS-specific networks, e.g., reliability issues, fault tolerance, etc

Dailey, D. and L. Pond (January 2001). TDAD: an ITS archived data user services data mine. Transportation Research Board, 80th Annual Meeting. Paper no. 01-3226. Washington, DC, Transportation Research Board.

Dailey, D. J. (1998). A Statistical Algorithm for Estimating Speed from Single-Loop Volume and Occupancy Measurements.

Algorithm for estimating mean traffic speeds using volume and occupancy data from a single inductance loop.

Dailey, D. J., et al., ITS Research Program, et al. (Jan. 1999). A Self-Describing Data Transfer Methodology for ITS Applications. research paper. W.A.**:** i-iii, 1-66.

"The wide variety of remote sensors used in Intelligent Transportation Systems (ITS) applications (loops, probe vehicles, radar, cameras, etc.) has created a need for general methods by which data can be shared among agencies and users who own disparate computer systems. In this paper, we present a methodology that demonstrates that it is possible to create, encode, and decode a self-describing data stream using the following: (1) existing data description language standards,

(2) parsers to enforce language compliance, (3) a simple content language that flows to of the data description language, and (4) architecture neutral encoders and decoders based on ASN.1."

Dailey, D. J., P. Harn, et al. (Apr. 1996). ITS Data Fusion. research paper. W.A.**:** i - iv, 1-100.

"The ATIS/ATMS Regional ITS Demonstration project report consists of three main parts: (1) an extensive, state-of-the-art literature review of data fusion technologies, (2) a detailed description of a current data amalgamation (fusion) project based at the University of Washington, and (3) the presentation of a new quantitative data fusion algorithm to estimate speed from volume and occupancy measurements. Data fusion technologies are categorized according to the level of detailed inference and user recommendations they provide from various data inputs. Five general methods of data fusion are discussed, with examples of specific fusion techniques; applications for those techniques are cited, and special attention is given to their implementation in ITS projects. In addition to a broad literature review, we describe two local data fusion projects that use highway sensor data to (1) aggregate loop data for reuse by traveler information systems and (2) generate reliable traffic speed estimates that can be used by regional commuters to guide their transit decisions. The architecture of the data fusion system based at the University of Washington consists of four major components. These components are partitioned among various computers that are located at different sites and connected by a local area network and T1 lines. Within these computers exist dedicated servers that handle specific processes. The TMSUWSUW server collects loop data from the RTDB main memory and then broadcasts them over a local area network. The loop rebroadcast server collects the broadcast data and retransmits them over a T1 line. The loop repeater server, located at the University of Washington, receives each data packet sent over the T1 link. This arrangement reduces the load on the loop rebroadcast server and provides for future expansion. The loop server, the final component of the system, provides highway data for end users. This data includes occupancy and volume information for each loop and station, as well as details on the average speed and length for each speed trap. This project has accomplished three significant tasks. First, a state-of-the-art literature review has provided an organizational framework for categorizing the various data fusion projects that have been conducted to date. A popular typology was discussed that situates data fusion technologies in one of three levels, depending on the degree to which sensor data are correlated to provide users with meaningful transit recommendations. The trade-offs that accompany higher-level data fusion efforts — in terms of computing power and memory requirements — were noted. The

advantages of multiple-sensor data fusion projects in terms of cost, accuracy and reliability were also discussed, and contrasts were drawn with the traditional deployment of highly accurate, single sensors. Specific techniques of data fusion were described and their possible application to ITS projects was explored. In fact, this report is one of the first to consider how data fusion technology might be productively applied to the needs of transportation management. A second major component of this report is the description of a local data fusion application. This project employs data fusion techniques to correlate input from multiple highway sensors and generate reliable traffic predictions. The resulting information can be displayed for use by commuters as they choose from among various transit options. The architecture of this data fusion system is described in detail. The third component of the project was to create a statistically based algorithm to estimate speed from volume and occupancy measurements. The algorithm presented explicitly accounts for the statistics of the problem and provides a robustness test for the speed estimate.."

Dailey, D. J. and L. Li (ITS Research Program for TransNow) (Mar. 1999). Video Image Processing to Create a Speed Sensor. research paper. Seattle, WA**:** i-iii, 1-41.

Image processing has been applied to traffic analysis in recent years, with different goals. In this report, a new approach is presented for extracting vehicular speed information, given a sequence of real-time traffic images. We extract moving edges and process the resulting edge information to obtain quantitative geometric measurements of vehicles. This differs from existing approaches because we use simple geometric relations obtained directly from the image instead of using reference objects to perform camera calibrations. Our method allows the recovery of the physical descriptions of traffic scenes without explicit camera calibrations. In this report, extensive experiments using images from active TMS (Transportation Management System) freeway cameras are reported. The results presented in this report demonstrate the validity of our approach that requires neither direct camera control nor placement of a calibration object in the environment. We further argue that it is straightforward to extend our method to other related traffic applications.

Dailey, D. J., H. Xu, et al. (10/14 -18/96). Data Fusion for Multimodal Traveler Information in a Wireless Environment. Orlando, FL, University of Washington**:** pp.1-8.

Two aspects of data fusion for a multimodal traveler information application are: (1) system architecture, and (2) analytical estimation of the state variable speed from the observed quantities volume and occupancy. The paper describes how the analytical estimation procedure is integrated into the overall architecture.

"This paper presents two aspects of data fusion for a multimodal traveler information application. The two aspects are: (1) system architecture and (2) analytical estimation of the state variable speed from the observed quantities Volume and Occupancy. The paper describes how the analytical estimation procedure is integrated into
the overall architecture

In this paper, we describe a structured approach to developing an Intelligent Transportation System (ITS) data fusion application. We use this approach to develop a distributed computing application that is suitable for distributing dynamic data in real time to a large group of users. Our discussion focuses on two aspects of data fusion for traveler information. The first aspect is the communication architecture that provides support for multiple data sources and sinks. The second aspect is the specific data fusion algorithm, which estimates mean vehicle speeds using single inductance loops sensors. These two aspects of data fusion are combined and used to demonstrate how a specific algorithm is implemented in the context of the overall data fusion architecture of an ITS application. The application under consideration was created and deployed in support of a wireless Multimodal traveler information system, the Seattle Wide-area Information for Travelers (SWIFT) project, a federal highway administration (FHWA) operational test (FOT). The paradigms used in developing the SWIFT data fusion application fit within the context of the FHWA ITS Architecture"

Daum, F. (1/1/90). Fundamental limitations in Data Fusion.
A theoretical bound on the limitations of multisensor data fusion is described.

Decker, S. and S. Melnik (Sept/Oct 2000). The Semantic Web: The Roles of XML and RDF. IEEE Internet Computing**:** 63-74.
Discussion of ontologies for domain conceptualization and tradeoffs among XML and RDF (Resource Description Framework), each a W3C recommendation. XML and RDF are the current standards for establishing semantic interoperability on the Web, but XML addresses only document structure. RDF better facilitates interoperation because it provides a data model that can be extended to address sophisticated ontology representation techniques.

Desai, B. and R. Shinghal (1996). Resource Discovery: Modeling, Cataloguing and Searching. IEEE. Montreal, Canada**:** 70-75.
In seeking information resources on the Internet existing search systems exhibit uneven selectivity. This problem has prompted a number of researchers to turn their attention to the development and implementation of metadata models for use

in indexing and searching on the WWW and Internet. The objective of our project is to design a system to enable users to access data of a catalog nature stored in heterogeneous distributed information systems. These data describe resources available from virtual libraries on the Internet, in general, and the World Wide Web, in particular. We present our version of metadata for modeling document like resources. We also present our approach to modeling the expertise of librarians for cataloging, user entry and search using a rule-based system is also discussed.

Downie, J. (Feb. 2001). In-Vehicle Telematics - Key Market Trends, Opportunities, Issues and Challenges: Presentation to Microsoft Telematics Conference.

(presentation) Key telematics market trend and issues.

DSRC (1997). Web Resources for DSRC Standardization. Austin, TX.

A list of Web site with background information on key issues underlying DSRC standards

Durand, A. (Jan/Feb 2001). Deploying IPv6. IEEE Internet Computing**:** 79-81.

IPv6 is a natural evolution from Version 4 of the Internet Protocol (IPv4) and attempts to address many of the older protocol's shortcomings. The core specifications have been standardized through the LETF IPng working group, and the NGtrans working group is studying issues surrounding the challenging task of smoothly transitioning from IPv4 to IPv6.

EIA and USDOT (Apr 2001). CEA/EIA-794: Data Radio Channel (DARC) System ITS Standards (Fact Sheet). ITS Standards Fact Sheet. Washington, DC.

Coversheet. EIA-794, Data Radio Channel (DARC) System specifies the technical details for a system for the delivery of data services to mobile, portable, and fixed receivers using subcarrier signals within the standard FM broadcast band. It specifies the modulation and coding schemes and content to the transmitted signal and describes the organization of the multiplex for the DARC system.

EIA and USDOT (December 1999). CEA/EIA-795: Subcarrier Traffic Information Channel (STIC) System
(fact sheet).

The Subcarrier Traffic Information Channel (STIC) system is a digital system designed for ITS and other applications using subcarriers on broadcast FM stations. This standard defines the system and focuses on the broadcast protocols for the lower layers of the open system interconnection (OSI), Technology and

Standards R6-Mobile Electronics Committee and is published as an Electronics Industry Alliance (EIA) document.

ENTERPRISE, DELCAN, et al. (8/12/00). ITS Internet Applications, ENTERPRISE, DELCAN, NET.

(presentation) A presentation on frameworks for developing an open architecture for information dissemination and presentation of data over the Internet; establishing guidelines for the exchange of data in graphical, tabular and textual formats; and co-ordinate and promote guidelines.

ETTM (6/11/01). FCC Proposes to Allocate Spectrum in 5.9 GHz Range for ITS Uses.

(news) The FCC proposed to allocate 75 megahertz of spectrum for transportation services to improve highway safety and efficiency as part of the U.S. Department of Transportation's Intelligent Transportation Systems (ITS) national program.

Evanco, W. M. (Mar. 1996). A Data Fusion Framework for Meta-Evaluation of Intelligent Transportation System Effectiveness. MITRE, FHWA Project #0495 18B40A. Washington, DC, MITRE, FHWA.

The study presents a framework for the meta-evaluation of Intelligent Transportation System effectiveness. The framework is based on data fusion approaches that adjust for data biases and violations of other standard statistical assumptions. Operational test characteristics that have a bearing on meta-evaluation methodology are identified in the context of the experimental paradigm. Data fusion approaches are presented for various types of measures of effectiveness and techniques for handling biases of various kinds are developed.

Fastenrath, U. (January, 2002). Floating car data on a larger scale, FleetNet.

FCC (7/1/98). NPRM on Petition for DSRC at 5.8 GHz Published in Federal Register : 47 CFR Parts 2 and 90, Federal Register Online via GPO Access (wais.access.gpo.gov).

Federal Communications Commission (FCC) is proposing to allocate 75 megahertz of spectrum for use by Dedicated Short Range Communications (DSRC) of Intelligent Transportation Systems (ITS).

FCC (Office of the Secretary) (11/9/00). Before the Federal Communications Commission/ In the Matter of Wireless E911 Phase II Automatic Location Identification Requirements: Report of U.S. Wireless Corporation Regarding Network-Based Enhanced Services Docket No. 94-102. Docket No. 94-102. Washington, DC.

U.S. Wireless Corporation's report in response to the Federal Communication Commission's Third Report and Order in revision of the Commission's Rules to

Ensure Compatibility with Enhanced 911 Emergency Calling Systems, CC Docket No. 94-102, Third Report and Order, 14 FCC Rcd 17388 (1999)(E911 Third Report and Order).

FHWA (1/31/01). Information Requirements to Support Traffic Management Services on the National Highway System: Status Report to FHWA No. 4260-P1-2d. Status Report to FHWA No. 4260-P1-2d. Washington, DC.

(slide) Project update on developed High-Level Matrix (FHWA input) of freeway, arterial, and bridges and tunnels.

FHWA and DOT Intelligent Transportation System Architecture and Standards 23 CFR Parts 655 and 940. Washington, DC.

"ITS Architecture Final Rule": A final rule to implement section 5206(e) of the Transportation Equity Act for the 21st Century (TEA-21), enacted on June 9, 1998, which required Intelligent Transportation System (ITS) project funded through the highway trust fund to conform to the National ITS Architecture and applicable standards. This rule requires that the National ITS Architecture to be used to develop a local implementation of the National ITS Architecture, which is referred to as a "regional ITS architecture."

FHWA and FTA (Nov.2000). Communications for Intelligent Transportation Systems: Successful Practices A Cross-Cutting Study. Intelligent Transportation Systems. Washington, DC.

In support of the ITS program, DOT addresses the system-related needs to understand the requirements. Through a cross-cutting study of regions, telecommunications requirements, use of regional ITS architecture, and development of a telecommunications architecture for transportation applications are discussed.

FHWA and (Prepared by ARINC) (Jan. 1997). Task D/E Report: Assessment of Candidate Communications Systems and Technologies for Use with Intelligent Transportation Systems (ITS). McLean, VA.

(report) The summaries of the efforts performed under subtasks D&E of the ATIS Communications Technology Alternatives Task for the FHWA Turner Fairbanks Highway Research Center. Tasks D&E were to facilitate further examination of wireless communications technologies identified during Task C activities. Specific emphasis was placed upon technologies that are candidates for prototyping, modeling, or other in depth analysis. For those, operational concepts, test objectives, and modeling requirements were developed as appropriate.

FHWA and Texas Transportation Institute (March 1998). Travel Time Data Collection Handbook. Report No. FHWA-PL-98-35. Washington, DC.

FHWA Office of Travel Management (Jan. 2001). Guidance on Including ITS Elements in Transportation Projects.

"The purpose of the document is to provide guidance for including ITS equipment/technologies as part of traditional transportation construction or maintenance projects."

Flammia, G. (Jul/Aug 1999). The Skinny on MetaData. IEEE INTELLIGENT SYSTEMS.

Background (nontechnical) on metadata concepts and applications. RDF will slowly become a widely accepted standard on the Internet, especially for large-scale catalogs that combine domain knowledge about multiple domains.

Franklin, S. and C. Blodgett (1/1/93). An Example of Satellite Multisensor Data Fusion. Computers & Geosciences Vol. 19, No. 4**:** 577-583.

Fusion techniques used in spatial information generation

G. Grune and C. J. H. Jacobes (1990). Parsing Techniques: A Practical Guide. Chichester, England, Ellis Horwood Ltd.,.

various data parsing techniques

Gaudin, S. (7/2/2001). Network World Fusion, "Cell Phone Facts and Statistics".

Glassco, R., T. Passin, et al. (3/15/01). Conversion of ATIS ASN.1 to Traveler Information Markup Language, Market Systems.

Mitretek Systems has drafted a XML schema corresponding to SAE's J2354, "Message Sets for Advanced Traveler Information Systems (ATIS)." XML Scheme Part 0: Primer can be found at http//www.w3.org/TR/xmlschema-0/.

Gray, P. M. D., et al. (1997). KRAFT: Knowledge Fusion from Distributed Database and Knowledge Bases Proceedings of the 8th Intl. Workshop on DEXA '97. IEEE. Aberdeen.

The KRAFT project aims to investigate how a distributed architecture can support the transformation and reuse of a particular class of knowledge, namely constraints, and to fuse this knowledge so as to gain added value, by using it for constraint solving or data retrieval.

Grossmann, P. (1998). Multisensor Data Fusion. The GEC Journal of Technology, VOL15, No.1, 1998**:** 27-37.

Growing demand for better sensing and monitoring systems and for more effective means of processing the increasing flow of information has led to the wider implementation of multisensor data fusion techniques. With the recent rapid developments in sensor technology and in the advanced methods of signal and data processing, multisensor data fusion is becoming one of the most important new techniques to be used in many military, industrial and commercial applications. This article offers a brief overview of the fusion area illustrated by several examples of established techniques, their limitations, proposed new solutions and other new developments.

Hall, D. (1992). Mathematical Techniques in Multisensor Data Fusion. Mathematical Techniques in Multisensor Data Fusion. Norwood, MA, Artech House, Inc.

Multisensor data fusion mathematical techniques

Hall, D., et al., (3/31/97). Engineering Guidelines for Selection of Correlation Algorithms: Paper for David Betzler Lockeed Martin/Booz Allen.

The document introduces the concept of data fusion and provides engineering guidelines for a subset of the processing. The contents are: (1) Introduction of Multisensor Data Fusion; (2) Introduction of the data Association/Correlation Problem; (3) Process Model for Correlation; (3) Engineering Guidelines for Algorithm Selection; and (5) Applications of Engineering Guidelines to Data Fusion System Design.

Hall, D. and J. Llinas (1997). An Introduction of Multisensor Data Fusion. Proceedings of the IEEE, Vol. 85, No.1 Jan. 1997. University Park, PA, IEEE**:** 6-23.

Basic concepts of multi-sensor data fusion. Basis for project analytic framework. Multisensor data fusion is an emerging technology applied to Department of Defense (DoD) areas such as automated target recognition, battlefield surveillance, and guidance and control of autonomous vehicles, and to non-DoD applications such as monitoring of complex machinery, medical diagnosis, and smart buildings. Techniques for multisensor data fusion are drawn from a wide range of areas including artificial intelligence, pattern recognition, statistical estimation, and other areas. This paper provides a tutorial on data fusion, introducing data fusion applications, process models, and identification of applicable techniques. Comments are made on the state-of-the-art in data fusion.

Havinoviski, G. N. (1/10/00). Data Security and Privacy Task Force: Brief Overview of Activities: A Presentation to the ITS America ATIS Committee, Wilbur Smith Associates.

promoting awareness of ITS data security an privacy concerns.

Hicks, B. and M. Carter (12/1/00). What Have We Learned About Arterial Management.

Chapter 3 in a larger report: What Have We Learned About ITS. Presents what has been learned (levels of deployment, benefits, deployment challenges, and future steps) for four principal areas of arterial management: Adaptive Control Strategies, ATIS, automated enforcement, and integration. For ATIS, limited dissemination is in part due to lack of surveillance on arterial streets and the absence of commonly understood method of describing conditions on arterial streets. Advent of new technologies increase the likelihood that arterial information will make its way into traveler information systems.

Holt, S. and I. Mitretek Systems Weather Scenarios URL Listing Page.

list of weather related URL (NOAA/NWS sites).

Hong, L., A. Wei, et al. (1/1/97). Multi-Sensor Data Fusion Method To Discern Point Targets.

A subjective Bayesian Method is adopted to fuse recognized results from a given network configuration (3 data collection points).

Hu, P., E. Chang, et al. (11/30/00). "Initial ADUS Studies and Reviews: Cross-Cutting Studies and State-of-the-Practice Reviews Interim Report 1 Cross-Cutting Studies and State-of-the-Practice Reviews Interim Report 1".

"Intelligent Transportation Systems (ITS) provide and use information about transportation conditions to improve system performance in such areas as safety, mobility, efficiency and environment. Typically, ITS generates massive amounts of data about the current situation 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, even 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 US 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 includes reports covering the data and applications for various subject areas..

The subject areas include: (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 reported in a recent report ."

Hunter, J. and L. Armstrong (1999). A Comparison of Schemas for Video Metadata Representation. Computer Networks 31**:** 1431-1451.

To enable the resource recovery of audiovisual documents over the World Wide Web, it will be necessary to define content description standards or metadata standards of complex, multi-layered, time-depending information-rich audiovisual data streams. In particular, this is the primary goal of the emerging MPEG-7 standard, the "Multimedia Content Description Interface" under development by the MPEG group. In the past, a lot of effort has gone into generating descriptors and description schemes for video indexing but comparatively little research has been done on schemas capable of defining the structure, content and semantics of video documents and enabling validation and higher levels of automated content checking. This paper compares the capabilities of the RDF Schema. Extensible Markup Language (XML), Document-type Definitions (DTDs), Document Content Description (DCD), and Schema for Object-Oriented XML (SOX), for supporting and validating hierarchical video descriptions base on Dublin Core, MPEG-7 and a specific hierarchical structure. Finally, this paper proposes a hybrid schema base on features from each of these schemas which ill satisfy the MPEG-7 Description Definition Language (DDL) requirements. Keywords: Video; Metadata; Schema; Dublin Core; MPEG-7

Hunter, J. and R. Iannella (9/21-23/98). The Application of Metadata Standards to Video Indexing in Research and Advanced Technology for Digital Libraries: Second European Conference, ECDL '98 Heraklion, Crete, Greece. C. a. S. Nikolaou, C. (eds.). Crete, Greece, Springer.

(book part of proceeding The paper first outlines a multi-level video indexing approach based on Dublin Core extensions and the Resource Description Framework (RDF). The advantages and disadvantages of this approach are discussed in the context of the requirements of the proposed MPEG-7 ("Multimedia Content Description Interface") standard. Finally a hybrid approach is proposed based on the combined use of Dublin Core and the currently undefined MPEG-7 standard within the RDF that will provide a solution to the problem of satisfying widely differing user requirements.

ICDN Key Issues in Deploying ITS Applications at 5.9 GHz: A Discussion with ITS America's Paul Najarian.

(discussion) ICDN Editor discussed commercial and public sector applications of 5.9 GHz, the issues on standards, and its impacts on deployment decisions with an expert on 5.9 GHz ITS applications, Paul Najarian, Director of Telecommunications at ITS America.

IEEE and USDOT (August. 1999). The Survey and Analysis of Existing Standards and Those Under Development Applicable to the Needs of the Intelligent Transportation System (ITS) Short-Range and Wide-Area Wireless Communications. IEEE ITSPP#5. Washington, DC.

Cover sheet: IEEE ITSPP#5, The Survey and Analysis of Existing Standards and Those Under Development Applicable to the Needs of the Intelligent Transportation System (ITS) Short-Range and Wide-Area Wireless Communications, inventories existing international, national and regional standard for wireline and wireless (radio) communications that may be used to support ITS operations.

IEEE and USDOT (February 2000). IEEE Std 1455-1999: Standard for Message Sets for Vehicle/Roadside Communications
(fact sheet).

This standard is applicable to short-range communications (DSRC). Within the overall context of DSRC operations, this standard specifies the message set, data dictionary and communications protocol above the open system interconnection (OSI) data link layer for the DSRC wireless interface. These communications protocols define the low-level commands used to control transponder resources

and thereby enable message transfer. This standard also specifies the resources that may be present on a vehicle's transponder and the means by which the roadside equipment can control those on-board equipment resources.

IEEE and USDOT (July 2000). IEEE Std 1488-2000: Trial-Use Standard for Message asset Template for Intelligent Transportation Systems.

This message set template specifies the format and common terms and attributes for ITS message sets. Through the implementation of this standard, and other related standards, data can be unambiguously exchanged and reused by ITS systems.

IEEE and USDOT (July 2000). IEEE Std 1512-2000: Standard for Common Incident Management Message Sets (IMMS) for use by Emergency Management Centers (EMCs) (fact sheet).

This standard addresses the message communicated among different agencies' emergency management centers during and after the occurrence of an emergency incident. It has been carefully tailored to allow wide range of local variation in implementation, consistent with the National Intelligent Transportation System (ITS) Architecture. The standard included the base standard and its companion volumes. It provides a framework for the exchange of messages among emergency management centers. It dose not limit the data contained in the messages; rather, it allows the transmission of any mutually agreed-upon messages among centers, as well as messages composed of standard ITS data elements.

ISO TC 204 WG9, E., CEN, AASHOTO, ITE, NEMA (1/12/98). Transport Information and Control Systems - Data Interfaces Between Centers for Transport Information and Control Systems - **Part 1**: Message Definition Requirements. ISO 14827 - 1 international ISOSTD.

ISO 14827 consists of the following parts: Part 1: Message Definition Requirements; and Part 2: DATEX-ASN (Data Exchange Protocol in ASN.1) which is used to exchange data between central systems.

ISO TC 204 WG9, E., CEN, AASHOTO, ITE, NEMA (1/12/98). Transport Information and Control Systems - Data Interfaces Between Centers for Transport Information and Control Systems - **Part 2**: DATEX-ASN ISO 14827 - 2 international ISOSTD. ISO 14827 - 2 international ISOSTD.

ISO 14827 consists of the following parts: Part 1: Message Definition Requirements; and Part 2: DATEX-ASN (Data Exchange Protocol in ASN.1) which is used to exchange data between central systems.

ITE and AASHTO (10/30/00). TMDD & MS/ETMCC Guide.

Presents current set of standards for travel management data dictionary and message sets for external traffic management center communication.

ITE, AASHTO, et al. (August 2000). ITE-AASHTO TM2.01 (Draft): Message Sets for External Traffic Management Center Communication (MS/ETMCC).

This standard includes message sets that were developed specifically for ITS traffic management systems. It consists of nineteen message sets organized into six message groups. It was developed under the oversight of a national steering committee composed of representatives of both ITE and AASHTO and is being published as a joint standard.

ITE, AASHTO, et al. (August 2000). ITE-AASHTO TM 1.03 (Draft): Standard for Functional Level Traffic Management Data Dictionary (TMDD).

This standard was developed for ITS systems that manage traffic. It provides a functional level data dictionary consisting of and defining a set of data element necessary to support data flows within and among traffic management systems. Specifically, as a data dictionary standard, it provides meta attributes for each DE including definitions (semantics) and specific format (syntax) for individual DEs. The TMDD, as a national functional level data dictionary, provides a standardized national set of DEs that are intended to be the basis of individual application-level data dictionaries implemented at specific sites.

ITE and USDOT (March 2001). ITE 9603-1 (Draft): Advanced Transportation Controller (ATC) - Application Programming Interface (API).

This standard defines the specifications for an application program interface that acts as a universal interface between application programs and the ATC unit including the computer operating system, the central processing unit and the associated hardware. As illustrated in the diagram show below, the API facilities the development of application programs that would operate over a variety of different operating systems and hardware platforms. It also allows multiple programs to operate concurrently in the same controller. ATC manufactures would supply corresponding API library appropriate for their operating system and hardware platform.

ITE and USDOT (March 2001). ITE 9603-2 (Draft): Advanced Transportation Controller (ATC) Cabinet.

This standard defines an assembly that will house and support the ATC controller unit. This assembly, along with controller itself, is meant for installation in the

field. The majority of these units will most likely be installed at traffic signal controller equipment box locations. This design of the cabinet is modular to allow the assembly to be scaled to fit the desired location. For most installations, there are seven major subassemblies: cabinet housing; power distribution assembly; controller; modular bus assemblies (3); input assembly(s); cabinet monitoring system; and output assembly(s).

ITE and USDOT (March 2001). ITE 9603-3 (Draft): Advanced Transportation Controller (ATC).

The purpose of this standard is to define the architecture of the controller unit, which will allow for easy upgrades to the "engine board," or central processing module, of the unit. This is needed to accommodate newer and more powerful processors without having to replace the entire unit. It will also allow several different exterior packages to fit an EIA 19-inch rack, on a shelf, or in more specialized packages for specific applications. This unit with a standard API will allow a variety of application software to be operated on units from different manufactures. It also has the potential to operate several different applications at the same time on the same unit. For example, this unit will allow one controller to operate a traffic signal and a ramp meter.

ITS America (February 9-10, 2000). ATIS Data Collection Guidelines Workshop: Workshop Summary. Scottsdale, AZ, ITS America.

ITS America (Jan 2000). 511: National Traveler Information Number January 2001 Update (Interim Summary of Issues).

Interim Summary of Issues includes: Services Offered, Guidelines on Content Quality, Research Needs, Business Plans & Finance, and Next Steps

ITS America, USDOT ITS Joint Program Office, et al. (1/9-10/98). ITS as a Data Resource: Workshop Proceedings. Washington, DC.

In January 1998, ITS America, in association with the Federal Highway Administration, Federal Transit Administration, the Bureau of Transportation Statistics, and the Association of Metropolitan Planning Organization, sponsored a Workshop entitled: ITS As a Data Resource. At the onset, the purpose of the Workshop was to identify opportunities for tapping data produced by Intelligent Transportation System for use in: Transportation Planning Applications (covering both highway and transit); Transportation Operations (including state and local traffic engineering); and Commercial Vehicle and Intermodal Freight Planning.

ITS Cooperative Deployment Network Seasoning rWeather: Lessons Learned in Providing Road Weather Information to Travelers: A Discussion with Project Manager Bill Brown from Washington State DOT**:** 10 pages.

newsletter. The rWeather web site in Washington State is one of the more ambitious attempts yet to provide traveling public with timely information about roadway weather condition. The site enables travelers to access approximately 350 weather stations, traffic cameras, and pass reports across the state. ICDN Editor Jerry Werner discussed the evolution of the Web site with rWeather Project Manager Bill Brown from Washington State DOT.

Ivan, J. N. and V. Sethi (9/1/98). Data Fusion of Fixed Detector and Probe Vehicle Data for Incident Detection.

Describes a system for automatically detecting incidents using artificial neural networks and statistical prediction methods. When compared with the statistical methods, neural networks consistently performed at least as well as discriminant analysis models when adjusted to avoid false alarms.

IVHS America (5/20/1992). Strategic Plan for Intelligent Vehicle-Highway Systems in the United States. Washington, DC. **Report No: IVHS-AMER-92-3**.

The purpose of this Strategic Plan is to guide development and development of Intelligent Vehicle-Highway Systems (IVHS) in the United States. The plan includes: goals and objectives for a national IVHS program; challenges to deployment and ways to resolve them; suggested roles for public, private, and academic participants; a course of action; and cost estimates.

Jarno, K. (1999). System Specification of Wireless Multimedia Engines: A Data Fusion Approach. IEEE. Tampere, Finland, IEEE, Nokia, Wireless Data**:** 458-465.

Definition of the system architecture for a wireless platform serving multimedia applications. The paper presents a pragmatic approach to the specification of wireless multimedia terminals, covering the requirement capture, functional specification, and system architecture selection phases of wireless engines. The emphasis is on the definition of the system architecture for the wireless engine platform. The accurate technology evolution estimates and technology planning is regarded as the main driving force in the long-term, continuous technology development. Well-defined technology roadmaps shorten the time used for requirement capture process. An "appreciation based" approach concentrating on the most demanding, new terminal sub-systems is suggested for functional specification of open, multi-system terminal platforms. Also, an interactive and semi-automatic "data fusion" process is proposed for the engine architecture selection. In the data fusion process, advanced EDA tools are seen as design

assistants, serving the decision making towards a feasible system architecture, but not dominating or restricting the specification and design of multimedia driven engine platforms.

Johnson, R. C. (1/1/99). Data Fusion New Darling in Smart Technology.

Describes the emerging technology of data fusion. Data fusion's origin, how data fusion works, and current applications.

Junliang, Z. and Z. Yuming (4/1/99). A General Software Design for Multisensor Data Fusion.

Definition of six functional modules: data collection, D/B management, GIS, target display, and alarming data, simulation. Information flows and modular relationships are discussed

Kamakura, W. A. and M. Wedel (11/1/97). Statistical data fusion for cross-tabulation.

Presents a statistical data-fusion model that allows researchers to perform statistical tests of association using multiple imputations. The article also describes a basic notation for statistical data-fusion, case studies, parameter estimates of the model in a consumer satisfaction research, and steps in computing the actual and imputed frequencies of data.

Khan, A. and M. A. Zohdy (1/1/97). A Genetic Algorithm for Selection of Noisy Sensor Data in Multisensor Data Fusion.

Addresses three basic problems of data fusion: selection, fusion, and estimation. Focus is on pre-processing of data for noisy sensor environments - Sources and Level 1 of the analytic framework.

Kizoom Transport for London's WAP Site. London.

(news) The Transport for London mobile site brings together information about London's Public Transport services into a single point of focus for easy access on WAP enabled mobile phones. The service is available at: http://tflwap.gov.uk.

Klapsing, R., et al (Apr/Jun 2001). Semantics in Web Engineering: Applying the Resource Description Framework. IEEE**:** 62-68.

An extensive Web modeling framework that applies the Resource Description Framework to Web engineering, providing an interoperable exchange format is presented. This framework uses the same (meta) data model to specify a Web application's structure and content, to make statements about a web application's elements, and to reason about the data and metadata.

Klein, L. (January 2000). Dempster-Shafer data fusion at the traffic management center. Transportation Research Board, 79th Annual Meeting. Paper no. 00-1211. Washington, DC, Transportation Research Board.

Klein, L., P. Yi, et al. (January 2002). Decision support system for advanced traffic management through data fusion and mining. Transportation Research Board, 81st Annual Meeting. Washington, DC, Transportation Research Board.

Klein, L. A. (1/9/00). Dempster-Shafer Data Fusion at the Traffic Management Center.

> "Although applications of several sensor and data fusion techniques (e.g., pattern recognition, artificial neural networks, fuzzy logic, expert systems, and Kalman filtering) to traffic management have occurred, other data fusion algorithms may potentially aid traffic management personnel in detecting and verifying incidents and other events that impact the normal flow of traffic. These algorithms include Dempster-Shafer inference, Bayesian inference, and voting logic for incident confirmation. This paper is concerned with the application of Dempster-Shafer inference at a traffic management center (TMC) to support incident detection and the identification of other events of concern to traffic managers. Dempster-Shafer inference, a statistical-based data fusion classification algorithm, is used when the sensors or other data sources contributing information cannot associate a 100 percent probability of certainty to their output decisions. The algorithm captures and combines whatever certainty exists in the object discrimination or event classification capability of the sensors and other sources of information. Knowledge from multiple sources about the events is combined using Dempster's rule to find the intersection or conjunction of the events and the associated probability. The application of the algorithm to incident detection and verification is illustrated with an example consisting of three possible events, where data are supplied from three different types of sources. The available information is combined using Dempster's rule and the most probable event is identified."

Lam, W., et al. (Nov/Dec 1999). Automatic Text Categorization and Its Application to Text Retrieval. IEEE Transactions on Knowledge and Data Engineering, Vol. 11, No. 6**:** 865-879.

> "We develop an automatic text categorization approach and investigate its application to text retrieval. The categorization approach is derived from a combination of a learning paradigm know as instance-based learning and an advanced document retrieval technique known as retrieval feedback. We demonstrate the effectiveness of our categorization approach using two real world document collections from the MEDLINE database. Next, we investigate the application of automatic categorization to text retrieval. Out experiments clearly

indicate that automatic categorization improves the retrieval performance compared with no categorization. We also demonstrate that the retrieval performance using automatic categorization achieves the same retrieval quality as the performance using manual categorization. Furthermore, detailed analysis of the retrieval performance on each individual test query is provided."

Lander, S. and V. Lesser (Mar/Apr 1997). Sharing Metainformation to Guide Cooperative Search Among Heterogeneous Reusable Agents. IEEE Transactions on Knowledge and Data Engineering, Vol. 9, No. 2**:** 193-208.

A reusable agent is a self-contain computational system that implement some specific expertise and that can be embedded into diverse applications requiring that expertise. Systems composed of heterogeneous reusable agents are potentially high adaptable, maintainable, and affordable, assuming that integration issues such as information sharing, coordination, and conflict management can be effectively addressed. In this article, we investigate sharing metalevel search information to improve system performance, specifically with respect to how sharing affect the quality of solution and the runtime efficiency of a reusable-agent system. We first give a formal description of sharable metainformation in system where agents have private knowledge and database and where agents are specifically intended to be reusable. We then present and analyze experimental results from a mechanical design system for steam condensers that demonstrate performance improvements relate to information sharing and assimilation. Finally, we discuss the practical benefits and limitations of information sharing in application system comprising heterogeneous reusable agents. Issues of pragmatic interests include determining what type of information can realistically be shared and determining when the costs of sharing outweigh the benefits.

Lappin, J. (2/9 -10/00). Advanced Traveler Information Service (ATIS): What do ATIS Customers Want? Cambridge, MA, EG&G Services/Volpe Center.

(presentation) Based on the work of the MMDI Customer Satisfaction evaluation team. Synthesizes findings from customer satisfaction research and evaluations dating back to 1996, including several field operational tests.

Lappin, J. (12/1/00). What Have We Learned about ATIS and Customer Satisfaction.

Chapter 4 in a larger report: What Have We Learned About ITS. Synthesizes customer satisfaction findings from ATIS research and evaluations dating from 1996. Finds that demand for ATIS is based on 4 factors: regional traffic context, quality of ATIS services, individual trip characteristics, and characteristics of the traveler.

Liu, Y., et al. (1998). Fuzzy Logic Fusion Capabilities for Efficient Implementation of Data Association Proceedings of ICSP '98. ICSP. Xi'an, China**:** 1315-1318.

"In this paper, we propose a data association algorithm employing fuzzy logic based on multisensor and the multi-feature of targets to solve the uncertainty of the data received from sensor measurements in high noised environment. The learning method to train fuzzy data association system with full-fuzzy model based on a steepest descent gradient is analyzed. The improvement of many primary sensors data fusion on data association is analyzed. The innovation lies to gain the improvement of data association performance by fusing many features of targets while at the same time not increasing the computational structure of the tracking filter. The theoretical analysis and example demonstrate the feasibility of efficient fusing data of different forms using fuzzy logic system for data association in multisensor multi-target tracking."

Lockheed Martin (Odetics Intelligent Transportation Systems Division) (December 1999). ITS Logical Architecture - Traceability Matrix. Washington, DC, Prepared for FHWA.

Traffic Surveillance shall include a Data Collect function to provide the capability to collect data that are needed for determining traffic flow and prediction.

Lockheed Martin Federal Systems (Odetics Intelligent Transportation Systems Division) (Jan. 1996). ITS Standards Development Plan. Washington, DC, USDOT FHWA.

The Standards Development Plan identifies potential standards areas, reviews existing standards efforts, describes a general process to assist standards development, and suggests beneficial actions to support and encourage ITS deployment. This document is intended for use as a guide to using the architecture. It is directed toward standards development organizations, product developers, service providers, and public agencies at all levels.

Lockheed Martin Federal Systems (Odetics Intelligent Transportation Systems Division) (Dec. 1999). Executive Summaries. Washington, DC, USDOT FHWA.

ITS opportune and overview of National ITS Architecture

Lomax, T., S. T. T. I. Turner, et al. (September 2001). Traffic Congestion and Travel Reliability: How bad is the situation and what is being done about it? A. U. o. W. O'Brien.

McKinsey Quarterly (April 7, 2002). The road to telematics. McKinsey Quarterly, Special to CNET News.com.

In the mid-90s, all telematics was expected to bolster the stagnant car industry by offering a flood of new revenue. But telematics, now seems less likely to alter the economics of the automotive industry so radically. Automakers should shift their strategies and focus on dominating a few core telematics applications -- not all of them.

Mitretek Systems, I. (1/24/00). Surface Transportation Weather Decision Support Requirement: Draft (truncated*) Version 1.0 Advanced-Integrated Decision Support Using Weather Information for Surface Transportation Decisions Makers. Washington, DC, MITRETEK.

The Surface Transportation Weather Decision Support Requirements (STWDSR) document, version 1.0 provides background for stakeholder participation in the development of requirements for a concept called the Weather Information for Surface Transportation Decision Support System (WISTDSS). This STWDSRV1.0 gives baseline information on current practice and deficiencies and outlines the methodology for stakeholder participation.

Murphy, R. R. (Nov/Dec 1998). Sensor and Information Fusion for Improved Vision-Based Vehicle Guidance. IEEE Intelligent Systems. FL**:** 49 - 56.

Sensor fusion is an important area of automated highways and intelligent vehicles research. This article discusses sensor fusion's role in vehicle guidance, general methods for fusing data, and how to organize sensor-fusion activities within a hybrid deliberative-reactive robot architecture.

Myllyla, J. and Y. Philli-Sihvola Floating car road weathering monitoring.

Nagao, K., et al. (2001). Semantic Annotation and Transcoding: Making Web Content More Accessible. IEEE**:** 69-81.

A method for constructing a superstructure on the Web using XML and external annotations to Web documents is proposed. Three approaches for annotating documents are: linguistic, commentary, and multimedia. The result is annotated documents that computers can understand and process more easily, allowing content to reach a wider audience with minimal overhead.

NEMA and USDOT (1996). NTCIP 1101: National Transportation Communications for ITS Protocol-Simple Transportation Management Protocol (STMF)
(formerly TS 3.2-1996)
(summary).

Describes the simple transportation management framework used for managing and communicating information between management stations and transportation

devices. Covers integrated management of transportation networks, networking devices, and transportation-specific equipment attached to NTCIP based networks.

NEMA and USDOT (1996). NTCIP 1201: National Transportation Communications for ITS Protocol (NTCIP) Global Object Definitions
(formerly TS 3.4-1996)
(summary).

The standard for messaging between Transportation Management and field devices is accomplished by using the NTCIP Application Layer services to convey requests to access or modify values stored in a given device; these values are referred to as objects. The purpose of this publication is to identify and define these objects definitions that my be supported by multiple device types (e.g., actuated signal controllers and variable message signs). The grouping of objects for a given device type is performed in the device-type-specific object definition standard.

NEMA and USDOT (1996). NTCIP 2001: National Transportation Communications for ITS Protocol-Class B Profile
(formerly TS 3.3-1996)
(summary).

A communications protocol standard for interconnecting transportation and traffic control equipment. It establishes a common method of interconnecting ITS field equipment, such as traffic controllers and variable message signs (VMS), define the protocol and procedures for establishing communications between those components, and references common data sets to be used by all such equipment.

NEMA and USDOT (2000). NTCIP 1405: Standard on Spatial Representation (SP) Objects
(summary).

NTCIP 1405's main application is to provide a vocabulary and format for representing common attributes for referencing object in space.

NEMA and USDOT (April 2001). NTCIP 2104 (Draft): National Transportation Communications for ITS Protocol (NTCIP)-Ethernet Subnetwork Profile.

This standard specifies base standards and protocols that are used to provide specific communication functions and services and requirements for specific types of coaxial cable, twisted wire pairs, and fiber-optic media at communication rates of 10 megabytes per second. It addresses layers 1 (physical) and 2 (data link layer) of the Open Systems Interconnection (OSI) Reference Model (ISO/IEC

7498), a seven-layered model that describes the basic functions and services of communication protocols. It specifies the requirements for an implementation based on the function and operation defined in the "Ethernet" family of standards. Ethernet is a type of networking technology that is used to allow a number of computers in a network to communicate with each other.

NEMA and USDOT (April 2001). NTCIP 8003 (Draft): National Transportation Communications for ITS Protocol (NTCIP) Profile Framework.

This standard provides the principles and classification schemes for NTCIP profiles. It also specifies aspects of the formatting and the technical content of NTCIP Profiles. In effect, it represents information management policy of the NTCIP Joint Committee. Its ultimate goal is to provide a basis for the development of uniform, nationally recognized communication profiles and conformance and compliance requirements for the profiles.

NEMA and USDOT (December 2000). NTCIP 1407 (Draft): Transit Communications Interface Profiles (TCIP) Control Center Business Area Standard
(Formerly ITE-TCIP-CC)
(Fact Sheet).

This standard defines the data needs of the functions related to control center (transit management center) applications and describes the semantics and data elements (called "objects") for control center systems.

NEMA and USDOT (February 2000). NTCIP 1400 (Draft): Transit Communications Interface Profiles (TCIP) Framework Standard.

This standard defines a transit classification scheme, naming conventions, rules for identification of data elements and messages, guidance on the use of the ASN.1 syntax, and levels of conformance for all TCIP standards. It covers data used to carry out public transportation operations, service, and planning. It pertains to all data that is sent or received in transit business areas such as fare collection (FC), scheduling (SCH), passenger information (PI), incident management (IM), onboard (OB), transit control center (CC), and traffic management (TM). Other transit business areas that support or cut across these business areas are also included, for example, spatial representation (SP) and common public transportation (CPT).

NEMA and USDOT (March 2001). NTCIP 1102 (Draft): NTCIP Octet Encoding Rules.

This standard is a presentation layer standard that defines NTCIP objects are encoded (i.e., the exact digital representation of the value of an object that is to be transmitted over a communications path). It is used in conjunction with

application layer protocols defined in other standards. This standard is applicable to both center-to-roadside and center-to-center communications. Unlike the other types of encoding rules used in standards-based implementations, such as ASN.1 basic encoding rules (BER) and packed encoding rules (PER), OER addresses the specific needs of certain application layer protocols used by the transportation community.

NEMA and USDOT (March 2001). NTCIP 2101 (Draft): National Transportation Communication for ITS Protocol (NTCIP)-Point to Multi-point Protocol Using RS-232 Subnetwork Profile.

This standard specifies a set of requirements for implementation of a communications network typically found in traffic signal controller systems. It permits other devices, such as dynamic message signs and ramp meter, to be integrated with controllers and to share a common communications media. It also defines a subset of base standards and protocols used to provide specific functions and services at layers 1 (physical) and 2 (data link) of the Open Systems Interconnection (OSI) Reference Model (ISO/IEC 7498). This seven-layers model describes the basic functions and services of communication protocols.

NEMA and USDOT (March 2001). NTCIP 2103 (Draft): National Transportation Communications for ITSP Protocol (NTCIP)-Subnet Profiler for Point-to-point Protocol over RS-232.

This standard specifies the requirements for an implementation based upon functions and operation as defined in the Internet Advisory Board (IAB) standard for the point-to-point protocol (PPP) and a physical interface based upon the RS-232 interface. PPP provides the definition of layer 2 of the Open System Interconnection (OSI) Reference Model services and functions. The RS-232 interface standard (now referred to as EIA/ITA-232) provides the definition of layer 1 services and functions. This subnetwork profile also provides the interface requirements between it and higher layer protocols (layers 3-7) or network profiles.

NEMA and USDOT (March 2001). NTCIP 2302 (Draft): -Application Profiler for Trivial File Transfer Protocol.

This standard defines the rules and procedures for simple file exchange between two entities. It is intended for applications that do not require complex interactions between the entities involved in the transfer. It specifies the requirements for the implementation of a simple file transfer mechanisms in a roadside device of traffic management center and adapts an Internet standard (IAB STD 33-RFC 1350:1992, RFRP Protocol) to transportation. It restricts

operations only to transfers and does not provide the basic functions and services of a communication protocol.

NEMA and USDOT (March 2001). NTCIP 2303 (Draft): National Transportation Communications for ITS Protocol (NTCIP)-Application Profile for File Transfer Protocol.

This standard combines various base standards and protocols into a coordinated set of functions and procedures related to large file transfers. It specifies a subset of features that must be supported by all implementations of the profile. It also specifies the requirements for the implementation of a full-featured file transfer mechanisms in transportation-related devices and traffic management centers and it describes requirements for interactive access, formatting data, and authentication control. It adapts an Internet standard (IAB STD 9-RFC 959:1985, FTP) to transportation.

NEMA and USDOT (March 2001). NTCIP 2304 (Draft): NTCIP Application Profile for Data Exchange ASN.1 (DATEX-ASN).

This standard is one of two center-to-center protocols defined by the NTCIP, the other being NTCIP 2305, Common Object Broker Architecture (CORBA). This standard specifies how DATEX-ASN is to be used within the United States. DATEX-ASN is also an international standard (ISO 14827 Parts 1 and 2) developed by the NTCIP Center-to-Center Working Group in cooperation with the International Organization for Standardization (ISO). The main DATEX-ASN specification permits various options; this standard ensures all implementations of DATEX-ASN within the US use the same base options and therefore can be made to interoperate. If different traffic or transit management centers were to select different options, it could lead to a failure to interoperate, even though both use DATEX-ASN.

Orski, C. K. (1/1/01). The Traveler Information Industry Today. Traffic Technology International.

Like much of the entire ITS industry, the traveler information sector is in a state of flux. Contributing to the ferment are rapidly evolving technology, rising competition, and changing expectations concerning market demand and profitability.

Palacharla, P. and P. Nelson (1/1/99). Application of Fuzzy Logic and Neural Networks for Dynamic Travel Time Estimations.

Use of a fuzzy reasoning model to convert loop detector data into link travel times obtained from empirical studies.

Paulson, L. (Jul/Aug 2000). Data Quality: A Rising E-Business Concern, IT Pro.

(article) Data quality isn't just cleaning up individual records - it's about making data continue to serve business needs.

Poe, R. and B. 2.0) (5/1/01). Traffic Control.

Traffic.com (Wayne, Pa.), has begun rolling out a system in partnership with the U.S. DOT to make radio traffic reports more accurate. Traffic.com's Traffic Pulse currently covers Pittsburgh and part of Philadelphia, and will extend its reach to 40 U.S. cities within three years. The network gets data from sensors posted atop 20-to 30 foot poles positioned along major commuter rotes. The sensors use microwave radar to measure the speed, number, and density of vehicles. Every 60 seconds, their wireless modems send collected information to a main data center in Philadelphia over networks run by AT&T and Verizon Communications.

Pond, L. (6/3/99). A comparison of three methods of data transfer for Center-to-Center communications, University of Washington ITS Research Group.

Pretorius, P. (2/9-10/00). ATIS Data Collection Guidelines Workshop. Scottsdale, Arizona, Kimley-Horn and Associates.

ATIS data collections and the data gap.

Project Statement Draft Statement of Work: Data Fusion for Delivering Advanced Traveler Information Services. FHWA HTV-3.

Statement of objectives for the research, Data Fusion for Delivering Advanced Traveler Information Services.

Radin, S. (2/9-10/00). Private Sector Perceptions and Public Sector Activities. Scottsdale, AZ, USDOT/Volpe Center.

"Synthesis of Metro ITS Deployment Surveys with the purpose of determining the nature and extent of the data gap: Private sector needs
Public & private sector data availability"

Raymund, P., T. L. Kunii, et al. (Jan/Feb 1999). Software Metrics Knowledge and Databases for Project Management. IEEE Transactions on Knowledge and Data Engineering, Vol. 11, No. 1, IEEE**:** 1041-4347.

"Construction and maintenance of large, high quality software projects is a complex, error-prone, and difficult process. Tools employing software database metrics can play an important role in efficient execution and management of such large projects. In this paper, we present a generic framework to address this

problem. This framework incorporates database and knowledge-base tools, a formal set of software test and evaluation metrics, and suite of advanced analytic technique for extracting information and knowledge from available data. The proposed combination of critical metrics and analytic tools can enable highly efficient and cost effective management of large and complex software projects. The framework has potential for greatly reducing venture risks and enhancing the production quality in the domain of large software project management."

Rupert, B. (1/25/01). 511 Traveler Information Telephone Number. 511 Workshop, USDOT FHWA.

511 Traveler Information and USDOT activities

Russo, F. (1/1/94). Fuzzy Methods for Multisensor Data Fusion.

Feature extraction and feature definition are performed by adopting a class of "fuzzy" (possibly multidimensional) membership functions that address the cases of possibility and admissibility.

SAE Advanced Traveler Information Systems Committee Project Scope.

(news) The purpose of SAE ATIS Data Dictionary and SAE J2354 ATIS Core Message List And Data Dictionary projects is to develop a minimum set of medium-independent messages and data elements needed by potential information service providers (ISP's) to deploy ATIS services, and provide the basis for future interoperability of ATIS devices.

SAE (1/10/01). SAE ATIS Standards: Current Status and Future Directions.

presentation. Society of Automotive Engineers Advanced Traveler Information Systems (ATIS) Standards (presentation and a related article on Web).

SAE and USDOT (Aug. 2000). SAE J2353: Advanced Traveler Information Systems (ATIS) Data Dictionary. ITS Standards Fact Sheet. Washington, DC.

Coversheet. SAE Advanced Traveler Information Systems (ATIS) Data Dictionary and its information.

SAE and USDOT (August 2000). SAE J1746: ISP Vehicle Location Referencing Standard.

This standard describes format and vocabulary for location referencing between centers, such as transportation management centers, and vehicles. A traffic management center must use this interface standard when sending or receiving

locational data and vehicles must expect to send and receive references thorough this interface standard as well.

SAE and USDOT (August 2000). SAE J2313: On-Board Land Vehicle Mayday Reporting Interface.

This standard is intended to standardize industry requirements regarding the message content which vehicles can be expected to exchange with receiving response agencies, and to establish a common message set, basic message support requirements, and simple protocols of data exchange. It prescribes various protocol methods so that vendors with different communication methods can "speak" to response agencies in a standardized format.

SAE and USDOT (December 2000). SAE J2354: Advanced Traveler Information Systems (ATIS) Message Sets.

This standard provides the messages that are exchanged among information provides, traffic management centers, and other ITS centers.

SAE and USDOT (October 1999). SAE J2374: Location Referencing Message Specification (LRMS) Information Report.

This information report describes seven LRMS profiles. Profiles are defined for commonly cited location referencing methods and for particular application communities that have unique requirements. Therefore, some profiles within the LRMS are more speculative than others and will be developed further as applications evolve and needs arise.

Saricks, C. L., J. L. Schofer, et al. (1995). Evaluating Effectiveness of Real-time Advanced Traveler Information Systems Using a Small Test Vehicle Fleet. Transportation Research Record 1588 Paper No. 970585.

ADVANCE was an in-vehicle advanced traveler information system (ATIS) providing route guidance in real time that operated in the northwestern portion and northwest suburbs of Chicago, IL. It used prove vehicles to generate dynamically travel time information about expressways arterials, and local streets. Tests found that the user features of an in-route guidance system must be able to accommodate a broad range of technological sophistication and network knowledge among the population likely to become regular users for such a system. For users who know the local network configuration, only a system giving reliable real-time data about nonrecurring congestion is likely to find a market base beyond specialized applications. Probe data greatly improve static (archival average) link travel time estimates by time of day, although the guidance algorithms that use these data should also include arterial traffic signal timings.

Moreover, probe- and detector- based incident detection on arterial networks shows considerable promise for improved performance and reliability.

Schileiffer, C., R. Reynaud, et al. (1995). High-performance Multi -Target Multi-Sensor Tracking for a Geographically Distributed System. IEEE. Orsay, France**:** 483-488.

The paper deals with two parts of the methodology of the fusion of multisensor data: conceptual and applied. In the conceptual part, we present a high-performance algorithm for tracking maneuvering targets using different sensors distributed on two geographical points. Each site is connected to the fusion center and transmits its observations. The results of computational examples using synthetic data and close models sensors are presented and discussed in the second part.

Schintler, L. and M. A. Farooque (2001). Partners In Motion and Traffic Congestion in the Washington, D.C. Metropolitan Area, Center for Transportation Policy and Logistics, School of Public Policy, George Mason University.

The study uses a traffic simulation model to aid in the evaluation of Partners In Motion of its objectives: improving the quality, quantity, and availability of travel information to transportation agencies, the media, and the public in the Washington, D.C. metropolitan area. The report evaluates Partners In Motion, as it has developed over the last two years and how it may evolve over the next decade, with respect to the goal of reducing congestion.

Schuman, R. (1/11/01). Environmental Scan for ATIS. Washington, DC, PBS&J.

Review ATIS vision/goals from program formation, and options on activities needed to continue progress (5-10 year horizon)

Schuman, R. (2/27/01). 511 Case Studies -- Arizona.

Case study focusing on the State of Arizona and its implementation of statewide 511 services. Explains existing services and plans to reprogram switches, expand capacity, include call forwarding to reach appropriate transit agency, and deploy signage to advertise 511.

Schuman, R. and U. I. J. P. Office (Nov. 2000). 511 Case Studies Kentucky.

A case study on the Commonwealth of Kentucky. The document contains five sections: History/Perspective - Pre-511; Institutional Background in Kentucky; Plans/Vision; Ongoing Activities; and Lesson Learned

Schuman, R. and PBS&J (1/10/01). 511 Update.

511 Case Studies (Arizona, Kentucky, Minnesota, San Francisco). State of Practice Review of ATIS Business Models

Schuman, R. and PBS&J (August 2001). Summary of Transportation Operations Data Issues.

Schwartz, J. (Nov. 2000). Cars Get Wired. The Forrester Report. Cambridge, MA**:** 1-18.

Telematics will bring the wireless Internet to cars. Safety and entertainment services will succeed quickly, but interactive navigation and information will struggle for three years with ill-defined packages and benefits. Companies strive to bring media into cars. But technical roadblocks and driver distraction issues cloud the prospect of car-based interactivity. The promise of telemetric is five years off. Even as safety and entertainment sell well in the next three years, consumers won't buy into navigation and information's confusing value proposition. But by 2005, device-aware consumers, a new wireless landscape, and open standards will help drive Net-based products and services into 30 million vehicles. Cars will provide their own real-time traffic data. Privacy concerns create a balance between risk and benefit. Personal headsets get a boost, and car dealers will get hardware upgrade business.

Senecal, K. (2000). The Twofold Promise of the CORC Project. OCLC Systems & Services Vol. 16(2)**:** 84-90.

The two-pronged approach of OCLC's CORC project is described by a participant in the project's beta test. One element is the building of a collection of catalog records of Internet accessible resources, reflecting two different metadata standards. The development of automated cataloging features and the issues of link maintenance are discussed. The second major element of the project is building database of metasites or "pathfinders" that serve as subject guides to the Internet. The two types of pathfinders are examined along with the important role that they can play in a library's organization of Web resources.

Shahbazian, E., P. Bergeron, et al. (1/1/99). Data Fusion Applications for Military and Civilian Purposes Developed on DND/LM Canada Decision Support Testbed.

Candidate Decision Support Systems, Blackboard Testbeds, and Data fusion algorithms transferred from military applications (LM - Lockheed Martin)

Skarpness, B. and Battelle (5/5/00). Evaluation of the FORETELL(TM) Consortium Operational Test: Weather Information for Surface Transportation, FHWA Weather and Winter Mobility Program Surface Transportation Weather Decision Support Requirements.

SmartRoute Systems (2/21/01). SmartRoute Systems Company Information (Public Sector Partnership Division).

Focuses exclusively in traveler information data collection, fusion, and dissemination. Creates public/private partnerships with government agencies to build out the traveler info center and staff and operate the center. Public sector commitment is to provide information to the database and to purchase services.

Smils, J. (1999). Spatial Metadata: An International Survey of Clearinghouses and Infrastructures**:** 321-343 (Book part?).

Key words: Spatial metadata; Geospatial Data Infrastructure; Geospatial clearinghouses; GGDI; GSDI; Visual Geographical Interface.

Smith, B., et al. Transportation Management Applications of Anonymous Mobile Call Sampling. Charlottesville, VA**:** pp. 1-4.(?) pages missing?

"This paper describes the ongoing evaluation study of anonymous mobile call sampling for transportation applications underway in the Washington, D.C. metropolitan area. The Universities of Maryland and Virginia, with support from their respective State Departments of Transportation, are investigating the potential of the RadioCamera technology invented by U.S. Wireless Corporation to provide critical data for traffic management applications. This method of data collection is contrasted with other probe and point detection mechanisms. Descriptions of prototype transportation management applications employing this technology are offered. Potential technical limitations are described, as well as means by which they might be obviated. The planned economic evaluation is outlined, including the economic measures to be quantified, the range over which valuation will be conducted, and the means by which benefits will be enumerated. Finally, some conclusions are offered."

Smith, B. L. and B. E. Smith (Nov. 2000). An Evaluation of the Need for Configuration Management in Transportation Management Systems. TRB. Charlottesville, VA, TRB**:** 2-32.

"Configuration management, a process developed to control change in complex information technology-based systems, has attracted an increasing amount of attention from the transportation engineering community. As the intelligent transportation systems (ITS) program accelerates, and transportation departments develop and operate increasingly complex transportation management systems, the need for configuration management grows. This research effort examines the need for configuration management within transportation management systems by exploring the foundations of configuration management, analyzing the key

functions of transportation management, surveying transportation officials, and conducting a case study to examine the configuration management process used by the Georgia Department of Transportation."

Smith, C. R. (1/1/92). A Bayesian Approach to Multisensor Data Fusion.
Definitions and concepts to formulate multi-sensor data fusion in the presence of noise and interference.

Southwest Research Institute (1/7/1998). In-vehicle navigation system Model Deployment Initiative Acceptance Test Plan: Version 1.1. San Antonio, TX, Prepared for Texas Department of Transportation, TransGuide. **SwRI Project No. 10-8684 P.O. No. 7-70030 Req. No. 60115-7-70030**.

Starr, A. and M. Desforges (1/1/99). Strategies for Data Fusion - Sorting Through the Tool Box.
Map and validate a general schema for data fusion problems.

Tan, K.-L., et al. (Sept/Oct 2000). Query Rewriting for SWIFT (First) Answers. IEEE Transactions on Knowledge and Data Engineering, Vol. 12, No. 5**:** 694-714.
Traditionally, the answer to a database query is construed as the set of all n-tuples that meet the criteria stated. Strict adherence to this notion in query evaluation is, however, increasingly unsatisfactory because decision makers are more prone to adopting an exploratory strategy of information search which we call "getting some answers quickly, and perhaps more later." From a decision-maker's perspective, such strategy is optimal for coping with information overload and make economic sense (when used in conjunction with a micropayment mechanism). These new requirements present new opportunities for database query optimization. In this paper, we propose a progressive query processing strategy that exploits this behavior to conserve system resources and to minimize query response time and user waiting time. This is accomplished by the heuristic decomposition of user queries into subqueries that can be evaluated on demand. To illustrate the practicality of the proposed methods, we describe the architecture of a prototype system that provides a nonintrusive implementation of our approach. Finally, we present experimental results obtained from an empirical study conducted using an Oracle Server that demonstrate the benefits of the progressive query processing strategy.

Telcordia Technologies, I. (Aug 2000). Telcordia Notes on .... the Evolution of Enhanced Emergency Services. Telcordia Technologies Special Report SR-NOTES-SERIES-04 Issue 1.

The document is intended for anyone with a need to know about current and future E9-1-1 service capabilities and architectures. This include local exchange carrier personnel; including E9-1-1 planning, operations, and marketing personnel; E9-1-1 network equipment suppliers; E9-1-1 PSAP customer Premises Equipment suppliers; and any public safety community personnel across the nation.

The 511 Deployment Coalition (January 2002). Deployment Assistance Report #1: Business Models and Cost Considerations.

The Weather Team and Office of Safety and Traffic Operations Research and Development FHWA USDOT (5/15/98). Weather Information For Surface Transportation: A White Paper on Needs, Issues and Actions.

The White Paper focused on the needs of surface transportation decisions for better support by weather information, integrated with other information in the ITS. Findings are included from a special team workshop and feedback from conference presentations, representing wide participation by transportation and meteorological experts, in the public and private sectors. The goals of the ITS program and of the FHWA National Strategic Plan are to be met by a conceptual Weather Information for Surface Transportation (WIST) System that will be part of the ITS for use by surface transportation operators and travelers. The goal of the WIST System is to achieve better outcomes in the surface transportation system, and weather information is a resource to decision making that can achieve this goal. Weather itself is a natural constraint on transportation, but weather information as part of better decision support can improve treatment of weather effects on surface transportation facilities, allow travelers to cope better with conditions, and expedite responses to weather-induced problems.

Thornely, J. (2000). Metadata and the Deployment of Dublin Core at State Library of Queensland and Education. OCLC Systems & Services, v16. n. 3. Queensland, Australia**:** 118-129.

Case studies of the deployment of Dublin Core at two significantly different institutions in Queensland, Australia.

Tiwana, A. and B. Raesh (May/Jun. 2001). Integrating Knowledge on the Web. IEEE Internet Computing, IEEE**:** 32-39.

The web provides a ubiquitous medium for seamlessly integrating distributed applications, formats, and content, making it well suited for enterprise knowledge management.

Transportation Research Board (January 2000). Evaluating Intelligent Transportation Systems, Advanced Traveler Information systems, and Other Artificial Intelligence Applications: Planning and Administration. Transportation Research Record: Journal of the Transportation Research Board. Washington, DC. **1739**.

Transportation Research Board (January 2000). Human Performance: Driver Behavior; Road Design, and Intelligent Transportation Systems
Safety and Human Performance. Transportation Research Record. Washington, DC, Transportation Research Board
National Research Council. **1724**.

Transportation Research Board (January, 2001). Artificial Intelligence and Intelligent Transportation Systems: Planning and Administration. Transportation Research Record: Journal of the Transportation Research Board. **1774**.

This issue includes: Autonomous Agents for Traffic Simulation and Control (pp.1-10); PEDFLOW: Development of an Autonomous Agent Model Pedestrian Flow (pp. 11-7); Hybrid Simulated Anneling and Case-Based Reasoning Approach for Computationally Intensive Transportation Problems: Rationale and Design Issues (pp. 18-24); Use of Fuzzy Interference for Modeling Prediction of Transit Ridership at Individual Stops (pp. 25-35); Advanced Technology and Integrated Public Transit: San Gabriel Valley Smart Shuttle Field Operational Test (pp. 44-51); Measuring Aggregate Productivity Benefits from Intelligent Transportation System Applications: The California Experience (pp. 52-59);Benefits Evaluation of Basic Information Dissemination Services (pp. 60-70); Use of the National Architecture to Develop an Intelligent Systems Strategic Plan: Case Study for a Medium-Sized Area (pp. 71-9); Development of Canadian Architecture for Intelligent Transportation Systems (pp. 80-9); Evaluation of the Environmental Effects of Intelligent Cruise Control Vehicles (pp. 90-7); Implementing Adaptive Driving Systems for Intelligent Vehicles by Using Neuro-Fuzzy Networks (pp. 98-105); Automated Vehicle Identification Tag-Matching Algorithms for Estimating Vehicle Travel Times: Comparative Assessment (pp. 106-14); and Evaluation Framework for Dynamic Vehicle Routing Strategies Under Real-Time Information (pp. 115-122).

Turner, S. T. T. I. (September 2001). Guidelines for Developing ITS Data Archiving Systems. College Station, TX, Sponsor: Texas Depart men of Transportation, USDOT FHWA.

U.S. Wireless Corporation (12/13/00). U.S. Wireless Accelerates Location of Network Deployment in Washington DC.

Announcement of selection of Wireless Facilities, Inc as the prime contractor in the current build-out of Washington DC location and traffic network. This deployment phase expands U.S. Wireless' network coverage to include the entire Beltway, as well as the B-W Parkway, all of Arlington County, and portions of Tysons Corner.

USDOT logical flow national architecture.

USDOT (3/21/00). National Civilian GPS Services. Washington, DC.

USDOT initiative on potential of satellite navigation to improve both safety and efficiency of the national transformation infrastructure. Definition and policy on civilian GPS service augmentation for air and surface-transportation are delineated.

USDOT, C. Alliance, et al. (10/23/00). Recommendations of the National Mayday Readiness Initiative.

USDOT and FHWA (7/6/99). U.S. Transportation Secretary Slater Announces 17 Critical Standards for Intelligent Transportation Systems. Washington, DC.

(news) U.S. Department of Transportation has identified 17 standards as critical to the smooth operation of intelligent transportation systems (ITS) throughout the United States, including one that will enable an equipped vehicle to receive traveler information anywhere in the country.

USDOT and (FTA) (Feb. 2000). Assessment of the Seattle Smart Traveler. Washington, DC**:** 1-39.

The report documents the development, operation, and evaluation of the Seattle Smart Traveler (SST), a dynamic ridematching system at the University of Washington.

USDOT FHWA (Dec. 2000). What Have We Learned About Intelligent Transportation Systems?

Overall evaluation of the National ITS Program. The seven areas reviewed are: Freeway, Incident, and Emergency Management, and Electronic Toll Collection; Arterial Management; Traveler Information Systems; Advanced Public Transportation Systems; Commercial Vehicle Operations; and Cross-Cutting Technical and Programmatic Issues.

USDOT ITS Joint Program Office (12/20/00). Background Discussion on Guidance: Telecommunications Installations Limited Access Highway Right-of-Way.

The document presents the key elements of the Federal Communication Commission (FCC) decision on the Minnesota agreement and then discuss the rationale for guidelines with respect to that decision to arrive at an approach than addresses both transportation statutory and regulatory issues, as well as those issues posed by the Telecommunications Act of 1996 ("TCA'). In developing these guidelines, the staffs of the Federal Highway Administration (FHWA) and the FCC Common Carrier Bureau have worked together to understand the issues of the various statutory, regulatory, and policy frameworks.

USDOT ITS Joint Program Office (Aug. 1998). Developing Traveler Information Systems Using the National ITS Architecture. FHWA-JPO-98-031. Washington, DC.

This is one of documents providing support for deploying Intelligent Transportation Systems (ITS). This series addresses Traffic Signal Control Systems, Freeway and Incident Management Systems, Transit Management Systems, and Traveler Information Systems. The National ITS Architecture provides a common structure for deploying these systems. The document focuses on traveler information system, a component of ITS. It aims to provide practical help for the transportation community with deploying traveler information system in an integrated, multimodal environment using the National ITS Architecture. The document covers the basics of traveler information ITS applications (including public-private partnerships), the role the National ITS Architecture can play in traveler information system project development, the development process for a regional architecture, some challenges faced by transportation management agencies, and some best practices and lessons learned for developing and deploying advanced traveler information systems. The regional architecture will indicate how current and future systems in the region may be integrated to obtain the added benefits available through information of these systems.

USDOT ITS Joint Program Office (Oct. 1997). Developing Traveler Information Systems Using the National ITS Architecture Technical Edition. Washington, DC**:** 1-65.

The document provides practical guidance to the traveler information systems community for deploying intelligent Transportation Systems (ITS) consistent with the National ITS Architecture.

USDOT ITS Joint Program Office (Oct. 2000). Broadband Wireless & Integrated Services.

"The report discusses some of the newer broadband wireless communications alternatives and describes how they could be used to provide high-speed

connections between fixed, transportable, and mobile facilities. it also introduced the new integrate service technologies - devices used to bundle voice, data, and video services for transmission over a single link. In this case, it's a broadband wireless link. Together, the new broadband wireless and integrated service technologies can be used to provide efficient, cost-effective, and flexible multi-service provisioning. The report introduces this concept and discusses the potential for ITS applications."

USDOT ITS Joint Program Office, FHWA, et al. (9/30/00). Department of Transportation's Intelligent Transportation Systems (ITS) Projects Book.

The document describes ITS projects, tests, and studies initiated through September 30, 2000, that partially or totally have been financed from Federal ITS funds. Completed projects plus those projects anticipated to be completed by the end of December 2000, as well as ongoing projects are included in the document.

USDOT ITS Joint Program Office and A. R. Kane (12/22/00). Guidance on Longitudinal Telecommunications December 22, 2000 Installations on Limited Access Highway Right-of-Way.

A number of States have altered their utility accommodations policies to allow longitudinal access to their limited access highway Right-of-Way (ROW) for telecommunications installations; usually fiber optic cable. Several of these installations to date have been public-private partnerships with the telecommunication industry generally referred to as AShared Resource@agreements. In December 1999, the Federal Communications Commission (FCC) issued an opinion in the Minnesota Department of Transportation (DOT) case involving such a partnership that defined the FCC's interpretation of the Telecommunications Act of 1996 (TCA) and its application to the Minnesota agreement, which has potentially broad implications for transportation agencies. As a result of the FCC's opinion, the Federal Highway Administration (FHWA) engaged in a discussion with the FCC to clarify how these partnerships and other similar telecommunications installations should be conducted to avoid conflict with the TCA and be consistent with FHWA's requirements for highway safety and ROW management."

van Eck, P., J. Engelfriet, et al. (May/June 2001). A Survey of Languages for Specifying Dynamics: A Knowledge Engineering Perspective. IEEE Transactions on Knowledge and Data Engineering, Vol. 13, No. 3, IEEE**:** 1041-4347.

"During the last years, a number of formal specification languages for knowledge-based systems has developed. Characteristics for knowledge-based systems are a complex knowledge base and an inference engine that uses this knowledge to

solve a given problem. Specification languages for knowledge-based systems have to cover both aspects. They have to provide the means to specify a complex and large amount of knowledge and they have to provide the means to specify the dynamic reasoning behavior of a knowledge-based system. This paper focuses on the second aspect. For this purpose, we survey existing approaches for specifying dynamic behavior in related areas of research. In fact, we have taken approaches for the specification of information systems (Language for Conceptual Modeling and TROLL), approaches for the specification of database updates and logic programming (Transaction Logic and Dynamic Database Logic) and the generic specification framework of Abstract State Machines."

Vetterli, T., A. Vaduva, et al. Metadata Standards for Data Warehousing: Open Information Model vs. Common Warehouse Metamodel. Switzerland, The work partially supported by Swiss Federal Office of Professional Education and Technology under grant KTI-3979.1 (SMART).

Two standards for metadata in the context of their uses in the data warehousing context are examined.

Vidal, J., P. Buhler, et al. (Jan/Feb 2001). Inside an Agent. IEEE Internet Computing.**:** 82-86.

The implementation and internal appearance of Internet agents are discussed. It is necessary to understand an agent's architecture for multiagent system platforms and in creating agent-based systems.

Virginia Department of Transportation (April, 2000). Policy on Access to Smart Traffic Center Data and Video Imagery (DRAFT).

VDOT policy to disseminate the data and video imagery for its transportation management system as widely as possible in order to: reduce crashes and otherwise improve the safety of the surface transportation system; inform the public and enhance the quality of transportation services; facilitate route and mode choice among transportation system users; and foster the development of traveler services information by the private sector. Access to the imagery/data shall be tightly governed by VDOT to ensure the security of the systems. The number, location and method of access to the imagery/data will be determined by VDOT.

W3C (Mar. 2000). XML Protocol Comparisons.

The purpose of the document is to compare and contrast a variety of XML protocols.

Wang, H. and C. T. Goh (1/1/99). Fuzzy Logic Kalman Filter Estimation for Two-Wheel Steerable Vehicles.

Use of DGPS, gyroscopic, and odometer data are fused to identify vehicle location using Kalman filtering.

Waugh, A. (1998). Specifying Metadata Standards for Metadata Tool. Configuration Computer Networks and ISDN Systems 30 (1998). Australia**:** 23-32.

A critical problem for metadata application is flexibility. A metadata application must be sufficiently flexible to cope with changes to metadata standards over time and to allow users to extend a standard to cope with local requirements. A key component of supporting flexible metadata applications is software that can be dynamically configured by a specification of the metadata standard. By contrast, in current metadata software the embedded standard is embedded in the code, making changes relatively more difficult and expensive. Configurable software also leas to better tools at a lower coast, as it is not necessary to re-implement functionality for every new metadata standard. This paper describes a metadata specification designed to support dynamic configuration of metadata software by capturing features of metadata standards. The specification comprises three components: the classification of the metadata standard, the metadata schema, and the metadata expression.

Weatherby, B., H. Rahka, et al. (10/19/98). SWIFT: Seattle Wide-area Information for Travelers Architecture Study. McLean, VA, SAIC.

The SWIFT (Seattle Wide-area Information For Travelers) Field Operational Test was intended to evaluate the performance of a large-scale urban Advanced Traveler Information System (ATIS) deployment in the Seattle area. The features of the SWIFT ATIS were the provision of information for multiple transportation modes, the delivery of this information using three different devices, and the use of the FM sideband as the primary communication medium. The SWIFT Architecture Study is one of five component studies to the overall system evaluation. The report details the results of the SWIFT Architecture Study based on the evaluation objectives that were initially identified in the SWIFT Architecture Study test plan (1996). Specifically, four evaluation objectives are identified in the SWIFT Architecture Study test plan. The first two of these objectives relate to the system performance when the system is operating according to its functional specifications, and is essentially free of any component of failures. In contrast, the third and fourth objectives focus on what happens when part of the system becomes unavailable due to system component failures. For each of these conditions, the performance of the architecture will be

examined from both the user (objectives 1 and 3) and system (objectives 2 and 4) perspective.

Wheatley, S. (5/21/01). Toad CE Explains Developing Telematics Business in Wall Street Transcript Interview.

interview Toad PLC's CE Stephen Wheatley told that the company planed to develop a market position in telematics, while continued developing its core businesses, corporate, Audio Express (wholesaling business), and its security business.

Wheatman, V. (12/7/01). New XML Framework to Enable E-Commerce Digital Signature and Data Encryption, Gartner FirstTake.

(news) A consortium of technology companies, led by Microsoft, VeriSign and webMethods, announced XKMS, which will allow software developers to integrate digital signatures and data encryption into the programming language of e-commerce applications. The consortium will submit the XKMS specification to Web standards bodies for consideration as an open Internet standard. Moreover, Microsoft intends to incorporate support for XKMS into its .NET architecture for use in business-to business and business-to-consumer environments.

Witty, R. and J. Pescatore (11/20/00). XML-Based Authorization Standards Promise Path to Interoperability, Gartner FirstTake.

(news) Secruant announced that it is facilitating a working group to further the development of AuthXML, the company's XML-based product for securing e-commerce transactions. Netegrity announced that it is working with a group of companies to develop Security Services Markup Language (S2ML), its XML-based standard for securing e-commerce transactions.

Wunderlich, K., M. Hardy, et al. (Jan, 2001.). On-Time Reliability Impacts of Advanced Traveler Information Services (ATIS): Washington DC Case Study, FHWA, MITRETEK.

Using results from a large-scale case study in Washington DC, study shows that even though over time ATIS users realize only marginal reduced in-vehicle travel time, they do realize substantial time management benefits from improved on-time reliability and trip predictability

Yang, X. and L. Jiao (1998). Fast Global Optimization Neural Network and Its Application in Data Fusion Proceedings of ICSP '98. ICSP. Xi'an, China**:** 1351-1354.

The paper presents a neural network with a fast global optimization algorithm and its application in the data fusion. This neural network is based on the global

property of generic algorithm and the high speed property of expectation maximization (EM) algorithm. Simulation results show the this neural network is of robustness in the data fusion.

Zhang, X. (1998). An Information Model and Method of Feature Proceedings of ICSP '98. ICSP. Dalian, China**:** 1389 -1392.

For a specific pattern recognition problem, many kinds of feature information can be extracted by different signal analysis means. How to use efficiently such kinds of feature information is widely concerned in the field of pattern recognition. This paper presents an information network model that considers the algorithms of feature extractions, feature fusion and classification as information engines. A measuring criterion of feature fusion is proposed by analyzing the feature fusion mechanism. In addition, a fusion method based on dynamic programming is presented. In the sense of dynamic programming, a complex process obtaining the global satisfactory solution could be dramatically simplified. The application in the classification of underwater acoustic signals obtained satisfactory result.

Zhou, Y. and H. Leung (1/1/98). A Maximum Likelihood Estimator for Multisensor Data Fusion Applications.

Algorithms for calculations of the scaling parameters under noisy input conditions, assuming knowledge of noise covariance

Zhou, Y., H. Leung, et al. (1/1/97). Sensor Alignment Using the Earth-Centered Earth-Fixed Coordinate System.

Reference systems for GIS and data fusion techniques.

Zimmerman, C. B., M. B. Raman, et al. (January 2002). Sharing Data for Public Information: Practices and Policies of Public Agencies. Washington, DC, Sponsoring Agency: ITS Joint Program Office
USDOT.

As the primary source of basic data on travel conditions, public agencies through their data sharing practices can have a powerful effect on deployment of 511 telephone numbers and other types of traveler information services. This report documents the current state of the practice, describing how the public and private sectors deal with data ownership and sharing, and examines policies aimed at facilitating data sharing and ultimately improving the quality and quantity of information that reaches travelers. "Data" in this report encompasses digital, video, and verbal forms of information.

The report is based on information collected from two sources. Surveys were conducted with thirty-four public agencies and seven private firms. The surveys consisted of interviews with representatives of public and private sector entities that are active participants in data sharing. The 30-minute interviews included a variety of questions about data sharing practices, such as the types of information shared, recipients of the data, and types of conditions placed on users of the data. The surveys were complemented with a review of the literature about data sharing practices related to traveler information and other types of data.

Major findings of the research are presented along with policy issues related to data sharing. The policy considerations relate to the philosophy about the nature of public sector data and the public sector's role and responsibilities in making data available to other parties.

Data Quality References

Arnold, J. (Jan/Feb 2001). New Applications Make NDGPS More Pervasive, FHWA Turner-Fairbanks HWY Research Center.

Nationwide Differential Global Positioning System (NDGPS) will increase the accuracy of the positioning information obtained via radio signals emitted by the 24 Global Positioning System (GPS) satellites traveling in orbit around the Earth.

ASTM and USDOT (June 2000). ASTN PS 105-99:Specification for Dedicated Short Range Communication (DSRC) Data Link Layer: Medium Access and Logical Link Control.

Standards for dedicated short-range communication (DSRC) are intended to meet the communications requirements between vehicles and roadside devices, as defined in the National ITS Architecture. The standard includes requirements that minimize interference between neighboring sites and between active and backscatter systems. To operate at the power levels allowed in this standard consistent with the out-of-band emissions requirements and to minimize interference between systems and sites, specific frequency designations are made for both active and backscatter up link and down link operations. A critical implication of the use of this standard is the assumption that the data rate will be 500 kilobytes per second on both the up-link and down-link.

Baldonado, M., et al. (1997). The Stanford Digital Library Metadata Architecture. International Journal of Digital Libraries (1997) 1**:** 108-121.

The overall goal of the Sanford Digital Library project is to provide an infrastructure that affords interoperability among heterogeneous, autonomous digital library services. These services include both search services and remotely usable information processing facilities. In this paper, we survey and categorize the metadata required for a diverse set of Stanford Digital Library services that we have built. We then propose an extensible metadata architecture that meets these requirements. Our metadata architecture fits into our established infrastructure and promotes interoperability among existing and de-facto metadata standards. Several pieces of this architecture are implemented; other are under construction. The architecture includes attribute model proxies, attribute model translation services, metadata information facilities for search service, and local metadata repositories. In presenting and discussion the pieces of the architecture, we show how they address our motivating equipments. Together, these components provide, exchange, and describe metadata for information objects and metadata for information services. We also consider how our architecture relates to prior, relevant work on these types of metadata. Key words: Metadata architecture;

Interoperability; Attribute model; metadata repository; Proxy architecture; Heterogeneity; Metadata survey.

Bergholz, A. (Jul/Aug 2000). Extending Your Markup: AN XML Tutorial. IEEE Internet Computing.

Tutorial on XML. Definition and capabilities of XML, which introduces a family of languages to provide a more semantic management of information than HTML

Biezunski, M. and S. R. (Apr/Jun 2001). XML Topic Maps: Finding Aids for the Web. IEEE. P. Liu, IEEE**:** 104-108.

Topic maps superimpose an external layer that describes the nature of the knowledge represented in the information resources. There are no limitations on the kinds of information that can be characterized by topic maps. The purpose of the Extensive Markup Language topic maps (XTM) initiative is to apply the topic maps paradigm in the context of the World Wide Web.

Biron, P. and A. W. C. Malhotra (10/24/00). XML Schema Part 2: Datatypes.

The Part 2 datatypes (Schema) allow for the definition of datatypes to be used in specifications for XML, ver 1.0. XML Schema: Datatype is part 2 of the specification of the XL Schema language. It defines facilities for defining datatypes to be used specifications. The datatype language, which is itself represented in XML 1.0, provides a superset of the capabilities found in XML 1.0 document type definitions (DTDs) for specifying datatypes on elements and attributes.

Bongki Moon, J., et al. (Jan/Feb 2000). Analysis of the Clustering Properties of the Hilbert Space-Filling Curve IEEE Transactions on Knowledge and Data Engineering, Vol. 13, No. 1. IEEE**:** 124-129 (?) (page missing).

Several schemes for the linear mapping of a multidimensional space have been proposed for various applications, such as access methods for spatial-temporal databases and image compression. In these applications, one of the most desired properties from such linear mapping is clustering, which means the locality between objects in the multidimensional space being preserved in the linear space. It is widely believed that the Hilbert space-filling curve achieves the best clustering. In this paper, we analyze the clustering property of the Hilbert space-filling curve by deriving closed-form formulas for the number of clusters in a given query region of an arbitrary shape (e.g., polygons and polyhedral). Both the asymptotic solution for the general case and the exact solution for a special case generalize previous work. They agree with the empirical results that the number of clusters depends on the hypersurface area of the query region and not on its

hypervolume. We also show that the Hilbert curve achieves better clustering than the z curve. From a practical point of view, the formulas given in this paper provide a simple measure that can be used to predict the required disk access behaviors and, hence, the total access time.

Burnett, K., K. B. Ng, et al. (1999). A Comparison of the Two Traditions of Metadata Development. Journal of the American Society for Information Science 50(13)**:** 1209-1217.

Metadata has taken on a more significant role than ever before in the emerging digital library context because the effective organization of networked information clearly depends on the effective management and organization of metadata. The issue of metadata has been approached variously by different intellectual communities. The two main approaches may be characterized as: (1) the bibliographic control approach (origins and major proponents in library science); and (2) data management approach (origins and major proponents in computer science). This article examines the different conceptual foundations and orientations of the two major approaches contributing to the metadata discussion. An examination of the on-going efforts to establish metadata standards, and comparison of different metadata formats, supports a proposal for an integrated concept of metadata to facilitate the merging of the two approaches.

Cathro, W. (Aug. 1997). Metadata: An Overview. Australia.

(conference paper) Paper given at the Standards Australia Seminar, "Matching Discovery and Recovery". Definitions of metadata, and the description of the Dublin Core Standard

Chengalur-Smith, I., et al. (Nov/Dec 1999). The Impact of Data Quality Information on Decision Making: An Exploratory Analysis. IEEE Transactions on Knowledge and Data Engineering, Vol. 11, No. 6**:** 853-864.

The paper describes an experiment that explores the consequences of providing information regarding the quality of data used in decision making. The subjects in the study were given three types of information about the data's quality: none, two-point ordinal, and interval scale. This information was made available to the subjects, along with the actual data. Two decision strategies were explored; conjunctive and weighted linear additive. Two decision environments were used: a simple environment and a relatively complex environment. Various combinations of these factors were employed to explore several issues. These include complacency, consensus, and consistency. The paper provides preliminary insights into which type of data-quality information is most effective and the circumstances in which data-quality information is most effective. Such

knowledge would be of value to those responsible of designing databases that support decision-makers. Overall, we find that in a situation where subjects are confronted with clearly differentiate alternatives, the inclusion data-quality information impacted the selection of the preferred alternative while maintaining group consensus.

Committee on Statewide Transportation Data and Information Systems and e. a. Tate-Glass Data, Data, Data - Where's the Data?
TRB A1D09.

Transportation data collection cases in Kentucky and California

Cover, R. (1/24/01). XML Cover Pages.

Definition of Topic Maps based on ISO standards and applied to XML environment. Bibliography of topics and standards related to topic maps. Topic map information. Topic map provides a standardized notation for interchangeably representing information about the structure of information resources used to define topics, and the relationship between topics. A set of one or more interrelated documents that employs the notation defined by this International Standard is called a 'topic map'.

Cowan, J. and R. T. (W3C) (Feb. 2001). XML Information Set: W3C Working Draft 2.

The specification providing a set of definitions for use in other specification that need to refer to the information in an XML document

Cutler, M., S. Cahill, et al. (1/7/01). An Evaluation of the Deployment of ATIS in Minneapolis/St. Paul Metro Region.

Evaluation, including empirical field data and customer market research, of Ramp Queue Wait Signs and the Traveler Information Center. Evaluation of Ramp Queue Wait Signs found that signs had desired effect and resulted in increased tendency to change route. Evaluation of TIC found that data was accurate to most dimensions, but achieved low levels of market penetration and nit contributed to increasing satisfaction or use of traveler information services.

Dailey, D. J. and L. Li (ITS Research Program for TransNow) (Mar. 1999). Video Image Processing to Create a Speed Sensor. research paper. Seattle, WA**:** i-iii, 1-41.

Image processing has been applied to traffic analysis in recent years, with different goals. In this report, a new approach is presented for extracting vehicular speed information, given a sequence of real-time traffic images. We extract moving edges and process the resulting edge information to obtain quantitative geometric measurements of vehicles. This differs from existing

approaches because we use simple geometric relations obtained directly from the image instead of using reference objects to perform camera calibrations. Our method allows the recovery of the physical descriptions of traffic scenes without explicit camera calibrations. In this report, extensive experiments using images from active TMS (Transportation Management System) freeway cameras are reported. The results presented in this report demonstrate the validity of our approach that requires neither direct camera control nor placement of a calibration object in the environment. We further argue that it is straightforward to extend our method to other related traffic applications.

Dailey, D. J. and L. Li An Algorithm to Estimate Vehicle Speed Using Un-Calibrated Cameras. Seattle, WA**:** 1-7.

"In this paper we present a new algorithm to estimate speed using a sequence of video images form an un-calibrated camera. The algorithm uses frame differencing to isolate moving edges and track vehicles between frames. The algorithm uses a known vehicle length distribution with image information to estimate speed".

D'Angelo, M. (Jan. 2000). White Paper 5: ATIS Data Collection Guidelines Input. Scottsdale, AZ, PBS&J, FL.

The paper proposes a set of guidelines, for review and discussion at the Feb. 9-10, 2000 ATIS Data Collection Workshop, aimed at assisting reigns (or stakeholders) in developing data collection strategies to support advanced traveler information services. The focus is on real-time/dynamic road-related information.

Decker, S. and S. Melnik (Sept/Oct 2000). The Semantic Web: The Roles of XML and RDF. IEEE Internet Computing**:** 63-74.

Discussion of ontologies for domain conceptualization and tradeoffs among XML and RDF (Resource Description Framework), each a W3C recommendation. XML and RDF are the current standards for establishing semantic interoperability on the Web, but XML addresses only document structure. RDF better facilitates interoperation because it provides a data model that can be extended to address sophisticated ontology representation techniques.

Decker, S., P. Mitra, et al. (Nov/Dec 2000). Framework for the Semantic Web: An RDF Tutorial. IEEE Internet Computing.

An RDF (Resource Description Framework) tutorial - W3C recommendation in February 1999.

Duffy, C. (1997). An Introduction to the Performing Arts Data Service. Literary and Linguistic Computing, Vol. 12(4). Glasgow, UK.

The paper outlines the remit and structure of the Performing Arts Data Service (PADS), the Arts and Humanities Data Service (AHD), and the role of the PADS within the service as a whole. The PADS, as one of five service providers of the AHDS, covers film and theatre resources along with music broadcast arts, and dance; its initial task is to undertake a broad survey aimed at discovering the current availability of and access to digital resources as well as user equipments, after which it will seek to provide targeted services. The type of collections of digital data resources envisaged by the PADS and its role in contributing to metadata standards to support integrated access to distributed collections is considered.

Durand, A. (Jan/Feb 2001). Deploying IPv6. IEEE Internet Computing**:** 79-81.

IPv6 is a natural evolution from Version 4 of the Internet Protocol (IPv4) and attempts to address many of the older protocol's shortcomings. The core specifications have been standardized through the LETF IPng working group, and the NGtrans working group is studying issues surrounding the challenging task of smoothly transitioning from IPv4 to IPv6.

Fernandez, M. and J. e. Robie (5/11/00). XML Query Data Model.

Defines the XML Query data model and its relationship to the W3C XML Query Algebra (under development). The Data model plus the query algebra will provide precise semantics for the XML Query Language.

FHWA and FTA (Aug. 2000). What's Yours, Mine, and Ours: Overcoming Intellectual Property Rights Issues: A Cross-Cutting Study Facilitating Private Sector Participation and Expediting Deployment, FHWA, FTA.

Cases on copyright issues over the ownership and use of intellectual property developed jointly by public and private sectors for ITS test or model deployment.

Flammia, G. (Jul/Aug 1999). The Skinny on MetaData. IEEE INTELLIGENT SYSTEMS.

Background (nontechnical) on metadata concepts and applications. RDF will slowly become a widely accepted standard on the Internet, especially for large-scale catalogs that combine domain knowledge about multiple domains.

Glassco, R., T. Passin, et al. (3/15/01). Conversion of ATIS ASN.1 to Traveler Information Markup Language, Market Systems.

Mitretek Systems has drafted a XML schema corresponding to SAE's J2354, "Message Sets for Advanced Traveler Information Systems (ATIS)." XML Scheme Part 0: Primer can be found at http//www.w3.org/TR/xmlschema-0/.

Hunter, J. and L. Armstrong (1999). A Comparison of Schemas for Video Metadata Representation. Computer Networks 31**:** 1431-1451.

To enable the resource recovery of audiovisual documents over the World Wide Web, it will be necessary to define content description standards or metadata standards of complex, multi-layered, time-depending information-rich audiovisual data streams. In particular, this is the primary goal of the emerging MPEG-7 standard, the "Multimedia Content Description Interface" under development by the MPEG group. In the past, a lot of effort has gone into generating descriptors and description schemes for video indexing but comparatively little research has been done on schemas capable of defining the structure, content and semantics of video documents and enabling validation and higher levels of automated content checking. This paper compares the capabilities of the RDF Schema. Extensible Markup Language (XML), Document-type Definitions (DTDs), Document Content Description (DCD), and Schema for Object-Oriented XML (SOX), for supporting and validating hierarchical video descriptions base on Dublin Core, MPEG-7 and a specific hierarchical structure. Finally, this paper proposes a hybrid schema base on features from each of these schemas which ill satisfy the MPEG-7 Description Definition Language (DDL) requirements. Keywords: Video; Metadata; Schema; Dublin Core; MPEG-7

Hunter, J. and R. Iannella (9/21-23/98). The Application of Metadata Standards to Video Indexing in Research and Advanced Technology for Digital Libraries: Second European Conference, ECDL '98 Heraklion, Crete, Greece. C. a. S. Nikolaou, C. (eds.). Crete, Greece, Springer.

(book part of proceeding The paper first outlines a multi-level video indexing approach based on Dublin Core extensions and the Resource Description Framework (RDF). The advantages and disadvantages of this approach are discussed in the context of the requirements of the proposed MPEG-7 ("Multimedia Content Description Interface") standard. Finally a hybrid approach is proposed based on the combined use of Dublin Core and the currently undefined MPEG-7 standard within the RDF that will provide a solution to the problem of satisfying widely differing user requirements.

Institute of Transportation Engineers (2/27/01). Traffic Management Data Dictionary and Message Sets for External Traffic Management Center Communications.

Overview info on standards.

International Organization for Standards (1/1/98). ISO 14000 - Meet the Whole Family.
Overview info on ISO 14000

ISO TC 204 WG9, E., CEN, AASHOTO, ITE, NEMA (1/12/98). Transport Information and Control Systems - Data Interfaces Between Centers for Transport Information and Control Systems - **Part 1**: Message Definition Requirements. ISO 14827 - 1 international ISOSTD.
ISO 14827 consists of the following parts: Part 1: Message Definition Requirements; and Part 2: DATEX-ASN (Data Exchange Protocol in ASN.1) which is used to exchange data between central systems.

ISO TC 204 WG9, E., CEN, AASHOTO, ITE, NEMA (1/12/98). Transport Information and Control Systems - Data Interfaces Between Centers for Transport Information and Control Systems - **Part 2**: DATEX-ASN ISO 14827 - 2 international ISOSTD. ISO 14827 - 2 international ISOSTD.
ISO 14827 consists of the following parts: Part 1: Message Definition Requirements; and Part 2: DATEX-ASN (Data Exchange Protocol in ASN.1) which is used to exchange data between central systems.

ITE and AASHTO (10/30/00). TMDD & MS/ETMCC Guide.
Presents current set of standards for travel management data dictionary and message sets for external traffic management center communication.

ITS America (Jan 2000). 511: National Traveler Information Number January 2001 Update (Interim Summary of Issues).
Interim Summary of Issues includes: Services Offered, Guidelines on Content Quality, Research Needs, Business Plans & Finance, and Next Steps

ITS America and FHWA (7/1/00). Closing the Data Quality Gap: Guidelines for Quality ATIS Data: Version 1.0.
Collaborative effort of ATIS Committee to develop initial guideline concepts and awareness raising.

ITS America and USDOT (Sept. 2000). Closing the Data Gap: Guidelines for Quality Advanced Traveler Information System (ATIS) Data.
ATIS-related data collection and data quality guidelines

ITS America, USDOT ITS Joint Program Office, et al. (1/9-10/98). ITS as a Data Resource: Workshop Proceedings. Washington, DC.

In January 1998, ITS America, in association with the Federal Highway Administration, Federal Transit Administration, the Bureau of Transportation Statistics, and the Association of Metropolitan Planning Organization, sponsored a Workshop entitled: ITS As a Data Resource. At the onset, the purpose of the Workshop was to identify opportunities for tapping data produced by Intelligent Transportation System for use in: Transportation Planning Applications (covering both highway and transit); Transportation Operations (including state and local traffic engineering); and Commercial Vehicle and Intermodal Freight Planning.

Jizba, L. (1997). Reflections on Summarizing and Abstracting: Implications for Internet Web Documents, and Standardized Library Cataloging Databases. Journal of Internet Cataloging, Vol. 1(2).

Abstracts or summary notes and automated summarization techniques would be highly useful if routinely applied to cataloging or metadata for Internet documents and documents in other databases. Information seekers need external summary information to assess content and value of retrieved documents. Traditional models for writers, in library audiovisual cataloging, journal databases and archival work are examined, along with innovative new model databases featuring robust cataloging summaries. Recent developments in automated techniques, computational research, and machine summarization of digital images are noted. Recommendations are made for future designers of cataloging and metadata standards.

Kelly, D. (2/1/00). Using US Standards for Traveler Information within the WWW.

Prepared for use at the Feb 00 "Workshop on Position Dependent Information Services: Meeting of the W3C Mobile Access Interest Group.

Klapsing, R., et al (Apr/Jun 2001). Semantics in Web Engineering: Applying the Resource Description Framework. IEEE**:** 62-68.

An extensive Web modeling framework that applies the Resource Description Framework to Web engineering, providing an interoperable exchange format is presented. This framework uses the same (meta) data model to specify a Web application's structure and content, to make statements about a web application's elements, and to reason about the data and metadata.

Lam, W., et al. (Nov/Dec 1999). Automatic Text Categorization and Its Application to Text Retrieval. IEEE Transactions on Knowledge and Data Engineering, Vol. 11, No. 6**:** 865-879.

"We develop an automatic text categorization approach and investigate its application to text retrieval. The categorization approach is derived from a

combination of a learning paradigm know as instance-based learning and an advanced document retrieval technique known as retrieval feedback. We demonstrate the effectiveness of our categorization approach using two real world document collections from the MEDLINE database. Next, we investigate the application of automatic categorization to text retrieval. Out experiments clearly indicate that automatic categorization improves the retrieval performance compared with no categorization. We also demonstrate that the retrieval performance using automatic categorization achieves the same retrieval quality as the performance using manual categorization. Furthermore, detailed analysis of the retrieval performance on each individual test query is provided."

Lander, S. and V. Lesser (Mar/Apr 1997). Sharing Metainformation to Guide Cooperative Search Among Heterogeneous Reusable Agents. IEEE Transactions on Knowledge and Data Engineering, Vol. 9, No. 2**:** 193-208.

A reusable agent is a self-contain computational system that implement some specific expertise and that can be embedded into diverse applications requiring that expertise. Systems composed of heterogeneous reusable agents are potentially high adaptable, maintainable, and affordable, assuming that integration issues such as information sharing, coordination, and conflict management can be effectively addressed. In this article, we investigate sharing metalevel search information to improve system performance, specifically with respect to how sharing affect the quality of solution and the runtime efficiency of a reusable-agent system. We first give a formal description of sharable metainformation in system where agents have private knowledge and database and where agents are specifically intended to be reusable. We then present and analyze experimental results from a mechanical design system for steam condensers that demonstrate performance improvements relate to information sharing and assimilation. Finally, we discuss the practical benefits and limitations of information sharing in application system comprising heterogeneous reusable agents. Issues of pragmatic interests include determining what type of information can realistically be shared and determining when the costs of sharing outweigh the benefits.

Lappin, J. (1/1/00). Advanced Traveler Information Services (ATIS): Private Sector Perceptions and Public Sector Actives.

Results of study to determine the data gap between the needs of private sector ATIS providers (ISPs surveyed) and the public sector (state and local public agencies surveyed) data they receive. Most important observations deal with inadequate geographic coverage, inaccurate data, inconsistent data, inadequate spatial resolution, requirements for greater temporal coverage, willingness to transfer data.

Lappin, J. (12/1/00). What Have We Learned about ATIS and Customer Satisfaction.
Chapter 4 in a larger report: What Have We Learned About ITS. Synthesizes customer satisfaction findings from ATIS research and evaluations dating from 1996. Finds that demand for ATIS is based on 4 factors: regional traffic context, quality of ATIS services, individual trip characteristics, and characteristics of the traveler.

Lassila, O. and R. Swick (2/22/99). RDF Model and Syntax.
W3C Recommendation on RDF.

Limoges, E. and et al. Future of Urban Transportation Data
TRB A1D08. TRB A1D08, Committee on Transportation Data and Information.
The Transportation Research Board Committee on Urban Transportation Data and Information Systems leads the research community in the area of urban transportation data with the issues of data collection and data quality.

Lu, S., C-Y and J. Cai (Sept/Oct 2000). STARS: A Socio-Technical Framework for Integrating Design Knowledge Over the Internet. IEEE Internet Computing**:** 54-62.
The article presents a conceptual framework for supporting knowledge integration by modeling stakeholder's design perspectives. Social -Technical analysis Research System (STARS), a prototype implementation system developed at the IMPCACT Lab that uses advanced networking techniques to support stakeholders' interaction in collaborative design is described.

Mamdani, E. and J. Pitt (Sept/Oct 2000). Responsible Agent Behavior: A Distributed Computing Perspective. IEEE Internet Computing**:** pp. 27-31.
The legal aspects of autonomous, synchronously communicating, and intelligent software, especially in open systems of artificial intelligence (AI) are discussed.

NEMA and USDOT (1996). NTCIP 1202: National Transportation Communications for ITS Protocol (NTCIP) Object Definitions for Actuated Traffic Signal Controller Units
(formerly TS 3.5-1996)
(summary).
This NTCIP Device Data Dictionary Standard defines the data elements and conformance requirements for Actuated Traffic Signal Controller Units. It defines requirements that are applicable to specific environments for which they are intended. The data elements are defined using the Simple Network Management Protocol (SNMP) object-type formerly as defined in RFC 1212 and

would typically be exchanged using one of the NTCIP recognized Application Layers (e.g. SNMP)

NEMA and USDOT (1997). NTCIP 1203: NTCIP Object Definitions for Dynamic Message Signs (DMS)
(formerly TS 3.6-1997)
(summary).

This NTCIP Device Data Dictionary Standard defines the data elements and conformance requirements for Dynamic Message Signs. It defines requirements that are applicable to all NTCIP Dynamic Message Sings and it also contains optional and conditional clauses that are applicable to specific environments for which they are intended. The data elements are defined using the Simple Network Management Protocol (SNMP) object-type format as defined in RFC1212 and would typically be exchanged using one of the NTCIP recognized Application Layers (e.g. SNMP)

NEMA and USDOT (1998). NTCIP 1204: NTCIP Object Definitions for Environmental Sensor Stations (ESS)
(formerly TS 3.7-1998)
(summary).

This NTCIP Device Data Dictionary Standard defines the data elements and conformance requirements for Environmental Sensor Stations. IT defines requirements that are applicable to all NTCIP Environmental Sensor Station, and it also contains optional and conditional clauses that are applicable to specific environments for which they are intended. The data elements are defined using the Simple Network Management Protocol (SNMP) object-type format as defined in RFC 1212 and would typically be exchanged using one of the NTCIP recognized Application Layers (e.g., SNMP).

NEMA and USDOT (2000). NTCIP 1401: TCIP-Common Public Transportation (CPT) Business Area Standard
(summary).

NTCIP 1401's main application is the data and data concepts that describe the set of infrastructure (fixed and rolling) data such as vehicles, employees, facilities, and assets.

NEMA and USDOT (2000). NTCIP 1402: Standard on Incident Management (IM) Objects
(summary).

NTCIP 1402's main application is production of all data needed to identify the date, time, and location of events, the source of the information about the event, codes for indication the type and severity of the incident.

NEMA and USDOT (2000). NTCIP 1403: Standard on Passenger Information (PI) Objects
(summary).

NTCIP 1403's main application is the input of data associated with traveler preferences (departure time, arrival time, mode, cost, etc.), estimated time of arrival, published schedules, and other types of information.

NEMA and USDOT (2000). NTCIP 1404: Standard on Scheduling/Runcutting (SCH) Objects
(summary).

NTCIP 1404's main application is the input of data needed to develop the master schedule, trip sheet run guides, paddles, inventory files, and other supplemental information.

NEMA and USDOT (December 2000). NTCIP 1406: TCIP On-Board (OB) Business Area Standard
(Draft)
(fact sheet).

This standard describes the semantics (descriptions of words and symbols) and formats of objects (e.g., data elements) and messages for on-board systems applicable to non-rail PTVs, specifically buses.

NTCIP Joint Committee (12/1/00). NTCIP Overview.

Overview of the role of NTCIO in the ITS standards family.

Paul, R., et al. (Jan/Feb 1999). Software Metrics Knowledge and Databases for Project Management. IEEE Transactions on Knowledge and Data Engineering, Vol. 11, No. 1**:** 255-26.

Construction and maintenance of large, high-quality software is a complex, error-prone, and difficult process. Tools employing software database metrics can play an important role in efficient execution and management of such large projects. In this paper, we present a generic framework to address this problem. This framework incorporate database and knowledge-base tools, a formal set of software test and evaluation metrics, and a suite of advanced analytic techniques for extracting information and knowledge from available data. The proposed combination of critical metrics and analytic tools can enable highly efficient and

cost-effective management of large and complex software projects. The framework has potential for greatly reducing venture risks and enhancing the production quality in the domain of large software project management.

Paulson, L. (Jul/Aug 2000). Data Quality: A Rising E-Business Concern, IT Pro.

(article) Data quality isn't just cleaning up individual records - it's about making data continue to serve business needs.

Prahalad, C. K. and M. S. Krishnan (Sept/Oct 1999). The New Meaning of Quality in the Information Age. Harvard Business Review Sept./Oct. 1999**:** 109-118.

Businesses are adopting the emerging view of quality: adjusting to the dynamically shifting expectation of costumers. In software and information products, the concept of quality usually incorporates both the conformance and service views of quality. In addition, customers' expectation including technical support, etc., should also be emphasized as the critical part of software quality.

Proper, A. and R. Maccubbin (8/29/00). ITS Benefits: Data Needs Update 2000: Prepared in Connection with the 12 July ITS Benefits Data Needs Workshop, MITRETEK.

The summary highlights where gaps or limited knowledge exists concerning the benefits of ITS services.

Qiu, B., et al. (1998). A Basis Function Network for Remote Sensing Classification Proceedings of ICSP '98. ICSP. Beijing, China**:** 1339-1392.

For the problem of remote sensing classification, a basis function network is proposed in this paper. Compared with BP network, it avoids the problems of the hidden nodes selection and the weights initialization. The experiment results show that this basis function network has a better performance of classification for the complex remote sensing pattern with fast training velocity.

Qiu, B. and P. L. Woon (1998). The Hardware Implementation of a Generic Fuzzy Rule Processor Proceedings of ICSP '98. ICSP. Clayton, Australia**:** 1343-1346.

Description of the hardware design and implementation of a generic fuzzy processor. The processor allows the user to chose from a large range of inference and defuzzification methods. The number of inputs and outputs was limited to 3, with a width of 8-bits for each. Rule base size and the number of inferences that can be performed per second were not a critical factor as larger and faster specifications will simply increase the end cost. Design and simulation using Altera's Max+plus2 programmable logic development software was then conducted, and verified correct operation. The generic fuzzy processor was ultimately realized via construction using Altera FLEX 8000 FPGAs.

Rational Software Corporation (2000). Mapping Object to Data Models with the UML: Rational Software.

Software developers deal with object oriented software development and use the logical class model to represent the main view at the application, while the Database team designs, models, builds and optimizes the database. The UML and the UML Profile for Data Modeling can help solve the challenge of interface and overlap between the set of distinct responsibilities in database application development.

Raymund, P., T. L. Kunii, et al. (Jan/Feb 1999). Software Metrics Knowledge and Databases for Project Management. IEEE Transactions on Knowledge and Data Engineering, Vol. 11, No. 1, IEEE**:** 1041-4347.

"Construction and maintenance of large, high quality software projects is a complex, error-prone, and difficult process. Tools employing software database metrics can play an important role in efficient execution and management of such large projects. In this paper, we present a generic framework to address this problem. This framework incorporates database and knowledge-base tools, a formal set of software test and evaluation metrics, and suite of advanced analytic technique for extracting information and knowledge from available data. The proposed combination of critical metrics and analytic tools can enable highly efficient and cost effective management of large and complex software projects. The framework has potential for greatly reducing venture risks and enhancing the production quality in the domain of large software project management."

Rehor, K. What is VoiceXML?

Definition of voiceXML (a language for creating voice-user interfaces, particularly for the telephone), and the systems architecture.

Rehor, K. (1/17/01). VoiceXML.

Background on Voice XML - non-technical.

Schaaf, M. and F. Maurer (Jan/Feb 2001). Integrating Java and CORBA: A Programmer's Perspective. IEEE Internet Computing. Canada**:** 72-78.

A case study using a small chat room application to describe how a programmer can combine Java RMI's ease of use with CORBA's language neutrality

Schintler, L. and M. A. Farooque (2001). Partners In Motion and Traffic Congestion in the Washington, D.C. Metropolitan Area, Center for Transportation Policy and Logistics, School of Public Policy, George Mason University.

The study uses a traffic simulation model to aid in the evaluation of Partners In Motion of its objectives: improving the quality, quantity, and availability of travel information to transportation agencies, the media, and the public in the Washington, D.C. metropolitan area. The report evaluates Partners In Motion, as it has developed over the last two years and how it may evolve over the next decade, with respect to the goal of reducing congestion.

Schuman, R. and PBS&J (August 2001). Summary of Transportation Operations Data Issues.

Senecal, K. (2000). The Twofold Promise of the CORC Project. OCLC Systems & Services Vol. 16(2)**:** 84-90.

The two-pronged approach of OCLC's CORC project is described by a participant in the project's beta test. One element is the building of a collection of catalog records of Internet accessible resources, reflecting two different metadata standards. The development of automated cataloging features and the issues of link maintenance are discussed. The second major element of the project is building database of metasites or "pathfinders" that serve as subject guides to the Internet. The two types of pathfinders are examined along with the important role that they can play in a library's organization of Web resources.

Smils, J. (1999). Spatial Metadata: An International Survey of Clearinghouses and Infrastructures**:** 321-343 (Book part?).

Key words: Spatial metadata; Geospatial Data Infrastructure; Geospatial clearinghouses; GGDI; GSDI; Visual Geographical Interface.

Smith, B. L. and B. E. Smith (Nov. 2000). An Evaluation of the Need for Configuration Management in Transportation Management Systems. TRB. Charlottesville, VA, TRB**:** 2-32.

"Configuration management, a process developed to control change in complex information technology-based systems, has attracted an increasing amount of attention from the transportation engineering community. As the intelligent transportation systems (ITS) program accelerates, and transportation departments develop and operate increasingly complex transportation management systems, the need for configuration management grows. This research effort examines the need for configuration management within transportation management systems by exploring the foundations of configuration management, analyzing the key

functions of transportation management, surveying transportation officials, and conducting a case study to examine the configuration management process used by the Georgia Department of Transportation."

TCIP (2/27/01). Transit Communications Interface Profiles.

Overview info of TCIP -- a suite of data interface standards for the transit industry

Thompson, H., et al. (W3C), (10/24/00). XML Schema Part 1: Structures.

Specification of the XML Schema definition language, which sets the constraints and structure of the contents of XML ver 1.0 documents. XML Schema: Structures specifies the XML Schema definition language, which offers facilities for describing the structure and constraining the contents of XML1.0 documents, including those which exploit the XMLNamespace facility. The schema language, which itself represented in XML 1.0 and uses namespaces substantially reconstructed and considerably extends the capability found in XML 1.0 document type definitions (DTDs).

Thornely, J. (2000). Metadata and the Deployment of Dublin Core at State Library of Queensland and Education. OCLC Systems & Services, v16. n. 3. Queensland, Australia**:** 118-129.

Case studies of the deployment of Dublin Core at two significantly different institutions in Queensland, Australia.

Turner, D. and K. W. E. I. Ross (Apr/Jun 2001). A Comprehensive Architecture for Continuous Media Email. IEEE. France**:** 88-98.

To address quality of service, message deletion, and forwarding and replying problems, integrated sender- and recipient-stored delivery approach is addressed.

Vetterli, T., A. Vaduva, et al. Metadata Standards for Data Warehousing: Open Information Model vs. Common Warehouse Metamodel. Switzerland, The work partially supported by Swiss Federal Office of Professional Education and Technology under grant KTI-3979.1 (SMART).

Two standards for metadata in the context of their uses in the data warehousing context are examined.

Vidal, J., P. Buhler, et al. (Jan/Feb 2001). Inside an Agent. IEEE Internet Computing.**:** 82-86.

The implementation and internal appearance of Internet agents are discussed. It is necessary to understand an agent's architecture for multiagent system platforms and in creating agent-based systems.

Villani, S. (12/20/00). ITS Data Registry Public Release in January 2001. Piscataway, NJ.
(news) The Institute of Electrical and Electronics Engineers Standards Association (IEEE-SA) announces the public release of the Intelligent Transportation systems Data Registry (ITS DR) for 1 January 2001. The ITS DR is a centralized dictionary for all formally specified ITS terms and messages which currently contains data elements and concepts form the Traffic Management Data Dictionary (TMDD), Transit Communications for ITS Profiles (TCIP), National Transportation Communications for ITS Protocol (NTCIP), etc.

Virginia Department of Transportation (April, 2000). Policy on Access to Smart Traffic Center Data and Video Imagery (DRAFT).
VDOT policy to disseminate the data and video imagery for its transportation management system as widely as possible in order to: reduce crashes and otherwise improve the safety of the surface transportation system; inform the public and enhance the quality of transportation services; facilitate route and mode choice among transportation system users; and foster the development of traveler services information by the private sector. Access to the imagery/data shall be tightly governed by VDOT to ensure the security of the systems. The number, location and method of access to the imagery/data will be determined by VDOT.

W3C (2/24/99). Resource Description Framework (RDF) Model and Syntax Specification: W3C Recommendation. (www.w3c.org/RDF/)
A W3C recommendation on RDF model and syntax specification

Wallace, B. and R. Whiting (9/20/99). Data Quality Moves to the Forefront.
Provides the results of the Information Week survey that gauged the technology and spending plans of IT executives. Also provides short "case study" descriptions of data quality efforts at various organizations.

Waugh, A. (1998). Specifying Metadata Standards for Metadata Tool. Configuration Computer Networks and ISDN Systems 30 (1998). Australia**:** 23-32.
A critical problem for metadata application is flexibility. A metadata application must be sufficiently flexible to cope with changes to metadata standards over time and to allow users to extend a standard to cope with local requirements. A key component of supporting flexible metadata applications is software that can be dynamically configured by a specification of the metadata standard. By contrast, in current metadata software the embedded standard is embedded in the code, making changes relatively more difficult and expensive. Configurable software

also leas to better tools at a lower coast, as it is not necessary to re-implement functionality for every new metadata standard. This paper describes a metadata specification designed to support dynamic configuration of metadata software by capturing features of metadata standards. The specification comprises three components: the classification of the metadata standard, the metadata schema, and the metadata expression.

Whiting, M. (11/17/97). Self-Describing Data.

Background on metadata (SDD). Definitions and examples of Self-Describing Data (SDD).

Zhou, Y., H. Leung, et al. (1/1/97). Sensor Alignment Using the Earth-Centered Earth-Fixed Coordinate System.

Reference systems for GIS and data fusion techniques.

Zimmerman, C. B., M. B. Raman, et al. (January 2002). Sharing Data for Public Information: Practices and Policies of Public Agencies. Washington, DC, Sponsoring Agency: ITS Joint Program Office
USDOT.

As the primary source of basic data on travel conditions, public agencies through their data sharing practices can have a powerful effect on deployment of 511 telephone numbers and other types of traveler information services. This report documents the current state of the practice, describing how the public and private sectors deal with data ownership and sharing, and examines policies aimed at facilitating data sharing and ultimately improving the quality and quantity of information that reaches travelers. "Data" in this report encompasses digital, video, and verbal forms of information.

The report is based on information collected from two sources. Surveys were conducted with thirty-four public agencies and seven private firms. The surveys consisted of interviews with representatives of public and private sector entities that are active participants in data sharing. The 30-minute interviews included a variety of questions about data sharing practices, such as the types of information shared, recipients of the data, and types of conditions placed on users of the data. The surveys were complemented with a review of the literature about data sharing practices related to traveler information and other types of data.

Major findings of the research are presented along with policy issues related to data sharing. The policy considerations relate to the philosophy about the nature of

public sector data and the public sector's role and responsibilities in making data available to other parties.

Model Deployment Initiatives and Field Test Evaluations

Dailey, D., M. Haselkorn, et al. (1/1/98). A Structured Approach to Developing Real-Time Distributed Network Applications for ITS Deployment.

Framework for addressing ITS-specific networks, e.g., reliability issues, fault tolerance, etc

Dailey, D. and W. S. T. C. (TRAC) (May 2001). Smart Trek: A Model Deployment Initiative Final Research Report. Seattle, Washington, Prepared for Washington State Reason Commission, and USDOT FHWA. **Research Project T9903 Task 78 Timesaver Backbone**.

FASTLINE (11/19/97). Embarc System Design Report. Phoenix, AZ, prepared for AZTech Model Deployment Initiative.

FHWA and FTA (Aug. 2000). What's Yours, Mine, and Ours: Overcoming Intellectual Property Rights Issues: A Cross-Cutting Study Facilitating Private Sector Participation and Expediting Deployment, FHWA, FTA.

Cases on copyright issues over the ownership and use of intellectual property developed jointly by public and private sectors for ITS test or model deployment.

Ice, R. and ITS America (6/10/97). Applying the National ITS Architecture to the Model Deployment Initiatives.

Lappin, J. (1/1/00). Advanced Traveler Information Service (ATIS): Who Are ATIS Customers?

Based on the work of the MMDI Customer Satisfaction evaluation team. Sections include: external factors influencing customer demand, using attitudes and values to segment the ATIS market, classification of MMDI customers, ATIS traffic customer characteristics, ATIS transit customer characteristics

Lappin, J. (2/9 -10/00). Advanced Traveler Information Service (ATIS): What do ATIS Customers Want? Cambridge, MA, EG&G Services/Volpe Center.

(presentation) Based on the work of the MMDI Customer Satisfaction evaluation team. Synthesizes findings from customer satisfaction research and evaluations dating back to 1996, including several field operational tests.

Pond, L. (6/3/99). A comparison of three methods of data transfer for Center-to-Center communications, University of Washington ITS Research Group.

Science Applications International Corporation Automated Vehicle Identification Tags in San Antonio: Lessons Learned from the Metropolitan Model Deployment Initiative.

Science Applications International Corporation (10/19/98). Seattle Wide-Area Information for Travelers: Architecture Study. Seattle, Washington, prepared for WSDOT. **Contract Number: WSDOT Y-5908**.

Science Applications International Corporation (March 2001). Automated Vehicle Identification Tags in San Antonio: Lessons Learned from the Metropolitan Model Deployment Initiative - Unique Method of Collecting Arterial Traveling Speed Information**:** 12.

Science Applications International Corporation (March 2001). Phoenix's Roadway Closure and Restriction System, Lessons Learned from the Metropolitan Model Deployment Initiative, AZTech.

Science Applications International Corporation (March 2001). San Antonio's Medical Center Corridor: Lessons Learned form the Metropolitan Model Deployment Initiative.

Science Applications International Corporation (May 2000). Metropolitan Model Deployment Initiative: San Antonio Evaluation Report. Washington, DC, Sponsoring Agency: USDOT.

Science Applications International Corporation (October 2001). Cross-Jurisdictional Signal Coordination in Phoenix & Seattle: Removing Barriers to Seamless Arterial Travel.

Southwest Research Institute (1/7/1998). In-vehicle navigation system Model Deployment Initiative Acceptance Test Plan: Version 1.1. San Antonio, TX, Prepared for Texas Department of Transportation, TransGuide. **SwRI Project No. 10-8684 P.O. No. 7-70030 Req. No. 60115-7-70030**.

Southwest Research Institute (1/23/1998). Automated Vehicle Identification Model Deployment Initiative System Design Document Version 1.0. San Antonio, Texas, Prepared for Texas DOT, TransGuide. **SwRI Project No. 10-8694**
P.O. No. 7-70030
Req. No. 60115-7-70030.

Southwest Research Institute (2/19/98). Traveler Information Kiosk Model Deployment Initiative System Design Document Version 1.0. San Antonio, TX, Prepared for Texas DOT, TransGuide. **SwRI Project No. 10-8684, P.O. No. 60115-7-70030, Reg. No. 60115-7-70030**.

Southwest Research Institute (11/3/97). Traveler Information Kiosk Model Deployment Initiative Acceptance Test Plan. San Antonio, TX, Prepared for Texas DOT, TransGuide. **SwRI Project No. 10-8684, P.O. No. 60115-7-70030, Reg. No. 60115-7-70030**.

Texas DOT (10/22/1999). TransGuide Model Deployment Initiative.

Texas Department of Transportation TransGuide Data Server System Design Document Data Server Acceptance Test Plan In-Vehicle Navigation System Design

The University of Washington and Battelle (6/23/99). Smart Trek ITS Backbone.

Traffic Station (2/22/01). Traffic Station Company Information.

Provider of personalized, interactive traffic, transportation, and traveler information for the Internet, wireless, and telematics markets. Currently offers services to 28 major metro markets across North America. Has been chosen for several MMDIs: AZTech in Phoenix, Trips 123 in the New York Metro Area, and TravInfo in the San Francisco Bay Area.

USDOT (May 2000). Metropolitan Model Deployment Initiative: Seattle Evaluation Report. **Publication No.: FHWA-OP-00-020**.

USDOT (September 1999). Regional ITS Architecture Development: A Case Study New York-New Jersey-Connecticut Region.

USDOT and The Architecture Team (February 1999). National ITS Architecture Team Support for Model Deployment Initiatives.

To facilitate the showcasing of compatibility of various interfaces among the Model Deployment Initiative (MDI) sites, the Architecture Team has identified interface opportunities that present the greatest potential.

Washington State DOT and USDOT (8/29/97). Self Describing and Self Extracting Data Flows (SDD/SED): Client User Information Bulletin.