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Advanced Public Transportation Systems:

The State of the Art

Update '98

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13. Abstract

This report documents work performed under FTA's Advanced Public Transportation Systems (APTS) Program, a program structured to undertake research and development of innovative applications of advanced navigation, information, computer, and communication technologies that most benefit public transportation.

This report is the latest in a series of State-of-the-Art reports, the last of which was published in January 1996. It contains the results of an investigation of the extent of adoption of advanced technology in the provision of public transportation service in North America. It focused on some of the most innovative or comprehensive implementations, categorized under four types of services/technologies: Fleet Management, Traveler Information, Electronic Fare Payment, and Transportation Demand Management. The objective of this effort was to increase the industry's knowledge of successful applications of advanced technologies with the expectation that this will lead to their widespread adoption.

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PREFACE

This report contains the results of a limited investigation of the extent of adoption of advanced technology in the provision of public transportation service in North America. It is an update of the prior state-of-the-art assessments produced in April 1991, April 1992, January 1994, and January 1996. The objective of this effort is to increase the industry's knowledge of successful applications of advanced technologies with the expectation that this will lead to their widespread adoption.

This research was conducted by the Research and Special Programs Administration/Volpe National Transportation Systems Center of the United States Department of Transportation, under the sponsorship of the Advanced Public Transportation Systems Program, Federal Transit Administration and the guidance of Mr. Walter Kulyk, Director of the Office of Mobility Innovation, Federal Transit Administration. Appreciation goes to all of the researchers and professionals who supplied information for this report, most of whom are listed as contacts in Appendix A.

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LIST OF ACRONYMS AND ABBREVIATIONS USED IN THIS REPORT

AATA	Ann Arbor Transportation Authority (Ann Arbor, Michigan)
ADA	Americans with Disabilities Act of 1991
ADART	Autonomous Dial-a-Ride Transit
AOS	Advanced Operating System
APC	Automatic Passenger Counter
APTS	Advanced Public Transportation Systems
ATC	Automatic Train Control
ATMS	Advanced Traffic Management System
ATS	Automatic Train Supervision
AVI	Automatic Vehicle Identification
AVL	Automatic Vehicle Location
BART	Bay Area Rapid Transit District (San Francisco-Oakland, California)
BC	British Columbia (Canada)
BECS	Bus Emergency Communications System
BSDA	Bi-State Development Agency (St. Louis, Missouri)
BSMS	Bus Service Management System
CAD	Computer-Aided Dispatch
Caltrans	California Department of Transportation
CASM	Computer-Aided Support System
CBTC	Communications-Based Train Control
COTA	Central Ohio Transit Authority (Columbus, Ohio)
CTA	Chicago Transportation Authority (Chicago, Illinois)
DART	Dallas Area Rapid Transit (Dallas, Texas)
DEC	Digital Equipment Corporation
DOT	Department of Transportation
EMV	Europay/MasterCard/Visa
FCC	Federal Communications Commission
FTA	Federal Transit Administration
GIS	Geographic Information System
GPS	Global Positioning System
HOV	High Occupancy Vehicle
HSR	Hamilton Street Railway Company (Hamilton, Ontario, Canada)
IRTIS	Interregional Traveler Information System
ISO	International Standards Organization
ITS	Intelligent Transportation Systems
IVR	Interactive Voice Response
LIRR	Long Island Railroad (Jamaica, New York)
Loran-C	Long Range Aid to Navigation

LIST OF ACRONYMS AND ABBREVIATIONS USED IN THIS REPORT(continued)

MARTA	Metropolitan Atlanta Rapid Transit Authority (Atlanta, Georgia)
MBTA	Massachusetts Bay Transportation Authority (Boston, Massachusetts)
MDI	Model Deployment Initiative
MDT	Mobile Data Terminal
MDU	Mobile Data Unit
Metro	Metropolitan Transit Authority of Harris County (Houston, Texas)
MMS	Mobility Manager System
MnDOT	Minnesota Department of Transportation
MRTMA	Missoula Ravalli Transportation Management Association (Missoula, Montana)
MTA	Metropolitan Transportation Authority (New York City, New York)
MTC	Metropolitan Transportation Commission (San Francisco Bay Area, California)
MTS	Milwaukee Transit System (Milwaukee, Wisconsin)
Muni	San Francisco Municipal Railway (San Francisco, California)
NJT	New Jersey Transit (Newark, New Jersey)
NYCT	New York City Transit (New York City, New York)
OCC	Operations Control Center
OCS	Operations Control System
OCTA	Orange County Transportation Authority (Orange County, California)
OIC	Operations Information Center
PA	Public Address
PARIS	Passenger Routing and Information System
PATI	Public Access to Transportation Information
PRTC	Potomac-Rappahannock Transportation Commission (Woodbridge, Virginia)
RATP	Regional Automated Trip Planning
RDS	Radio Data System
ROCC	Railroad Division Operations Control Center
ROCSIM	Railroad Operations Computer Simulation
RTD	Regional Transportation District (Denver, Colorado)
SAE	Society of Automotive Engineers
SATIN	Service Area Traveler Information Network
SCADA	Supervisory Control and Data Acquisition
SCAG	Southern California Association of Governments (Los Angeles Area, California)
SEPTA	Southeastern Pennsylvania Transportation Authority (Philadelphia, Pennsylvania)
SMART	Suburban Mobility Authority for Regional Transportation (Detroit, Michigan)
SORTA	Southwest Ohio Regional Transit Authority (Cincinnati, Ohio)
SST	Seattle Smart Traveler (Seattle, Washington)
STATIS	Subway Train and Traffic Information System
STO	Societe’ de Transport de l’Outaouais (Hull, Quebec, Canada)
SWIFT	Seattle Wide-Area Information for Travelers (Seattle, Washington)

LIST OF ACRONYMS AND ABBREVIATIONS USED IN THIS REPORT (continued)

TATS	Traveler Advisory Telephone System
TC	Technical Committee
TCIP	Transit Communications Interface Protocols
TCRP	Transit Cooperative Research Program
TDDS	Talking Directory Display System
TDM	Transportation Demand Management
TIC	Traveler Information Center
TMC	Transportation Management Center
TRANSCOM	Transportation Operations Coordinating Committee (New York City Area, New York)
TRANSMIT	TRANSCOM's System for Managing Incidents and Traffic (New York City Area, New York)
TRANSPAC	Central Contra Costa Transportation Partnership and Cooperation (Contra Costa County, California)
Tri-Met	Tri-County Metropolitan Transportation District of Oregon (Portland, Oregon)
TRIPS	Traveler Itinerary Planning System
TV	Television
TxDOT	Texas Department of Transportation
VAN	Vehicle Area Network
VIA	Metropolitan Transit (San Antonio, Texas)
VLU	Vehicle Logic Unit
VMS	Variable Message Sign
WAG	Working Advisory Group
WG	Working Group
WSDOT	Washington State Department of Transportation
WSTA	Winston-Salem Transit Authority (Winston-Salem, North Carolina)

EXECUTIVE SUMMARY

This report describes the extent of adoption of new technologies in the public transportation industry in the United States and Canada. This is the latest edition in the series of State of the Art reports. The previous one was published in January 1996 and is referred to in this report as **Update '96**.

FLEET MANAGEMENT

Fleet management incorporates many of the vehicle-based Advanced Public Transportation Systems (APTS) technologies and innovations for more effective vehicle and fleet planning, scheduling, and operations. Fleet management focuses on the vehicle, improving the efficiency and effectiveness of the service provided (the "supply side"), and on passenger safety. By making transit more efficient and reliable, it should be more attractive to prospective riders and the municipalities they serve.

Communications Systems

The public transportation community already makes substantial use of communications in everyday operations. Currently, public transportation mainly uses conventional analog land mobile communication services. The application of new communication technologies to the transit industry has been limited to date.

Implementation of the "Smart Vehicle" and the application of ITS/APTS technologies to public transportation will bring about additional communications requirements. It is questionable whether currently utilized communications and spectrum capability will meet these new requirements. This will be especially true for the transition period when ITS technology will be phased-in, but current operations must continue uninterrupted. Alternative communication approaches include: low earth orbit satellite services; FM subcarrier RDS; personal communication services; spread spectrum systems; shared spectrum; wireless data services; commercial mobile radio; and integrated communications systems.

A number of current spectrum issues may impact transit telecommunications. An important consideration are the changes underway, and under consideration, in the telecommunications spectrum allocation arena. These include: the refarming or partitioning of the mobile radio communication bands into narrower channels, the spectrum requirements of law enforcement agencies, and the reallocation of the spectrum formerly controlled by Federal government agencies which is being turned over to the FCC. This situation represents both a challenge and an opportunity to transit.

Geographic Information Systems

A geographic information system (GIS) is a special type of computerized database management system in which databases are related to one another based on a common set of locational coordinates. This relationship allows users to make queries and selections of database records based on both geographic proximity and attribute values.

In the past few years, the use of GIS by public transportation systems has increased significantly. The most frequent use has been in the application of urban bus service route and schedule information maintenance and presentation of this information to customers. Geographic information systems are also being used to evaluate the quality of the service provided by existing bus routes and in planning for future routes and/or modifications to existing routes.

A relatively new application for GIS is in the area of "Welfare-to-Work" programs. Welfare-to-Work GIS applications are being used to locate potential employer and current welfare recipient addresses in order to assess the suitability of public transportation in meeting these commutation needs.

As more data become available, either from public or private sources, the applications for GIS in the public transportation arena will expand significantly. It is certain that as computing and telecommunications power increases and precise spatial data become available, the use and influence of GIS in public transportation systems, particularly in the area of special request and special needs transportation, will increase.

Automatic Vehicle Location Systems

Automatic vehicle location systems (sometimes referred to as automatic vehicle monitoring or automatic vehicle location and control systems) are computer-based vehicle tracking systems. These systems are used extensively both for military and civilian purposes, including transit and trucking fleets, police cars, and ambulances. Their use in transit applications continues to grow, driven by a number of expected benefits.

Automatic vehicle location (AVL) systems operate by measuring actual real-time position of each vehicle, and relaying the information to a central location. Actual measurement and relay techniques vary, depending on the needs of the transit system and the technology (or technologies) chosen. Each AVL system employs one or more of the following location technologies: dead-reckoning, ground-based radio, signpost and odometer, or global positioning system (GPS).

In prior years, the most common form of AVL chosen by transit agencies was the signpost and odometer system. Although some major bus systems are in the process of installing new signpost and odometer systems, most agencies are choosing GPS-based systems.

Last year, the Federal Transit Administration published **Advanced Public Transportation System Deployment in the United States,** a report which listed 86 transit agencies either operating, implementing, or planning/testing/demonstrating AVL systems.

Automatic Passenger Counters

Automatic passenger counters are a well-established, automated means for collecting data on passenger boardings and alightings by time and location. Typically, a small percentage of an agencies buses are equipped. An APC system has three basic components: a method of counting passengers; a location technology; and data management. The two most prevalent types of counters are treadle mats and infrared beams.

APC data may be used for a number of applications, both real-time and delayed, including: input to dispatcher decisions on immediate corrective action; input to real-time passenger information systems; National Transit Database reporting; future scheduling; positioning new shelters for waiting passengers; and fleet planning.

It is anticipated that APCs will achieve the following: decreased data collection costs; increase the type and range of data available; decreased time and effort required to process collected data; and increased overall operating efficiency due to better service planning.

The first generation of APCs were deployed over 25 years ago. Some of these systems are still in use, often with updated equipment. An agency implementing a new APC installation in the 1990s is most likely to be putting them in as part of an AVL system. Whether or not the agency takes advantage of collecting the data in real-time, the ability to make use of existing location and/or data transmission technology greatly decreases the capital cost of the APC system and makes it more fiscally feasible.

The **Advanced Public Transportation System Deployment in the United States,** listed 31 fixed-route bus systems planning, installing, or operating APCs.

Transit Operations Software

Transit operations software has the capability to automate, streamline, and integrate many transit functions and modes. Computer applications such as computer-aided dispatching, service monitoring, and supervisory control and data acquisition (and the APTS technologies which provide the data to them) can improve the effectiveness of operations dispatching, scheduling, planning, customer service, and other agency functions.

Fixed Route Bus

Software for fixed-route bus operations is rapidly evolving from traditional run cutting, operator bid processing, timekeeping, and dispatching software to include integrated fleet management applications. Using technologies such as global positioning systems, such software is designed to help make operational decisions in real time and archive data for a variety of other transit agency decision-making needs.

A key feature of CAD software is its ability to manage communications. Nevertheless, some agencies still need to upgrade their communications infrastructure to support deployment of a CAD system. CAD software (in concert with AVL) also facilitates tracking the on-time status of each vehicle in a fleet. Not only do operators and dispatchers benefit from regular updating of on-time status, but customers benefit as well through the information systems. CAD systems also provide organizations with archiving and targeted retrieval of historical operating data.

Rail

Operations software for rail transit systems are generally built upon existing or upgraded supervisory control and data acquisition systems (SCADA) which include: the wayside monitors for switches, signals, and interlockings; wayside sensors for electrical and mechanical subsystems; a communications backbone such as fiber optic cable; and software for processing and displaying the data. These applications typically allow the integration of SCADA data with other control systems such as automatic train control, automatic vehicle identification, traffic signal loop detectors (for light rail signal priority at grade crossings), and automated train dispatch.

Rail systems continue to upgrade their operations software, usually in concert with the construction of or improvements in an operation control center. Often, part of these changes are enhancements of both the dispatchers' consoles and the large wall displays that enable dispatchers, supervisors, emergency personnel, and others to view real-time location of trains and status of critical mechanical and electrical subsystems.

Paratransit

The Americans with Disabilities Act has inspired many transit agencies to implement new paratransit operations software systems, mainly scheduling and dispatching software, for improved performance and increased passenger-carrying capability of their demand-responsive vehicles operating in shared-ride mode. Customers are able to make reservations, check on the status of their rides, and obtain billing information using a variety of devices, including touch-tone telephone, personal computers, kiosks, the Internet and e-mail.

Although only a few agencies have installed the most sophisticated of the paratransit operations software systems, many have implemented one or more of their features. The high-end systems have integrated automated scheduling and dispatching software with AVL, GIS, and advanced communications systems, so that, in some cases, the dispatcher's role is limited to interventions in special circumstances, such as no-shows or trip cancellations. The system itself can automatically receive orders via touch-tone telephone, schedule the trips, and transmit the schedules to the drivers. Some systems can interface with fixed route service.

In some systems, customers have the option of speaking to a dispatcher or entering the required information via touch-tone telephone, Internet connection, or e-mail. They can not only make reservations, but also check on their accounts, find out when their ride will arrive, and cancel rides.

Currently under development is a demand-responsive operations software system that will all but eliminate the role of the dispatcher in paratransit service. Known as autonomous dial-a-ride transit or ADART, it employs fully automated order-entry and dispatching systems that reside on board the vehicles. Under normal conditions, the customer is the only human involved in the entire process of requesting a ride, assigning trips, scheduling arrivals, and routing the vehicle.

Traffic Signal Priority Treatment

Traffic signal priority treatment is a technology by which a traffic signal may be held green (or made green earlier than scheduled) so that a particular vehicle may pass through the intersection more quickly. This technology has been in place for a number of years for emergency vehicles. For transit, giving buses or light rail vehicles priority at signals helps to keep to their schedule and avoid "bunching."

Traffic signal priority treatment for transit has its opponents, however. There are many traffic and transportation professionals who are concerned about delaying traffic on cross streets.

In the 1970s, there were a number of tests for priority treatment on transit. These systems were manual (they were either driver-actuated or continuous) and always gave priority. In the 1990s, the technology has advanced significantly. Often, modern traffic signal priority systems are implemented as part of AVL systems. This allows for selective priority, giving priority only to those transit vehicles running behind schedule. This alleviates some of the objections of traffic engineers.

TRAVELER INFORMATION

Traveler information systems provide travelers with information on one or more modes of transportation to facilitate decision making before their trip as well as during the trip (en-route).

Information can be provided to trip makers at home, work, transportation centers, wayside stops, or on-board vehicles. With links to automatic vehicle location, traveler information systems specifically for transit are beginning to provide real-time information, such as arrival times, departure times, and delays. Travelers can access this information through a variety of media.

Pre-Trip Transit Information

Pre-trip information systems are a means of alleviating the uncertainty about transit schedules and routes that is often cited as a reason for not using transit. Providing accurate and timely information to all travelers before their trips will enable them to make informed decisions about modes, as well as routes and departure times.

Pre-trip information can cover a wide range of categories, including transit routes, maps, schedules, fares, park-and-ride lot locations, points of interest, weather, and more. Often this information can support itinerary planning, which can provide information on a whole trip from one point to another, even if it involves multiple modes.

Many transit agencies are now offering trip itinerary planning via touch-tone telephone, as well as via the Internet, kiosks, and/or hand-held communications devices. The most common medium is the touch-tone telephone. Innovative methods of disseminating pre-trip traveler information to the public are growing in use, however. In particular, the use of the Internet for providing pre-trip traveler information services has greatly expanded in the last two years. Almost every transit agency, regardless of size, has a page on the World Wide Web. Other increasingly common methods for disseminating pre-trip traveler information include personal pagers, hand-held data receivers, and cable television.

There is a move toward regional systems that provide information on multiple modes of public transportation across more than one jurisdiction. Transit bus, commuter rail, ferry, heavy rail, intercity bus, tourism, recreational, and airport transportation services are frequently seen in this type of information system. Hindering the development of these systems in several cases is the lack of a standard electronic format among agencies for bus routes and schedules, the time and cost to input the data, and the cost to develop software to handle the frequent schedule updates experienced by the transit industry.

Another trend is the interfacing of transit information with real-time traffic conditions.

In-Terminal/Wayside Transit Information

In-terminal and wayside customer information systems offer a wide variety of information to public transit riders who are already en-route. This information is being communicated via media such as electronic signs, interactive information kiosks, and closed-circuit television monitors. The information may include real-time arrival and departure information as well as traditional static service information.

Since **Update '96**, there has been a significant increase in the deployment and expansion of APTS technologies, particularly AVL, that facilitate en-route information. The ongoing design and deployment of a variety of APTS technologies is steadily improving the breadth and accuracy of en-route customer information, and is expanding the amount of multi-modal information that is available.

At least three projects have designed, deployed, and evaluated in-terminal/wayside information systems for persons with visual impairments. Some of the agencies with rail systems are working to provide real-time train arrival or departure information, in addition to other types of real-time information. The deployment of both bus terminal and bus stop real-time information systems is increasing.

New efforts to integrate multi-modal information, to provide intelligent itinerary planning software, and to tie kiosk operations to the interfaces of World Wide Web sites show promise for this customer information technology. Several new projects are attempting to secure private sector partners to make these systems financially self-sustaining through advertising and other revenues.

In-Vehicle Transit Information

The major impetus for in-vehicle customer information systems is to provide useful en-route information to riders and to comply with the applicable provisions of the Americans with Disabilities Act of 1991. Many transit operators are supplying some combination of audible and visual next stop, major intersection, and transfer point information to achieve both objectives. Two primary media are used: automated annunciators and in-vehicle displays.

As with in-terminal and wayside customer information systems, the ability to deploy automated on-board information display and annunciation is usually made possible by the installation of automatic vehicle location systems. Automating the provision of in-vehicle information also allows the vehicle operator to concentrate on the task of driving and reduces potential driver distraction.

Another development is integrating bus destination signs with AVL systems to ensure that destination information displayed to passengers waiting at the curb is accurate, especially on multi-route corridors or multiple-branch routes. Finally, several bus operators are enhancing their fleet management systems so that passengers who are already on-board can request and get confirmation on transfers to other transit services.

Multimodal Traveler Information

One factor common to most multimodal traveler information systems is that they typically combine data from one or more transit services with real-time and static traffic data. The methods for collecting, fusing, reformatting, and disseminating these two information streams back to the public is as diverse as the programs themselves. With regard to transit, multimodal traveler information systems often include pre-trip, in-terminal/wayside, and in-vehicle information systems.

Multimodal traveler information systems enable travelers to make fully-informed mode choice decisions, both pre-trip and en-route. Traveler information telephone lines, interactive kiosks, and World Wide Web sites are the most common distribution media. Park and ride, and ridesharing information are also distributed in some multimodal traveler information systems.

Data formatting and compatibility (especially for spatially-referenced data) stand as key issues in successful multimodal information efforts.

ELECTRONIC FARE PAYMENT

Transit managers across the country are exploring and adopting electronic fare payment system concepts. One of the major incentives for this shift is that transit operators want to decrease expenditures on fare collection and lessen the associated security risks connected with collecting large amounts of cash and tokens while providing greater convenience for transit riders. Nevertheless, implementing a modern transit fare collection system is a complex initiative involving a variety of technological considerations, partnership issues, institutional changes, legal considerations, as well as rider acceptance issues.

Automated Fare Payment Systems

The system or environment in which a card will be issued or used is a fundamental issue. Generally, cards will either be used in what is commonly referred to as an "open" (multiple card issuers and multiple service providers) or "closed" (a single card issuing organization) system. Historically, a closed system is how many transit agency fare programs have operated.

Currently, transit authorities in the U.S. are using three types of fare payment media: magnetic stripe cards; credit cards; and smart cards. There are three types of smart cards: contact; contactless; and combi-cards.

Extensive technological developments in many forms of payment media have recently occurred. The trend towards a "electronic cashless commerce" is a growing business practice being implemented worldwide. Interest from the financial, postal, and telecommunications industries are contributing to the rapid pace of technological advancement. Advancement in card technology will facilitate the acceptance of electronic payment media programs as a viable payment option for transit operators. Currently, stored-value and multi-use programs are in limited trials in U.S. cities. Multi-use transit projects are already in operation in other parts of the world. Ultimately, the success of electronic payment programs will depend on the degree of acceptance of the media by issuers, merchants and, most importantly, consumers.

Standards and Interoperability

The question of standards and interoperability are key concerns being raised by transit managers considering an electronic payment system. Regional fare coordination can only occur if there is compatibility with payment systems of other transportation operations within the region. Currently, standards exist for certain aspects of smart cards and there are several international organizations working on card standards. However, at this time, there is no specification to ensure complete interoperability among the different card types and operating systems.

TRANSPORTATION DEMAND MANAGEMENT TECHNOLOGIES

Transportation demand management technologies are those which combine innovative approaches and advanced technologies to better utilize existing infrastructure. In each case, the goal of these technologies is to maximize the ability of the current transportation network - roads and transit - to serve the recent rapid increase in demand for transportation. This is accomplished through a combination of, among other things, increased incentives towards shared rides, coordination of transportation service providers, and enhanced incident management.

Dynamic Ridesharing

Dynamic ridesharing (also called real-time ridesharing) is that form of ridesharing that is used to obtain a ride for a single, one-way or round trip rather than for trips made on a regular basis. Dynamic ridesharing can be either an organized program run by an official agency or informally operated by participants.

In organized dynamic ridesharing programs, a request for a ride is submitted to a central database or operations center. A trip request may be made for any time of the day or any destination, but ridematches are more likely to be found for travel in peak periods and in principal commutation directions. When a trip request is received, the database of trips that have been offered by drivers registering for the ridesharing program is searched to see if any match the approximate time and destination of the request. Normally, the person requesting the trip will contact the potential provider(s) to make the ridesharing arrangement.

Dynamic ridesharing could benefit individuals by reducing the cost of driving, by eliminating the onerous task of driving, by providing an alternative when the usual trip mode is unavailable, and by possibly eliminating the need for an additional car just for occasional use. The environment would also benefit from reduced vehicle emissions.

Tests of this concept in a few sites have either been terminated or were never implemented. The results of the terminated programs have been disappointing. On the whole, it does not appear that organized dynamic ridesharing programs will attract large numbers of users or eliminate significant numbers of automobiles from the roadways. Nevertheless, it can be a useful adjunct to other ridesharing services as long as the cost of operation is low.

The informal type of dynamic ridesharing (called casual carpooling) has been shown to be quite successful in two very specific situations (Oakland, California and Northern Virginia) where daily users average in the thousands.

Automated Service Coordination

Automated service coordination involves multiple transportation providers in a region that provide service with the help of APTS technologies. The technologies are critical to integrating and coordinating the services. Often these technologies include central and remote automated scheduling and dispatching; automatic vehicle location; advanced communications, including data communications; and automated fare payment.

While an increasing number of transit agencies are taking on the role of automated service coordinators, they are often initiating the coordination efforts without technology and adding the technology later. The addition of the technology has been found to greatly enhance the efficiency of service integration and coordination, and in many cases has provided smaller agencies with automated tools that they may not have had ordinarily to link them directly with other service providers in their region.

The most prevalent APTS technologies that assist in automated service coordination are automated scheduling and dispatching systems, and AVL systems. Several transit agencies are currently providing coordinated service using these technologies.

Research and demonstration efforts are still being conducted in the area of automated service coordination.

Transportation Management Centers

The term "transportation management center" (TMC) refers to a facility that combines traffic and public transit operations, communications, and/or control. To date, there are several TMCs that accomplish this integration at a rather high level. In many cases, the TMC is more or less 'virtual' in that separate traffic and transit facilities share real-time information.

The most effective examples of TMCs are those that locate transit and traffic operations in the same building, if not in the same room, such that direct communications and subsequent decision-making can occur readily between the respective operators during peak traffic periods, incident detection and management, or special events. Also, transportation management centers can be critical in developing traffic signal priority systems for transit vehicles which improve transit service while minimizing the impact on other vehicular traffic.

High-Occupancy Vehicle Facility Monitoring

The objective of creating high occupancy vehicle facilities is to encourage carpooling and reduce the number of vehicles on the road. However, illegal use can slow traffic flow on the lanes and decrease their advantage over adjacent lanes, thereby diminishing the incentive to carpool or use public transit. In order to ensure that these lanes are accomplishing the desired objective and not being improperly used by drivers to bypass congested sections of highway or avoid tolls, these lanes are usually monitored for compliance with specified minimum vehicle occupancy requirements.

The process by which HOV lanes are currently monitored normally consists of police stationed by the side of the facility to observe the number of occupants in each vehicle and to stop and issue citations to drivers carrying less than the minimum number of passengers. This manual enforcement process is labor intensive and costly, as well as a potential safety hazard. In addition, it requires the presence of police officers who otherwise could be performing more useful functions. For these reasons, some jurisdictions have sought an automated means of enforcing the HOV lanes.

Potential technologies for automating HOV facility enforcement include video, near infrared, millimeter wave, thermal infrared, and transponders. All have some deficiencies. All except the transponder approach will require an image-acquisition subsystem, a central processing unit for image processing and control, a hardware- or software-based image recognition engine, and a storage or transmission subsystem for data. The technology approaches undergoing testing at this time are video and near infrared.

While video cameras have not previously been used to determine the number of occupants in a vehicle in other than a couple of test situations, it has been successfully applied to other traffic enforcement operations including violations of bus-only lanes and running red lights. The percentage of valid license plate identifications that can be obtained in high-speed traffic is an issue and can be affected by weather, lighting conditions, and vehicle position within the lanes.

The use of digital cameras is being considered by some cities. These would provide better images, but would be more expensive.

The other approach, which will be tested in January 1998, uses an infrared camera to capture images which are then processed to generate a "picture" of the inside of a passing vehicle. Near infrared can be used throughout the entire day as it is not dependent on external lighting. However, inclement weather is likely to cause deterioration in picture quality.

FTA-SPONSORED FIELD OPERATIONAL TESTS

Testing in a real-world environment is essential for a complete and proper evaluation of any technology, system, or innovation. As part of the Advanced Public Transportation Systems program, the Federal Transit Administration is sponsoring several Field Operational Tests of various innovative technologies throughout the country. These tests will include a full assessment of each promising technology with test results widely disseminated. This will allow service providers interested in implementing APTS technologies and innovations to benefit from the FOT information generated by others. It should reduce trial-and-error inefficiencies and may eliminate wasteful implementation of systems that are inappropriate.

There are several FTA-sponsored FOTs planned or in progress. They are listed in Table 6.1 of this document. More information also is available from the appropriate FTA contact.

SYSTEMS ARCHITECTURE

A system architecture is simply a description of how system components interact to achieve system goals. A system architecture defines: complete system operation; what each component does; and what information is exchanged among components. For simple systems, an architecture may provide little benefit, but for a large complex system, a system architecture is tremendously helpful. A system architecture, however, is not a system design. It does not specify how each component accomplishes its task or a component's "look and feel." It is an organization of functions, not a specification of equipment. Nevertheless, it does have a strong influence on the design.

The U. S. Department of Transportation, in June 1996, completed its development of a National ITS Architecture. The foundation of the National ITS Architecture is a collection of interrelated user services for application to the Nation's surface transportation problems.

The Federal Transit Administration participated in the ITS system architecture development process through an effort to identify transit-specific requirements. In support of FTA, the DOT Volpe National Transportation Systems Center and Sandia National Laboratories developed a set of information flow charts which represent the logical information flows necessary to satisfy the needs of the APTS user services

In an effort to assist the public transportation community to better understand and use the ITS system architecture, a report "ITS Deployment Guidance for Transit Systems," April 1997, has been developed by the U. S. DOT ITS Joint Program Office.

STANDARDS DEVELOPMENT

A national architecture facilitates the development of necessary ITS and APTS standards in the U.S. Several transit standards activities are currently actively underway.

Vehicle Area Network Standard

One of the first ITS standards was an APTS standard for public transit vehicle area networks (VAN), developed through the efforts of ITS America's APTS Committee/Bus Vehicle Area Network Working Group. The standard was based on Society of Automotive Engineers (SAE) standard SAE J1708 (hardware and communications format), and related standards, SAE J1587 (protocols) and SAE J1455 (environmental requirements). Work is currently underway to convert a "de facto" standard cable and connector to a SAE standard; this is expected to be completed in 1998.

Transit Communications Interface Profiles

A second major standards development project, initiated in November 1996, is for Transit Communications Interface Profiles (TCIP). The TCIP draft specification document was filed with the Institute of Transportation Engineers (ITE) on September 2, 1997. The draft specification includes data definitions and message sets for seven key transit object areas: fare collection, incident management, onboard/control center, passenger information, scheduling and runcutting, spatial representation, and traffic management. The standards were not designed to replace existing interfaces, but to extend them. The profiles will act as a layer between proprietary systems; with TCIP, rather than writing an interface between each system, agencies can specify just one.

The final draft specifications are targeted for completion on February 20, 1997. At that time, they will be passed to the National Transportation Communications for ITS Protocols (NTCIP) project for further review and balloting. Officially sanctioned standards are expected to be available by summer 1998.

International Standards Organization Technical Committee 204

On the international front, the International Standards Organization (ISO) has established Technical Committee (TC) 204, composed of 16 international Working Groups (WG), to develop ITS standards. There are currently 18 participating countries and 27 observing countries in ISO/TC 204. The U.S. is the International Secretariat of ISO/TC 204 and also convenes five of the 16 WGs. ISO/TC 204's WG 8, convened by the U.S., is chartered with developing international ITS standards in the areas of public transport and emergency services.

U.S. Working Advisory Group 8 has carried both the VAN standard and TCIP forward for consideration in ISO/TC 204 WG 8. The vehicle area network standard (SAE J1708) has been approved as a new item of work for the WG 8 program. TCIP was approved by ISO/TC 204 as a preliminary work item, allowing time for the standards to be developed and approved in the U.S.

1. INTRODUCTION

Purpose of Report

This report describes the extent of adoption of new technologies in the public transportation industry. The Federal Transit Administration (FTA) believes that the knowledge of applications of advanced technologies in public transportation will lead to their more widespread deployment. This is the latest edition in a series of reports. The last edition was published in January 1996 and is referred to in this report as **Update '96**.[1]

Background

FTA created the Advanced Public Transportation Systems (APTS) program as part of the U.S. Department of Transportation's initiative in Intelligent Transportation Systems (ITS). ITS applies current and emerging technologies in the fields of electronics, communications, navigation, information processing, information displays, computers, and control systems to all forms of surface transportation. The APTS program was established to encourage the use of technology to improve the quality and usefulness of public transportation and ridesharing services. The APTS program is testing these technologies, with many projects involving the integration of multiple technologies. Effectively integrated and deployed, ITS technologies can enhance safety, transportation mobility, operational efficiency, and environmental protection. The Federal Highway Administration's ITS program, which features traffic and roadway safety and operations enhancements, often is integrated with the APTS program in multimodal projects.

Scope

This report culminates a short-term investigation of the status of developments and advancements in the adoption of new technology in public transportation services in the United States and, to a lesser degree, Canada. It was not an exhaustive search of every city or transit

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[1] Casey, Robert F. et. al., **Advanced Public Transportation Systems: The State of the Art *Update '96***, Volpe Center of the U.S. Department of Transportation for the Federal Transit Administration of the U.S. Department of Transportation, Report #FTA-MA-26-7007-96-1/DOT-VNTSC-FTA-95-13, January 1996.

authority which has tested, planned, or implemented an advanced technology concept. Rather, it focused on some of the most innovative or comprehensive examples of new technology approaches. It must be emphasized that this study did not encompass an examination of advanced technology applications in Europe, Japan, or other foreign countries.

Report Organization

This report is organized in accordance with FTA's Advanced Public Transportation Systems program. Technologies and applications are discussed under the most applicable of four categories: Fleet Management, Traveler Information, Electronic Fare Payment and Transportation Demand Management. These sections are preceded by an Executive Summary and this Introduction, and are followed by a list of current APTS projects, FTA and non-FTA sponsored, and Appendices containing a comprehensive list of the individuals contacted during this study, and a brief discussion of ITS architecture and standards development activities.

2. FLEET MANAGEMENT

Fleet management incorporates many of the vehicle-based APTS technologies and innovations for more effective vehicle and fleet planning, scheduling, and operations. Fleet management focuses on the vehicle, improving the efficiency and effectiveness of the service provided (the "supply side"), and on passenger safety. By making transit more efficient and reliable, it should be more attractive to prospective riders and less costly to the municipalities they serve. The technologies and innovations described in this chapter are:

- Communications Systems;
- Geographic Information Systems;
- Automatic Vehicle Location;
- Automatic Passenger Counters;
- Transit Operations Software; and
- Traffic Signal Priority Treatment.

2.1 COMMUNICATIONS SYSTEMS

Telecommunications is in a period of growth and change. The following has stimulated this activity:

- A crowded electromagnetic spectrum;
- Actions by the Federal Communications Commission (FCC) and the National Telecommunications Information Agency;[2] and
- Telecommunications technology advances.

The public transportation community already makes substantial use of communications in everyday operations. Implementation of the "Smart Vehicle"[3] and the application of APTS technologies to public transportation will bring about additional communications requirements. It is not clear whether existing communications capabilities and spectrum can support these additional requirements.

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[2] The Federal Communications Commission allocates spectrum to the private sector, including the transit industry; the National Telecommunications Information Agency allocates spectrum to Federal agencies.

[3] The "Smart Vehicle" is a transit vehicle equipped with ITS technologies.

APTS and Smart Vehicle technology will require communications for such integrated functions as:

- Bus and control center interactions;
- High-occupancy vehicle (HOV)/express bus lane access;
- Traffic signal priority;
- Intermodal interfaces;
- Workplace/home transit and intermodal information;
- Wayside/transfer center transit and intermodal information; and
- On-board information.

Of all the APTS functions requiring communications, by far the most critical is the vehicle/control center link. Most communications systems which radiate energy must be licensed by the FCC in terms of their use of the electromagnetic spectrum. Many other APTS functions can be satisfied by low-power, unlicensed electromagnetic transmitters and receivers. However, the bus/control center link in most instances requires communications coverage over a large metropolitan area, which almost certainly dictates a licensed service.

The vehicle/control center communication requirement may be satisfied by broadcast services instead of direct dedicated communications links. The spectrum allocated to a given FM broadcast station exceeds that which is required for the broadcast audio signal. Therefore, the resulting "excess" spectrum is available to transmit other services. APTS information could be overlaid on transmissions by conventional commercial FM radio stations and other such transmitters. Some examples of this approach are Advanced Highway Advisory Radio and Radio Data System (RDS). Such approaches, while operational in Europe, are, for the most part, only at the conceptual stage in the U.S.

Those functions which require detailed information such as safety and warning messages, and route guidance may require a dedicated communication link. Public transportation may have to turn to alternative telecommunication approaches.

Alternative communication approaches include:

- Analog/digital cellular: conventional cellular services cover most metropolitan areas but are nearing saturation levels; digital cellular will expand availability;
- FM subcarrier RDS: traffic and other information can be transmitted in frequency sidebands of commercial FM radio stations;

- Personal communication services: still in the development stages, but will allow communications anywhere;
- Spread spectrum systems: rather than operating at a single frequency, spread spectrum systems transmit a low power signal with the information to be transmitted distributed over a band of frequencies. "Receiver intelligence" is used to decode the transmitted information. Such low powered systems need not be licensed by the FCC;
- Shared spectrum: co-existing on a shared spectrum basis with other non-transit public safety users through use of digital features of trunking;
- Low earth orbit satellite services: satellite communication services under development, i.e., IRIDIUM system;
- Developing a state-of-the-art shared communications system with area public safety and/or public utility agencies;
- Wireless data services: utilization of wireless data services such as Cellular Digital Packet Data, and commercial services such as ARDIS;
- Commercial mobile radio; and
- Integrated communications system: making use of a combination of mobile radio and other services such as those outlined above.

An alternative to using dedicated spectrum for transit communications is to participate as a partner in a shared communications system, or to seek status as a secondary user. In a shared system, local public agencies can share the cost of developing and operating a state-of-the-art "trunk" system. Trunking, under which the available spectrum is partitioned into a number of channels and received or transmitted signals are automatically directed to whatever channel is not currently in use, can typically be used to allow multiple agencies to simultaneously use the system with minimal interruption and greatly increased message throughput. Secondary user status, where the FCC is asked for permission to operate on a non-interfering basis to primary users (which hold the spectrum allocation), may also be possible for a transit agency.

"Spread spectrum" techniques lend themselves to some transit applications, since only low power signals need to be radiated at any given frequency, and "receiver intelligence" is used to reconstruct the transmitted information. Digital cellular is an application of this approach. In digital cellular systems, the voice information is sampled to form a digital replica of the analog voice signal. (Digitization leads to the ability to use spectrum-efficient signal processing techniques.) As analog cellular systems have approached a saturation level, the application of spread spectrum techniques will allow an improvement in spectrum utilization efficiency of from three to 15 times for digital cellular systems.[4]

The selection of an approach will not only depend on meeting system needs and performance requirements, but also the development cost, cost of operation, and availability of spectrum. Use of state-of-the-art commercial communication services, rather then transit property operated systems, should be considered.

State-of-the-Art Summary

Currently, public transportation mainly uses conventional analog land mobile communication services. The application of new communication technologies to the transit industry has been limited. Some transit authorities have replaced their older analog communications systems with newer digital systems, and a number have converted or are planning to convert to either analog or digital trunked communications system.

Many properties that have updated their communications systems have done so in conjunction with introduction of APTS functions such as automatic vehicle location. The additional requirements brought about by the introduction of ITS technology to public transportation make it questionable whether currently utilized communications and spectrum capability will meet these new requirements. This will be especially true for the transition period when ITS technology will be phased-in, but current operations must continue uninterrupted.

Application Examples

Examples of transit systems which are employing or planning state-of-the-art telecommunication technologies, include:

- Pace Suburban Bus (Chicago area) - trunked system;
- Chicago Transit Authority - trunked system;
- Denver Regional Transportation District - digital, mobile data terminals (MDTs);
- Milwaukee County Transit System - updated trunked system, MDTs;
- New Jersey Transit (Newark) - trunked analog system;

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[4] **U.S. National Spectrum Requirements Projections and Trends**, U.S. Department of Commerce publication, March 1995.

- Southeastern Penn. Transit Authority (Philadelphia) - updated system, unlicensed 900 MHz;
- Bi-State Development Agency (St. Louis) - digital, MDTs;
- Pierce Transit (Tacoma) - trunked 900 MHz system, MDTs; and
- Washington Metropolitan Area Transit Authority - trunked analog, MDTs.[5, 6]

Chelan/Douglas County, Washington

In the state of Washington, there is an excellent example of what can be done by a transit agency to develop a modern communications system, given the spectrum limitations in existence. In need of a new communications system, Chelan/Douglas County Public Transit Agency made an extensive search to determine if they could partner with another public agency in the area that was planning to develop a new communications system. With the assistance of the Washington State Department of Transportation (DOT), that search was successful, and the transit agency is partnering with a local public utility to develop, and share, a state-of-the-art trunked 800 MHz mobile radio communications system.

Telecommunications Spectrum Issues

A number of current spectrum issues may impact transit telecommunications. An important consideration are the changes underway, and under consideration, in the telecommunications spectrum allocation arena.

One major issue facing transit is the refarming or partitioning of the mobile radio communication bands into narrower channels. Although refarming the current 25 KHz channels will open up new channels, it may force most transit agencies to replace their existing communications systems with new, tighter-tolerance equipment. In addition, transit agencies now upgrading need to make sure that replacement communications systems and equipment are compatible with refarming requirements. This issue was the subject of a recent Transit Cooperative Research Program. A report, **Impact of Radio Frequency Refarming on Transit Communications**,

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[5] ITS America Communication Spectrum Working Group; responses to questionnaires on current telecommunication usage and future needs.

[6] A.D. Little, Inc.; responses to questionnaires on current transit telecommunications and future plans.

documenting the results of the study, was published by the Transportation Research Board in December 1995.[7]

Another issue is in the public safety spectrum. The Telecommunications Act of 1996 and Congressional concerns about public safety communications have lead to a focused examination of public safety communications and spectrum requirements. These efforts are meant to protect law enforcement agencies from spectrum auctioning, identify needs for additional spectrum, and make more spectrum available to law enforcement agencies. To date, the transit industry has only had minimal representation in this process.

The spectrum formerly controlled by Federal government agencies which is being turned over to the FCC for reallocation to private sector use is another concern. For the most part, this spectrum and other newly identified spectrum opportunities will most likely be auctioned off to the telecommunications industry. The FCC has increasingly turned to auctioning as the preferred means of allocating new spectrum. Current policy exempts public transit spectrum, as part of the public safety service, from being subject to the auctioning process. However, auctioning may limit transit attempts to obtain new spectrum, and the cost of optional commercial services will most likely increase.

Thus, the current environment represents both a challenge and an opportunity to transit. The challenge is to be aware of changes and developments in the spectrum arena; the opportunity is that new telecommunications alternatives and technologies resulting from the newly allocated spectrum may help transit meet its future telecommunications needs. The transit industry needs to have a strong voice in the spectrum allocation arena, not only to obtain additional spectrum, but also to protect that which they already have.

2.2 GEOGRAPHIC INFORMATION SYSTEMS

A geographic information system (GIS) is a special type of computerized database management system in which geographic databases are related to one another via a common set of

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[7] Instructions on how to obtain copies of the report can be obtained from the Transit Cooperative Research Program office at (202) 334-3886.

locational coordinates. This relationship allows users to make queries and selections of database records based on both geographic proximity and attributes. For example, with a GIS in a public transportation system, a user can locate all bus stops that are within one half mile of a specified location, find the nearest subway station that complies with the Americans With Disabilities Act (ADA), or determine the best route from one's residence to a specified shopping location.

Information on guidelines on development of transit GIS systems and data exchange is being developed through the Transit Communications Interface Profiles (TCIP). The TCIP effort is a national effort in developing a family of standards for transit communications. These new standards will provide the interfaces among transit applications (including GIS) that will allow data to be shared among transit departments and other operating entities such as emergency response services and regional traffic management centers.

State-of-the-Art Summary

In the past few years, the use of GIS by public transportation systems has increased significantly. This has come about largely through a natural extension of cooperation between state and local departments of transportation and environmental agencies, who generally have pioneered the implementation of GIS, and the public transportation agencies. Capitalizing on these developments, as well as leadership and assistance from the Federal Government, some local transportation agencies are now at the leading edge of public transportation management and public service.

The most significant use of GIS by the public transportation sector has been in the application of route and schedule information maintenance and presentation for urban bus service. At the most basic level, agencies can respond to telephone requests from patrons who want to know what bus or buses to take to get from one location to another, and what time to catch the buses. Telephone operators locate the origins and destinations on a GIS and, with a few simple queries, find the most appropriate route and schedule for the callers. The more advanced transit providers have put these systems on the Internet, allowing patrons to directly access the system and make their own inquiries. This approach also has been used in travel involving both bus and fixed guideway systems.

Customers can call in or, if there are Internet provisions, get on-line with the system and evaluate the travel modes, routes and travel times associated with the public transportation alternatives.

Geographic information systems are also being used today to evaluate the quality of the service provided by existing bus routes and in planning for future routes and/or modifications to existing routes. By examining the current routes and stops for a given bus system in relation to demographic data associated with the potential riders, transit agencies can evaluate their service to the public.

A relatively new application for GIS is in the area of "Welfare-to-Work" programs. Since recent Federal legislation has mandated that states implement a program to move current welfare recipients off welfare and into the work force, states and municipalities are all working to develop an implementation plan which address the transportation needs of recipients. FTA's National Transit GIS contains a vast amount of transit data that could be applied to research the issues associated with welfare-to work. This information is on-line and available as a potential resource to the public and those interesting in applying GIS to this challenging social issue. Potential employer and current welfare recipient addresses are being entered into GIS. These data are overlaid on a base map of the roadways and transit system routings for the local area. By examining the accessibility of public transportation between the residences and the employers, it becomes possible to examine the amount of service which much be added or altered to address the Federal mandate.

Accessibility, in this case, encompasses several critical components. First, the existence of public transportation between the two locations must be determined. Given that some form of public transportation does exist, appropriate routes and schedules; total travel time; number of transfers required; relationship between residences, job sites, and available child care; and costs can be easily studied. Without the use of GIS, transit agencies, acting on behalf of the states and municipalities obligated by the Federal mandate, would find this complex evaluation almost impossible.

As more demographic and geographic data become available, either from public or private sources, the applications for GIS in the public transportation arena will expand significantly. This will be especially true in the area of special request and special need requirements. For example, data is becoming available on ADA accessible bus and subway/streetcar stations, providing information that can be a part of a GIS. Scheduling for on-demand or dial-a-ride services are starting to be streamlined through the use of GIS. In addition, some of the more advanced transit agencies are installing real-time vehicle location devices on their rolling stock. Technology such as global positioning systems (satellite-based location; see Section 2.3) are being used in their control centers to determine actual versus scheduled location of buses or paratransit vehicles, thus, greatly enhancing the efficiency of overall operations.

It is certain that as computing and telecommunications power increases and precise spatial data become available, the use and influence of GIS in the management of public transportation systems will increase. Each public transportation agency should know where their vehicles are in relation to where they need to be in order to run their transit system efficiently and effectively. GIS has and will continue to assist in obtaining and displaying this information and providing decision support for public transportation planning and operations.

Application Examples

Cape Cod, Massachusetts

The Cape Cod Regional Transit Authority was awarded an FTA grant to create a Rural Advanced Intermodal Transportation System. This award was brought to fruition by using GIS in a decision support environment as a precursor to implementation of the intelligent transportation system. Based on planned designs developed by this GIS prototype which served as a spatial data integrator, paratransit trip and demographic data was used to lessen demand for paratransit service by redesigning local fixed-route service. Operations decisions related to integrating paratransit service with regional and community-based fixed route transit were also supported by this GIS prototype. With the aid of GIS, planning decisions to advance intermodal transit connections throughout the Cape Cod Region ultimately have become the underlying technology for the provision of more reliable and efficient transit service.

Portland, Oregon

An extensive survey and data collection program was recently undertaken in the Portland metropolitan district to obtain source data for a sophisticated travel demand modeling effort. By applying demographic data to a GIS representation of the land, residences, and existing transportation systems, the Portland, Oregon Metropolitan Service District (Metro) is better able to recommend and help coordinate land use and transportation planning.[8]

Broward County, Florida

The Broward County Operations Project is designed to demonstrate the feasibility of a multimodal transportation system to serve persons with disabilities. By examining existing public transit systems in relation to the origin or destination locations of people with specific disabilities, evaluations could be made as to the proper mix of public and private (e.g., taxi, special vans, etc) modes of travel.[9]

Corpus Christi, Texas

A very specialized form of GIS is being evaluated in Corpus Christi, Texas for scheduling paratransit pick-ups. This system, called Autonomous Dial-A-Ride Transit (ADART), is not what one usually thinks of as GIS because there is no visible map from which a user makes decisions. In this case, the map is internal and the computer system itself, makes the decisions. With the assistance of GIS, the network of computers in the vehicles selects the vehicle which can most efficiently handle each trip request and displays driving directions to each pick-up location to the selected vehicle's operator. (See Section 2.5.3 for a further discussion of ADART.)

2.3 AUTOMATIC VEHICLE LOCATION SYSTEMS

Automatic vehicle location systems (sometimes referred to as automatic vehicle monitoring or automatic vehicle location and control systems) are computer-based vehicle tracking systems. These systems are used extensively both for military and civilian purposes, including transit and

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[8] Cambridge Systematics, Inc., **Data Collection in the Portland, Oregon Metropolitan Area**, *Case Study*, prepared for the Federal Highway Administration, Federal Transit Administration Office of the Secretary, and the U. S. Environmental Protection Agency, Report Number DOT-T-97-09, June 1996.

[9] Harman, L. J. and R. H. Thatcher, **Using Geographic Information Systems for Integrated Transit Service Delivery**, Broward County Florida Transit Options Project, 1996, prepared for FTA Project ACTION, National Institute for Accessible Transportation.

trucking fleets, police cars, and ambulances. Their use in transit applications continues to grow, driven by the following expected benefits:

- Increased overall dispatching and operating efficiency;
- More reliable service;
- Quicker response to service disruptions;
- Inputs to passenger information systems;
- Increased driver and passenger safety and security;
- Quicker notice of mechanical problems with the vehicles;
- Inputs to traffic signal preferential treatment actuators; and
- More extensive planning information collected at a lower cost than manual methods.

At a minimum, each automaticvehicle location (AVL) implementation includes a specific location technology (or technologies) and a method of transmitting the location data from the bus to dispatch. Additionally, each system usually has one or more tie-ins to other features such as:

- Schedule adherence monitoring;
- Silent alarm - which can be activated by a driver in an emergency;
- Automated traveler information systems (see Chapter 3);
- Vehicle component monitoring - engine conditions out of tolerance (e.g., high engine temperature, low oil pressure) are flagged and dispatch notified;
- Automatic passenger counters (APCs; see Section 2.4);
- Computer-aided dispatch (CAD; see Section 2.5);
- Traffic signal preferential treatment - avoiding the need for driver intervention; and
- Automated fare payment systems (see Chapter 4).

Location Technology

Automatic vehicle location systems operate by measuring actual real-time position of each vehicle, and relaying the information to a central location. Actual measurement and relay techniques vary, depending on the needs of the transit system and the technology (or technologies) chosen.

Each AVL system employs one or more of the following location technologies:

- Dead-reckoning
- Ground-based radio
- Signpost and odometer
- Global positioning system (GPS)

Update '96 described these technologies in some detail.

For transit, a single location technology is usually insufficient for position determination at all times. Often, the primary location technology is supplemented with another, due either to the environment in which the system operates (e.g., tall buildings along the route) or the demands of the agency's application of the AVL system.

Dead-reckoning is the most autonomous form of vehicle location. In pure dead-reckoning, the bus determines its own location, without the aid of external technologies. First, the bus is told its starting location. The vehicle then measures distance traveled from that location by odometer readings and determines the direction of that travel by compass headings. Because of the need to reset the equipment frequently from a known location, dead-reckoning technology seldom is used by itself. Most of the time, dead-reckoning is supplemented by one of the other technologies, such as a few signposts at strategic points along the route, or GPS.

Another location technique is the ground-based radio Long Range Aid to Navigation (Loran-C). Loran-C is a land-based radio navigation system which uses low-frequency waves to provide signal coverage. A drawback for Loran-C is its susceptibility to radio-frequency and electromagnetic interference which can cause significant errors (as much as 1,000 meters) in position location. There are also problems with signal reception in urban canyons. As a result, Loran-C is no longer widely used for intensive real-time tracking of transit vehicles.

There is a form of ground-based radio system, offered by private vendors, which can be effective in certain situations. This system operates on radio frequencies in the 900 MHz band. Transmitting and receiving towers are placed strategically throughout the metropolitan region. Through triangulation, the vendor is able to locate a vehicle within 150 feet. Subscribers pay a fee based on how often and how long they query the system for information. If the subscriber does not require many queries per month, this system can be very inexpensive. However, if the subscriber needs to make a lot of queries per month, such as for real-time use of the data, this type of system can be expensive. Further, as is the case with Loran-C this system has problems with signal reception in urban canyons.

In the signpost system, a series of radio beacons are placed along the bus routes. The beacons send out a low power signal which is detected by a receiver on the bus. The bus then reports its position to dispatch according to the distance (taken from the odometer) the bus has traveled since passing the last signpost. An alternate strategy is for the signpost to receive signals from the bus and report that information to dispatch. The limitations of this technology are that changes in bus routes could require the installation of additional signposts and the system is incapable of tracking vehicles which stray off-route.

GPS technology uses signals transmitted from a network of 24 satellites in orbit to determine position through triangulation. GPS works anywhere the satellites will reach, so it is far more robust than signpost and odometer. However, satellite signals do not reach underground and can be interrupted by the presence of tall buildings or foliage. In areas where this is a problem, GPS is often supplemented with an odometer and/or compass headings for extrapolation of location from the last GPS reading, or a signpost strategically placed where there are known problems. With the U.S. military degrading the satellite signals (called selective availability), the position accuracy is decreased. To overcome this, a number of transit operations are installing "differential GPS" which can correct for these inaccuracies.

Data Transmission to Dispatch

Typically, position information is stored on the vehicle for a time. Sometimes the information is relayed to the dispatch center in raw form, and sometimes it is processed on-board the vehicle. The two most common methods of transmitting location data to dispatch are polling and exception reporting. Under polling, the computer at dispatch asks each bus, in turn, for its location. Since location accuracy is a function of how often the buses are polled, and since there is a limited number of radio frequencies available in many urban areas, many transit agencies have chosen "exception reporting." With exception reporting, each bus reports its location to dispatch only at a couple of specified points or when the bus is running off schedule beyond a specified tolerance (for example, more than one minute early or more than five minutes late). Exception reporting requires each bus to know not only its position, but also its scheduled position. This approach makes more efficient use of available radio channels. Many agencies use a combination of polling and exception reporting.

State-of-the-Art Summary

In prior years, the most common form of AVL chosen by transit agencies was the signpost and odometer system. Although some major bus systems are in the process of installing new signpost and odometer systems, most agencies are choosing GPS-based systems.

Last year, the Federal Transit Administration distributed **Advanced Public Transportation System Deployment in the United States,**[10] a report with a comprehensive list of APTS implementations across the U.S. According to this report, there were 86 transit agencies either operating, implementing, or planning/testing/demonstrating AVL systems. Over 80 percent were using GPS location technology.

Application Examples

Since the **Deployment** report is to be a biennial report (in the years when **The State of the Art** is not published), the comprehensive table of AVL implementation, included in previous **State of the Art** reports is not included here. What follows are a few implementations using each location technology.

A.1 Signpost and Odometer (United States)

Newark, New Jersey

New Jersey Transit (NJT) is implementing a new signpost and odometer system. The system will operate primarily in Essex County (Newark area), although all of their buses are equipped with the requisite hardware and software. Hardware implementation is about complete, including on-board equipment on all buses and signposts at every garage, at strategic places in Essex County, and at the Port Authority Bus Terminal in New York City, the terminus of many of their routes. NJT is now in the process of inputting all route data into the central computer and training their dispatchers on the use of the system. NJT notes that the software capabilities are now catching up to the

[10] Casey, Robert F. and Lawrence N. Labell, **Advanced Public Transportation Systems Deployment in the United States,** Volpe Center of the U.S. Department of Transportation for the Federal Transit Administration of the U.S. Department of Transportation, August 1996.

hardware which has been available for a number of years. NJT is implementing the AVL system in order to better manage their bus operations. [11]

Seattle, Washington

King County Metro has had an operational signpost and odometer AVL system on all of its buses since 1993. Original system cost was about $15 million. The system includes computer-assisted dispatching. Each bus has a mobile data unit (MDU) and silent alarm for the driver. Over the last two years, the AVL has been linked to automatic passenger counters, which Metro has been operating on 12 percent of its buses since 1980 (see Section 2.4). Previously, the APCs had their own location equipment. Now, the bus' MDUs are capable of feeding bus location information directly to the APCs, eliminating the need for a separate signpost network.

The AVL also provides the information for "Bus View," a real-time passenger information system on the Internet (see Section 3.1) Bus View gives, in text form, bus schedules and vehicle status. Metro is also upgrading the CAD and AVL software, and is to have this completed by early 1998. Future system enhancements may include links to smart card readers on the buses, electronic fareboxes, electronic destination signs, and automatic vehicle identification tags. Metro cites the benefits of AVL as an increased availability of operations data, a greater ability to respond to service disruptions and emergencies, and the ability to offer transfer protection to their riders. [12]

Westchester County, New York

The Westchester County DOT (White Plains area) has been operating a signpost and odometer AVL system, including a silent alarm for the driver, on most of their 332 buses since 1983. The system has served the agency quite well, but the agency feels it is time to replace the system. The DOT has hired a consultant to conduct a review of the current conditions and interview the personnel working on the AVL system. They expect to complete a system design by the end of 1997 and release a request for proposals sometime in the second quarter of 1998. The new system will

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[11] Jim Kemp, New Jersey Transit, Newark, New Jersey.

[12] Dan Overgaard, Seattle Metro, Seattle, Washington.

(most likely) be GPS-based and will be designed to link into their two-way communications and the bus' "black box" (destination sign, farebox, etc.).[13]

A.2 Signpost and Odometer (Canada)

Hull, Quebec

Since 1984, the Societe' de Transport de l'Outaouais (STO) has been operating a signpost and odometer system on all of its 183 fixed-route buses. The AVL provides input to an extensive pre-trip telephone passenger information system, called "Infobus." The system is also supplemented with computer-aided dispatch, and each bus is fitted with a silent alarm and engine condition monitoring. Additionally, by the end of 1998, STO expects to begin implementation of a smart card system on their buses, which they will use (among other things) to get passenger counts.

STO is quite satisfied with the system and cited several benefits. One such benefit is a reduction in maintenance costs and service disruptions because of the engine condition monitoring. Another is the availability of better planning information. Finally, STO cites an increase in driver and passenger security, due to the silent alarm.[14]

B. Global Positioning System

Portland, Oregon

The Tri-County Metropolitan Transportation District of Oregon (Tri-Met) is just finishing installation of a GPS AVL system. All 640 of its fixed-route vehicles are equipped, and installation on its 140 paratransit vehicles, begun in September 1997, was to be complete within two months. Although they have not reached final acceptance, the fixed-route fleet is being dispatched using the AVL. The system also includes APCs (see Section 2.4) and real-time information for telephone operators to respond to passenger inquiries. (Future plans call for providing the real-time information

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[13] Richard Stiller, Westchester County DOT, White Plains, New York.

[14] Sallah Barj, Societe' de Transport de l' Outaouais, Hull, Quebec, Canada.

directly to the public, without the need for a human interface.) Three pilot tests of preferential treatment have been conducted and is now scheduled for permanent installation in a fifteen mile corridor. (Early buses will not receive preferential treatment.) The AVL is part of a regional ITS system, which is proceeding. Transit buses will be used as probes for traffic monitoring, and the highway department will provide the traffic information back to Tri-Met. [15]

Atlanta, Georgia

The Metropolitan Atlanta Rapid Transit Authority's (MARTA) ITS system received final acceptance on March 30, 1997. Of the system's 750 buses, 250 are equipped with AVL. The system is linked to the Georgia DOT's traffic management center for inter-agency cooperation. Also, 15 buses are currently equipped with automatic passenger counters, and 60 more will be added in the near future (see Section 2.4). Some of the buses are equipped with on-board annunciators (automatically actuated by the AVL), and there are electronic signs at a few bus stops and monitors at some bus-rail transfer stations. Although the real-time bus location information is not yet fed into the many electronic passenger information kiosks around the city, they are hoping to do this soon.

MARTA is pleased with its AVL system and notes concrete benefits. They believe they can more effectively improve on-time performance with the greater information AVL provides. Another benefit is greater safety. For example, when an off-route bus had an accident, the dispatcher sent assistance directly to the bus' current location, even though the driver had identified the bus as still being on-route. Another instance involved a bus, making the last trip of the night from a rail station, left before its scheduled time. The dispatcher saw that the bus had left too early, and called it back to the rail station, so that the passengers exiting the train would not be stranded. [16]

Denver, Colorado

The Regional Transportation District (RTD) has had an operational AVL system on all of its 900 buses since the end of 1995. AVL data are also used to post real-time departure information on

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[15] Ken Turner, Portland Tri-Met, Portland, Oregon.

[16] Mary Ruiz, Metropolitan Atlanta Rapid Transit Authority, Atlanta, Georgia.

signs at the two Mall stations, downtown. The system, which cost about $11 million, includes an extensive computer-aided dispatch system. RTD feels that the AVL system gives them better control of the fleet, while freeing a number of on-street supervisors for other important duties. Schedule adherence is improved since the installation of AVL. Disabled buses can be located and serviced much more quickly. Also, one fewer person is necessary at the downtown Mall stations where many of their routes terminate.

The agency also believes that AVL greatly heightens passenger safety. Police are now much more willing and able to respond to emergencies on buses, because the bus now can be located to within a few feet. Prior to the implementation of AVL, it could take a long time to locate the bus if it was off-route. In one situation, AVL greatly assisted RTD and the police in re-uniting a mother with her child which she had left behind on a bus.

Future plans center around use and dissemination of the bus location data. RTD is not currently using the schedule adherence function, nor are the AVL data being used by the scheduling department. This will happen when the schedule adherence function is working satisfactorily.

Current plans are to put passenger information data on the Internet. Additionally, there are information kiosks around the city, which may be fed AVL information in the future. Finally, there are plans to transmit the data to the Colorado DOT Traffic Operations Center for intermodal coordination of transportation in the region.[17]

Ann Arbor, Michigan

At the end of 1997, the Ann Arbor Transportation Authority (AATA) gave final approval to a new radio backbone and AVL system for their entire revenue fleet - 70 fixed-route buses and ten paratransit vehicles. The system, costing $2.3 million, uses both differential GPS and dead-reckoning, which can locate a vehicle within two to three meters. At dispatch, there are computer stations controlling fixed-route and paratransit operations. The system includes GIS maps, CAD, run-cutting software, and real-time paratransit dispatching software. The AVL system also has a

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[17] Lou Ha, Regional Transportation District, Denver, Colorado.

provision for "transfer protection," under which a bus, to which a passenger wishes to transfer, may be held at a major transfer point until the bus he or she is riding arrives.

The vehicles are fitted with several pieces of APTS equipment. There is a mobile data terminal on each vehicle, and each vehicle is fitted with sensors for automated monitoring of several engine components. The AVL also is being integrated with each vehicle's registering farebox. Each vehicle is equipped with internal and external digital signs and audible annunciators, actuated automatically by the AVL. Finally, nine of the vehicles are equipped with APCs.

AATA is also testing two types of security cameras on 51 of their vehicles. Thirty-seven vehicles are equipped with standard video cameras, three per bus. Images are recorded on video tape. Fourteen vehicles are equipped with digital cameras, two per bus. Digital cameras store their recorded images on computer media.

In addition to the on-vehicle passenger information equipment, the AVL feeds an extensive pre-trip and wayside real-time passenger information system. Real-time traveler information will be available over the Internet in the near future, and AATA plans to get this information onto cable television (TV) at a later time. There also will be monitor screens at the transit center.

Finally, there are plans to include smart cards in the system. The University of Michigan has issued 60,000 smart cards to University students, staff, and faculty and is in the process of updating the technology. Once the University has chosen the new technology, AATA and the University have plans to allow the new cards to be used for both transit and for parking. This would increase not only the usefulness of the card to riders, but also encourage intermodalism, providing the flexibility for a rider to take transit one day and drive the next, without paying two entities.[18]

Milwaukee, Wisconsin

The Milwaukee Transit System (MTS) approved the purchase of a GPS AVL system in 1992 for approximately $7.8 million. Installation of the system is complete on all vehicles (543 buses and 60 support vehicles), and final acceptance was issued in August of 1996. The system includes a

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[18] William Hiller, Ann Arbor Transportation Authority, Ann Arbor, Michigan.

control head and a silent alarm in each bus, and CAD, which (among other things) will prioritize communications, alerting dispatchers to the more serious emergencies first.

MTS is pleased with the system. Since installation, the AVL system has met the needs of the city and "has helped us provide better, more reliable service to our customers." [19] More specifically, MTS says that between January 1994 and September 1996, "...the number of off-schedule buses (more than one minute early or three minutes late) has been reduced by 40 percent ... during a time period in which the route schedule adherence function was not operational on all buses..." Further, "AVL has improved relations with law enforcement officers ... now sent to an exact location, not an estimated location ... improving their response time and eliminating frustrating searches for the vehicle." [20]

As advice to others purchasing an AVL system, MTS advises the careful definition of clear, reasonable objectives that meet the needs of the area and a close, positive working relationship with the vendor. Prepare a detailed specification for prospective vendors, including a phased acceptance testing program, and be realistic about the timetable for project completion. [21, 22]

Chicago, Illinois

In April 1996, the Chicago Transportation Authority (CTA) issued a Notice to Proceed on the installation of a combination dead-reckoning/GPS system on 1,558 of its nearly 2,100 buses. CTA expects the installation to be complete at the end of 1998. Because of the many tall buildings lining the streets of downtown Chicago, CTA is using a combination of dead-reckoning and GPS to enjoy the advantages of GPS, yet compensate for the times the GPS signals are blocked by buildings.[23] The system will include a Bus Service Management System (see Section 2.5.1), which will aid dispatchers to more quickly and easily correct deviations to the schedule, whether they be

[19] "Milwaukee Turns 'SmartTrack' Concept into Reality," **Passenger Transport,** Monday, September 2, 1996, Page 8.

[20] Ibid.

[21] Ibid.

[22] Michael Giugno, Milwaukee Transport Services, Inc., Milwaukee, Wisconsin.

[23] David Phillips, Chicago Transit Authority, Chicago, Illinois.

major disruptions to service or simply buses drifting off schedule in rush-hour traffic. The AVL will also include a Bus Emergency Communications System, a fully integrated communications base that enhances the effective delivery of bus service using a new two-way voice and data radio system (see Section 2.5.1).[24] CTA also operates APCs on 25 of its buses (see Section 2.4). These are currently operated separately from the AVL, but there is consideration of linking the two.[25]

New York City, New York

In October 1996, New York City Transit (NYCT) awarded a contract for an 18-month demonstration project of an AVL system. The New York City environment also provides extremely heavy ridership, headway variability, and bus bunching, all of which have to be addressed in system design, installation, training, and operation. As of September 1997, the project had passed the critical design phase and had begun the construction and installation phase. The AVL will locate primarily by GPS, but will also rely heavily on interpolations between GPS signal receptions with dead-reckoning, due to the challenging environment of New York City. Tall buildings lining both sides of most streets make it difficult to obtain GPS signals, making position determinations by GPS less frequent.

Approximately 170 buses from the 126th Street depot in Manhattan will be equipped with differential GPS receivers and dead-reckoning technology, connected to mobile data terminals (from which the driver will receive information). Anticipated accuracy of the vehicle location is about ten meters. The on-board processor (vehicle logic unit) will store uploaded schedule information and will use time and locational data to compute schedule adherence for both the driver and the dispatch center. Problems will be transmitted on an exception basis. However, a default polling interval of 40 seconds will be used to provide the timely vehicle location data required by the customer information system that is being developed simultaneously (see Section 3.2). Drivers will use a soft key vehicle control head to communicate both digital messages and requests to make voice contact over the upgraded 800 MHz radio network. Radio system upgrades include de-trunking of five of

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[24] Ronald Baker, Chicago Transit Authority, Chicago, Illinois.

[25] Ross Petronsky, Chicago Transit Authority, Chicago, Illinois.

their 15 channels to provide dedicated channels for transmission of AVL data to the related CAD system (see Section 2.5.1). Archival data and reports will be used to optimize routes, schedules, and operations.[26]

Akron, Ohio

The Akron Metropolitan Area Transit Study, an extensive test of a European GPS AVL system, is in progress at METRO Regional Transit Authority. In order to "prove the concept of [the] system under U.S. conditions,"[27] 14 buses have been equipped with "COPILOT/Softkey/GPS and data radio"[28] plus an extensive in-vehicle communications network (vehicle area network). The vehicle area network connects the on-board computer, GPS receiver, odometer, vehicle logic unit, mobile data terminal, door open/close detection switch, all radio communication equipment, and any other related equipment on the bus. Each bus also is capable of initiating traffic signal priority at four intersections in the metropolitan area. Two buses are equipped with automatic passenger counters, and two buses have in-vehicle passenger information systems (both by visual sign and audible annunciator). One bus stop has a wayside monitor.

Data may be transferred both to and from the bus by a couple of methods. The primary link is by radio, but the on-board computer also may be linked directly to a laptop computer. Although data is primarily transferred *from* the on-board computer (to a more permanent storage device), a possible future enhancement to the system will allow for direct *uploading* of information, such as new routes or schedules to the on-board computer.

The central dispatch station is equipped with both dispatch, control, and communications equipment and "real-time operation performance monitoring." The system also is capable of integrating engine component monitoring and automated control of destination signs, although these two items are not part of the current test.[29]

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[26] Isaac Takyi, New York City Transit, Brooklyn, New York.

[27] Info sheet, **INIT Info: USA Akron, Ohio**, Init Project 97071.

[28] Ibid.

[29] Ibid.

Phoenix, Arizona

AZTech is one of the four U.S. DOT ***Model Deployment Initiative*** locations that is implementing new traffic and transit ITS technologies and integrating them with existing ones. As part of the transit component, 88 buses will be equipped with a GPS AVL system. Part of the test is an effort intended to test the integration of multiple AVL systems into a single AZTech data server. To this end, 65 of the buses will run on four long, high-ridership routes that operate through multiple jurisdictions in the Phoenix metropolitan area, and the remaining 23 buses will be deployed on six routes in neighboring Mesa. Installation of the AVL system was expected to be complete in November 1997.

Torrance, California

Torrance Transit is implementing a limited GPS AVL system on its entire, 85-vehicle fleet, including both paratransit vehicles and fixed-route local and express buses. Expected to be completed in November 1997, this AVL implementation is "limited," because the location information (as currently planned) will not be used for traditional AVL functions, such as computer-aided dispatch. However, the AVL system is designed so that it can feed a CAD system if future plans call for this feature and communications capacity is increased. For the present time, the AVL system primarily will be used to feed information to the real-time passenger information systems, both in-vehicle and wayside (see Section 3.3). The AVL system will also be used for vehicle component monitoring, an advanced fare payment system, automatic passenger counters (on 15 of the 85 vehicles), and a test of traffic signal priority treatment (see section 2.6). [30]

C.1 Dead-Reckoning (United States)

Houston, Texas

The Metropolitan Transit Authority (Metro) is planning to procure a full AVL system for all the vehicles it operates - 1,200 fixed-route buses, 153 demand-response vehicles, 154 police cars, 4

[30] Bob Meyers, City of Torrance, Torrance, California.

motorcycles, and 263 support vehicles. Previously, they awarded a $22 million contract for the communications backbone, complete with a new radio system, and a vehicle area network, which complies with the J1708 standard, for their buses. (The installation of this backbone was to be complete by January 1998.) The desired location method "is specified as dead-reckoning supplemented with another proven location technology. Final determination of the 'other' [location technology] has not been made."[31]

The communications backbone is designed to support several other APTS applications. The base system will be linked to both the electronic farebox and the destination signs on the exterior of the bus. In addition, there is funding in place for the procurement of approximately 250 automatic passenger counters. Possible future additions to the system include annunciators and remote engine monitoring.[32]

C.2 Dead-Reckoning (Canada)

Hamilton, Ontario

A rare application of nearly pure dead-reckoning, the Hamilton Street Railway Company (HSR) has been operating its AVL system since 1991. The system was purchased at a cost of $6 million (Canadian) and included odometer sensors and integrated compasses for all 240 buses HSR operates. Additionally, two signposts were placed along each route for periodic corrections to the dead-reckoning. HSR also operates automatic passenger counters on a percentage of their buses, independently of the AVL (see Section 2.4).[33]

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[31] Lloyd Smith, Metropolitan Authority of Harris County, Houston, Texas.

[32] Ibid.

[33] Kevin Smith, Hamilton Street Railway, Hamilton, Ontario, Canada.

D. Ground-Based Radio

Santa Monica, California

The Santa Monica Municipal Bus Lines continues to employ an alternative form of vehicle location. As described in **Update '96**, the agency has had the AVL system in regular operation since October 1992. For $130,000, the agency purchased a workstation equipped with a modem, an electronic map with a detailed database of the streets and addresses in the Los Angeles area, and communications and control software. Buses are located by using a network of transmitting and receiving antennas.

The agency's workstation communicates with the control center through standard telephone lines, and the agency pays a monthly subscription fee, based partly on the amount of time its workstation is connected to the central computer. The agency does not connect their workstation to the central computer too often, because the cost would be prohibitive. The AVL, therefore, does not operate in real-time. Santa Monica Municipal Bus Lines uses the information for planning and problem investigation only. [34]

2.4 AUTOMATIC PASSENGER COUNTERS

Automatic passenger counters are a well-established, automated means for collecting data on passenger boardings and alightings by time and location. Typically, between 10 and 20 percent of an agency's buses are equipped. An APC has three basic components:

- Counter - capable of counting each passenger as they board and alight and distinguish between boardings and alightings;
- Location technology - capable of determining the bus' location at least at the time boardings and alightings occur; and
- Data management - capable of storing the data long enough so that it can be transferred from the vehicle.

The two most prevalent types of counters are treadle mats and infrared beams. In the case of treadle mats, a mat is placed on each (must be at least two) of the stairs leading onto the vehicle.

[34] Janet Shelton, Santa Monica Municipal Bus Lines, Santa Monica, California.

As passengers board or alight, they step on the mats in a particular order, from which the APC processor can determine if the event was a boarding or alighting. This technology is simple and straightforward, but is subject to some hazards, such as water or slush leaking into the mat and shorting out the electronics, and the wear of many, many footsteps. They also have some trouble counting if two people step on the mat at the same time (either both boarding or one boarding and another alighting).

Infrared beams use the same principle as treadle mats, but, in this case, a pair of beams are set up in the path of boarding and alighting passengers. Usually, these beams are mounted horizontally, and go from one side of the doorway to the other. Occasionally, they are mounted vertically, and go from the ceiling of the vehicle to the floor (but they are still set-up near the door). Infrared beams are far less sensitive to snow, rain, or heavy footsteps than are treadle mats, but they are vulnerable to high concentrations of airborne particles, such as dust, soot, or pollen. Also, like treadle mats, they have some trouble counting if two people pass the beams at the same time.

The options for location technology are similar to those discussed in Section 2.3. In fact, an APC installation is often a component of an automatic vehicle location system. Whether a component of AVL or a stand-alone system, the most common options are signpost and odometer, GPS, or dead-reckoning.

The choice of a particular means of data storage and transmission approach is driven largely by both the infrastructure in place (especially for other APTS systems), and the transmission options available. If there is an AVL system, an APC system can take advantage of an AVL system's data transmission conduit to send its data as well, as long as there is sufficient capacity. The options for receiving APC data can be generalized as:

- Removing the storage media and replacing with a fresh storage media (e.g., removing a full floppy disk or data tape and putting a new one into the storage device);
- Physical data connection (e.g., attaching a cable to the storage box and downloading to a laptop or central computer);
- Short-range wireless connection (e.g., downloading over low-power radio signal once the vehicle has returned to the garage); and
- Long-range wireless connection (e.g., downloading over dedicated radio frequency, possibly every few minutes).

Each option has different strengths and weaknesses. While a dedicated radio frequency delivers the data quickly and efficiently without the need for personnel to retrieve the data manually, it requires the dedicated frequency, which can be expensive and hard to obtain. The choice of storage and transmission will depend on the agency's needs and anticipated uses for the data.

APC data may be used for a number of applications, both real-time and delayed, including:

- Input to dispatcher decisions on immediate corrective action (e.g., short-turn the empty bus, not the full one);
- Input to real-time passenger information systems (e.g., "two buses are coming on the #7 route, the first is five minutes away and full and the second is eight minutes away and nearly empty");
- National Transit Database reporting (of passenger trips and passenger miles; formerly known as "Section 15 reporting");
- Future scheduling;
- Positioning new shelters for waiting passengers; and
- Fleet planning.

It is anticipated that APCs will achieve the following:

- Decrease data collection costs;
- Increase the type and range of data available;
- Decrease time and effort required to process collected data;
- Increase overall operating efficiency due to better service planning; and
- Provide data to passenger information systems.

State-of-the-Art Summary

The first generation of APCs were deployed over 25 years ago. Since these systems pre-dated not only modern AVL systems, but also nearly all of the computer and digital radio technology now utilized, their applications were limited to scheduling, planning, and similar functions. Although the technology of the 1990s is far more dazzling than these old systems, the APCs of the 1970s still provided accurate data more quickly and at a lower cost than could be achieved with manual data collection by human checkers. Some of these systems are still in use, often with updated equipment.

An agency installing an APC system in the 1990s is most likely to be putting it in as part of an AVL system. Whether or not the agency takes advantage of collecting the data in real time, the ability to make use of existing location and/or data transmission technology greatly decreases the capital cost of the APC system and makes it more fiscally feasible.

In fact, very few agencies with existing APC systems with the capability to transmit data in real time actually use that data in real time. Nearly all those with APC systems use the data for planning, scheduling, or detailed analyses. This is due largely to the fact that most agencies equip only a sample of their buses with APCs, which limits the number and benefit of real-time data applications. Additionally, many agencies have barely enough radio capacity to transmit the AVL information in real time. Adding passenger count data to that would put a further strain on the system and create greater delays in getting the location information to dispatch.

According to the **Advanced Public Transportation System Deployment in the United States** report, there are 31 fixed-route bus systems and one commuter rail system either planning, installing, or operating APCs. Of these, 11 are operational, six are under implementation, 13 are being planned, and two are being tested.[35]

Application Examples (United States)

Columbus, Ohio

The Central Ohio Transit Authority (COTA) is performing a major upgrade to its automatic passenger counting system. COTA procured the original 37 infrared-beam APCs (to cover roughly 10 percent of their fleet) and 105 signposts for $171,000 in the early 1980s. The agency has operated this system since 1984. Currently, a technician transfers data from each bus every few days by replacing a full 3-1/2" diskette with an empty one. (This is a recent upgrade from slower, less-reliable cassette tapes. The diskettes also hold four to five times as much data as do the old tapes.) COTA is considering a transition from signposts to GPS in about three years, if funding can be obtained.

According to COTA, the counts provided by the APCs are 95 percent accurate, and the counters are automated and require no driver input. COTA uses the data for most of the standard

[35] Casey, Robert F. and Lawrence N. Labell, **Advanced Public Transportation Systems Deployment in the United States,** Volpe Center of the U.S. Department of Transportation for the Federal Transit Administration of the U.S. Department of Transportation, August 1996.

purposes including: their annual National Transit Database report, schedule adherence (though not in real time), and system planning.[36]

Portland, Oregon

Tri-Met's system became operational in 1982 and cost $4,500 per APC. Location was determined by combining time with knowledge of schedule and layover points. Plans call for expanding the number of APCs to 20 percent of the fleet (currently on 80 of Tri-Met's 635 buses). Today, the new counters are much cheaper, costing only about $1,000 per bus. The APC system has been linked to Tri-Met's AVL system, which provides much more accurate location information than did the old method. Finally, there also have been advances in retrieving the data from the bus. Now they are transmitted along with the AVL data over the reserved radio frequencies, although the data are still not used in real time. Formerly, data was retrieved by special units, which collected the data automatically from each APC-equipped bus via infrared link when the bus returned to the garage.

Tri-Met states that the APCs provide easier and quicker access to passenger data and is less expensive than manual counting.[37]

Atlanta, Georgia

The Metropolitan Atlanta Rapid Transit Authority acquired 15 infrared-beam APCs as part of its original AVL system. Currently, they are purchasing 60 more, citing the ease of data collection, which can be used for things such as bus stop re-alignment or identification of unproductive trips or parts of trips. [38]

Chicago, Illinois

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[36] Khaled Shammout, Central Ohio Transit Authority, Columbus, Ohio.

[37] Ken Turner, Tri-County Metropolitan Transportation District of Oregon, Portland, Oregon.

[38] Mary Ruiz, Metropolitan Atlanta Rapid Transit Authority, Atlanta, Georgia.

In June 1997, the Chicago Transit Authority signed a contract to install treadle-mat APCs on 25 of their buses. They are working on Phase II, which would expand the system to 40 more buses. Data are uploaded daily, over an infrared link in the garage. There are tentative plans to link the counters to the AVL system when it becomes operational (see Section 2.3)[39]

Application Examples (Canada)

Calgary, Alberta

The City of Calgary operates a relatively new APC system. Brought on-line in 1990, the original system cost approximately $300,000 (Canadian). Included were 70 signposts and 25 treadle-mat APC units, enough to equip about five percent of their regular bus fleet. The agency has since upgraded the original system by moving from signposts to GPS. By the end of 1997, four low-floor buses also will be equipped with APC sensors.

Other recent improvements to the APC system include automation of route key-in during data collection and an update of the software for processing the data. Currently, the driver of an APC-equipped bus inputs the route it will travel at the start of the run. In order to avoid human error and to save the driver the additional task, the agency plans to automate this input by comparing the stops the bus reaches to known route data. The agency is also upgrading the software which generates reports to be more automated. The new software will be able to correct small errors faster and help the agency keep up with the large data flow.

Benefits are still in-line with those cited two years ago: the data are of a type, detail, and extent that they could not acquire by any other method. They regard the count data as "extremely accurate," and the point-to-point bus travel times as very valuable for future planning. Further, they cited that it would cost approximately $2 million (Canadian) annually to collect the data they now collect for $18,500 (Canadian) - $2,500 for power, $10,000 for maintenance, and $6,000 for software support.[40]

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[39] Ross Petronsky, Chicago Transit Authority, Chicago, Illinois.

[40] Neil McKendrick, City of Calgary Transportation Department, Calgary, Alberta, Canada.

Hamilton, Ontario

The Hamilton Street Railway Company is implementing significant upgrades to its 10-year-old APCs. HSR's new, low-floor buses are being equipped with vertical infrared beams, which operate on the same principle as horizontal infrared beams but point downward. HSR also would like to upgrade the on-board data storage to make it more reliable, and the data retrieval system to make it more automated.[41]

2.5 TRANSIT OPERATIONS SOFTWARE

Transit operations software has the capability to automate, streamline, and integrate many transit functions and modes. Computer applications such as computer-aided dispatching, service monitoring, and supervisory control and data acquisition (and the APTS technologies which provide the data to them) can improve the effectiveness of operations dispatching, scheduling, planning, customer service, and other agency functions. The use of operations software can result in more reliable service to the customer, more efficient operations for the agency, and enhanced safety for vehicle operators and customers. Like ITS technology for highways, APTS systems integrated with operations software permit maximum use of existing infrastructure (for example, allowing shorter headways on rail lines) while maintaining safe operating conditions.

Transit operations software systems can enable the identification of incidents and can assist in managing response and service restoration effectively. Although integration of transit modes like fixed-route bus, paratransit, and rail has increased since January 1996, it can still be characterized as in the early stages of development.

2.5.1 Fixed-Route Bus

Given the increasing competition for radio communications capacity, and the concomitant increase in data transmission that results from automatic vehicle location, automatic passenger counting and other APTS technologies, a key feature of CAD software is its ability to manage

[41] Bob Krbavak, Hamilton Street Railway Company, Hamilton, Ontario, Canada.

communications. Nevertheless, some agencies still need to upgrade their communications infrastructure to support deployment of a CAD system.

Using on-board technologies such as vehicle logic units (VLU) and mobile data terminals that allow bus operators to both send and receive digital messages, CAD systems are critical in reducing the amount of voice traffic, and prioritizing the importance of both voice and digital transmissions. Silent alarms, for example, allow the operator to covertly inform dispatch of emergency situations. Dispatchers can, in turn, knowing the exact location of the affected vehicle, dispatch emergency personnel more quickly to the scene.

CAD software (in concert with AVL) facilitates tracking the on-time status of each vehicle in a fleet. Not only do operators and dispatchers benefit from regular updating of on-time status, but customers benefit as well through the information systems described in Chapter 3. CAD systems enable central dispatchers to 'see' the location and status of each bus in their control area. Therefore, they are equipped to address service irregularities, such as bus bunching, and can efficiently respond to a variety of incidents. CAD systems also provide organizations with archiving and targeted retrieval of historical operating data. These capabilities benefit the operations, planning and scheduling, and management departments.

State-of-the-Art Summary

Software for fixed-route bus operations is rapidly evolving from traditional run cutting, operator bid processing, timekeeping, and dispatching to include integrated fleet management applications. With the advent of APTS technologies, transit operators are able to deploy computer-aided dispatch software that assimilates a range of data collected and processed on in-vehicle processors to improve the efficiency and safety of operating fixed-route fleets. Using technologies such as global positioning systems, such software is designed to help make operational decisions in real time and archive data for a variety of other transit agency decision-making needs.

Application Examples

Montgomery County, Maryland

The Montgomery County Department of Public Works and Transportation's Transit Division has installed a differential global positioning system AVL and CAD system on about one-half of its 225 buses. This system features "intelligent vehicle" technology that continuously calculates vehicle positions so that the on-board mobile data terminal can report exceptions between one minute polling intervals. Exceptions such as emergency communications are transmitted immediately. The CAD system also initiates a 'health check' of each vehicle every five minutes. An important characteristic of this fleet management system is its location within the county's transportation management center (see Section 5.4).[42]

The final implementation of a three-channel (two voice, one data) radio system necessary for full implementation is expected during Fall 1997. The CAD system not only prioritizes the flow of data communications and requests to talk (voice transmission), but also assigns radio transmissions to the most appropriate channel to maximize the radio system's capacity. It allows transit coordinators to send voice or data transmissions to a single vehicle, all vehicles on a single route, all vehicles in any geographic area, or to the entire fleet.

Ride-On's APTS installation will have many common CAD features. Operators will be continuously informed of their schedule adherence by the transit control head, and will be notified with an alarm when they are two minutes ahead of schedule or five minutes behind. The alarm will sound again for each additional minute the driver falls behind schedule. At dispatch, transit coordinators will also be notified of schedule adherence and can determine the best schedule restoration strategy. This strategy can then be communicated to the operator via a data or voice message.

The hardware and software can seamlessly integrate other APTS technologies such as APCs, which is one of the next major components the Transit Division would like to incorporate.

The system is equipped with a silent emergency alarm feature which allows the operator to covertly inform dispatch of an emergency "only in life threatening situations when using the handset

[42] Marc Atz and Alfie Steele, Montgomery County Department of Public Works and Transportation, Rockville, Maryland.

may cause the threatening person to harm the operator or a passenger."[43] This feature also allows transit coordinators to trigger a covert microphone on the bus and track the bus' location as emergency personnel are notified. Once the CAD system has logged an emergency event, the alarm will continue to sound at the dispatching console until the event has been resolved. Initial discussions have taken place with the local police to automatically inform them of bus emergencies by integrating Ride-On's CAD with the new radio and CAD system the County is developing for its emergency services.

The CAD system is set up to assign drivers, blocks, and vehicles based on schedule and "driver pick" information. It is expected that almost all of the vehicles will be automatically assigned by the CAD system. The advantages of this feature include saving time for supervisory personnel at the garages and ensuring that pullouts occur on time.

By the end of 1997, Ride-On is planning to deploy a remote CAD workstation at one of its bus garages. This will allow supervisory personnel to track driver reporting and change daily assignments if needed. The software will automatically notify the supervisor if any drivers have not reported for duty by a prescribed time, giving them the information and advance notice to reassign the work or vehicle. The county plans to add another remote workstation at its second garage during 1998.

Milwaukee, Wisconsin

The Milwaukee Department of Public Works' Transit Division has been operating a computer-aided dispatch system since 1992, when it began installation of a GPS AVL system on its entire vehicle fleet of buses and service vehicles. The CAD software performs schedule adherence, route adherence, manual schedule restoration, and covert emergency messaging/microphone activation. A significant improvement in the system's original capabilities was a software upgrade that included route termini as time points, allowing the CAD system and dispatchers to monitor layovers and departures.[44]

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[43] **Ride-On Central Radio Dispatch Guide.** Internal training material for Montgomery County Department of Public Works and Transportation bus operators.

[44] Ron Rutkowski, Milwaukee County Department of Public Works, Milwaukee, Wisconsin.

The schedule adherence component signals both drivers and dispatchers when a bus is running two minutes ahead or three minutes behind schedule. In the majority of instances, the information provided on the transit control head is sufficient to get the driver back on schedule.

An important and related capability of the CAD software is its ability to archive operating data for supervisory or planning purposes. For example, operations center staff can produce reports that identify operators who consistently run off-schedule, and can subsequently take appropriate actions in the field to improve the situation. As for scheduling and planning, historical data is being manually fed into the agency's scheduling software to optimize schedule parameters on individual routes such as running time requirements and duration of layovers. Although the interface between the two systems could be automated, schedulers are satisfied with the current setup.

The Transit Division is upgrading the software for its legacy AVL system to be compatible with both the Society of Automotive Engineers (SAE) J-1708 and J-1587 interface standards which were not in existence when the system was originally installed. The upgrade is now necessary for both the long-term addition of other APTS technologies and in the short term to support the installation of APCs on 35 buses. The APC installation on a portion of the fleet and systems upgrade on all vehicles began in September 1997 and is to be fully operational by Spring 1998. The upgrade will also allow the agency to add mechanical component monitoring via existing communications ports that will send equipment status such as oil pressure and engine temperature information directly to the maintenance garage.

Once the vehicle logic units (VLU) have been upgraded, the Transit Division will be able to begin implementation of ADA-compliant "next-stop" annunciators and displays. The agency currently expects full deployment of this feature in 1999.

Seattle, Washington

King County Metro is in the process of upgrading its CAD and AVL systems. Originally specified in 1989 and procured in 1992, Metro Transit is changing the CAD's user interface from the keyboard-only Unix/DOS platform to Windows NT's mouse-based graphical user interface. This is being done to improve the speed and efficiency of the control center's communication coordinators during peak periods and incidents by providing a point-and-click interface. The agency is also migrating the main fleet management processor from a Digital Equipment Corporation (DEC) 5400 platform to two DEC Alpha computers, one providing on-line processing and the other expanding the archiving capacity of the system. Scheduled for completion during 1998, the improvements will also include upgrading the AVL tracking subsystem computer.[45]

The CAD software is being upgraded to improve vehicle tracking and real-time event reporting. The improvements will allow the CAD to automatically group incidents by type and rank them by severity so that the five communications coordinators, who may be handling up to five incidents simultaneously during the peak period, are better informed and able to handle the high volume of events. A significant impetus for the CAD system redesign is to manage the 950 buses during adverse weather conditions, when over a third of the fleet can be disabled.

The CAD system already allows communications coordinators to monitor schedule adherence. Route adherence cannot be tracked due to the AVL's signpost/odometer technology. The CAD system prioritizes communications and includes a silent alarm function. The agency's APCs, which have been on approximately 12 percent of the buses since the late 1970s, will be integrated into the CAD system during 1997.

Two other improvements are being implemented as part of the project. The CAD software will include a window for tracking internal resources. Although updated manually, it will allow operations center personnel to quickly determine the status and availability of district supervisors, Metro Transit police, and maintenance vehicles. This will reduce needless communication among the communications coordinators and enable quicker response to a variety of incidents. The addition of the second CAD server will increase the amount of on-line data available. At the same time, it will facilitate report generation for internal users of the operating information such as service development, scheduling, operations, and customer assistance staff.

Chicago, Illinois

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[45] Dan Overgaard, King County Department of Transportation, Metro Transit, Seattle, Washington.

The Chicago Transit Authority is implementing APTS technologies through its Bus Emergency Communications System (BECS) and Bus Service Management System (BSMS). The BECS is a fully integrated communications base that enhances the effective delivery of bus service using a new two-way voice and data radio system. The BSMS is a demonstration of several APTS technologies, including computer-aided dispatching, which provide schedule and headway adherence monitoring for 100 buses operating on two of CTA's major routes. When the location data show that there is a problem on the street, the BSMS will assess the current situation on the street and compare it to ideal conditions, as previously defined. The BSMS will then suggest alternative corrective actions to the dispatcher. The dispatcher can then choose from among the alternatives, and issue instructions to the relevant drivers. The BSMS will also test traffic signal priority at five major intersections and will provide displays that show actual expected arrival times to waiting passengers at two bus stops. These tests will use standard interfaces that will allow CTA to consider adding other fleet management functions after system-wide deployment of both systems.[46]

Portland, Oregon

The Tri-County Metropolitan Transit District of Oregon is in the process of upgrading its computer-aided dispatch system for its bus and paratransit fleets. The agency has been operating the new system in test mode on its fixed-route vehicles since July 1996. Operational on the entire 640 vehicle fixed-route fleet since July 1997, it will be installed on the 140 vehicle paratransit vehicle fleet by the end of 1997. At the same time, Tri-Met expects that acceptance testing for the entire project will be completed.[47]

The CAD system uses exception reporting to limit radio traffic, combined with a five-minute default polling cycle referred to as a "health report." This strategy ensures that the CAD database at the bus dispatch center is updated with at least the minimum information required for tracking and reporting purposes. The CAD system is expected to be especially important for managing the

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[46] Ron Baker, Chicago Transit Authority, Chicago, Illinois.

[47] Ken Turner, Tri-County Metropolitan Transportation District of Oregon, Portland, Oregon.

previously overburdened radio network for the paratransit operation, which was creating communication delays.

Like many CAD systems, schedule adherence information is available to the bus operator and a dispatch staff person on a continuous basis. A unique feature of Tri-Met's system is the variable on-time window. Instead of being locked into the current two minute and eight minute schedule parameters, the bus dispatch center can change the parameters via digital message to one bus, several buses, all buses on a single route, or the entire fleet depending on incidents, detours, route congestion, or adverse weather (when most buses would be running behind schedule anyway). Firmware in each vehicle logic unit stores route, time, and location specific data and automatically computes adjustments to the on-time window without driver input based on the message from the bus dispatch center. Even though this is a complex schedule adherence algorithm, dispatchers only see color-coded icons on the screen that indicate a vehicle's current on-time parameters. Therefore, they don't need to keep track of the changing schedule adherence settings. Although the CAD system will not automate schedule restoration strategies, Tri-Met expects that once its dispatchers are fully trained, they will be able to use existing strategies much more quickly and effectively.

The CAD system manages silent alarms, emergency and priority messaging, and triggers covert microphones on the buses. Using the VLU, it also automatically updates the Luminator destination signs. Automatic passenger counting is also handled by the VLU. In the future, Tri-Met will integrate mechanical diagnostics into the CAD system. By purchasing new buses that trigger engine warning lights through electronic error codes, the VLUs can be programmed to automatically transmit the data to the bus dispatch center.

The Tri-Met system is designed to gather an enormous amount of data, both on-board and at the bus dispatch center. All data stored by the VLU or sent to dispatch is time, date and location stamped. This permits spatial analysis of any subset of the digital information.

Because of the sheer quantity of data that is collected directly by the CAD server and by the VLUs, Tri-Met has undertaken development of standardized report applications for the CAD system. This effort will allow time-based data analysis to produce highly usable reports for operations staff, schedulers, service planners, and customer service staff. Reports are being designed that can be targeted to a particular driver, trip, block, or route and will look at performance of these variables over any period of time.

Tri-Met has also set up an evaluation methodology to determine the system's benefits. The agency is working with Portland State University to do a study. Performance measures include on-time performance, trip times, and vehicle spacing during the peak period.

New York City, New York

New York City Transit is in the process of implementing an AVL demonstration project (also see Section 2.3). NYCT awarded a contract in October 1996 for the 18 month, $5 million project using Congestion Management and Air Quality funding. As of September 1997, the project has passed the critical design phase and is now in its construction and installation phase. [48]

Approximately 170 buses from the 126th Street Depot in Manhattan will be equipped with AVL. The CAD software will be used to process the data. It will integrate an expert system called the Computer-Aided Support System (CASM), that will enhance the service and control technologies. CASM will help control center personnel decide how to respond to various events and incidents by providing them with options. Once a CASM action is taken (for example, a bus is short-turned), the CAD system is updated based on that action. In addition, the server controlling the passenger information system will also be updated to ensure that wayside customer information remains up-to-date.

Among the benefits anticipated of the new system are:

- Improved service regularity by anticipating gaps in service and correcting vehicle bunching;
- Real-time exception report (ahead or behind schedule, and off-route);
- Effective management of emergency situations through the use of a silent alarm and covert microphone;
- Quick response to service disruption sites; and
- Ensuring critical transfers. [49]

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[48] Isaac Takyi, New York City Transit, Brooklyn, New York.

[49] "Intelligent Transportation Systems Projects for New York City," presentation by Andrew Bata to NTI meeting August 1, 1997.

2.5.2 Rail

Operations software for rail transit systems are generally built upon existing or upgraded supervisory control and data acquisition systems (SCADA) which include: the wayside monitors for switches, signals, and interlockings; wayside sensors for electrical and mechanical subsystems; a communications backbone such as fiber optic cable; and software for processing and displaying the data. These applications typically allow the integration of SCADA data with other control systems such as automatic train control (ATC), automatic vehicle identification (AVI), traffic signal loop detectors (for light rail signal priority at grade crossings), and automated train dispatch. Vehicle location is usually accomplished using signal block occupancy and/or AVI transmitters.

State-of-the-Art Summary

Rail systems continue to upgrade their operations software, usually in concert with the construction of or improvements in an operation control center. Often, part of these changes are enhancements of both the dispatchers' consoles and the large wall displays that enable dispatchers, supervisors, emergency personnel, and others to view real-time location of trains and status of critical mechanical and electrical subsystems.

Important system enhancements are being tried. For example, the Massachusetts Bay Transportation Authority in Boston reports consolidating several of its wayside train control towers into its central control facility. The San Francisco Bay Area Rapid Transit system has been able to increase the throughput on its interlockings when an incident or maintenance requires it to go to single track operation. Portland Tri-Met is integrating its train control information into the bus dispatcher's consoles in order to facilitate transfers between its fixed-route bus system and light rail line.

Where new communications backbones are being installed, agencies report the ability to improve customer communications either with public address or in-terminal/wayside displays using vehicle location information from a tracking system.

Application Examples

New York City, New York

New York City Transit has completed design work and partial testing on a number of systems to improve the operations and safety of its subway system. The four major components - automatic train supervision (ATS), subway train and traffic information system (STATIS), Six-Wire modernization, and communications-based train control (CBTC) - are features of the Control Center Modernization Project's rail control center that was reported on in **Update '96**.

ATS

The ATS system will provide for centralized service management of the subway trains by incorporating real-time train tracking, monitoring, and operations control from a centralized location. The ATS is based on software that will use information from the existing supervisory control and data acquisition system to monitor and control standard operating procedures. The ATS is roughly equivalent to a computer-aided dispatch system.

The ATS system will be implemented first on the agency's A division and then rolled out on its B division during Phases 2 and 3. The initial deployment of the ATS and construction of the rail control center is expected to be completed in 2001 at a cost of approximately $162 million.

STATIS

STATIS is a computerized version of train register sheets and gap sheets that will make it easier for subway operating personnel to access information regarding train consists and schedules. The Phase 1 demonstration onthe Flushing Line (#7 train) has been completed. Phase 2 will include full installation on the Flushing Line and Queens Boulevard Lines (#E, F, G, and R trains). In addition to managing critical operating information, STATIS will provide train arrival and departure information to customer information signs (described in Chapter 3).

CBTC

The CBTC system will enhance the train monitoring and control capabilities of the ATS by using a variable block train tracking technology rather than the existing fixed block method. The variable block tracking system will involve installation of wayside electronic readers that will result in communications-based signals and thus allow shorter control segments than the fixed block signals permit. With its specially designed software, CBTC will enable NYCT to safely shorten headways. The CBTC systemwill also facilitate fully-automated dispatching from rail yards and line terminals to ensure on-time departures. The system is scheduled for completion in 2001.

Emergency/Incident Response

A key element of the system-wide upgrade is the Six-Wire Modernization. This project is designed to supplement existing voice-based communications devices. It will incorporate an on-line, real-time system that will provide digital notification of emergencies to all NYCT operatin g departments monitoring the system. The new fire incident response system and train incident reporting system (described below) will also be integrated with the improved six-wire system. This will provide accurate initial incident reports to operating departments and the police.

The Train Incident Reporting and Fire Incident Reporting Systems will assist the Subway Control Center in managing response to fires, derailments, and other emergencies. The two communication systems are based on a software application that automatically superimpose s schematic draw ings of the subway system onto street maps in the vicinity of the incident while providing location information if a tr ain is involved in the incident. These systems show the locations of emergency exists, ventilation plants, signals, stairways, and platforms to assist NYCT an d emergency personnel to effectively respond to incidents. [50]

San Francisco Bay Area, California

The Bay Area Rapid Transit District's (BART) operations control center (OCC) wa s established in 1994 to modernize its train control system. This modernization effort required that new control features would be integrated with the existing 22-year-old train monitoring system to create a single dispa tch interface. Currently, about 20 percent of the BART rail network is equipped with the modernized technology. The train monitoring system combines block signal occupancy

[50] Isaac Takyi, New York City Transit, Brooklyn, New York.

tracking with an automatic vehicle identification system. The hardware and software in some of the (unstaffed) wayside train control rooms are being upgraded. [51, 52]

Since December 1995, BART has added five passenger stations on three different lines. The hardware and software of the Supervisory Control and Data Acquisition system was enhanced to monitor additional subsystems at the new passenger stations as well as new power substations. The computer-aided dispatch software at the OCC was upgraded as well during 1996 to include system status information from the extensions.

One major improvement is software modifications that control interlockings. During situations that require single tracking (trains from both directions sharing the same section of track) such as a stalled train, power loss to a track section, or emergency condition, previously BART could have only a single train occupy the section of track between two interlockings. However, with the improved software, BART can safely control multiple trains through interlockings thus reducing operational bottlenecks.

An interesting aspect of BART's OCC design is the separate wall displays for train status and monitoring and electrical power system/subsystem monitoring. Instead of combining the electrification and train control displays which would make it more difficult for train controllers to perform their duties, the agency decided on separate displays. [53]

Boston, Massachusetts

Since January 1996, the Massachusetts Bay Transportation Authority (MBTA) has completed construction of its new operations control center and is now operating its Operations Control System (OCS). This project includes migrating all dispatch operations from their old locations to the new center and integrating both light and heavy rail supervision. Full service will commence in 1998. The

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[51] BART is also upgrading its two computer servers. Although the new computer hardware will run the existing software, BART will be able to expand its train control capabilities with the additional processing and storage capacity. Although the system will soon be able to safely support shorter headways, BART does not have the rolling stock to do so at this time.

[52] Rocky Green and Betty Soo Hoo, Bay Area Rapid Transit, Oakland, California.

[53] In fact, BART's OCC is staffed with a power support controller whose main responsibility is to monitor the electrical system display.

new system integrates the OCS with existing systems such as the SCADA power distribution and management system and AVI technology. The location technology on the three heavy rail lines is based on the existing block signal system augmented by the AVI system which utilizes radio frequency tags and wayside readers located at critical track locations such as automatic switches that involve route selection. A future enhancement to the OCS will upgrade the light rail line, from AVI, to an AVL system. This will be done to improve the accuracy of vehicle location. [54]

The major goal of the OCS project is to establish a common platform of control and to centralize all information processing. Once in full revenue service, the OCS will eliminate track control towers on three of the heavy rail lines by consolidating their functions into the operations control center. Two other control towers on the heavy rail lines will remain because the Red Line yard control operations have not been integrated with the OCC. The OCC project includes installation of automated train dispatch workstations at several rail line termini to ensure on-time pullouts.

The CAD software is capable of calculating schedule adherence. The system is also able to archive all data so that it can be used off-line for operations, scheduling, and planning purposes. The CAD software supplies dispatchers with a prioritized event queue which allows them to respond to incidents in the order of importance. The MBTA is currently working with the Massachusetts Institute of Technology to research, develop, and test expert system software that would be capable of offering specific instructions to operators for a variety of potential operating events and incidents. The agency envisions that this project will lay the groundwork for full expert assistance in the operations control center in the future. This research project began in 1996 and is expected to be completed during 1998.

Philadelphia, Pennsylvania

[54] Jeff Parker, Massachusetts Bay Transportation Authority, Boston, Massachusetts.

The Southeastern Pennsylvania Transportation Authority (SEPTA) is in the process of deploying a multi-use train simulation program from LS Transit called the Railroad Operations Computer Simulation (ROCSIM). The system is designed as a stand-alone tool that will enable the agency to simulate rail operations for the entire SEPTA commuter rail network from a personal computer (PC)-based platform. As of October 1997, the agency was finishing the input of location data for cab and wayside signals, interlockings, and automated blocks needed to complete the simulation database. SEPTA is simultaneously making final confirmation that the database matches the physical plant and is in the process of performing final verification of the software. It expects that the system will be operational by early 1998. Central to the system is integration with SEPTA's geographic information system and design software.[55]

When fully operational, ROCSIM will, for example, have the ability to simulate the impact of grade crossing gate down times, system-wide power consumption, track capacity, headway changes, throughput on interlockings during single track operation, and changes in passenger flow. ROCSIM will allow SEPTA to answer innumerable what-if questions. For example, staff will be able to model the impact of reconfiguring signal locations to determine if capacity can be improved. ROCSIM will also be capable of using historical data from the automated train dispatching system to reconstruct and analyze operating events such as incidents.

Besides ROCSIM, SEPTA is also planning the construction of a modern Railroad Division Operations Control Center (ROCC) that will consolidate the existing seven remote control towers and the existing ROCC of its commuter rail network. The ROCC design has been completed and the agency plans to go out to bid toward the end of 1997. When completed, all train dispatch operations will be centralized into a state-of-the-art facility which will house new centralized train control and communications systems.[56] The agency's existing supervisory control and data acquisition system will be integrated with the centralized train control systems and power dispatchers will be moved into the new facility.

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[55] Michael Monastero and John Bukowski, Southeastern Pennsylvania Transportation Authority, Philadelphia, Pennsylvania.

[56] From Project Overview provided by John Bukowski.

The existing train dispatching system, which currently supports some of the operating functions planned for the ROCC, will be integrated into the ROCC as well. Functions of the ROCC will include:

- Train control and tracking;
- Manual and automatic train routing;
- Data archiving and message playback; and
- A training simulator for new dispatchers.

Portland, Oregon

As part of the construction of the Westside MAX light rail extension, Tri-Met has been upgrading its train control system. Tri-met has laid fiber optic cable along the entire MAX right-of-way. This connects all subsystems with a high capacity communications backbone and enables improved operational communication and customer information. The enhancements integrate all substations, switches, signals, traffic signal loops (to provide MAX with signal priority when it is operating at grade), and video. In the future, it will provide the means to transmit wayside status information to customers. When completed in 1998, the 33 mile long MAX line, with 46 stations and 72 vehicles, will carry riders from downtown Gresham to Hillsboro via downtown Portland. [57]

Train location is accomplished with a combination of signal block occupancy technology, traffic signal loop detectors, and an AVI system. The agency can track the location, direction of travel, and schedule adherence of individual train consists.

One major improvement is interfacing SCADA data with its CAD system (see Section 2.5.1). Because the SCADA system was designed more for monitoring and control of trains, traction power, and electrical subsystems, its data was not easily converted into information that could be used by dispatchers or the public. By processing the data through the bus CAD system, location and schedule adherence information is in the same format as the rest of the CAD data. This integration will allow bus dispatchers to use the location and schedule adherence data from MAX to ensure connections between feeder bus routes and the MAX system.

[57] Ken Turner, Tri-Country Metropolitan Transportation District of Oregon, Portland, Oregon.

St. Louis, Missouri

The Bi-State Development Agency (BSDA) opened its light rail system, MetroLink, in 1993 and redesigned much of its fixed-route bus network to feed the new rail line. The system serves 18 stations with 31 Siemens light rail vehicles in one or two train consists powered by overhead wires. In BSDA's commitment to providing a safe, secure transit environment for MetroLink passengers, it has a comprehensive security plan that is managed from MetroLink Central Control.[58]

Central Control uses a SCADA system operating over a fiber optic cable backbone to track and control trains, traction power, and electrical and mechanical subsystems. The software includes automatic train control, a system that ensures operator compliance with speed limits and track signals. For example, if an operator does not brake within 10 seconds after receiving a lower speed cab signal, the train is brought to a complete stop. The ATC system also stops trains 50 feet short of red signals if the operator does not brake to a speed which is less than two times the safe braking distance. Trains are also stopped 50 feet short of malfunctioning grade crossings.

The SCADA system uses signal block occupancy to track trains running on elevated, at-grade, and below grade tracks. The train control system allows MetroLink to operate on three minute headways if needed during special events. It also facilitates single track operation in the event of a stalled train or other incident by automatically controlling the operation of interlockings. The control software includes an alarm event queue which alerts operations staff if substations or other secured areas are entered improperly. In the future, BSDA expects to monitor the status of escalators, elevators, and self-serve ticket machines so that service staff can be promptly dispatched for repairs.

2.5.3 Paratransit

The Americans with Disabilities Act has inspired many transit agencies to implement new scheduling and dispatching software for improved performance and increased passenger-carrying capability of their demand-responsive vehicles operating in shared-ride mode. In addition to advanced trip reservations, standing orders and immediate requests, paratransit services are now able

[58] Anthony Webb, MetroLink, St. Louis, Missouri.

to offer new features to their clients, such as route deviation service, intermodal connections, and interagency connections. Customers are able to make reservations, check on the status of their rides, and obtain billing information using a variety of devices, including touch-tone telephone,[59] personal computers, kiosks, the Internet and e-mail. Advances in paratransit operations software have contributed toward making transportation fully accessible to the disabled.

State-of-the-Art Summary

Although only a few agencies have installed the most sophisticated of the paratransit operations software systems, many have implemented one or more of their features. The high-end systems have integrated automated scheduling and dispatching software with AVL, GIS, and advanced communications systems, so that, in some cases, the dispatcher's role is limited to interventions in special circumstances, such as no-shows or trip cancellations. The system itself can automatically receive orders via touch-tone telephone, schedule the trips, and transmit the schedules to the drivers.

Some paratransit systems can interface with fixed-route service. They automatically analyze trip requests to see if they can reasonably be served with fixed-route service for a significant part of the journey. They can monitor in real time both the fixed-route and paratransit portions of the route for schedule adherence to determine if the scheduled interface is still valid, and modify the trip plans as necessary.

Dispatchers are able to view maps of the service area with the locations of all the vehicles in the fleet updated every half minute, and to get tabular displays of the information as well. Drivers have mobile data terminals displaying the next hours' pickups and drop-offs. They press an "Arrive" button to signal the dispatcher they have arrived at a stop, a "Perform" button when a customer has successfully entered the vehicle, and a "No Show" button when a customer is not at the scheduled pickup point. They can communicate with the dispatchers via voice radio or through their MDTs.

[59] The technologies discussed in the report rely on receiving *tones* from the customer's phone. Phones incapable of generating these tones (e.g., rotary phones) cannot be used for these applications.

Clients have the option of speaking to a dispatcher or entering the required information via touch-tone telephone, Internet connection, or e-mail at home or at kiosks in remote locations. They can not only make reservations, but also check on their accounts, find out when their ride will arrive, and cancel rides. They receive notification before their rides arrive by telephone, pager or other electronic means.

Currently under development is a demand-responsive operations software system that will all but eliminate the role of the dispatcher in paratransit service. Known as autonomous dial-a-ride transit or ADART, it employs fully automated order-entry and dispatching systems that reside on board the vehicles. Under normal conditions, the customer is the only human involved in the entire process of requesting a ride, assigning trips, scheduling arrivals, and routing the vehicle; no dispatcher is involved. The computers on board the vehicles "talk" to each other, and "bid" for the incoming trip request based on the vehicle's cost to serve it. The trip is assigned to the vehicle that is able to incorporate the trip most efficiently. The driver simply follows the routing instructions from the vehicle's computers. A system prototype is expected to be in testing by late 1998.

Application Examples

Ann Arbor, Michigan

Ann Arbor's paratransit service ("A-Ride"), as part of its advanced operating system deployment, has implemented computer-aided dispatch, automated scheduling, and advanced communications for its own five AVL-equipped specialized paratransit vehicles and three subcontracted vehicles. This integrated automated system is able to provide service 24 hours per day, seven days a week, with the services of a dispatcher needed only to take reservations from callers, confirm rides, receive cancellations, and intervene in special circumstances, such as "no shows." Eventually, an interactive voice response system is expected to reduce the number of calls dispatchers will have to handle in person.

Each of the eight paratransit vehicles has an 800 megahertz radio, onboard computer, and MDT. The system minimizes voice transmissions by providing data messages regarding vehicle status, operating condition, and location over a data channel. A voice channel is available when necessary for drivers and dispatchers to speak to each other.

The MDTs have graphical screens with menu options and preprogrammed keys to interact with the various onboard systems, including the radio. This allows the driver to select an appropriate time to read and respond to text messages sent from the dispatcher. The MDTs have various buttons for the driver to hit at key points of a pickup: an Arrive button when the driver arrives at a stop, a Perform button when a customer has successfully entered the vehicle via the lift, and a No Show button when the customer is not at the scheduled pickup point.[60]

The GPS-based AVL enables the system to perform dynamic scheduling: if a vehicle is running early or a customer does not show up at a stop, additional trips may be inserted into a vehicle's schedule and transmitted to the vehicle's MDT automatically; conversely, stops may be eliminated from a route if traffic conditions prevent the vehicle from arriving at its stops in a timely manner. Dispatchers add or remove trips, and the system automatically adjusts the schedules and transmits them to the drivers. Schedules are sent to drivers 60 minutes in advance.[61]

A-Ride serves about 550 clients per day. Trips on the eight specialized paratransit vehicles equipped with lifts are reserved for approximately 150 daily ADA clients that cannot travel any other way. AATA finds it more economical to use taxicabs for the remaining 400 clients who do not require lifts on vehicles.

Houston, Texas

METROLift, Houston Metro's specialized paratransit service, installed AVL on all of its 110 vans and 55 sedans in 1993. Since that time, METROLift has implemented scheduling and dispatching software in conjunction with the AVL for real-time scheduling. As described in **Update '96**, an evaluation of a 1993 demonstration revealed improvements over the pre-AVL system in many performance measures, including location accuracy, service efficiency, customer satisfaction, and dispatcher satisfaction.

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[60] "The Advanced Operating System" from Ann Arbor Transit Authority's web page.

[61] William Hiller, Ann Arbor Transportation Authority, Ann Arbor, Michigan.

Key AVL capabilities that METROLift managers were especially enthusiastic about were: verification of the location of drivers when they were calling the dispatcher; reallocation of the vehicle closest to a client whose originally scheduled ride was late; and automatic measurement of on-time performance.

In December 1997, METROLift plans to integrate its AVL, dispatching and scheduling system, and radio communications. As of this writing, the specific integration software has not been identified. Specifications call for the software to feature proximity verification and automatic schedule updating. They will be installing MDTs in all vehicles to receive continually updated schedules as well as other data. Their plan is to allow the drivers to see only the next few trips they are to make, rather than the current practice of revealing the entire day's schedule in advance. Alterations in the day's schedules will then be transparent to the drivers. Trunked radio communications will travel over the agency's ten allocated channels - two reserved for voice and eight for data communications. METROLift hopes the integration will enable it to serve its 2,750 daily riders better by more efficiently routing its vehicles when cancellations and no-shows occur. [62]

Corpus Christi, Texas

The Corpus Christi Regional Transportation Authority, with a Research and Development grant from FTA, is in Phase 2 of a project to develop an operational version of a "many-to-few" demand responsive or "dial-a-ride" transportation service, known as autonomous dial-a-ride transit. ADART employs fully automated order-entry and dispatching systems that reside on board the vehicle. "Fully automated" means that, under normal operation, the customer is the only human involved in the entire process of requesting a ride, assigning trips, scheduling arrivals and routing the vehicle; no dispatcher is involved. One vehicle's on board computer receives a customer request, inserts this request into the vehicle's schedule, and plans an optimal route to accomplish the schedule. The vehicle's on-board computer passes on the request to all other ADART vehicles. The

[62] Jim Laughlin, Houston METROLift, Houston, Texas.

vehicle which can service the request at the lowest cost is assigned the trip. The driver plays no role in the process and simply follows routing instructions from the vehicle's computer. [63]

Phase 1 of the project developed a conceptual approach to the system and produced a report comprised of seven technical papers prepared by the Volpe Center and MatchWare Technologies on the following topics:

- Mobile wireless communications -- for data communication among vehicles and with the centralized accounting and call distribution systems. The Wi-LAN wide area wireless ethernet products were recommended for ADART.
- Interactive voice response -- for facilitating fully automated order-entry of trip requests from ADART customers to the call distribution system. Dialogic call processing software seemed best suited for ADART.
- Computerized vehicle navigation -- for tracking and plotting the vehicle's location on the street network using GPS.
- Automated geocoding -- for converting trip-end addresses, intersections, and landmarks into locations on the street network as contained in the Geographic Data Technology enhanced Census Bureau's TIGER file.
- Automated vehicle routing and scheduling algorithms -- for optimally assigning trips among vehicles operating on a street network, modifying vehicle routes to satisfy new trip requests or cancellations, and handling unexpected events such as vehicle breakdowns or delays. These would require from one to three DOS- or UNIX-based computers per vehicle, as ADART evolved over the years.
- Dial-a-ride state-of-the-practice -- to acquire a sense of dial-a-ride economics; i.e., supply, demand, and pricing.
- Prototype software design -- to synthesize the knowledge gained from the technology studies and to provide structure for the planning of the next phase of ADART development.

Phase 2, to be completed by mid to late 1998, is the development and testing of prototype software for the on board computers. This software includes the order-entry, central accounting, routing and scheduling, trip bidding, vehicle positioning, and driver interface systems. Phase 3 will conduct a controlled experiment to test the pre-operational system on nonrevenue-producing vehicles, and Phase 4 will conduct limited tests of the system on the revenue fleet.

An ADART system is expected to offer some advantages over the more conventional centralized dispatching system. With ADART, a vehicle fleet will efficiently serve travel demand in

[63] Dial, Robert B., "Autonomous Dial-A-Ride Transit Introductory Overview", *Transportation Research*, Part C, Vol. 3, No. 5, 1995, pp. 261-275.

a large geographic area without need of phone operators to receive calls or centralized dispatchers to assign trips to vehicles or to plan routes. (A central management staff would still be necessary for vehicle and data maintenance, technical trouble shooting, service quality control, pricing, hiring, firing, automatic call distribution, billing, and accounting.) Due to its distributed command and control, ADART may provide better service, greater reliability, higher productivity levels, and lower operating costs than conventional dial-a-ride. Applicable to private, public, or quasi-public operation of a variety of service types, ADART is a flexible system that may be the answer for transit service to low-density areas, serving a host of customers at a satisfactory cost to both consumer and supplier. Of course, substantiation of this claim requires site- and service-specific demand studies, simulations, and service demonstrations, which will follow completion of Phase 4.

Santa Clara County, California

OUTREACH, the paratransit provider of Santa Clara County, has completed Phase III of the $750,000 Federal- and state-funded Smart Paratransit Project to implement and demonstrate an automated scheduling and dispatching system. The system integrates a digital geographic database by Navigation Technologies, automated scheduling and routing software, and an AVL system. Communications are via a newly assigned radio frequency. Although the system currently handles OUTREACH's 65 AVL/GPS vehicles, it has the capacity to expand to 1,000 vehicles. It integrates display terminals and communications handling equipment with mobile and base station radios to provide current vehicle position information in order to enhance dispatch assignment decisions and intermodal connections to fixed route. The data are displayed in map and tabular form with detailed vehicle location information. The operator can view the reported position of all the vehicles in the fleet as an overlay on the map. The system continually polls the entire fleet in 20 to 30 second intervals and can position them within three meters. Each vehicle has a 3" by 5" display head with a built-in menu system by which a driver can track and respond to eight current variable mail messages as well as eight predefined status messages.

It was only in Phase III that a paratransit interface with fixed-route transit became possible for eligible clients. Trip requests are automatically analyzed to determine if the origin or destination of the trip is within the corridor serviced by the fixed route. If possible, the trip is split into multiple segments, one or more paratransit and one fixed-route. The fixed-route segment is automatically selected based on the fixed-route schedule and the time requirement of the ride request. The paratransit legs are scheduled on available paratransit vehicles so that the connection is successful. Vehicle schedule adherence is monitored in real time to determine if the scheduled interface is still valid.

An evaluation of the program by the University of California at Berkeley concluded that without the automated trip scheduling system OUTREACH would not have been able to accommodate the increases in paratransit demand that began in 1993 nor to meet full ADA compliance in January 1997. OUTREACH did so with savings of almost $500,000 in its first full year of operation. Other advantages included an increase in shared rides from 38 percent to 55 percent a reduction in fleet size from 200 to 130 vehicles, and improved productivity.[64] The information provided by AVL supported daily operations through analysis of schedule adherence, on-time performance, and ability to track vehicles in real time. The capability AVL provides for the transferring of passengers between paratransit and fixed-route service should offer cost savings to the paratransit system as well as greater choice of service to the disabled riders in the 15-city, 324 square mile Santa Clara County area.[65]

San Gabriel Valley, California

The Southern California Association of Governments (SCAG) is developing the Smart Shuttle personalized public transportation service in the San Gabriel Valley cities of Arcadia, Monrovia, and Duarte. These cities, as well as Foothill Transit, have joined with SCAG and the California Department of Transportation to participate in the San Gabriel Smart Shuttle Field Operational Test, which builds on an earlier project, the ATHENA project, in Ontario, California. The ATHENA project designed a computer system to match ride requests and vehicles. The program focused on utilizing private individuals and their privately owned vehicles. In the San Gabriel Valley, Smart Shuttle will also require a computer system to match ride requests with

[64] Taylor, Steven T., "Reaching out with ITS", *ITS World*, March/April 1997.

[65] Project Summary Sheets, Dr. Kathryn Heatley, OUTREACH, Santa Clara County, California.

available vehicles; however, Smart Shuttle will employ only public transit vehicles with commercial drivers.[66]

The system will consist of AVL, a communications component including MDTs in the vehicles to allow data communications between dispatchers and drivers, and a computer-assisted dispatch capability to match ride requests with vehicles in real time. It will allow the participating agencies to enhance their current services and to provide additional services if they choose, such as route-deviation service, intermodal connections, and interagency connections. The system will be capable of accepting trip requests by telephone, personal computers, kiosks, the Internet, and e-mail. It will be capable of notifying riders that their vehicle is about to arrive. Messages will be sent to riders by telephone, pager or other electronic means.

The operational test's goals are to: develop, integrate, and test the integration of emerging technologies that may have been successfully deployed separately, but not tested together; identify and mitigate any institutional barriers that might interfere with the implementation of the new services as well as to determine how well the different agencies and institutions work together; and test the public acceptance of the new services provided by the participating agencies. The demonstration service should start by June 1998.

The project is especially unique because it will demonstrate how agencies with widely varied approaches to paratransit service can overcome their differences to agree on one new service model for all, and then work together to implement it to produce efficient service throughout the entire region. The participating local agencies are described below:

- The City of Arcadia operates a general public Dial-a-Ride service with an 18-vehicle service of sedans and vans. Their seven-day service carried over 140,000 riders in fiscal year 1996. Their vehicles are equipped with AVL equipment and MDT's, and they recently implemented a computer-assisted dispatch capability.
- The City of Monrovia operates a general public Dial-a-Ride with a seven-vehicle fleet covering not only the City, but also parts of Los Angeles County, Arcadia, and Duarte. Their seven-day service carried over 100,000 riders in fiscal year 1996. They employ no technology more advanced than voice radio, using manual dispatching and relying on drivers and dispatchers to know the location and heading of the vehicles.

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[66] William Tournay, Caltrans New Technology Programs, Sacramento, California.

- The City of Duarte operates two fixed-route, fixed-schedule shuttles six days a week with four vehicles. Their radios share the City-owned channel with other City uses. Duarte has no full-time dispatcher.
- Foothill Transit is the regional bus operator in the San Gabriel Valley offering fixed-route, fixed-schedule service in the three participating cities and throughout the San Gabriel Valley. [67]

Detroit, Michigan

The Suburban Mobility Authority for Regional Transportation (SMART) has implemented automated scheduling and dispatching software for paratransit. It is currently being integrated with their automatic vehicle location system. This software is currently being upgraded to a Windows NT platform, which will assist in providing remote scheduling capability to other service providers in the greater Detroit area. SMART has begun installing remote scheduling and dispatching capability at five contract operators. One year later, SMART expects to have 25 contract operators with that capability. [68]

Folsom, Pennsylvania

Community Transit of Delaware County is implementing a sophisticated automated system that includes automated scheduling and dispatching software, in-vehicle mobile data terminals, advanced communications technology, and an automated identification system for customers. Since January 1996, Community Transit had made significant progress in deploying this system.

The automated scheduling and dispatching software was fully installed by November 1996. In February 1997, 100 ruggedized MDTs were purchased. These MDTs are pen-based computers and were delivered in March 1997. Simultaneously, wireless modems for the MDTs were purchased to provide communications capability. [69]

In October 1997, 15 of the MDTs with wireless modems were installed and became operational as part of a pilot test. The MDTs were connected to the scheduling and dispatching

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[67] **Request for Proposals to Provide Technology Integration Services for the San Gabriel Valley Smart Shuttle Field Operational Test.**

[68] Ronald R. Ristau, Suburban Mobility Authority for Regional Transportation, Troy, Michigan.

[69] Judith McGrane, Community Transit of Delaware County, Folsom, Pennsylvania.

software in real time via cellular digital packet data communications technology. Community Transit is using cellular digital packet data service for the communications aspect of this system. After the pilot test, Community Transit will phase in the MDTs in groups of 15 until all MDTs are installed. It is expected that the entire fleet will be outfitted with MDTs by January 1998.

The automated identification aspect of this system is in the process of being implemented. Because of the capability of the MDTs, a customer's image (digitized photograph) can be displayed on the MDT and/or printed on a driver's manifest. This image will be used to verify a customer's eligibility to ride. As of October 1997, Community Transit is in the process of obtaining photo images of their customers by means of a camcorder.

Transit Cooperative Research Program - Project A-6: Computerized Paratransit Dispatching

In February 1994, the Transit Cooperative Research Program (TCRP) awarded $200,000 to Systan, Inc. for a project to:

- Specify industry-wide functional requirements for future computer software to manage and operate demand-responsive transit systems; and
- Develop an implementation handbook to assist transportation providers in the procurement of such systems.

The software requirements are documented in a February 1994 preliminary draft report entitled "Software Requirements for Demand-Responsive Transit." The report identifies and recommends: (1) functions to be accomplished by the software; (2) features that incorporate ADA complementary paratransit requirements; (3) features that take advantage of other advanced technology; and (4) software industry standards that should be followed. Although the Transportation Research Board never formally published this report, it was distributed in draft form to software developers, thus accomplishing the purpose of the grant.[70]

In 1996, the TCRP published "A Handbook for Acquiring Demand-Responsive Transit Software." It is written for staff members and policy makers of organizations that provide demand-responsive transit, because many providers have little experience in making software decisions. It is intended to help them decide whether computerization of their operating functions would be

[70] Roy Lave, Systan, Inc., Los Altos, California.

beneficial, and to assist them in the selection and procurement of the most appropriate software. The report describes the range of available software to perform the following operating functions : determination of caller eligibility; trip reservation; service scheduling; vehicle dispatching; vehicle routing; and reporting. It gives an overview of demand-responsive transit system history, functions, operations, and computer hardware, and offers a step-by-step guide for making the software decision and acquiring the product. In addition, it lists information sources and software vendors. The report is available through the Transportation Research Board publications section. [71]

2.6 TRAFFIC SIGNAL PRIORITY TREATMENT

Traffic signal priority treatment, formerly referred to as "signal pre-emption," is a technology by which a traffic signal may be held green (or made green earlier than scheduled) so that a particular vehicle may pass through the intersection more quickly. This technology has been in place for a number of years for emergency vehicles, such as police, fire, and ambulance, since there are times when it is very important for these vehicles to arrive at their destination as soon as possible.

In the case of transit, there are similar, yet different reasons for giving a vehicle priority. Although many hold to the strategy of maximizing the number of vehicles passing through an intersection each cycle, an alternative strategy is to maximize the number of *people* passing through an intersection each cycle. Since transit vehicles (especially buses) generally carry more people than the average automobile, it is consistent with this alternative strategy to shorten their delay as much as possible.

Another benefit arises in very large cities and when headways are short. A common problem under these conditions is "bunching," a situation in which one or more vehicles closely follow another. Thus, if the headway were five minutes, one might see two buses in close proximity, and then not see another for close to ten minutes. Although there are many causes for this occurrence, one remedy is to give priority to buses that are running late, but not those that are running ahead of schedule or closely following another bus. In this way, the spacing between the two is increased.

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[71] Lave, Roy E., Roger Teal and Patrisha Piras, **A Handbook for Acquiring Demand-Responsive Transit Software**, Transit Cooperative Research Program Report 18, National Academy Press, 1996.

There are many issues to address, however, if priority treatment is not to upset other traffic control measures in place. For example, traffic signals on many major streets are timed so that vehicles traveling at the speed limit will be held by as few red lights as possible. Advancing or extending the green signal phase for an approaching bus may upset this timing if appropriate strategies are not implemented. The effect on traffic on cross streets also must be considered, especially if these cross streets are major streets. These issues make traffic signal priority treatment for transit vehicles an issue of debate, both among transportation professionals and the automobile-driving public. If not carefully done, granting buses preferential treatment may degrade traffic flow for automobiles and adversely affect bus movements as well. This would be particularly harmful if traffic volumes are approaching saturation levels. The placement of bus stops is also an issue. Bus stops should not be located so that a bus would be at a stop picking up passengers (before reaching an intersection) after having triggered the preferential treatment at the signal.

State-of-the-Art Summary

Traffic signal priority is an established technology for rail systems. The existence of a fixed guideway (the rails), provides a conduit for sensors and wires which may be connected directly to either railroad crossing gates or traffic signals. Many years ago, railroad operators and transit systems developed and implemented this technology and have made it commonplace.

The absence of a fixed guideway, as in the case of bus operations, made it necessary to develop a different method of implementing traffic signal priority. The first priority systems were for emergency vehicles, whose need for the quickest path to their destination is very clear. In the 1970s, there were a number of tests for priority treatment on transit. These systems were manual; they were either driver-actuated or continuous, always giving priority. In each case, the bus, independent of any central control, was loaded with hardware which sent out a signal - either an infrared beam, similar to a remote control or garage door opener, or low-powered radio signals - to activate the priority.

In the 1990s, although priority for transit is still not widespread, the technology has advanced significantly. Often, modern traffic signal priority systems are implemented as part of AVL systems. This not only saves hardware costs, but allows for selective priority. For example, priority may be denied to a bus which is running ahead of schedule, so that it does not get further ahead of schedule. Also, it does not leave the decision of priority to the driver, who might want to finish his or her route as quickly as possible.

Application Examples

Minneapolis/St. Paul, Minnesota

The Minnesota DOT traffic management center, which manages traffic on Twin Cities metropolitan freeways and coordinates a variety of programs with Metro Transit (see Section 5.3), also controls bus priority. Minnesota DOT's original bus priority test was the "Speedlight" project that allowed buses to pre-empt ramp meters at one location on I-394. Seen as a precursor to a network of ramp bypass lanes (discussed below) needed to address 10- to 15-minute ramp queues at many locations, Speedlight successfully provided signal pre-emption to buses equipped with electronic tags. The tag notified the signal controller to shorten the ramp signal cycle for the approaching bus and any other vehicles queued ahead of it.

Although Speedlight was a successful test, the Minnesota DOT is implementing a more flexible system, dubbed "Synchrolight." Synchrolight involves shortening the ramp signal cycle on a pre-set basis from the centralized signal control center during the morning and evening rush hours. It is a low cost solution since no new equipment has to be purchased, tested, or installed. The agency is starting with a six- to eight-minute window based on the expected schedules of buses using the ramps at approximately 13 locations. A bus should receive priority even if it is running behind schedule since Synchrolight will probably have reduced the queue in advance of its arrival at the ramp. Again, this system is seen as an interim measure as the agency constructs ramp bypass lanes for both buses and emergency vehicles.[72]

Montgomery County, Maryland

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[72] Glen Carlson, Minnesota Department of Transportation Traffic Management Center, Minneapolis, Minnesota.

Traffic signal priority treatment for Ride-On buses is a key transit component of the Montgomery County Transportation Management Center (TMC; see Section 5.3). (The Ride-On transit system includes 3,000 miles of roadways and 200 miles of critical traffic links.) Unlike some signal priority schemes that involve direct communications between a bus' mobile data terminal and the traffic controller, the Montgomery County TMC receives location and on-time status information from vehicles, processes it, and sends directions to the signal controller that: 1) priority is not necessary because the signal is already in or about to change to a green phase; 2) grant priority by extending the green phase, or; 3) deny priority based on a combination of signal phasing, vehicle schedule adherence, impact on traffic in the vicinity, or known special events. The TMC has the capability to deny all priority requests based on traffic incidents such as special events, weather conditions, etc.

When implemented, the County is considering integrating automatic passenger counting data into the signal priority algorithm so that an extended green cycle would only be granted if the transit vehicle was carrying a minimum load.[73]

Seattle, Washington

The Washington State DOT uses King County Metro's AVL data to implement traffic signal priority treatment. In addition to using bus location information to help determine when to grant priority, the agency uses the buses as probes to determine the effect of priority on traffic flow. Because the signal priority arrangement is so new, the agency is planning to hire a staff person to coordinate with local transit service providers to develop protocols, procedures, and standards for signal priority. A primary concern of the Washington State DOT is the impact signal priority might have on the regular traffic flow.[74]

Chicago, Illinois

[73] Alfie Steele and Bill Corder, Montgomery County Transportation Management Section, Rockville, Maryland.

[74] Dave Berg, Washington Department of Transportation Northwest Region, Seattle, Washington.

As part of its new AVL installation (see Section 2.3), the Chicago Transit Authority is implementing traffic signal priority treatment for its buses at five downtown intersections. Like other large areas, downtown Chicago is a challenging environment for peak-hour bus operations. During rush hour, bus headways on some routes can be as short as 90 seconds. This, combined with high passenger loads and heavy vehicle traffic on the street, slows buses and can very easily lead to bunching. It is hoped that, by giving buses selective priority at these traffic signals (using the AVL system data to determine whether it is needed), even headways may be maintained.[75]

[75] David Phillips and Ronald Baker, Chicago Transit Authority, Chicago, Illinois.

3. TRAVELER INFORMATION

Traveler information systems provide travelers with information on one or more modes of transportation to facilitate decision making before their trip (pre-trip) as well as during their trip (en-route). Information can be provided to trip makers at home, work, transportation centers, wayside stops, or on-board vehicles. With links to automatic vehicle location systems, traveler information systems are beginning to provide real-time transit information, such as arrival times, departure times, incidents, and delays. Travelers can access this information through a variety of media.

Three types of traveler information systems for transit are discussed in this section:

- Pre-Trip;
- In-Terminal/Wayside; and
- In-Vehicle.

In addition, the last subsection covers multimodal traveler information systems that include transit.

3.1 PRE-TRIP TRANSIT INFORMATION SYSTEMS

Travelers' behavior and attitude toward public transit must change before they will give up the convenience of driving their own cars. Uncertainty about transit schedules and routes is often cited as a reason for not using transit. Pre-trip information systems are one means of alleviating this concern of potential transit riders. Providing accurate and timely information to all travelers before their trips will enable them to make informed decisions about modes, as well as routes and departure times.

Pre-trip information can cover a wide range of categories, including transit routes, maps, schedules, fares, park-and-ride lot locations, short-term passes, points of interest, weather, and more. Often this information can support itinerary planning, which can provide information on an entire trip from origin to destination, even if it involves multiple modes.

Methods of obtaining pre-trip information include touch-tone telephones, personal computers, pagers, hand-held personal communications devices, kiosks, the Internet, fax machines, and cable and interactive television. Automated data retrieval systems assist existing customer service operators in providing information to the caller in a timely manner.

State-of-the-Art Summary

New technology is increasing the range of ways transit agencies can disseminate pre-trip traveler information, and the types of information they can offer. Many transit agencies are now offering trip itinerary planning via touch-tone telephone, as well as via the Internet, kiosks, and/or hand-held communications devices. The most common medium, touch-tone telephone, handles customers either through a service representative who accesses the trip planning software, or by a customer-accessed menu-driven interactive voice response system "automated telephone tree," or a combination of the two. Trip planning software requires the input of the desired trip origin, destination, day and time of trip, and often specification of the optimization criteria, such as shortest time, shortest walking distance, mode of travel (typically bus or rail), least transfers, etc. Some software packages interface with a geographic information system. Use of trip planning software is transparent to a user accessing the system via telephone, but is visible on Internet Websites and kiosks, and is used by customer service representatives in responding to telephone calls.

Innovative methods of disseminating pre-trip traveler information to the public are growing in use. In particular, the use of the Internet for providing pre-trip traveler information services has mushroomed since January 1996. Many transit agencies, regardless of size, have a page on the World Wide Web, which gives the user a wealth of information on its services. Web pages range from those that provide interactive trip itinerary planning (Ventura County, California) at the high end of the spectrum to those that simply provide the telephone number to call for schedule information. Besides schedule information, Web page offerings may include: route maps; fares; schedules; interactive trip itinerary planning software; park-and-ride locations; points of interest; bicycle policies; special events; weather; delays; connections to other modes of travel; business opportunities; and more.

Other increasingly common methods for disseminating pre-trip traveler information include personal pagers, hand-held devices, and cable television. Bus systems that offer pagers to their customers usually have AVL-equipped buses. The rider can punch in the location of the bus stop to obtain the exact time of arrival of the bus, eliminating unnecessary waiting time. Hand-held devices are typically used in the same way, but may also be used to access real-time traffic conditions where available. Cable television and interactive television can provide a broader range of materials, and typically display the same information on a Web site.

There is a move toward regional systems that provide information on multiple modes of transportation across more than one jurisdiction. For public transportation, services that are frequently seen in this type of information system include bus, commuter rail, ferry, heavy rail, light rail, intercity bus, tourism, recreational, and airport transportation. Hindering the development of these systems in several cases are the lack of a standard electronic format among agencies for routes and schedules, the time and cost to input the data, and the cost to develop software to handle the frequent schedule updates experienced by the transit industry.

Another trend is the interfacing of transit information with real-time traffic conditions. Public-private partnerships have formed to undertake the enormous task of gathering traffic data, processing it into meaningful traffic conditions, and disseminating it to transit agencies and to the public. Several agencies are conducting operational tests to see if the availability of up-to-the-minute information on traffic congestion, delays, and other conditions combined with readily accessible public transit service schedules can affect commuter choice of transportation mode, and increase bus and train ridership.

*(For purposes of this **State of the Art** report, pre-trip information systems which include both transit and highway modes are described under Multimodal Traveler Information Systems - Section 3.4.)*

Application Examples (United States)

Seattle, Washington

Riderlink

Simultaneous to the implementation of the Smart Trek ***Model Deployment Initiative***, Seattle's Riderlink and EZRider projects are being enhanced. Started in December 1994, one of the key products of Riderlink is a Web site that provides access to Metro Transit information. Through Riderlink, travelers can already obtain information on transit schedules and fares, van and carpooling (which includes a rider matching service), HOV lanes, ferries, and park-and-ride access either directly or via links to other Web sites.

Riderlink expansion will be through development of Web sites at three other Puget Sound transit agencies - Kitsap Transit, Pierce Transit, and Community Transit. The original Riderlink Web site will provide access to these sites as well as providing assistance to transit users in planning trips that involve multiple transit operators and cross jurisdictional boundaries.

BusView

University of Washington staff will be responsible for developing BusView, a World Wide Web page that will incorporate an advanced application to geographically represent the location of all buses traveling throughout the Metro system. Users will click on any part of Metro Transit's service area map and select a bus route, causing icons to appear on the map showing the route number, direction of travel, and the time the bus passed that location. Clicking on the icon will automatically link the user to schedule information on the Riderlink Web site. Completion of BusView deployment is expected in October 1997.

Regional Automated Trip Planning

By early 1998, a Regional Automated Trip Planning (RATP) system will be in place for riders of King County Metro. This system is being developed jointly by King County Metro, Community Transit in Everett, and Pierce Transit in Tacoma, using Urbanized Area Formula Program (49 U.S.C.Š5307) funds, as well as their own contributions. Implementation of RATP for Community Transit and Pierce Transit is expected in 1999.

The system will allow callers to obtain trip itineraries from customer service agents who will interface directly with RATP's itinerary planning software. Once all three transit systems have input their schedules into the system database, RATP will be able to plan trips with origins and destinations in any of the three counties served by the transit agencies. Eventually, Washington State Ferries and Kitsap County will become part of the trip planning system.

EZRider

The EZRider I project includes installation of five interactive kiosks at the Boeing complex in Everett. These kiosks will be targeted at a population that may not have ready access to the Internet and will be providing the same information as the Riderlink Web site. Three kiosks will be installed in the main plant and one each in two different cafeterias. An additional three kiosks will be provided to users of the Washington State Ferries - two in ferry terminals and another on a newly constructed ferry that can be used en-route.

EZRider II, a planned expansion of the Riderlink/EZRider I efforts, will build on the RATP project. The goals of the EZRider II project include: (1) use of the RATP infrastructure as a basis for providing online itinerary planning; and, (2) the provision of additional kiosks.

(See Sections 3.2 and 3.4 for other traveler information projects in the Seattle area.)

Orange County, California

The California DOT (Caltrans) and the Federal Highway Administration are implementing a comprehensive traveler information system in Orange County, with two main components: Transit Probe and TravelTIP. (See Section 3.4 for a description of TravelTIP.) The Transit Probe project is a $3 million multi-jurisdictional transit demonstration project which will integrate transit and traffic management with advanced traveler information systems to benefit transit agency operations and foster partnerships with traffic management agencies. It will provide the public transit rider with real-time transit information from which better informed travel plans can be made.

Transit Probe calls for GPS-equipped fixed-route buses traveling on their routes within Orange County to act as probes, and provide highly accurate bus location, speed, and time data to a central dispatcher. Information such as arterial street and freeway traffic flow, incident data, and transit information will be derived from GPS data. The general public will access the information via strategically located kiosks throughout Orange County. They will also be able to use a trip itinerary feature at the kiosks to find the best transit route to their destination. [76]

The Transit Probe project will be divided into multiple deployment phases. In the initial deployment phase, expected to be completed in early 1998, 43 fixed-route vehicles will be equipped with GPS receivers and deployed on several bus routes. Transit Probe data and transit information will be disseminated to three public kiosks and the three partner agencies via dedicated leased digital lines until the TravelTIP system is operational. In future deployment phases, up to 750 fixed-route

[76] T. C. Sutaria, City Traffic Engineer, City of Santa Ana, California.

and paratransit vehicles will be equipped with GPS receivers throughout Orange County Transportation Authority routes.[77]

San Francisco Bay Area, California

TravInfo

TravInfo is one of several pre-trip information services for travelers either implemented or being planned for the San Francisco Bay Area and surrounding areas. TravInfo is an advanced traveler information system oriented toward the commuter. This ITS field operational test is being implemented through a public-private partnership, led by the Metropolitan Transportation Commission (MTC). Phase I installed the TravInfo traveler advisory telephone system (TATS). Operational since September 1995, the system is accessed via a single and usually toll-free seven-digit telephone information number[78] that can be used from anywhere in the nine-county region to reach nearly two dozen public transit operators. With the opening of the traveler information center, traffic information has been added to the TATS phone menu.[79] (This project is described in more detail under Multimodal Traveler Information Systems - Section 3.4.)

TranStar

Another traveler information system in the nine-county Bay Area is TranStar, a cross-operator trip planning system designed to generate intermodal transit trip itineraries. Because TranStar will eventually contain route, schedule, and fare information for all transit operators, it will be able to generate trip itineraries for short, single-operator trips as well as for trips involving multiple operators and transfers. The project was conceived because of the many transit operators in the region and the difficulty in planning transit trips that span more than one operator service area.

The TranStar project began as a demonstration in 1995 and was completed in February 1997, with four of the largest Bay Area transit operators participating in the system. The Metropolitan

[77] Transit Probe Fact Sheet, provided by Caltrans New Technology Programs.

[78] A single telephone number is being reserved for the TATS when it becomes state-wide. Every area code will use the same seven-digit number.

[79] Bill Tournay, Caltrans New Technology Programs, Sacramento, California.

Transportation Commission and the transit operators are now evaluating how to expand the transit trip planning features of TranStar to the remaining operators in the region.

The TranStar software is owned by the Southern California Association of Governments and licensed to the MTC and the Bay Area transit operators. The system is built around a centralized database to which transit agency telephone operators are directly connected to assist customers in planing local or regional (cross-operator) transit trips. Maintenance of the database requires that each transit operator enter its own schedule, fare, transfer, and incident information into the system and ensure the accuracy of its own data. TranStar relies on a regional digital base map which is being updated and will be made available to transit operators for other planning and analysis needs.

An Internet connection to TranStar will shortly be installed to provide similar trip planning features to the general public through the World Wide Web. Connections to kiosks and other media outlets are possible and are currently being evaluated.

World Wide Web

The Transit Information Web site is closely linked to TranStar. The site provides a map of the region's transit operator service areas, contact information for each operator, and detailed information about routes, schedules, and fares. Transit connections to popular Bay Area destinations are listed and a variety of other useful links to other travel information sources are also provided. MTC recently assumed responsibility for the Web site and is developing a process for uploading information from TranStar to the Web site to ensure that the data are as current and accurate as the information used by transit operators for trip planning purposes.

In response to the data sharing needs of TranStar and the Web site, MTC undertook development of the regional transit database. "The proposed [database] data management system will eliminate the duplication of data collection efforts and assure that comprehensive, accurate, and up to date transit information is provided to the public." [80] The architecture of the database will allow it to easily share information with other databases and data management systems including the TravInfo project.

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[80] Metropolitan Transportation Commission internal memorandum. (from Emilio Escudero, July 30, 1997)

With assistance from a consultant, MTC is updating the regional digital base map. Transit data will be geographically linked and, as data sets are added, they will be spatially referenced to the regional base map. The $75,000 design phase of the project is expected to be completed in February 1998. The development, testing, and implementation phase will immediately follow, with an expected completion date in the Fall of 1998.

Honolulu, Hawaii

Express-Time

Honolulu's transit system, TheBUS, offers pre-recorded telephone messages containing transit route information. The messages are recorded in English and Japanese. Upon dialing the local telephone number on a touch-tone phone, the caller is given a choice of either Express-Time information system catering to the local rider or the Visiting-on-TheBUS information system oriented toward the tourist. The user is then lead through a series of programmed choices until the desired origin and destination are established. The system provides a pre-recorded voice response with all appropriate routes, schedules, and expected trip duration. [81]

Visiting-on-TheBUS

Visiting-on-TheBUS provides information on transit services to 52 places of interest in Honolulu and on Oahu. It is advertised heavily in tourist brochures, hotel rooms, and senior citizen centers, with the result that it attracts over 700 calls daily.

World Wide Web

TheBUS also offers an Internet site on the World Wide Web. This site displays maps of the bus routes and gives regular bus schedules, routes to tourist attractions, and fare information.

Ann Arbor, Michigan

In conjunction with their new Advanced Operating System, the Ann Arbor Transportation Authority is planning two Internet services for debut by the end of 1997. One is a free e-mail subscription service that will allow travelers with Internet access to provide a travel profile and then

[81] William Haig, Customer Service Manager, Oahu Transit Services, Honolulu, Hawaii.

be automatically informed via e-mail if their bus is on-time or not. The second is the provision of real-time bus status information via its World Wide Web page.

New York City, New York

As part of the ***Model Deployment Initiative***, the Transportation Operations Coordinating Committee (TRANSCOM) is planning to implement the Traveler Itinerary Planning System (TRIPS) to provide travelers with one comprehensive source of transit information for trip planning throughout the New York City region. TRIPS will include schedules, fares, rates, and real-time travel times for all participating public and private transit providers in the New York City region, including the 14 TRANSCOM member agencies (New Jersey Transit, Port Authority Trans-Hudson, Metropolitan Transit Authority, New Jersey DOT, Connecticut DOT, New Jersey Highway Authority, New Jersey Turnpike Authority, New York City DOT, New York State DOT, New York State Police, New York State Thruway Authority, Palisades Interstate Park Commission, Port Authority, and Triborough Bridge and Tunnel Authority) as well as others. Travelers will be able to obtain itineraries for specified origins and destinations that involve multiple transit agencies and modes of transportation.

Access to this information will be via an interactive Internet site and an automated telephone information system. The degree of automation will depend on the results of the Request For Proposals, currently in progress. Kiosks throughout the city are expected to offer this information eventually.

The traveler information sources are varied. TRANSCOM already provides a traveler service that distributes travel incidents, special events, construction locations, and weather information. TRIPS will incorporate this with whatever real-time data individual transit agencies can provide to synthesize overall travel conditions in the area. TRIPS will benefit from many of the projects in the New York Metropolitan ***Model Deployment Initiative*** and independently implemented projects by agencies in the area. For example, the E-Z Pass toll collection technology will be applied to buses. Pass readers located at points along a bus route will be able to track the progress of buses equipped with E-Z Pass transponders, and make projections on bus arrival times at subsequent stops along their routes.[82]

TRIPS is expected to be fully implemented by August 1998.

Jamaica (Queens), New York

The Long Island Railroad's traveler information center plans to upgrade its Teletrip interactive voice response system to Super Teletrip by replacing its 286 PCs with 686 PCs with Pentium processors, cutting response times and increasing capacity. Customers will be able to call and obtain fare, schedule, up-to-date status of station parking lots, directions to stations, hours of station operation, on-time performance of trains, service disruptions, weekly tour availability information, and excursion package and tour information. When customers call the Teletrip number, they are presented with a menu of options, one of which is to speak to a customer service representative. During 1996, the system received 5 million calls; 70 percent were handled by the automated system, 30 percent by service representatives.[83]

Newark, New Jersey

Interactive Voice Response

The New Jersey Transit customers call an 800 number for schedule information, and may choose either the automated telephone information system, known as the Interactive Voice Response (IVR) system, or operator assistance. The IVR is being expanded from giving only rail schedule information to include schedules for buses serving park and ride locations. This system was installed to relieve some of the pressure on operators who answer about 9,000 of the approximately 12,000 daily calls for NJT schedule information. By offering some bus information, NJT hopes to reduce the number of operator-assisted calls even further.

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[82] Martha Morecock, Transportation Operations Coordinating Committee, New York City, New York.

[83] Frank Rizzo, Director, Management Information Center, Jamaica, New York.

Even with 40 telephone lines, customers often get busy signals. In the future, NJT plans to dedicate eight to ten additional telephone lines to IVR service only using a local number. They expect these lines will offer faster service to customers willing to pay for a local call.

Customer Service Operators

NJT is also installing a travel information system to aid the operators in answering customer requests. Upon obtaining a customer trip origin and destination, an operator will input them into a computerized itinerary planning system to obtain the optimized route and mode of travel (bus or train). The information system will allow the operator to vary parameters for customized results, such as the fastest trip, the fastest trip for a particular mode, the trip requiring the shortest distance to a bus stop (for disabled persons), etc.

World Wide Web

NJT's Internet page contains all bus and rail schedules. In the future, they plan to install the itinerary planning system on the Web. [84]

Winston-Salem, North Carolina

As part of Phase II of its FTA-funded Advanced Public Transportation Systems Mobility Manager demonstration project, [85] the Winston-Salem Transit Authority (WSTA) plans to integrate fixed route trip planning software into the existing computer aided dispatching and scheduling software system, install an integrated/automated telephone system to provide touch-tone user information for transportation services, install MDTs and AVL on WSTA's fixed-route system, and provide real-time paratransit and transit information via telephone, cable TV, and kiosks. Also, WSTA will evaluate the impacts of the different ITS technologies. Implementation of Phase II is scheduled for January 1998.[86]

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[84] Lou Wassong, Director, Transit Information Center, New Jersey Transit, Newark, New Jersey.

[85] Phase I implemented CADS software for WSTA' s entire paratransit fleet, and installed MDT's, AVL and contactless Smart Card Readers in three of the vehicles. This phase and its evaluation were described in Section 5.2 of **Update '96**.

[86] Nedra Woodyatt, Winston-Salem Transit Authority, Winston-Salem, North Carolina.

Atlanta, Georgia

MARTA's Passenger Routing and Information System (PARIS) helps 16 operators provide customers with bus and rail trip itineraries and schedule information. About 20 percent of traveler inquiries are for full itineraries, while the remaining 80 percent are requests for specific bus and train schedule information. For optimal trip itineraries, an operator requests trip origin, destination, and time specifications from a caller, and inputs the information into the Megadyne software to obtain the itinerary with the shortest duration. For schedule information, an operator is also required to interface with the automated system. PARIS is able to access AVL information provided by the one third of MARTA's buses equipped with AVL to answer schedule queries. An automated voice response system reports the desired information to the customer. At rail stations, MARTA has installed free ring-down telephones for passengers to connect directly with PARIS operators. [87]

Application Examples (Canada)

Vancouver, British Columbia

BC Transit in the city of Vancouver makes trip itinerary planning available to its customers via telephone. A clerk answers the calls and inputs the origin and destination and other required information into the system, which is linked to a GIS map display showing the roads, bus stops, rivers, water bodies, significant points of interest, and parks. The system contains the schedules for all buses, light rail trains, Skytrain commuter rail trains, Seabuses, and heavy rail trains in the Greater Vancouver Transportation District, which is Vancouver and the lower mainland of British Columbia. The trip planning software produces two or three optional itineraries based on the customer's origin, destination, and other specifications. The clerk informs the caller of the results. The system receives about 5,000 calls per day, or 175 calls per clerk per day. BC Transit is currently investigating interactive voice response and Internet options that would more than quadruple their ability to handle customer information requests. [88]

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[87] Mary Ruiz, Metropolitan Atlanta Rapid Transit Authority, Atlanta, Georgia.

[88] Wayne Dale, Information Technology Section, BC Transit, Vancouver, British Columbia, Canada.

London, Ontario

London Transit's signpost AVL system, in addition to providing real-time information for operating personnel, gives their customer service telephone operators access to the projected arrival times of the next two or three buses on each route at the major transfer location. This information, as well as any transit-related incidents that might affect their transit trip, will be passed on to callers. In addition, once the technology is fully operational, London Transit will implement an automated phone system consisting of an audiotext system that will use a standard telephone exchange with the four digit code of a bus stop to connect the caller immediately with information on that stop's next two or three arrivals. It is possible that there will also be the option of talking to a live customer assistance operator.

3.2 IN-TERMINAL/WAYSIDE TRANSIT INFORMATION SYSTEMS

In-terminal and wayside customer information systems offer a wide variety of information to public transit riders who are already en-route. This information is being communicated via media such as electronic signs, interactive information kiosks, and closed-circuit television monitors. The information may include real-time arrival and departure information as well as traditional static service information. The ongoing design, planning, and deployment of a variety of APTS technologies is steadily improving the breadth and accuracy of en-route customer information, and is expanding the amount of multi-modal information that is available.

State-of-the-Art Summary

Since January 1996, there has been a significant increase in the deployment and expansion of APTS technologies that facilitate en-route information. As many transit operators look beyond the initial impetus of installing AVL systems as a means to improve operational efficiency, and customer and driver safety, the agencies are beginning to use the same data to support customer information programs.

While various agencies are using different approaches, the overall goal is to provide information that will provide real-time bus and train arrival and departure times, reduce waiting anxiety, and increase customer satisfaction. At least three projects have designed, deployed, and evaluated in-terminal and wayside information systems for persons with visual impairments. Some of the agencies with rail systems are working to provide real-time train arrival or departure information. The deployment of both bus terminal and bus stop real-time information systems is increasing.

While it appears that interactive information kiosks are being deployed at an increasing rate, the experiences of some agencies that have already installed kiosks provide useful information about the utility and impact of kiosks. For example, Seattle Metro has determined that kiosk placement and content are critical issues. Thus, the kiosks that are being placed for the EZRider project are being installed in Boeing assembly plants and will cater to workers who might not normally have access to the information on the Web. In terms of content, the kiosk will not only provide transportation information, but will also offer access to company information that employees want, such as job postings. Ann Arbor Transportation Authority's research has helped it determine that their Web site should be in place first, that kiosks should have the same interface as the Web site, and that an itinerary planning application using real-time information will be keys to successful kiosk deployment. Several other new projects are attempting to secure private sector partners to make these systems financially self-sustaining through advertising and other revenues.

Application Examples (United States)

In addition to the examples described in this section, several sites that provide wayside transit information are described in Section 3.4 - Multimodal Traveler Information.

New York City, New York

Talking Directory Display System

The Baruch College Computer Center for Visually Impaired People, working with the Long Island Railroad (LIRR), recently completed a Project Action-funded demonstration called the Talking Directory Display System (TDDS). This project was conducted between late 1995 and March 31, 1997. Baruch College staff were responsible for system design, software development, and maintenance while LIRR staff were responsible for identifying a suitable location for the unit and briefing personnel about the kiosk's existence and function. [89]

The TDDS, nicknamed the "Talking Kiosk," is specially designed to assist visually impaired persons with locating LIRR facilities throughout Penn Station in New York City. Users are able to initially find the system by following an audible beacon coupled with recorded voice directions. Once a user approaches within two feet of the TDDS, a proximity sensor activates more detailed voice directions that provide initial orientation to the kiosk. This represents an improvement over the original system design reported on in **Update '96**, which called for activating the system with a pressure sensitive mat.

The TDDS consists of a tactile map of the station and a standard telephone keypad. One or both can be used to navigate through the system to obtain information about the location of services within Penn Station that make it easier for the visually impaired to find destinations such as the ticket counter, information booth, platforms, or specific tracks. One important feature of the key pad component is the availability of a brief tutorial on using the map. Three different levels of detailed information are available and are accessed on the map by repeatedly touching a particular map feature, a characteristic that is explained during the audio tutorial.

In a three-month period during the demonstration, the Talking Kiosk was used almost 13,000 times. It was estimated that around 99 percent of the usage was by persons with no visual impairment. A detailed evaluation of the system involving a series of trials by the visually impaired showed that: TDDS was user friendly; more people use the key pad than the map; and 18 out of 20 people who successfully completed the trial would use the TDDS again. Although the key pad was used more frequently, the evaluation found that users would also employ the map once they had become familiar with the general working of the system. The majority of participants indicated they would like to have similar installations in other locations.

The TDDS continues to operate since the end of the demonstration project. Baruch College and LIRR staff have discussed the possibility of physically integrating it with an installation that would also house a ticket vending machine. Funding for this equipment development, ongoing

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[89] Karen Luxton-Gourgey, City University of New York, New York City, New York.

maintenance of the original unit, and additional installations both inside Penn Station and at other LIRR facilities is currently being sought.

Public Address/Customer Information Signs

New York City Transit has started a major upgrade of its customer communication system, called Public Address/Customer Information Signs, throughout its subway network. Currently, a $49 million Phase 1 system is being installed which will integrate new customer information signs with new or upgraded public address (PA) systems in 140 stations (another 17 stations will receive information signs under separate station rehabilitation contracts). Completion of Phase 1 is expected in mid-1998. At that time, NYCT willbegin installing its subway train and traffic information system, which will use the existing block signal system to provide information to passengers on the platform via the signs and PA systems.[90] The announcements will tell passengers how many stations away the next train is. This "semi real-time" information is the precursor to real-time information that will become available during Phase 2.[91]

Phase 2 is a $78 million project that will result in installation of information signs in another 57 stations. Anticipated to be completed in 2001, the project will be integrated with the simultaneous installation of automated train supervision on the Number 4 line running through Brooklyn, Manhattan, and the Bronx (also slated for completion in 2001). Data from the ATS will be fed into the signs and PA system to provide customers with real-time information. The information will include arrival time of the next several trains, length of the next train (to allow customers to position themselves properly on the platform for long or short trains), and advisories regarding planned service disruptions and detours.

Wayside Information

As part of the automatic vehicle location project described in Section 2.3, New York City Transit is working with a public-private partnership to provide wayside information to bus

[90] As described in Section 2.5.2, the subway train and traffic information system will be replaced by an automatic train supervision system.

[91] Tarik Hussain, New York City Transit, Brooklyn, New York.

passengers.[92] The contract for systems integration of this FTA-funded field operational test was awarded to Transportation Management Solutions in November 1996. [93]

The objective of the project is to communicate real-time information to customers waiting at bus stops via variable message signs (VMS), video monitors, and interactive kiosks. The project is designed to use the locational and schedule adherence data from the AVL project as the source for the real-time customer information. Initial deployment is expected to begin in February 1998 with full implementation scheduled to be complete by October 1998. After the system is fully deployed, a one year evaluation will commence.

Twenty bus stops will be equipped with VMS and 10 will be equipped with flat screen video monitors that will provide information concerning:

- Estimated bus arrival times;
- Bus routes serving a given bus stop and their destinations;
- Service type available (limited stop or local service);
- Transfers;
- Alternate routes; and
- Service delays.

The VMS technology will consist of four-color Light Emitting Diode displays that are capable of displaying text, graphics, and animation. Both the VMS and video displays will be ADA-compliant, modular, weather- and vandal-resistant, and self-diagnosing. The units will also be capable of displaying advertising.

The kiosk component of this demonstration will employ four "smart" units that will be installed at major tourist/transfer locations. [94] These devices will provide a variety of information to the user, including:

- Automated pre-trip itinerary planning from origin to destination, by mode and time of departure;

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[92] In addition to New York City Transit, the partnership includes the Metropolitan Transportation Authority, New York City Department of Transportation, New York State Department of Transportation, the Federal Highway Administration, the Federal Transit Administration, Transportation Management Solutions, Bell Atlantic, and New York City's bus shelter maintenance contractor.

[93] Isaac Takyi, New York City Transit, Brooklyn, New York.

[94] Kiosks will be installed at the South Ferry terminal of the Staten Island Ferry, South Street Seaport, Rockefeller Center, and the New York University Medical Center.

- Primary transit routes in the vicinity;
- Schedules and fares;
- Planned service disruptions;
- Alternate routes;
- Tourist information; and
- Special events information.

The kiosks will employ touch screen and graphical user interfaces, have the capability to print information for the user, and display advertising. Like the VMS and video monitors, the kiosks will be fully ADA-compliant.

Newark, New Jersey

New Jersey Transit received $300,000 Planning and Research (49U.S.C.Š5314) grant to research the feasibility of providing real-time, in-terminal train information for its passengers. The station in Summit, NJ was chosen because it presents passengers with a relatively complex set of travel choices. It is a key junction for several rail lines leading to three possible destinations in each direction from the station. It also has three tracks that often require passengers to change platforms quickly.[95]

Using the existing block signal technology, NJT's main train control center, and its Train Control Processor technology, the system is being developed to provide real-time information in the station's waiting room and on the platforms. Travelers will be able to view on-time/arrival status, departure time, and track number information. In some cases where the software is able to identify a particular train (e.g., Train 605 to Manhattan), travelers will be given that information as well. The system is expected to be capable of providing information for trains up to 30 minutes away from the station.

The project started in mid-1995 and is currently scheduled to conclude in December 1997. Since this is a research project, only the quality and reliability of the information generated by the system is being addressed. Information provided to travelers is part of the second phase of the research project. For the second phase, NJT has received another $250,000 grant to research the type and format of information passengers desire. This second phase will start in January 1998 and is

[95] Jim Kemp, New Jersey Transit, Newark, New Jersey.

expected to run for approximately 10 months. It will include study, selection, and procurement of the display technology. The research may also include the purchase and integration of a radio frequency tag-based automatic train identification system. If successfully integrated, the traveler information would include the train numbers.

Cincinnati, Ohio

The Southwest Ohio Regional Transit Authority (SORTA) is developing the infrastructure needed to deploy in-terminal information kiosks and on-board annunciators/displays. [96] The components of the infrastructure include a new 10-channel trunked 800 MHz radio system, and installation of vehicle logic units to support AVL, CAD, and schedule adherence systems. The project is expected to be fully implemented by the Summer of 1998.

SORTA will implement bus stop kiosks when the AVL system is fully operational. SORTA is exploring the possibility of including traffic information from Advanced Regional Traffic Interactive Management and Information System (the traffic management center started by the Ohio Department of Transportation and the Kentucky Transportation Cabinet) on the information kiosks.

SORTA still plans to implement next stop annunciators, however it has been determined that they will be installed only on newer vehicles that are already equipped with the requisite equipment. On-board displays are also planned, but the specific technology has not been chosen.

Ann Arbor, Michigan

The Ann Arbor Transportation Authority is deploying its new Advanced Operating System, which supports a variety of traveler information technologies. AATA will begin in September 1997 to test its in-terminal passenger information system. Using a pair of 31” video monitors, the real-time data generated by the AVL system will be used to inform passengers at the downtown transit center about arrival status, delays, and departure times. The operations center will also be able to display real-time incident information that will assist passengers in making alternate plans if their bus will be

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[96] Greg Lind, Southwest Ohio Regional Transportation Authority, Cincinnati, Ohio.

delayed. Full implementation is expected in October 1997. The agency is currently reconsidering the effectiveness of interactive kiosks. [97]

Phoenix, Arizona

As part of the transit component of the AZTech ***Model Deployment Initiative***, 88 buses will be equipped with an AVL system (see Section 2.3). The AZTech server will process all real-time and static transit and traffic information for distribution through the system's three information channels. Using real-time transit information from the AVL, the AZTech server will feed displays at 10 or more bus stops, providing customers with real-time, next bus arrival information. Displays will be deployed on the Scottsdale/Rural road route and on the Tempe Red Line (which serves Arizona State University). Five interactive kiosks, including one at the downtown Phoenix transit terminal, another at the North Valley terminal, and three at malls served by several major routes, are also part of the project. The kiosks will provide bus information and traffic updates. All wayside and in-terminal display devices are expected to be operational by April 1998. [98]

As part of the AZTech deployment , the City of Phoenix is developing a touch-tone telephone itinerary planning system and plans are being developed to provide real-time transit and traffic information on a World Wide Web site. Bus information will be available through AZTech's On-line Bus Book.

Spokane, Washington

Since January 1996, Spokane Transit Authority has completed installation of its electronic passenger information system at its downtown transit center called the Plaza. This automated information system, which became fully operational in July 1995, provides passengers with three pieces of information. One monitor shows the scheduled arrival of the next bus on each route. A second monitor provides the actual departure time of the next bus on each route. The departure monitor also tells passengers the specific bus bay from which their bus will depart.

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[97] William Hiller, Ann Arbor Transportation Authority, Ann Arbor, Michigan.

[98] Yogesh Mantri, AZTech, Phoenix, Arizona.

Besides the in-terminal traveler information, the system supports bus bay availability indicators that show bus drivers waiting in the adjacent bus holding area when their assigned bay becomes vacant. In addition, the system records the actual arrival and departure time of each bus so that dispatchers and planners can use the information to determine if schedule adjustments are needed.

Seattle, Washington

BusLink

One part of Seattle's Smart Trek ***Model Deployment Initiative*** is BusLink. This is a real-time customer information system that will provide route, scheduled arrival, bus bay, status, and destination of buses at three major transit centers - Northgate, Bellevue, and the Westlake Tunnel Station in downtown Seattle. This information will be updated every few minutes and will come from King County Metro's AVL system. Data from the AVL system will be sent to and processed by staff at the University of Washington, which is also developing the predictive algorithms for the project. The University will thus house and maintain the information backbone for the system. An important component of the Smart Trek project is the enhancement of the signpost/odometer AVL system in order to improve the fleet tracking capability to support these new traveler information initiatives. Implementation is scheduled to be completed in March 1998.

Metro is also considering providing traffic incident information that affects bus service. Both video monitors and variable message sign technology are being evaluated. [99]

EZRider

In addition to the five interactive kiosks at the Boeing complex in Everett (see Section 3.1), an additional three kiosks will be provided to users of the Washington State Ferries - two in ferry terminals and another on a newly constructed ferry that can be used en-route. [100]

[99] Catherine Bradshaw and Robert Wade, King County Department of Transportation, Metro Transit, Seattle, Washington.

[100] Ibid.

San Francisco, California

Talking Signs - Rail

Update '96 reported that the San Francisco Municipal Railway (Muni) and Bay Area Rapid Transit District were evaluating "Talking Signs" technology for the visually-impaired at San Francisco's Powell Street station. "The Talking Signs system is comprised of infrared transmitters which convey specific messages to small receivers carried by blind travelers. Infrared transmission is directional. This means that when blind Talking Signs users pick up a message, they can also tell where it comes from." [101] These messages provide the user with the same content as the printed sign. The visually impaired person holding the receiver hears the sign's spoken message, which tells them where they are and what must be done at that location to reach and board the train or to find other services within the station complex. The test ran from June 1993 to June 1994. Originally planned to be removed after testing and evaluation, the visually impaired community prevailed on the agencies to continue operating the signs.

The test involved 93 transmitter signs ($500 each) which were located through the three levels of the station. Transmitters had a range from 10 to 60 feet depending on each sign's function. Of the 36 visually impaired subjects that participated in the evaluation of the Talking Signs installation, 86 percent successfully completed easy, medium, and hard routes within the station. The Steering Committee which oversaw the project stated at the tests conclusion that "…we recommend that remote infrared audible signage (specifically Talking Signs) is the preferred technology enabling print handicapped persons to travel independently in transit facilities." [102] According to Talking Signs, as of August 1997, both BART and Muni were considering a proposal to expand the system into another nine underground rail stations. [103]

[101] Crandall, W., Ph.D., B Bentzen, Ph.D., L. Myers, M.Ed., **Use of Talking Signs at Light Controlled Street Crossings: Preliminary Results**, The Smith-Kettlewell Eye Research Institute, San Francisco, California.

[102] Crandall, W., Ph.D., B Bentzen, Ph.D., L. Myers, M.Ed., and P. Mitchell, Ph.D., **Transit Accessibility Improvement Through Talking Signs Remote Infrared Signage: A Demonstration and Evaluation** - *Project Action*, The Smith-Kettlewell Eye Research Institute, San Francisco, March 1995.

[103] C. Ward Bond, President, Talking Signs, Baton Rouge, Louisiana. (August 19, 1997)

Talking Signs - Bus

In addition to the Talking Signs demonstration in a transit station setting, the San Francisco Municipal Railway participated in a test of a similar technology on buses. Integrated with electronic destination signs and next stop annunciators, the test involved 18 blind participants who used infrared receivers to locate and identify bus stops, and a number of individual stationary buses at the same stop in a busy transportation hub. Four infrared transmitters were connected to light-emitting diode arrays suitable for mounting on bus shelters, bus stop poles, and buses. The transmitters had a range of 50 feet for bus stops and 250 feet for buses.

The study found that "remote infrared audible signage provides way finding information for surface transit as it has previously been shown to do for transit stations, thereby enhancing independent use of public transit by person having visual impairments." [104] Talking Signs is currently working with Muni to develop a test to demonstrate the technology with moving vehicles.

Houston, Texas

Houston is one of four U.S. DOT ITS Priority Corridors, and several transit information or related projects are being implemented under its auspices. Beginning in September 1997, the Metropolitan Transit Authority of Harris County will be implementing a variable message sign project called the En-route Transit Information System. Estimated to cost approximately $750,000 from design to implementation, it will be funded by Metro and the Federal Highway Administration. The system will consist of four VMS installations, one at the downtown Houston transit center, one at a park and ride location, and two more at major downtown bus stops. Transit users will be able to find out what bus will arrive next and its projected arrival time. The project is currently in the functional requirements definition stage and is scheduled to be fully deployed by March 1999. [105]

A key component in the en-route information project is the implementation of a vehicle tracking system that will supply the necessary real-time information. Metro is considering either a

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[104] Crandall, W., Ph.D., B Bentzen, Ph.D., L. Myers, M.Ed., and P. Mitchell, Ph.D., **Remote Infrared Signage for People Who are Blind or Print Disabled: A Surface Transit Accessibility Study** - *Project Action*, The Smith-Kettlewell Eye Research Institute, San Francisco, April 1996.

[105] Gloria Stoppenhagen, Houston TranStar, Houston, Texas.

satellite-based AVL system or an electronic tag and reader-based automatic vehicle identification system. In developing the functional requirements and deciding between the two technologies, Metro will be considering the fact that it is already installing electronic tags on buses and tag readers at bus garages to automatically record pull-out/pull-in information for dispatch purposes. Another consideration is Metro's desire to see tag readers installed on arterials so that it can obtain travel time information on streets in the same way that TranStar [106] is collecting information on highways. The project is anticipated to cost approximately $1.0 million, with full implementation scheduled by March 1999.

Application Examples (Canada)

Vancouver, British Columbia

As part of its development of the Vancouver-Richmond Rapid Bus line system scheduled for start-up in 1999, BC Transit is planning to implement several transit information technologies. Using AVL technology, BC Transit expects to provide real-time information at 10 to 15 stops on the new line (which combines the operation of six separate bus routes currently providing service in the corridor). Waiting passengers will be able to consult a variable message sign or hear voice announcements of the arrival time of the next one or two buses. Passengers already on-board will be provided both audio and visual next stop information. The agency plans to operate the new system on a headway maintenance rather than on a scheduled service basis. That is, instead of publishing a set timetable, BC Transit will concentrate on maintaining a five to seven minute headway during peak periods and 10 to 12 minutes off-peak. The agency expects that with real-time arrival time information, customers will be better informed than trying to determine whether any particular train is on time. [107]

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[106] TranStar is the transportation operations and emergency management agency responsible for the planning, design, operations, and maintenance of transportation within the Greater Houston Area.

[107] "BC Transit to Bring Rapid Bus to Vancouver," *Passenger Transport*, June 23, 1997.

3.3 IN-VEHICLE TRANSIT INFORMATION SYSTEMS

The major impetus for in-vehicle customer information systems is to provide useful en-route information to riders concerning their transit trips and to comply with the applicable provisions of the Americans with Disabilities Act of 1991. Many transit operators are supplying some combination of audible and visual next stop, major intersection, and transfer point information to achieve both objectives.

State-of-the-Art Summary

As with in-terminal and wayside customer information systems, the ability to deploy automated on-board information display and annunciation is usually made possible by the installation of automatic vehicle location systems. In addition to compliance with ADA provisions and improving en-route information, automating the provision of in-vehicle information also allows the vehicle operator to concentrate on the task of driving and reduces potential driver distraction. The announcement and display systems will also make it possible for transit properties to communicate public service information when stop announcements are not being made.

Two primary media are used: automated annunciators and in-vehicle displays. Both communicate location-related information to customers typically based on vehicle location data processed on-board by a vehicle logic unit.

One challenge that has been faced by several operators since January 1996 is improving the accuracy of locational data to the point that accurate and timely information is communicated to on-board customers, especially next stop information. While this is sometimes related to the vehicle location technology in use, it can also result from seemingly unrelated factors such as the geographic accuracy of an agency's bus stop database.

Another development is integrating bus destination signs with AVL systems to ensure that destination information displayed to passengers waiting at the curb is accurate, especially on multi-route corridors or multiple-branch routes. This advance takes the responsibility off of the vehicle operator by automating the destination sign changes through the AVL/CAD system. Finally, several bus operators are enhancing their fleet management systems so that passengers who are already on-board can request and get confirmation on transfers to other transit services.

Application Examples (United States)

Newark, New Jersey

In-Vehicle Bus Information

As discussed in **Update '96**, New Jersey Transit was in the process of testing two different in-vehicle information technologies. The agency's goal is still to develop a viable automated voice annunciator system to enhance bus service and comply with provisions of the ADA. [108]

The first trial involved odometer tracking and display software, and display/annunciator technology integrated with the Siemens' global positioning system vehicle location technology. The result was that basic operation of the announcements and display worked correctly, but the vehicle location component was not able to recalibrate the odometer readings in the event that the bus made a deviation, such as those caused by periodic detours. Thus, the system would sometimes announce incorrect locations.

The other trial involved the Talking Bus System and GPS vehicle location technology. The results of this test were inconclusive.

Because of the mixed success of the first trial, NJT is in the process of developing a follow-up test on the heavily patronized Route 113 from Dunellen, NJ to New York City. This route is characterized by both long distance and local travel. The test will employ a single bus equipped with an updated version of the first trial system, which will again provide the odometer tracking and display software. This time the system will be integrated with a dead-reckoning and GPS location system called the Continuous Positioning System. The goal of this demonstration is for the new location system to successfully recalibrate the odometer readings and solve the problems that were present during the first demonstration. The new system will be capable of announcing and displaying each stop, major intersections, and the current intersection when the bus doors open. It will also audibly notify the bus driver in the event that the bus goes off route.

The test is expected to start during the Fall of 1997 and be completed within one year. If the test demonstrates sufficient reliability, NJT will consider expansion of the system to other bus routes.

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[108] Jim Kemp, New Jersey Transit, Newark, New Jersey.

NJT will be conducting a baseline survey and a follow-up survey after several months of operation to identify changes in public opinion since the initial installation.

In-Vehicle Rail Information

In January 1997, NJT placed 100 new rail coaches into service on its Hoboken and Newark divisions, which include the Morrison-Essex and Northeast Corridor lines. These units were designed to support a sophisticated on-board communication system, including processing of in-vehicle traveler information. The traveler information hardware consists of two liquid crystal displays and a public address system on each coach. The next station is displayed to passengers as the train approaches the station and just after it pulls out of the station. These messages are automatically triggered by a global positioning system on the train. In addition, the displays show a variety of standard customer service messages when next stop information is not being communicated. [109]

New York City, New York

After in-service testing for approximately four years, New York City Transit awarded contracts in July 1997 for 1,080 subway cars that will provide in-vehicle customer information. Delivery of the new equipment is scheduled for early 1999. [110]

The modern train cars feature a variety of traveler information communicated both via public address and light emitting diode displays at both ends of the car. Information provided will include automated next stop announcements, the side of the train on which doors will open at the next station, and standard customer information. In addition, electronic strip maps above each door will show passengers the train's current location (relative to the current or next stop) and in which direction it is traveling. The trains may also have automatic berthing (a system which will stop trains at exactly the right point on the platform depending on the train's length), and closed-circuit television in the operator's cab (a safety feature which will allow the operator to watch boarding and alighting activity).

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[109] Ibid.

[110] Isaac Takyi, New York City Transit, Brooklyn, New York.

Atlanta, Georgia

As of August 1997, the Metropolitan Atlanta Rapid Transit Authority had installed in-vehicle public address system, and light emitting diode displays on 100 of its 750 bus fleet. These provide next stop information for approximately 1,500 of MARTA's 10,000 bus stops. The displays also indicate the current route. [111]

Ann Arbor, Michigan

By September 1997, AATA will have installed a GPS AVL system in all 77 of its transit vehicles (see Section 2.3). The AVL will include in-vehicle annunciators and displays from which passengers will receive next stop and transfer information. The latter will take the form of announcements that identify valid bus transfers at upcoming intersections.

A special feature of the transfer system is the ability of bus operators to communicate transfer requests. When a bus operator receives a transfer request from a passenger, he/she inputs the information into the on-board console which allows the request to be processed by the dispatch computer. The dispatch computer calculates whether the transfer can be made given the schedule adherence of both the originating and connecting buses. If the transfer is possible, the bus driver is informed, notifies the requesting passenger, and the operator on the connecting bus is automatically advised to wait for a specified duration for the transfer. [112]

Torrance, California

Torrance Transit is using integrated on-board technologies to build a foundation for near-term and future APTS technology deployment. The basis of this development is a vehicle management system and an advanced fare transaction system on the entire 85-vehicle Torrance Transit fleet, including full size, fixed-route buses, paratransit vans, and express buses. The overall cost of this research and development effort is approximately $880,000, with installation on each vehicle costing between $7,000 and $10,000.

[111] Mary Ruiz, Metropolitan Atlanta Rapid Transit Authority, Atlanta, Georgia.

[112] William Hiller, Ann Arbor Transportation Authority, Ann Arbor, Michigan.

The vehicle management system will support in-vehicle annunciators and displays, automatic passenger counting on 15 buses (enough to meet reporting requirements for the National Transit Database), traffic signal priority, automated fare collection, and mechanical diagnostics via existing on-board system warning lights (e.g., oil pressure, etc.) A unique characteristic of this deployment, which began in June 1996 and is anticipated to be completed in November 1997, is that the GPS will be used solely for on-board technologies. That is, it will not provide data inputs to an automatic vehicle location system or related dispatch center, although its open systems architecture will permit the City of Torrance to add that capability in the future. The agency will need to increase its communication capacity beyond voice transmission to enable it to use AVL or CAD.

The vehicle management system utilizes GPS technology to provide passengers with next stop and major intersection announcements and display, both inside and outside the vehicle. In-vehicle displays are light-emitting diode technology. This service is fully compliant with ADA requirements. In the future, the agency plans to use the technology to announce and display other relevant transit information to passengers. The system will be placed in service during Fall 1997. [113]

Application Example (Canada)

London, Ontario

London Transit completed the demonstration project for the automatic vehicle location system implementation described in **Update '96** and is now in the implementation phase. With an upgraded and more robust radio system, AVL, and CAD technologies, the agency is taking the final steps of implementing the components needed to provide both in-vehicle and pre-trip traveler information. These technologies are expected to be fully installed and operational by late 1997 or early 1998.

The most unique feature of London Transit's in-vehicle traveler information system is the bus-to-bus transfer notification capability that is being developed. When fully implemented, a passenger will be able to request that the bus driver notify the next bus on a connecting route that

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[113] Bob Meyers, City of Torrance, Torrance, California.

a transfer has been requested. The bus driver does so by entering the connecting route number on the in-vehicle console. This will trigger a notification to the connecting bus operator to wait at the transfer point for a preset, limited amount of time (the duration of which is as yet undetermined).

One potential drawback to this strategy is the lack of communication from the connecting bus concerning its current location, schedule adherence, and ability to wait for the transferring passenger. The only information that can be communicated from the originating bus to the transferring passenger is that the connecting bus received the transfer request. In terms of any impact on schedule adherence, the agency plans to add sufficient running time to compensate for transfers.

London Transit believes that better transfer connections and schedule adherence information will translate into more riders and the increased fare revenue will more than cover the cost of the system.[114]

3.4 MULTIMODAL TRAVELER INFORMATION SYSTEMS

One factor common to most multimodal traveler information systems is that they typically combine data from one or more transit services with real-time and static traffic data. The methods for collecting, fusing, reformatting, and disseminating these two information streams to the public is as diverse as the programs themselves. In some cases, the responsibility for dissemination remains with the individual service provider. With regard to transit, multimodal traveler information systems often include pre-trip, in-terminal/wayside, and in-vehicle information systems.

State-of-the-Art Summary

Multimodal traveler information systems provide both real-time and static information on both transit and traffic to enable travelers to make fully informed mode choice decisions, both pre-trip and en-route. Traveler information telephone lines, interactive kiosks, and World Wide Web sites are the most common distribution media. Park and ride, and ridesharing information are also distributed in some multimodal traveler information systems.

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[114] Bill Brock, London Transit Commission, London, Ontario, Canada.

Data formatting and compatibility (especially for spatially-referenced data) stand as key issues in successful multimodal information efforts. In addition, the expansion of traffic data collection to major arterials and other surface streets adds to the usefulness of traffic condition information for transit operators and their customers. However, developing partnerships that involve private companies and that are designed to make traveler information systems self-sustaining is a challenge that must be faced if some of these information systems are to continue in operation.

Application Examples

Atlanta, Georgia

The Traveler Information Showcase project was developed to increase public awareness of the ITS program and demonstrate the benefits in daily commuting. The Showcase was initiated by the Federal Highway Administration in partnership with the Federal Transit Administration, the Georgia Department of Transportation, The Metropolitan Atlanta Rapid Transit Authority, among others. The Federal Highway Administration contracted for the implementation of the Showcase project.

The Showcase was one of five major ITS efforts in the Atlanta area spurred by the 1996 Summer Olympic Games. ITS MARTA '96, the Advanced Traveler Information Kiosks, the Advanced Transportation Management System, and the Atlanta Driver Advisory System were the other four. The Showcase demonstration ran from June through September 1996, with most of the systems continued through February 1997.

The Showcase project provided real-time information to travelers through the following five devices/technologies: personal communications devices; in-vehicle navigation systems; cable television; interactive television; and the Internet. The real-time transportation information that was communicated to the Showcase devices was made available through the Advanced Transportation Management System constructed by the Georgia DOT. Information communicated to the Showcase devices included: traffic incidents; congestion on major highways; updates on construction activities and road closures; bus and rail station locations; schedules and fares; airline schedules and flight information; and information on special events, tourist sites, and yellow pages information. [115]

All except the personal communications devices continue in operation at this time, although the interactive television system has been moved from a hotel to an apartment complex.

Internet

The Showcase's Internet site provided real-time traffic maps, route planning, and links to MARTA's transit system, as well as wide area travel, Olympic event, and other information. The Showcase Internet home page was visited on an average of 2,000 to 3,000 times a week during the first four months of the demonstration. During the two weeks of the Olympics, the home page averaged 10,000 visits a week.[116]

Personal Communications Devices

About 250 personal communications devices were available during the Showcase. These devices provided much the same information as the Internet home page. Visitors wishing to try the two different wireless hand-held devices could obtain them at local hotels and at the Atlanta-Hartsfield International airport. Some units were also provided to local businesses and government agencies. Participants could check the traffic maps on the PCD screen for the shortest or quickest route to their destinations or get information on transit options using bus and rail routes and schedules.

In-Vehicle Navigation Systems

Volunteers, visitors, and local fleet drivers were provided with turn-by-turn directions to their destinations, real-time traffic information, maps, and electronic yellow page information through their in-vehicle navigation display units. One hundred on-board computing units were installed in vehicles provided by Oldsmobile and BMW, Hertz rental cars, and local business and government fleet vehicles.[117]

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[115] The Traveler Information Showcase information kit.

[116] Atlanta Traveler Information Showcase 1996, Striking Gold in Atlanta, brochure.

[117] Ibid.

Cable Television

During the Showcase, cable systems in the City of Atlanta, DeKalb, Gwinnett, and Cobb Counties carried the real-time Georgia Traveler Information Television programming. Viewers received information from maps showing incident locations and traffic speeds, live surveillance video feeds from strategically placed roadside cameras, and traffic advisory bulletin boards. [118]

Interactive Television

Televisions in 285 rooms in the Crowne Plaza Hotel, Ravina, provided a host of services including real-time traffic and transit information to guests via the Interactive Channel. Guests could receive printed maps with directions to their destination. Using the remote control unit, the viewer could select from a menu of information options. The head end computer at the hotel processed the request and returned the information back to the television set. [119,120]

Participant Assessment

Users were asked about their use of the various Showcase information services. Between half and three quarters of respondents found the information provided to be helpful. At least 40 percent of respondents changed their travel plans or decisions at least once on the basis of information received. Most users felt that the devices provided an excellent way to present information. An in-vehicle device was the most likely to be purchased if the cost was reasonable. [121] The U.S. DOT considered the Showcase a resounding success.

Kiosks

There are approximately 39 interactive kiosks placed in or outside 22 MARTA rail stations in addition to more than 100 others in various locations. These kiosks provide a whole range of traveler information in addition to transit and traffic data. One potential upgrade that is being considered is changing from a typical Windows-based PC platform to a dumb terminal architecture that will provide the user with a World Wide Web browser to access Web sites containing desired

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[118] Ibid.

[119] Ibid.

[120] Atlanta Traveler Information Showcase 1996, the Traveler, Issue 4, May 1996, newsletter.

[121] Atlanta Traveler Information Showcase 1996, the Traveler, Issue 5, December 1996, newsletter.

information. One effect of this will be to eliminate the need to have a large database resident on each kiosk's processor and also put the onus on updating information on the respective Web site's sponsor. [122]

Washington, D.C.

Partners in Motion, a transportation partnership of 25 public agencies and 12 private organizations, launched Phase I of the SmarTraveler® Information System in the Washington, D.C. area in July 1997. This system provides pre-trip, in-terminal, and in-vehicle transit and traffic information to help travelers make informed decisions on the most efficient means of reaching their destinations, thereby reducing travel time and travel-related stress. Travelers can access on-demand, real-time, route-specific transit and traffic information from their homes or offices by making a free call or by logging onto the Internet via the World Wide Web. The SmarTraveler® Information System also provides construction, weather, and special event information. [123]

The system obtains information from a variety of data collection resources including: 100 video cameras that are monitoring traffic in the region; 1,000 regularly scheduled mobile probe trips; radio scanners monitoring police and emergency service communications; a two-way radio system for traffic reporting and special events coordination; two fixed wing aircraft; a static database of construction activities, events, mapping, and alternative route information; communications with private transportation carriers such as Super Shuttle; and direct communications with a host of public transit, transportation, and transportation-related agencies. The information from various sources is merged into a database for dissemination to users.

A traveler accessing the system via telephone can listen for the audio menu to select specific routes, transit services, or other information. Internet users will view the same menus on their screens. They may choose the option of connecting directly with area transportation lines including those of Metrorail and Metrobus Mobility Link, Virginia Railway Express, Maryland Railroad Commuter Services, Commuter Connections Ridesharing Program, and several other local transit

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[122] Mary Ruiz, Metropolitan Atlanta Rapid Transit Authority, Atlanta, Georgia.

[123] Jennifer Garfinkel, Account Executive, Global Exchange, Inc.

operations including Driving Alexandrians Safely Home, Loudoun County Transit, Fairfax Connector, Ride-On in Montgomery County, THE BUS in Prince George's County, Potomac-Rappahannock Transportation Commission OnmiLink, and Maryland National Capital Park and Planning Commission bicycle route information, as well as several paratransit services.

By early 1998, the later phases of implementation will add new methods of obtaining information including in-vehicle navigation devices, cable television, personal pagers, and kiosks at major sporting, shopping, and employment areas. There will be some charges for using these additional features of the system, but the telephone and Internet access will remain free of charge.

The public/private partnership provides the cooperation needed to make this project a success. The entire project is valued at $12.2 million, of which one third is being provided by the private sector and two thirds by the public sector. Benefits accrue to: the consumer in the form of free and for-fee services for a better trip; public agencies, who will receive 10 percent of the service fees for services other than the telephone and Internet; and the private companies who receive the remaining 90 percent of the fees.[124]

New York Metropolitan Region

The Transportation Operations Coordinating Committee is a consortium of 14 highway, public transit, and public safety agencies in the New York Metropolitan region. Contracting through the Port Authority of New York and New Jersey, it released a request for partnership proposals in October 1996 to encourage interest in its Service Area Traveler Information Network (SATIN) kiosk project. A network of about 20 kiosks will disseminate static and real-time transit and traffic information at locations such as transit centers, truck stops, and service areas in the New York, New Jersey, and Connecticut region. This project is intended to enable travelers to choose the best route based on current transit and traffic conditions. TRANSCOM anticipates a contract to be signed in October 1997, with initial implementation scheduled within a year of the notice to proceed.[125]

[124] Washington DC SmarTraveler Press Kit.

[125] Shelley Prettyman, Transportation Operations Coordinating Committee, Jersey City, New Jersey.

TRANSCOM's goal is to "select a private-sector partner, who will provide a final system design, implement the network, ensure the ongoing operational support of the network, and serve as broker for TRANSCOM in the marketing of revenue-generating services and/or information on the kiosk system." [126] TRANSCOM will contribute between $700,000 and $900,000 of its Federal funding in initial capital for the project. The private partner will be responsible for creating a financially self-sustaining system.

Besides a range of traffic data that will be provided, the kiosks will be designed to initially provide:

- Transit schedules;
- Stop/station locations;
- Fare information;
- Park and ride location related transit connections;
- Impacts on transit availability due to special events; and
- Details on connecting transit services.

This information will be available through a trip planning application that will allow the user to choose travel preferences such as mode, fewest transfers, shortest travel time, or lowest cost. Sources of the information will include TRANSCOM and its member organizations. An evaluation survey will also be incorporated into the kiosk menu to obtain users' comments on the service. TRANSCOM has identified at least six other types of information to be delivered in the later stages of development. The user interface will be designed with map-based screens containing pull-down windows for more detailed information.

The SATIN network will be controlled via a computer server at TRANSCOM's Operations Information Center, where general information will be downloaded to all units or site-specific updates could be transmitted to a single kiosk. Some of the most interesting capabilities available through the kiosks are: printing capability; audio capability; touch screen technology input; ADA accessibility; and the ability to read credit cards, debit cards, or other payment media.

[126] SATIN Request for Partnership Proposals. (provided by Shelley Prettyman, Transportation Operations Coordinating Committee, September 4, 1997)

Minneapolis, Minnesota

Travlink was the Twin Cities area's multimodal traveler information system operational test. Travlink operated from December 1994 to December 1995. There were three main outlets for Travlink information: three interactive kiosks; four variable message signs; two display monitors; and 210 videotext terminals.[127]

The Minnesota Department of Transportation's (MnDOT) follow-up to Travlink is ORION, a two year program of the Minnesota Guidestar ITS initiative that will facilitate information sharing among public agencies. It has a budget of approximately $40 million from public and private sources. With MnDOT Metro Division as the lead public sector agency, ORION will expand on Travlink's efforts using $7.5 million of the total funding for transit enhancements. ORION will equip 292 Metro Transit (formerly the Metropolitan Council Transit Operation) buses and service vehicles with AVL capabilities. ORION will use AVL to provide faster response to security incidents, to improve on-time performance, to create more accurate bus schedules, and to reduce average call times in the transit control center. It will also include improved transit trip planning software available both through Metro Transit's transit information center and on a World Wide Web site. Unlike Travlink, interactive information kiosks are not part of the ORION project.

In terms of multimodal content, the ORION project will include a traveler information center that will provide traffic as well as transit information. Traffic information will include incidents, travel speeds on both highways and major arterials, ramp queue wait times, parking availability, and other feedback that will help travelers make informed mode choice decisions. This information will be available by telephone through the information center and on a related Web page.

Houston, Texas

<u>*Municipal Kiosks*</u>

The Metropolitan Transit Authority of Harris County is participating with the Texas Department of Transportation (TxDOT) and the City of Houston to deploy interactive kiosks. Of the 20 total units being purchased that will primarily provide municipal information (such as how to

[127] Marilyn Remer, Minnesota Department of Transportation, St. Paul, Minnesota.

pay a parking ticket), 10 will also provide transit and traffic data. Although transit information will be limited to static schedule and fare information at the outset, it will include real-time information when it becomes available. [128]

Smart Commuter

Another project on which Metro is partnering is the Smart Commuter field operational test. The Smart Commuter program offers participants pre-trip transportation information, including real-time highway travel times, bus schedules, and real-time incident and road closure locations. Comparative link travel times (or speeds) for both high-occupancy vehicle lanes and regular travel lanes will allow travelers to decide the quickest means of travel (transit vehicles use the HOV lanes). Travel times and speeds are calculated by an automated system as transponder-equipped vehicles (some 30,000 in all) pass various automatic vehicle identification readers along their routes. The real-time traffic information system operates in the Interstate 45 North corridor.

This program started in 1996 with 260 participants, and was expected to grow to 700 participants by the end of 1997. Participants access this information at the transportation management center via telephone or through hand-held personal digital assistants, which are small enough (6" x 8" x 2") to carry conveniently. Houston Metro's objective was to determine whether giving commuters real-time traffic conditions on the main highways can affect their decision to take public transit or use the HOV lanes. Metro does not expect participants to convert from automobile commuters to full-time transit users, but hopes that they will become occasional to frequent users as they experience the advantages transit offers over congested highway driving. An evaluation of the program by the Texas Transportation Institute and Multisystems will be completed by October 1998.[129]

San Antonio, Texas

The Texas Department of Transportation and San Antonio's transit agency, VIA Metropolitan Transit, are working to implement several APTS technologies on the transit system as

[128] Gloria Stoppenhagen, Houston TranStar, Houston, Texas.

[129] Ibid.

part of the region's $13.39 million ***Model Deployment Initiative*** (MDI). One component of the MDI includes approximately 40 interactive kiosks. Between seven and 17 kiosks will be sited by VIA at its park and ride locations, key bus transfer centers, and major generators such as employment offices. The kiosks will offer static bus route and schedule information, bus fares, key tourist points of interest, elderly and disabled services, real-time traffic conditions, weather reports, and airport access information. The objective of the VIA kiosks is to assist travelers in switching from single occupancy vehicles to public transit. Installation of the kiosks was to be completed by December 1997.[130]

Seattle, Washington

The previously described BusLink and BusView projects are natural extensions of the Seattle Wide-area Information for Travelers (SWIFT) operational test which was recently completed. SWIFT provided transit information to 60 participants via laptop computers provided by the project. The computers allowed the users to have access to the real-time location of Metro transit buses as well as current freeway congestion and traffic incident information delivered over a wireless network.[131]

San Francisco Bay Area, California

<u>TravInfo</u>

TravInfo is the San Francisco Bay Area's Advanced Traveler Information System. The Federally-funded operational test, which commenced June 1, 1993, is now fully operational and scheduled for completion in September 1998. TravInfo was designed to test the thesis that making real-time information about traffic conditions readily available to the public would reduce congestion by inducing people to take public transit and to rideshare. TravInfo is jointly sponsored by Caltrans and the Federal Highway Administration. It is being implemented through a public-private

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[130] Brian Fariello, Texas Department of Transportation, San Antonio, Texas.

[131] Catherine Bradshaw and Robert Wade, King County Department of Transportation, Metro Transit, Seattle, Washington.

partnership, led by the Metropolitan Transportation Commission of the nine-county San Francisco Bay Area.[132]

TravInfo covers all modes of surface transportation in the Bay Area, providing travelers with timely and accurate multimodal information through a variety of public and commercial services. The traveler information center (TIC), operated under contract to the MTC, is where travel data is collected, processed and fused, reformatted, and made available for dissemination through a variety of channels described below.

A main component of TravInfo is the Travel Advisory Telephone System, an audiotext service available through the TIC to all residents of the Bay Area via a local call. Besides an extensive selection of recorded traffic related information that includes current conditions, carpooling options, and parking, callers can be connected directly to transit service providers to obtain schedule, fare, trip planning, and incident information. Individual transit operators have access to the full TravInfo database not only for providing information to customers, but can use the traffic and incident information to assist them operationally. Travelers can also get data from the registered participants that are providing reformatted information on a for-profit basis. Media through which TravInfo information may be provided include a World Wide Web site, digital FM radio, pagers, cellular phones, in-vehicle navigation systems, personal digital assistants, kiosks, and cable TV. Marketing of these private services is the sole responsibility of the vendors.

As of August 1997, approximately eight public organizations and 38 private organizations were participating in TravInfo. The private sector participants are involved as 'registered participants' who retrieve data from TravInfo's and some of the public sector participants' open-access databases and repackage it for dissemination to travelers. Looking ahead to the completion of the operational test, MTC has begun the process of developing a business plan to secure ongoing funding after 1998. The plan may include charging registered participants for the data that they access and disseminate to the public.

[132] TravInfo Fact Sheet, provided by the Caltrans New Technology Programs.

TransCal

A second project in the San Francisco Bay Area, TransCal, has three components: an Interregional Traveler Information System (IRTIS); an Emergency Notification System; and the Tahoe Frequent Passenger Project. Only the IRTIS involves pre-trip traveler information services. It covers the Interstate 80/US Highway 50 corridor (including feeder routes) between San Francisco, the Lake Tahoe basin, and the Reno/Carson City area. IRTIS provides roadway conditions, incidents, traffic, weather, alternative transportation options (bus, train, plane), and yellow pages information. Travelers will have what they need to pre-plan a trip through more than one region and be able to modify their trip while enroute. Data sources include:

- Caltrans Traffic Operations System;
- California Highway Patrol;
- Nevada Department of Transportation;
- Nevada Highway Patrol;
- National Weather Service; and
- TravInfo.

The TIC will gather all these data, fuse it into one database, and transmit it to dissemination services by wireless FM subcarrier broadcasts and via a land-line data server for computer users. It will support the traveler advisory telephone system, traditional broadcast media, in-vehicle navigation devices, personal digital assistants, and interactive traveler information kiosks. [133]

Transit data currently consist of only the telephone numbers of the appropriate transit agencies to contact, but future plans are to include actual schedules. The major obstacles are the lack of a standardized electronic format and the cost to input the data. To the extent that the participating transit agencies will have dynamic scheduling and real-time bus arrival information, TransCal will disseminate it. [134]

Contra Costa County, California

The Central Contra Costa County Transportation Partnership and Cooperation (TRANSPAC) Committee is a transportation consortium comprised of six jurisdictions with a population of

[133] TransCal Fact Sheet, provided by the Caltrans New Technology Programs.

[134] Elaine Houmani, Research Analyst, Caltrans, Sacramento, California.

approximately 320,000 in the East Bay area. It administers the area's transportation demand management program and implements trip reduction ordinances. Its purpose is to encourage the use of alternatives to single occupancy vehicles. It does so with a variety of incentive programs and a new traveler information project that will make the incentives more accessible.

The new traveler information project, called Public Access to Transportation Information (PATI), will include a kiosk network and a World Wide Web site. TRANSPAC's project fact sheet states that "Kiosk use eliminates vehicle trips by traveling the information super highway instead of local streets and arterials." [135] Up to 12 touch-screen devices will be deployed at locations with high pedestrian traffic and current excessive traffic congestion. Sites will include BART subway stations, junior colleges, park-and-ride lots, retail locations, hospitals, theaters, and intermodal transfer stations. The server will be located at, and operated by, TRANSPAC.

PATI will provide real-time trip planning information at its inception, and will likely incorporate automatic trip itinerary planning software in the near future. It will use both static and real-time data from MTC's TravInfo, TranStar, and Regional Transit Database services (see Section 3.3). A unique feature of the project is that it will provide on-line forms that allow eligible travelers to sign up for all of TRANSPAC's trip reduction incentive programs. These include:

- Transit Incentive Program that provides either five round trip bus passes or a $32 BART pass;
- Guaranteed Ride Home Program that provides vouchers to take a maximum of two free taxi trips per month or six per year to assist transit and carpool users;
- Vanpool Program that rewards the driver with $1,000 for keeping a minimum of seven riders for a year;
- Carpool Incentive Program that provides new carpoolers a gas scrip incentive of $20 per month per carpooler for two months and rewards two-person carpools for adding new riders; and
- School Carpool ride matching service that helps families share transportation responsibilities for their school-aged children with others (no public school bus service is provided in the county).

PATI will also integrate a range of other relevant traveler features, including:

- Intercity rail schedules and station information;
- Interstate bus schedules and station information;
- Biking facilities and bikes on transit information;

[135] Internal TRANSPAC Application/Fact Sheet. (provided by Lynn Osborn, September 8, 1997)

- Real-time incident and ramp closure notifications;
- The RIDES' (a regional ridesharing agency) ride match application form;
- Park-and-ride locations;
- Direct dial service to taxi and limousine companies;
- HOV lane locations and passenger requirements;
- Fact sheets on air quality campaigns;
- California State Automobile Association services; and
- Regional vanpool information.

This information service will be promoted through employee transportation coordinators at over 30 local companies in the area, as well as chambers of commerce, telecommunications companies, and city newsletters.

The project started in August 1997. The first five kiosks are scheduled to be fully operational by December 1997 with the remaining seven deployed by the end of 1998. The Web interface is also expected to be on-line by December 1997. Deployment of this multifaceted multimodal traveler information project will cost approximately $400,000 with funding provided by the Bay Area Air Quality Management District's Transportation Fund for Clean Air and Contra Costa County's Transportation Improvements fund. TRANSPAC is seeking revenue generation from private firms through advertising to make the PATI project financially self-sustaining after startup.

Orange County, California

TravelTIP is an information system that will integrate bus data with other modes of travel data, including rail transit, highway and arterial traffic, and special events. It will fuse the data into traveler and traffic management information, and disseminate it using many technologies, including radio, telephone, cable television, computer, kiosks, and others. TravelTIP will interface with Transit Probe (see Section 3.1) for real-time transit location data for route guidance and traffic management, and with at least four existing traffic management systems in Anaheim, Santa Ana, Irvine, and at Caltrans. TravelTIP will have an open architecture that allows for uninhibited exchange of information.

The project will also prove valuable to communities surrounding Orange County that have large populations of commuters into Orange County and Los Angeles County, by providing alternative route and mode options. The communications link with Caltrans will aid traffic management along the entire southern California corridor.[136]

[136] TravelTIP Fact Sheet, provided by Caltrans New Technology Programs.

4. ELECTRONIC FARE PAYMENT

Advancements in card technology have created new capabilities and opportunities for transit fare systems. The technological advancements include: radio-frequency proximity cards; contact chip/stored-value bank cards; combined contact/radio-frequency cards (combi-cards); improved microprocessors; and development of multi-application software. The opportunities this type of technology can provide are: security, multi-function capability, open software solutions, data capacity and portability, and the "contactless" potential. The added value of Smart Cards versus existing card solutions is the security of the transaction. Smart cards offer secure data banks, requiring on-board, rewriteable, flexible memory solutions. The development of new software environments provide open programming solutions for multi-applications. A considerable benefit of the contactless smart card for a transit application is quicker transaction time through the farebox or turnstile. This chapter will examine the spectrum of current and planned fare systems including the technology that makes them possible and the current challenges transit managers are confronting.

Transit managers across the country are exploring and adopting coordinated fare payment systems that promise greater flexibility in fare structures, less expense in collection, and greater convenience for riders. Transit, like other service areas, has the desire to reduce the use of cash payments while improving customer convenience. New card technology offers transit managers the opportunity to integrate a new generation of electronic fare media and equipment that will provide a more cost-effective distribution and a more secure fare collection process.

4.1 AUTOMATED FARE PAYMENT SYSTEMS

The system or environment in which a card will be issued or used is a fundamental issue. Generally, cards will be used in what is commonly referred to as an "open" or "closed" system. It is important to note that a system can and may evolve from a closed system to an open system. Two primary distinctions relevant to transit are: is the transit agency issuing and accepting it's own card; and is the transit authority accepting cards issued by other organizations. System definitions and overviews are detailed below.

Closed System Definition

A "closed" system is one in which the card is issued by a single organization and can be used for that organization's services and other agreed upon service providers. Historically, a closed system is how transit agency fare programs have operated. Today, "closed" systems are also emerging at many large universities, such as the University of Michigan and Florida State University. [137]

Closed Transportation-Only System Overview

Within a closed, transportation-only system, a transit agency or group of regional transit agencies issue fare media usable on any of the agencies' services. This system can be used to achieve an upgrade in the agencies' fare collection processes and/or generate additional ridership and revenue. Individual agency functions such as card production, distribution, revenue settlement, equipment acquisition and maintenance can be provided by one or more of the member agencies, a system integrator (contractor), or by a new organization created by the agencies. To achieve maximum benefits and efficiencies, re-engineering of operational procedures will have to be achieved. Coordinating the acquisition of equipment, installation and subsequent maintenance procedures will make multi-agency fare collection settlements more complex, but potentially more cost-effective. [138]

Open System Definition

The term "open" system can be interpreted differently. A truly open system can consist of multiple card issuers and multiple service providers (merchants). However, within the transit industry, an open system describes a fare payment system in which an outside organization's card (i.e., a bank or university) is accepted for use within the transit agency. There are three types of models that can be implemented in an open system. [139] These models are discussed later.

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[137] **Potential of Multipurpose Fare Media**, *Draft Final Report*, TCRP, Multisystems, Inc., Dove Associates, Inc., Mundle & Associates, Inc., June 1997.

[138] Ibid.

[139] Ibid.

Open System Overview

Within an open system, a transit agency accepts the fare payment media from one or more outside issuers. Open systems contain three principal models or scenarios in which a transit agency can participate:

- A transit agency can become a "merchant" in a participating program. Within this model, the agency will have to pay a transaction fee for their customer's usage. The principal benefit to this model is the agency reduces the risks associated with investing in rapidly changing technology and leverages infrastructure and card distribution costs with their partners. The card issuer will absorb this risk;

- The transit agency can become a formal partner; sharing the benefits and risks associated with such a venture. Partnering as a co-issuer of the card can result in additional revenues and maximum market penetration; or

- The agency can administer its own payment program. This model allows outside issuer cards to be used provided the cards comply with the program's requirements.

A primary benefit to any type of open system model is broader market penetration. In addition, successful partnerships will offer greater opportunity to generate additional revenue. However, with an open system, partnership agreements, issues and conflicts become more prevalent and complex. A major disadvantage of an open system is the transit agency will have less control over fare collection and less flexibility with pricing. [140]

Multi-Use System Definition

The emergence of a multi-use smart card system is gaining interest with members of the transit community. The advent of integrated circuit "smart" cards and the use of stored value has created new opportunities to integrate more than one market with a single payment option. A multi-use application card can be established in various institutional environments including: transit-only; a more general public environment; or in an open system.

[140] Ibid.

Transit Multi-Use Overview

Transit operators will implement a multi-use program for different reasons. The transit agency's goals and objectives are critical elements in determining the type of multi-use program that is pursued. Additional factors such as availability of funding resources and availability of technology will also influence the program type.

The nature of the institutional setting and partnership agreements will depend on the program initiator's goals and the capabilities and constraints of the organization. Adopting a multi-use payment system will require a fundamental change in the way an organization has previously operated. These changes will impact the consumer, participating merchants, banks, clearinghouses, and transit agencies. Many of the legal, regulatory, and policy issues concern the integration of multiple service providers, card issuers, as well as future technology development and deployment. environment.[141]

There is growing commercial acceptance and availability of multi-use payment options, particularly in the banking and financial industry. Banks and financial institutions are extremely interested in seeing what the transit industry will do with multi-use cards because of the broad, geographically focused market transit provides access to. It is their hope that they can establish valuable partnership agreements with regional transit agencies, which in turn may provide opportunities to share card distribution, infrastructure and costs. More pilot tests are needed to see if a multi-use smart card can accommodate integrated electronic payment in a diverse, institutional

While many obstacles exist, there are benefits to a transit authority in implementing a multi-use system. Potential benefits include:

- The desire to promote integrated, seamless regional transit through a "universal ticket";
- Increase market base;
- Generate additional revenues;
- Improve data collection and ridership information;
- Reduce fare collection costs; and
- Improve customer convenience. [142]

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[141] **Smart Cards Seizing Strategic Business Opportunities**, The Smart Card Forum, The McGraw-Hill Companies, Inc., 1997.

[142] "Smart Cards: Promoting Partnerships and Profits," briefing by Michael G. Dinning, Volpe National Transportation Systems Center, May 1997.

Closed Multi-Use Systems

In a closed multi-use system the transit agency issued fare media can be used for other purposes such as telephones, or retail. The institutional support to carry out the production and distribution of cards, and the acquisition and maintenance of equipment can be provided by the agency, private contractor, or through a partnership with a separate company. The potential benefits to this system can include creation of an innovative, integrated fare system and increased market penetration. However, the transit agency's expanded role in a complex collection process with multiple merchants will be a primary disadvantage. This system will involve complex legal, regulatory, and political hurdles which may be difficult to overcome. [143]

Types of Payment Media

The use of cash in transit fare collection has long been seen as a problem. Many transit operators have sought to minimize the associated risks in favor of some sort of prepaid option. Currently, transit authorities in the U.S. are using three types of fare payment media.

Magnetic Stripe Cards

BART, the San Francisco Bay Area Rapid Transit system, introduced magnetic stripe cards into the transit fare collection system. Now, nearly 30 years later, the magnetic stripe card continues to be implemented in various transit systems across the country. The magnetic stripe card is read by units located in computerized ticket machines and turnstiles. Ticket vending machines located in transit stations accept regular currency. The ticket value is then recorded onto the magnetic stripe. When the rider enters the system the turnstile read-write unit records the place and time of entry. For systems with a flat fare the reader deducts the fare from the value on the card and writes the remaining value. For systems with a distance-based fare, the exit station turnstile computes and subtracts the price of the trip based on length of trip, and in some transit systems, the time of day. [144]

The principal benefit of the magnetic stripe card is the read-write magnetic stripe "stored value." This stored value represents a convenience for the transit rider and a benefit to the transit agency. A mag stripe card can hold a large number of fares, greatly reducing the number of separate

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[143] **Potential of Multipurpose Fare Media**, *Draft Final Report*, TCRP, Multisystems, Inc., Dove Associates, Inc., Mundle & Associates, Inc., June 1997.

[144] Ibid.

fare purchase transactions a transit rider must engage in. The transit agency benefits from automated fare collection through lower labor costs and greater security in the handling of money.

Although the concept of stored value is a principal benefit of the mag stripe card, there are some shortcomings with this technology. The mechanical systems that transport fare cards inside the read-write units can be prone to failure. These types of systems require frequent maintenance, which is often costly. More importantly, the processing of transit riders through the turnstile is substantially slower with mag stripe cards than with cash or tokens. The slow transaction time at the turnstile is due in large part to the process of putting the card into a slot located at the turnstile and retrieving it. To reduce the transaction time, and increase card life, some transit agencies have tried plastic mag stripe cards of normal automated teller machine thickness, designed for hand-held swiping through a read-write unit. Transit operators have found that this process is subject to problems, including the unreliability of the write operations in swipe-type read-write units. [145]

Credit Cards

A major benefit of credit cards is that it offers transit riders the convenience of a cashless fare payment medium. The major disadvantage of this payment medium is that the transit authority incurs a risk of accepting invalid credit cards, and must pay the card issuer a transaction fee.

Smart Cards

Technically, "smart card" refers to a card with an embedded, pre-programmed integrated circuit or chip. However, many use the term to describe a variety of chipless automated cards.

There are three types of smart cards: contact; contactless; and combi-cards. Contact cards require physical contact between the card and the reader, typically requiring the user to insert the card into a slot. Transaction time for these cards is longer and may not meet some of transit's unique needs. Reliability of contact readers in the transit environment is also a concern. Additionally, financial cards require different security checks than a transit card. These issues make contact cards less preferable among transit managers. Because of these issues, separate purses may be required for retail/banking and transportation applications.

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[145] Holmstrom, F. Ross, **Smart Fare Payment Systems for Public Transit**, *Technical Brief*, Volpe National Transportation Systems Center, January 10, 1996.

Contactless cards do not require insertion into a unit slot or reader. Instead, these cards are read by passing the card close to the reader unit. Contactless cards speed up the transaction time of the transit rider through the turnstile providing a greater convenience to the rider. While the transaction time is a benefit to contactless cards, customers and operators have expressed concern about the security of a contactless card. Systems must be designed to assure customers that their card could not be read inappropriately from a card reader. Customers must also be assured that the value of their cards cannot be stolen. Encryption and verification software needs to developed to provide adequate security for consumers. [146]

The combi-card is a recent innovation in smart card technology that combines the characteristics of both the contact and contactless cards. Combi-cards can use either two separate purses for the interface or a single purse capable of being accessed in either manner. A electronic purse is an application in a card where value is stored for low dollar transactions. A card may be dedicated to the purse function or contain memory and programs for other applications. [147] Cards with separate memory and processing for the contact and contactless interfaces are called "hybrid" cards. Most developers are trying to integrate the microprocessor and memory into one card. This would reduce manufacturing costs and enable the user to access a single electronic purse in either contact or contactless mode if desired. Operational tests will assist in assessing the different card configurations and market acceptance implications. [148]

State-of-the-Art Summary

Extensive technological developments in many forms of payment media have recently occurred. The trend towards an "electronic cashless commerce" is a growing business practice being implemented worldwide. Interest from the financial, postal and telecommunications industries are contributing to the rapid pace of technological advancement. Transit, like other service areas, has the

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[146] **Potential of Multipurpose Fare Media**, *Draft Final Report*, TCRP, Multisystems, Inc., Dove Associates, Inc., Mundle & Associates, Inc., June 1997.

[147] **Smart Cards Seizing Strategic Business Opportunities**, The Smart Card Forum, The McGraw-Hill Companies, Inc., 1997.

[148] **Potential of Multipurpose Fare Media**, *Draft Final Report*, TCRP, Multisystems, Inc., Dove Associates, Inc., Mundle & Associates, Inc., June 1997.

desire to reduce the use of cash payments while improving customer convenience. Advancement in card technology will facilitate the acceptance of electronic payment media programs as a viable payment option for transit operators. Currently, stored-value and multi-use programs are in limited trials in U.S. cities. Multi-use transit projects are already in operation in the United Kingdom, Germany, France, Australia, Netherlands, South Korea, and Hong Kong. [149]

While there is considerable interest in multi-use programs, prospective participants will have to overcome many barriers. To successfully achieve the benefits of a regional fare payment system, many of the institutional aspects of the revenue collection process must be integrated or at least coordinated. Combining card production, distribution, and marketing of several agencies can be complex but it can produce significant cost savings. A clearinghouse or payment settlement process can be developed which can manage these processes. Participating agencies and merchants will have to agree on revenue management policies and procedures. Complex partnership agreements will need to be developed specifying each party's position with regard to responsibilities, ownership, costs, and revenues. Smart cards can produce a record of where the traveler has been. Many believe that it is important that this information be used only for purposes of providing ridership information so that riders' privacy is ensured. Since multi-use cards are in their earliest stages of development, few resolutions to these issues exist. [150]

Ultimately, the success of any of these electronic fare payment programs will depend largely on the degree of acceptance of the media by issuers, merchants, and most importantly, consumers.

Applications

Seattle/Central Puget Sound Area, Washington

In the Seattle/Central Puget Sound area, regional transit authorities have recently completed a smart card trial prototype demonstration project involving six transit agencies and the Washington State Ferry. The plan and implementation of a regional fare coordination program will enable

[149] Ibid.

[150] Ibid.

customers to use one fare card on multiple systems throughout the four county Central Puget Sound area. Contactless smart card fare collection technology will be used to allow linked trips between bus, rail, and ferries and to significantly expand each agency's strategic fare policy capabilities. [151] Contactless smart cards were distributed to transit riders participating in the revenue service tests. Cards were configured as a fixed period pass with unlimited rides, stored ride, or stored value. Revenue service testing included installation and operation of the prototype demonstration equipment on four King County Metro coaches serving Boeing custom bus routes, and four Pierce Transit coaches serving a Seattle Express route. Non-revenue service testing consisted of portable versions of the equipment in a variety of environments, demonstrating the equipment to agency and stakeholders groups. Overall reactions from both the customer survey and focus groups were positive.[152][153] The project is currently finalizing the business requirements phase. It was anticipated that these requirements would receive regional approval at the end of 1997 or early in 1998. [154]

San Francisco Bay Area, California

The TransLink system is being developed and implemented by more than 20 regional transit agencies in the Bay Area. The lead agency in this effort, The Metropolitan Transportation Commission, determined that the most appropriate form of technology would be a regional integrated system using contactless smart cards. An initial demonstration of magnetic stripe cards revealed that this technology was not flexible enough to meet regional needs. Partnerships with private companies have been encouraged. Private sector participation in system management, integration and operational processes, including clearinghouse functions, is expected to occur. [155, 156] An Industry Review Draft of the TransLink Contract Book was distributed in early October 1997.

[151] "Smart Facts: Central Puget Sound Regional Fare Coordination Project," October 1997.

[152] **Smart Card Prototype Demonstration Project**, *Final Report*, IBI Group, June 1997.

[153] Michael G. Dinning, Volpe National Transportation Systems Center, Cambridge, Massachusetts.

[154] Candace Carlson, King County Metro, Seattle, Washington.

[155] **Potential of Multipurpose Fare Media**, *Draft Final Report*, TCRP, Multisystems, Inc., Dove Associates, Inc., Mundle & Associates, Inc., June 1997.

[156] Michael G. Dinning, Volpe National Transportation Systems Center, Cambridge, Massachusetts.

The Contract Book serves as an introduction to MTC's planned regional fare payment systems. These documents have been distributed to firms, organizations, and agencies that have expressed interest in MTC's program.[157]

New York City, New York

In 1990, the New York Metropolitan Transportation Authority (MTA) began implementation of an automated fare collection system. The MetroCard is a magnetic stripe stored-value card. Read/write ticket processing units are installed on all buses and in all rail stations. Cards can be purchased at stations and nearby retail units in specific denominations. The initial project was designed with the intent of expanding usage of the card to other regional transit operators as well as for tolls and other uses. The MTA established a company, the MTA Card Company, to implement this broader plan by entering into a joint venture with a private company. The MTA entered into negotiations with a bank over the terms of the partnership agreement. The two sides were never able to agree on the terms of the deal and negotiations were terminated in May 1996. The MTA is still hoping to proceed with integration of a multi-use program. The mechanism for administering these functions has not been decided upon.[158]

Ventura County, California

Seven transit agencies are currently participating in a contactless smart card program in Ventura County. The Passport program, initiated in March 1996, is a monthly pass, stored-value card that can be used on any bus in Ventura County. On-board recharging of the smart card can be accomplished by all but one program participant. In addition to the card payment system, the Ventura County Transportation Commission has implemented other APTS technologies, including automatic vehicle location and automated passenger-counting systems. Linking smart cards with these systems will provide the agency with valuable ridership information.[159]

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[157] Russell Driver, Metropolitan Transportation Commission, Oakland, California.

[158] **Potential of Multipurpose Fare Media**, *Draft Final Report*, TCRP, Multisystems, Inc., Dove Associates, Inc., Mundle & Associates, Inc., June 1997.

[159] Ibid.

Ann Arbor, Michigan

The Ann Arbor Transportation Authority has over 80 buses equipped with card readers to accept the University of Michigan "M" smart card. More than 35,000 trips were made using the "M" cards during a trial period. The trial tested the feasibility of using the University cards on buses and found the transaction time too long for the bus environment. The Ann Arbor Transportation Authority is now studying potential fare equipment changes that could accept both the university card and a transit issued contactless card. [160, 161]

Atlanta, Georgia

The Metropolitan Atlanta Rapid Transit Authority (MARTA) partnered with Visa and three banks in the VisaCash stored value, contact card rollout initiated at the 1996 Summer Olympic Games. Visa covered the cost of installing two card read/write units in 33 MARTA stations. Card vending machines were also installed in key transit stations around Atlanta. During the Olympics, MARTA represented the single largest use of VisaCash cards, accounting for 25 percent of all VisaCash transactions. MARTA has extended the pilot through an agreement with one of the three banks.[162, 163]

Cleveland, Ohio

The Greater Cleveland Regional Transit Authority (GCRTA) has hired an evaluation firm to assist them in assessing the possibilities of integrating some form of electronic fare payment media into their system. GCRTA has been exploring possible multi-use arrangements with multiple partners including the Ohio Department of Human Services. [164]

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[160] Ibid.

[161] Michael G. Dinning, Volpe National Transportation Systems Center, Cambridge, Massachusetts.

[162] **Potential of Multipurpose Fare Media**, *Draft Final Report*, TCRP, Multisystems, Inc., Dove Associates, Inc., Mundle & Associates, Inc., June 1997.

[163] Michael G. Dinning, Volpe National Transportation Systems Center, Cambridge, Massachusetts.

[164] Joel Frielich, Greater Cleveland Regional Transit Authority, Cleveland, Ohio.

4.2 STANDARDS AND INTEROPERABILITY

The question of standards and interoperability are key concerns being raised by transit managers considering an electronic payment system. Regional fare coordination can only occur if there is compatibility with payment systems of other transportation operations within the region. Currently, standards exist for certain aspects of smart cards. However, there is no specification to ensure complete interoperability among the different card types and operating systems.

Card standards are being developed by several international organizations: the International Standards Organization (ISO), the American National Standards Institute, and the European Committee for Normalization.

Individual work groups (WG) and task forces have been established within these organizations. Card standards are being developed under ISO Standard Committee 17 (Identification Cards and Related Devices). The key working groups are WG1 (Mag Stripe Cards and Test Methods), WG4 (Contact Chip Cards), and WG8 (Contactless Chip Cards). [165]

Contact Cards

The basic set of standards for contact cards is known as ISO 7816. ISO 9992 and ISO 10202 (security) are additional standards that pertain specifically to financial transaction cards. In addition, a set of specifications is being developed to address the interoperability of card acceptance, security, and payment functions. The jointly developed Europay/MasterCard/Visa (EMV) Specifications govern financial (debit and credit) transactions using contact smart cards.

These EMV specifications only pertain to debit and credit transactions. Other organizations are working to produce standards for prepaid and electronic purse cards. This gap in standards and specifications leaves the issue of interoperability among prepaid and stored value unresolved. Stored value programs in operation or on trial are utilizing ISO-compatible contact smart cards. [166]

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[165] **Potential of Multipurpose Fare Media**, *Draft Final Report*, TCRP, Multisystems, Inc., Dove Associates, Inc., Mundle & Associates, Inc., June 1997.

[166] Ibid.

Contactless Cards

The development of standards for contactless cards is following contact cards. The efforts of most relevance to the transit industry is ISO 14443, Remote Coupling Cards, which addresses physical characteristics, radio-frequency interface, transmission protocols, and transmission security features.

The smart card industry is moving steadily toward the adoption of standards for contactless cards and combi-cards. These standards and guidelines will be necessary for a successful move towards interoperability. [167]

Functional standards

Functional standards and requirements also need to be developed and implemented. At the present time, there are several initiatives underway. ITS America has established an ITS Payment Systems Task Force to identify issues /concerns that may be involved in electronic payment programs in all modes. [168] In addition, under FTA sponsorship, the US DOT/Volpe Center is establishing a working group whose task is to define functional requirements and design guidelines for multi-use transit smart card applications. The APTA Fare Collection Committee also plans to consider the issue through a subcommittee. Finally, the Transportation and Multi-Application Work Groups of the Smart Card Forum are also reviewing multi-use card issues.

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[167] **Smart Cards Seizing Strategic Business Opportunities**, The Smart Card Forum, The McGraw-Hill Companies, Inc., 1997.

[168] ITS America Web Site.

5. TRANSPORTATION DEMAND MANAGEMENT

Transportation demand management (TDM) technologies are those which combine innovative approaches and advanced technologies to better utilize existing infrastructure. In each case, the goal of these technologies is to maximize the ability of the current transportation network - roads and transit - to serve the rapid increase in demand for transportation. This is accomplished through a combination of, among other things, increased incentives towards shared rides, coordination of transportation service providers, and enhanced incident management. Four TDM technologies are discussed in this chapter:

- Dynamic Ridesharing;
- Automated Service Coordination;
- Transportation Management Centers; and
- High Occupancy Vehicle Facility Monitoring.

5.1 DYNAMIC RIDESHARING

Dynamic ridesharing (also called real-time ridesharing) is that form of ridesharing that is used to obtain a ride for a single, one-way or round trip rather than for trips made on a regular basis. Dynamic ridesharing can be either an organized program run by an official agency or informally operated by participants. The emphasis in this report will be on the organized programs as they could apply anywhere rather than only in special situations.

In organized dynamic ridesharing programs, a request for a ride is submitted to a central database or operations center. Requests for ridematches can be made at any time, including close to the time when the ride is desired. A trip request may be made for any time of the day or any destination, but ridematches are more likely to be found for travel in peak periods and in principal commutation directions. A round trip request might be matched with two different trip offerors.

When a trip request is received, the database of trips that have been offered by drivers registering for the ridesharing program is searched to see if any match the approximate time and destination of the request. The offered trips that are potential matches are given to the requestor along with the name and contact information for the possible trip provider. Normally, the person requesting the trip will contact the potential provider(s) to make the ridesharing arrangement.

Dynamic ridesharing could benefit individuals by reducing the cost of driving, by eliminating the onerous task of driving, by providing an alternative when the usual trip mode is unavailable, and by possibly eliminating the need for an additional car just for occasional use. The environment would also benefit from reduced vehicle emissions.

State-of-the-Art Summary

There is only one site (Seattle, Washington) where a concerted effort has been made to develop an organized program of dynamic ridesharing and which is still in operation. (Single trip ridesharing is also possible in a few other locations as part of regular ridesharing programs, but these are incidental rather than serious dynamic ridesharing activities. One such location, Missoula, Montana, is described in this Section.) Tests of this concept in several other sites have either been terminated (Bellevue, Washington; Sacramento, California; and Los Angeles, California) or were never implemented (Ontario, California). The test in Houston, Texas is on hold. All except Missoula were discussed in **Update '96.** The terminated programs had low utilization. In the Bellevue, Sacramento, and Los Angeles tests, indications were that few ridematches were requested, fewer matches were obtained, and very few trips were actually taken. There are several potential reasons for this. The idea of getting into a car with a stranger may be inhibiting. The majority of the general population may be unaware of the service. The process of requesting a ride and contacting possible providers may be time consuming and cumbersome. The number of trips offered may be inadequate for obtaining decent matches. It may be difficult to obtain a return trip if one is needed.

In contrast, the Seattle program appears to have had some success. From their experience, there is evidence that the service may have value if it is well designed, properly promoted, and convenient to use. On the whole, however, it does not appear that organized dynamic ridesharing programs will attract large numbers of users or eliminate significant numbers of automobiles from the roadways. Even in Seattle, perhaps as close to an ideal setting for dynamic ridesharing as one might find, confirmed dynamic ridesharing trips taken averaged less than three per month. Nevertheless, it can be a useful adjunct to other ridesharing services as long as the cost of operation is low.

The informal type of dynamic ridesharing (called casual carpooling) has been shown to be quite successful in two very specific situations. **Update '96** described the situations in Oakland, California where drivers pick up passengers by the roadside in order to use the high occupancy vehicle (HOV) lane to cross the San Francisco-Oakland Bay Bridge into San Francisco, and in Northern Virginia where drivers pick up passengers in order to use the HOV lanes on the Shirley Freeway into and out of the District of Columbia. Time savings of up to 20 minutes for drivers and monetary savings for passengers (they do not pay for the ride), together with the ease with which rides are arranged (and the ability to reject any carpool that does not appear desirable), are sufficient to overcome many of the impediments found in organized dynamic ridesharing. Daily users at the two casual carpooling sites average in the thousands.

Application Examples

Seattle, Washington

The Seattle Smart Traveler (SST) is one component of a larger FHWA-funded ITS operational field test underway in the Seattle area. The SST is the dynamic ridematching system at the University of Washington. The project is being conducted by the Washington State Department of Transportation and the University. The World Wide Web is the major method being used to provide this real-time ridematching service. The target users of the SST are University students, faculty, and staff.

A potential user completes an application form, which includes their telephone number and e-mail address, on the Web. They then can offer or request trips. Requests can be for regular commuting trips, other regular trips, or occasional trips. A user enters the origin, destination, day of week, departure time, and arrival time for each desired trip. The system identifies potential matches and automatically sends an e-mail message with this information to the requestor. Final trip arrangements are usually made by e-mail.

The 15-month SST test was in operation through the spring quarter of 1997. Funding for the SST demonstration was provided by FHWA ($170,000) and Transportation Northwest, the region's University Transportation Center ($35,000).

Faculty and staff comprised approximately 68 percent of users, while students represented the other 32 percent. Approximately 500 ridematches were requested during the 15-month test period. Of these, some 150 matches were generated. At least 41 individuals (34 percent) actually established a carpool for trips. It is likely that more than 41 ridesharing trips were taken, since there was no requirement that actual trips be reported.

Survey respondents provided generally positive comments concerning ease of use of the SST ridematching process. Although some stated they would consider SST when their normal commute mode was not available, most noted that they normally ask a friend for a ride.

Although the test ended in June 1997, the SST continues to operate even though no staff are assigned to the project. Without staff support, the database is not updated or purged of former users. However, the potential to expand the system to the full Seattle area is currently being explored as are potential funding sources. [169]

Missoula, Montana

The Missoula Ravalli Transportation Management Association (MRTMA) operates a ridesharing program in a region 135 miles long by 90 miles wide, centered around Missoula. Because of the comparatively expensive cost of housing in Missoula, there are a large number of fairly long distance commuting trips from rural areas for students at the University of Montana and for employees of Missoula businesses. The MRTMA uses a rideshare matching program for matching new applicants with existing carpools. The rideshare registration process is frequently conducted on-site at the University or major employer locations. A laptop computer and a printer are used to register applicants and give them a match list (names and telephone numbers) for specific trip requests right away. It takes only about five minutes to register and produce a match list of potential carpools. The program has been in operation less than a year and has approximately 140 names in the carpool database. It is anticipated that several vanpools will be added to the program during the next year.

[169] Katherine Turnbull, Texas Transportation Institute, College Station, Texas.

Although most persons asking for carpool match lists are seeking to find regular carpools, there are at least 10 persons that make requests to join a carpool for individual one-way or round trips on an infrequent but recurring basis. Requests for these "one-time" rides occur at least once a week. There is no official screening of applicants, but new applicants for single rides are scrutinized during the application process. [170]

5.2 AUTOMATED SERVICE COORDINATION

In previous State of the Art reports, there was a section on "Mobility Manager" systems that attempted to integrate and coordinate transportation services in a particular region using a variety of APTS technologies (i.e., "one-stop shopping" for the traveler in that region). Since this term is not used as frequently as it once was, the term "automated service coordination" is replacing mobility manager in order to expand the mobility manager concept to include many different types of transportation services that use automated means to achieve the service integration and coordination.

Automated service coordination involves multiple transportation providers in a region that provide service with the help of APTS technologies. The technologies are critical to integrating and coordinating the services available in the region. Often these technologies include: central and remote automated scheduling and dispatching; automatic vehicle location; advanced communications, including data communications; and automated fare payment. The coordinating agency may provide scheduling and dispatching services for other local service providers using an automated scheduling system. Likewise, the coordinating agency may outfit local service providers' vehicles with AVL equipment in order to monitor all vehicles within the region. Further, they may provide customers with an automated fare payment device that can be used seamlessly on all regional service providers.

State-of-the-Art Summary

[170] Noel Larrivee, Missoula Ravalli Transportation Management Association, Missoula, Montana.

While an increasing number of transit agencies are taking on the role of automated service coordinators, they are often initiating the coordination efforts without technology and adding the technology later. The addition of the technology has been found to greatly enhance the efficiency of service integration and coordination, and in many cases has provided smaller agencies with automated tools that they may not have had ordinarily to link them directly with other service providers in their region.

The most prevalent APTS technologies that assist in automated service coordination are automated scheduling and dispatching systems, and AVL systems. Several transit agencies are currently providing coordinated service using these technologies.

Research and demonstration efforts are still being conducted in the area of automated service coordination as transit agencies attempt to offer the same level of service with less funding. A Transit Cooperative Research Program project, "Strategies to Assist Local Transportation Agencies in Becoming Mobility Managers," defines mobility management more broadly than we have defined automated service coordination. However, this project resulted in the identification of operational, technological, programmatic, and land use strategies and actions that can be used by agencies that are coordinating or wish to coordinate service in a region.

Application Examples

Beaver County, Pennsylvania

Since January 1996, Phases 1 and 2 of Beaver County Transit Authority's Mobility Manager Pilot Project have been completed. The Mobility Manager System (MMS) is envisioned as a "one-stop shopping" travel agent, providing integrated travel services such as scheduling, routing, information and billing, and service delivery using advanced communications and vehicle location technologies. Service providers will be part of the MMS network through in-vehicle mobile data terminals, and vehicle location and transmitter/receiver devices. Users of the MMS service will access services via telephone, computer, or kiosk.

Phase 1, the planning and development stage, resulted in the following activities:

- Identification of user services and functional needs;
- Evaluation of available technologies;
- Evaluation of system alternatives for initial design;
- Definition of system components;
- Assessment of human factors;
- Assessment of legal/institutional issues;
- Development of a deployment plan;
- Analysis of costs and benefits;
- Development of a concept of operations; and
- Development of an evaluation plan.

Phase 2, the design stage, resulted in a set of specifications for the components of the MMS, and the integrated MMS system. The components of the MMS are the communications subsystem, in-vehicle subsystem, and Beaver County Transit Operations Center.

Phase 3, initial implementation, is awaiting funding. This stage will involve the procurement, installation, testing, and acceptance of the pilot project. At this stage, the transit operations center, including AVL and CAD capabilities, will be built, and in-vehicle equipment will be installed on a limited number of paratransit and fixed-route buses. A basic passenger information system will be implemented at this time as well.

Subsequent phases, Phases 4 through 6, can be summarized as follows:

- Phase 4 - Expansion of the pilot system to include demand-responsive service;

- Phase 5 - Expansion of the basic passenger information system into a regional traveler information system using kiosks, and integration with the Pennsylvania Department of Transportation Freeway Management System and Pittsburgh Advanced Traffic Management System; and

- Phase 6 - Integration of all previous phases, addition of a clearinghouse function that allows electronic fare collection and payment of services, and coordination with all service providers.

Northern Virginia

The Smart Flexroute Integrated Real-time Enhancement System project, which combines flexibly-routed transit service (OmniRide) with APTS technologies, was officially inaugurated on October 1, 1997 at the Potomac and Rappahannock Transportation Commission (PRTC) in

Woodbridge, Virginia. OmniRide operates fixed-route, route deviation, and paratransit services. Service began in late 1994, but full implementation of the APTS components was not achieved until October 1997. The APTS components include:

- Global positioning system automatic vehicle location;
- Real-time call intake, scheduling and dispatching software;
- Digital dispatching and communication via mobile data terminals; and
- Geographic information system.

PRTC is anticipating that the use of these technologies will improve on-street and in-office efficiencies, enhance vehicle tracking and communications capability, and offer real-time reservation options. PRTC's goal is to reduce the 24- to 48-hour advance reservation to one hour, thereby making their flexible service even more attractive. Specific benefits expected from the addition of the aforementioned technologies include:

- Same-day reservations for flexibly-routed (route deviation) service;
- Improved customer communication;
- Improved fleet tracking;
- Increased efficiency and ridership;
- Enhanced operating data and collection;
- Improved working environment for customer service agents and drivers; and
- Capability to evaluate multimodal itineraries.

As of October 1997, the flexibly-routed service was handling 1,000 trips per day and growing. There was an average of 8.4 riders per revenue hour. Twenty percent of the riders formerly drove to work and 20 percent formerly drove alone to shop. PRTC's estimated annual savings from operating the flexibly-routed OmniRide instead of fixed route and paratransit was $560,000 (a 50 percent savings), eight vehicles and 62 daily service hours, with the majority of those savings due to eliminating the need to operate a separate paratransit service. [171]

Arrowhead Region, Minnesota

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[171] Eric Marx, Potomac and Rappahanock Transportation Commission, Woodbridge, Virginia.

"The Advanced Rural Transportation Information and Coordination operational test is intended to test and evaluate the effectiveness of intelligent transportation technology in a rural Minnesota environment. The ... project is coordinating the communication systems of several public agencies through the establishment of a centralized communication site. Communications for portions of Minnesota Department of Transportation District 1, the Minnesota State Highway Patrol, [Arrowhead Transit and Virginia Dial-a-Ride] are being consolidated to reduce costs, improve response time to accident and road condition emergencies, provide real-time vehicle status and schedule information, improve transit productivity and eliminate redundant communications systems. A centralized customer information and reservation service is being established for regional transit providers. In addition, alternative methods of communication with transit vehicles are being evaluated to determine the best system for emergency and dispatch level communications in rural areas."[172]

The new communications center in Virginia, Minnesota was completed in the Fall of 1996. As of October 1997, transit scheduling and dispatching software is being implemented along with an automatic vehicle location system. Final implementation of all project components is expected to be completed by the time the project test period begins in the Summer of 1998.

Detroit, Michigan

The Suburban Mobility Authority for Regional Transportation has implemented automated scheduling and dispatching software for paratransit. It is currently being integrated with their automatic vehicle location system. This software is currently being upgraded to a Windows NT platform, which will assist in providing remote scheduling capability to other service providers in the greater Detroit area. In late 1997, SMART expects to begin installing remote scheduling and dispatching capability at five service providers. One year later, SMART expects to have 25 service providers with that capability.

[172] Maddern, Richard and Joseph Kern, "Advanced Rural Transportation Information and Coordination," presented to the 13th National Conference on Rural Public and Intercity Bus Transportation, North Conway, New Hampshire, September 15, 1997, p. 2.

Folsom, Pennsylvania

Community Transit of Delaware County is implementing a sophisticated automated system that includes automated scheduling and dispatching software integrated with in-vehicle mobile data terminals, advanced communications technology, and an automated identification system for customers. Since January 1996, Community Transit had made significant progress in deploying this system.

The automated scheduling and dispatching software was fully installed by November 1996. In February 1997, 100 ruggedized MDTs were purchased. These MDTs are pen-based computers. Simultaneously, wireless modems for the MDTs were purchased to provide communications capability.

In October 1997, 15 MDTs with modems were installed as part of a pilot test. These MDTs were connected to the scheduling and dispatching software in real time via cellular digital packet data communications technology. After the pilot test, Community Transit will phase in the remaining MDTs. It is expected that the entire fleet will be outfitted with MDTs by January 1998.

The automated identification aspect of this system is in the process of being implemented. Because of the capability of the MDTs, a customer's image (digitized photograph) can be displayed on the MDT and/or printed on a driver's manifest. This image will be used to verify a customer's eligibility to ride. As of October 1997, Community Transit was in the process of obtaining photo images of their customers, using a camcorder and specific software application to record existing and new customers' photos.

Transit Cooperative Research Program - Strategies to Assist Local Transportation Agencies in Becoming Mobility Managers

This study, conducted by Crain & Associates, has been completed, and the resulting report will be available in early 1998. The definition of a mobility manager in this study is "a transportation organization serving the general public that responds to and influences the demands of the market by undertaking actions and supportive strategies, directly or in collaboration with others, to provide a full range of options to the single-occupant automobile." [173]

The study identified four categories of mobility manager functions: operational functions involve non-traditional methods of service delivery; technological functions involve the implementation of APTS technologies; informational/programmatic functions involve expanded mode choices based on more complete information and broad-based marketing; and land use functions involve encouraging ridership through links with land development.

The study also identified three institutional models for mobility management: full service provider; collaboration with other organizations; and extensive contracting. A full-service provider is defined as an agency that directly performs mobility management functions. An agency that collaborates with other organizations has some mobility management functions performed by other organizations outside the agency. The extensive contracting approach has mobility management services provided by organizations under contract to the agency.

Ten critical factors were identified as the most influential in the success of mobility management. These factors were determined based upon a survey of 60 North American transit agencies and case studies conducted with seven agencies. These factors are:

- High control factors:
  - Leadership
  - Organizational culture
  - Management
- Medium control factors:
  - Labor relations
  - Political environment
  - Institutional environment
  - Cost
  - Performance measures
- Low control factors:
  - Funding
  - Regulations

[173] Preliminary draft of final report provided by Crain & Associates, October 1997.

Finally, the study recommends specific actions that can be taken to address these ten critical factors that influence mobility management.

5.3 TRANSPORTATION MANAGEMENT CENTERS

The term "transportation management center" refers to a facility that combines traffic and public transit operations, communications, and/or control. To date, there are several TMCs that accomplish this integration at a rather high level. In many cases, the TMC is more or less "virtual." That is, separate traffic and transit facilities are sharing real-time information in order to enhance each operation.

State-of-the-Art Summary

The most effective examples of TMCs are those that locate transit and traffic operations in the same building, if not in the same room, such that direct communications and subsequent decision-making can occur readily between the respective operators during peak traffic periods, incident detection and management, or special events. Sharing of closed-circuit television feeds among agencies provides visual confirmation and clarification of situations in the field. Also, transportation management centers (in the broadest sense of the term) can be critical in developing traffic signal priority systems for transit vehicles which improve transit service while minimizing the impact on other vehicular traffic.

Application Examples

Anaheim, California

The City of Anaheim's traffic management center was designed in 1986. Several other agencies are involved with the traffic management system that is operated from the center, including the California Department of Transportation, FHWA, and the Orange County Transportation Authority (OCTA). The TMC provides traffic condition on local streets to Caltrans and receives similar information concerning the adjacent freeway system from Caltrans.

The TMC also transmits traffic condition data to OCTA that consists of lane occupancy, vehicle counts, and extrapolated speed data on local streets. OCTA fuses this data with other data streams and distributes it on its network of interactive information kiosks. The kiosks are part of a Federal field operational test that, as of July 1997, was in the installation and testing phase. In addition, the TMC and OCTA occasionally discuss signal timing parameters that may be having an adverse affect on OCTA's performance. [174]

Houston, Texas

Houston TranStar is a joint project of the City of Houston, the Metropolitan Transit Authority of Harris County, the Texas Department of Transportation, and Harris County. These agencies recognized the importance of developing a multi-modal, cross-jurisdictional facility to effectively manage growing traffic congestion in this rapidly expanding region. [175]

Operated out of a 52,000 square-foot facility that was officially opened in April 1996, TranStar was designed to integrate all of the metropolitan Houston's transportation-related agencies at a single site. "Houston TranStar is responsible for the planning, design, operations, and maintenance of transportation operations and emergency management operations within the Greater Houston Area. The service area encompasses 5,436 square miles with a population of 4.0 million." [176]

By December 1997, Metro bus dispatchers and Metro police will be using their fleet management consoles alongside the traffic operations staff. This setup will provide Metro staff with direct visual access to the wall-mounted displays mapping traffic speeds and incidents, and monitors showing closed-circuit television feeds from 90 locations. Metro staff will be able to use this real-time information to assist in managing its fleet in addition to using data from the future AVL system it is planning (see Section 2.3). This breadth of information will be augmented by the ability to communicate directly with traffic operations staff. TranStar staff anticipates that overall incident detection will be enhanced by having Metro dispatchers relay incident reports from bus drivers

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[174] John Thai, Anaheim Traffic Management Center, Anaheim, California.

[175] Gloria Stoppenhagen, Houston TranStar, Houston, Texas.

[176] TranStar Description, Houston TranStar World Wide Web site.

throughout the transit service area, adding over 1,000 'human sensors' to the traffic surveillance system. Incident response affecting all modes of transportation should be improved in the process.

TranStar collects its traffic condition data primarily via tag readers mounted along freeways that pick up signals from the approximately 200,000 electronic tag-equipped vehicles (the tags are typically installed in vehicles for use at a number of automatic toll facilities throughout the area). As part of its U.S. DOT Priority Corridor funding, TranStar is currently studying the possibility of installing tag readers on major arterials to calculate traffic condition information on surface streets as well as highways. As of October 1997, about five miles of the Hempstead Highway, a surface arterial running parallel to US 290, was instrumented. This test will determine the feasibility of using electronic tag data in the stop-and-go environment of signalized surface streets as input to traffic speed calculations. If the test is successful, this information would augment vehicle location information that will be available when Metro implements their AVL system.

Although MetroLift's paratransit operations center is not located at the TMC, TranStar is exploring the possibility of installing a communications link that would provide the paratransit operator with travel time and incident information.

Minneapolis/St. Paul, Minnesota

The Minnesota DOT traffic management center manages traffic on Twin Cities metropolitan freeways and coordinates a variety of programs with Metro Transit. Both agencies are involved in the Team Transit and incident coordination initiatives designed to improve both bus and traffic operations.[177]

The connection between MnDOT's TMC and Metro Transit's operations center is virtual. Located in different places, the TMC provides live video feeds to Metro Transit from its highway cameras via a fiber optic cable hookup. It also has the ability to provide freeway traffic condition data to Metro. On an institutional level, both agencies are working together on Team Transit, an effort to identify and implement other traffic measures that could benefit transit users. One of the first initiatives to be addressed will be Bus-Only Shoulders, a program that will allow buses to travel

[177] Glen Carlson, Minnesota Department of Transportation Traffic Management Center, Minneapolis, Minnesota.

on highway shoulders when the speed of traffic drops below 35 mph. The agencies have also recently formed a joint incident management team.

Montgomery County, Maryland

The Montgomery County Department of Public Works and Transit's Transportation Systems Management Section has deployed a strong foundation for its advanced traffic management system (ATMS). The ATMS is operated at the County's TMC, which has integrated traffic and transit operations since September 1996 (see Section 4.1). The coverage area of this management and control network includes the Ride-On transit system, 3,000 miles of roadways, and 200 miles of critical traffic links.

Surveillance and control equipment in the TMC provides crucial data for both traffic and transit management. The system's traffic-related hardware that helps integrate the transit and traffic management functions includes:

- 750 traffic signal controllers connected to the TMC;
- A signal control system;
- 45 closed circuit television cameras, with plans for 200; and
- 1,000 inductive loop detectors that collect the data necessary to determine traffic volumes and lane occupancy.

An important aspect of the traffic control system is its open architecture which allows the use of a large variety of both old and new signal controllers, allowing for more flexibility in the traffic signal priority arrangements discussed in Section 2.6.

Both the traffic technician and transit coordinator consoles consist of two monitors each. One is a combination computer-aided dispatch and event screen and the other is a GIS screen.[178]

Integration of the transit and traffic functions go well beyond being located in the same room, where the traffic and transit consoles are located within 10 feet of each other. Joint operation was designed to reduce jurisdictional issues, improve joint incident management, and develop special events plans that would help not only traffic management but transit operations as well. The TMC

[178] The consoles run on Sparc workstations connected to a Sun Microsystems server running a Sun INFORMIX relational database that is designed to process a variety of detector information.

joint operation is supported by the fact that each is part of the same County division. A newly developed department Intranet[179] allows for other types of information to be shared between the traffic and transit staff.

The traffic management team benefits from this relationship by being able to use the buses as traffic probes and as a complimentary component of its incident management system. The latter function is based on bus drivers calling in or sending digital messages from the in-vehicle transit control head when they encounter a traffic incident or unusual congestion. This often occurs before another part of the ATMS detects the problem. Using the transit vehicle locations, the traffic management team can immediately pinpoint the location of the incident. Both transit and traffic operations benefit from this shared incident detection and management response.

The TMC is also the nexus of communicating real-time and static traffic and transit information to the public. Much of the information available to the TMC operators is reformatted for use on the County's ATMS World Wide Web site. Averaging 20,000 hits per day, the number can jump to 40,000 during severe weather conditions and holidays. This ATMS Web site will be linked directly to two traveler information kiosks that are being deployed, and will thus provide a common interface for those who access the information en-route or from their home or office computer. Finally, the TMC houses the equipment to broadcast transit status and traffic information such as live video on the County's Cable Channel 55 and over its traffic advisory radio system.[180]

New York City Metropolitan Region

The Transportation Operations Coordinating Committee is a consortium of 14 highway, mass transit, and public safety agencies in the New York, New Jersey, and Connecticut area whose primary mission is to improve interagency response to recurring and non-recurring traffic incidents. Since its inception in 1985, TRANSCOM has become a recognized test bed for developing ITS

[179] Intranet describes a computer network that has the same interface and capabilities of the Internet but whose access is limited to a particular organization's staff.

[180] Alfie Steele and Bill Corder, Montgomery County TMC, Rockville, Maryland.

technologies. Its operations information center (OIC) is continually expanding its role through a variety of initiatives that benefit both traffic and transit operations in the Tri-State region. [181]

The core of TRANSCOM's OIC activities is its Regional Architecture. Designed to be compatible with the I-95 Corridor Coalition's highway-based Information Exchange Network and the U.S. DOT's National ITS Architecture, this project involves the creation of a common computer interface that will enable participating agencies to both share and access each other's traffic- and transit-related information. This information will include data collected and fused by TRANSCOM itself from its member agencies (and from other TRANSCOM projects described below).

The Regional Architecture project includes: automating the interface between ITS applications at participating agencies; providing computer workstations to each of the participants to operate this interface and connect to the Regional Architecture's server; and, developing the necessary communications network. The project's preliminary design was completed during the Summer of 1994. As of October 1997, TRANSCOM was preparing a request for proposals to procure the system, with deployment expected during the Winter of 1998.

An important component of the Regional Architecture will be the Interagency Remote Video Network, which will allow agencies to obtain real-time closed-circuit television video feeds from each other. About 13 agencies have agreed to provide viewing access to their cameras located at a range of traffic facilities, resulting in approximately 300 total cameras available system-wide.

TRANSCOM's System for Managing Incidents and Traffic (TRANSMIT) is another primary component of TRANSCOM's OIC. Phase 1 of this incident detection and traffic condition monitoring system was installed in 1994 and continues to operate. It uses automatic vehicle identification technology as an incident detection tool on about 20 miles of the New York State Thruway and Garden State Parkway. AVI tag readers along these highways receive information from vehicles equipped with electronic transponders (tags) to provide the base data required for monitoring. (Tag I.D. numbers are scrambled to maintain the privacy of individual drivers.) Software analyzes the travel time between tag readers to identify potential incidents by comparing actual to predicted travel times. When incidents are detected, TRANSCOM communicates the

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[181] Tom Batz and Pete Dwyer, TRANSCOM, Jersey City, New Jersey.

situation to its member agencies via a variety of methods. Phase 1 of TRANSMIT was a Federally-funded field operational test which cost approximately $3 million.

Phase 2 of TRANSMIT will instrument another 150 miles of roadway and represents a modal expansion of the Phase 1 deployment by equipping approximately 2,800 New Jersey Transit buses with tag readers. In this project, tag IDs will not be scrambled so that TRANSCOM can track individual bus status.

This field operational test is unique in that it will serve a number of important functions for at least three different transportation agencies that will have connections to the TRANSMIT server, including:

- Fleet management for NJT;
- Facility management for NJT staff at the Port Authority Bus Terminal, where over 1000 buses arrive and depart during peak periods;
- Facility management for the Port Authority of New York and New Jersey's Lincoln Tunnel; and
- Facility management for the New Jersey Department of Transportation's Route 495.

For NJT, staff will be able to monitor its vehicles along Route 495 and the New Jersey Turnpike into New York City. More importantly, the agency will be able to control bus traffic into and out of the Port Authority bus terminal. Newly developed software will integrate the AVI data with NJT's computer-aided dispatch system. Equipped with hand-held computers provided as part of the new system, dispatchers working on platforms at the bus terminal and at remote bus layover locations in Manhattan and New Jersey will be able to control the overall flow of bus traffic in and around the terminal. In addition, it will allow them to make dispatching decisions in real time, for example, by substituting a bus which arrives early for one that is running late, while automatically updating the schedule database of the CAD.

The entire Phase 2 TRANSMIT project is expected to be completed in the Fall of 1998 at a cost of about $6.0 million. The bus tracking and Port Authority Bus Terminal operations are expected to be $1.2 million of the total.

San Antonio, Texas

The San Antonio TransGuide is a 51,000 square foot ITS operations control center that opened in July 1995. Overseen by the Texas Department of Transportation, it houses TxDOT traffic management operations, local law enforcement, fire, 911, and VIA Metropolitan Transit. The central control room contains TxDOT traffic management staff, VIA transit dispatchers, and a 911 emergency dispatcher. VIA's paratransit operation, VIA Trans, is also located in the TransGuide facility. However, given the overriding need to have the paratransit dispatchers work closely with reservations clerks and schedulers, it is located in another part of the building and not in the central control room. In the future, TransGuide plans to install a direct communications link to VIA's five paratransit dispatchers.

Besides fleet management information from its existing signpost automatic vehicle location system, VIA's two bus dispatchers will have access to maps of highway travel speeds and incident locations calculated using the TxDOT's network of inductive loop and sonic traffic detectors. This information, as well as video feeds from about 60 TxDOT and one VIA closed-circuit television cameras, is projected onto the wall-mounted displays in the central control room. The bus dispatchers can also access this information and current variable message sign readouts at their dual-monitor operations consoles. VIA's closed-circuit television camera is installed at its largest park and ride facility to provide visual information regarding demand, especially during special events.

The physical proximity of the transit dispatchers to the traffic management staff allows direct consultation in the event of an incident. This is especially important when a major highway incident occurs and TxDOT staff changes the signal timing on highway access roads that are also used by VIA's fixed-route bus service.

Although TransGuide currently processes only highway traffic data, it is planning to instrument several major arterials with electronic tag readers to test the use of probe vehicles as a means to calculate traffic condition information. The probe vehicles will initially consist of about 100,000 persons who volunteer to mount the tags in their cars.

TxDOT is working with the Texas Transportation Institute to create a real-time, area wide travel database. The database will use a variety of sources, including the arterial data cited above, to develop information on historical travel behavior. One objective is to convert the data into "currently prevailing conditions of "link" travel time"[182] so that time of day travel information can be calculated. This effort will benefit VIA's paratransit operations by providing critical information to the in-vehicle navigation units that are being procured as part of the region's U.S. DOT-sponsored ***Model Deployment Initiative***.[183, 184]

Seattle, Washington

As a result of several developments since January 1996, the complexion of Washington State Department of Transportation's (WSDOT) North Seattle advanced traffic management system has changed considerably. Because the Seattle region was awarded one of four U.S. DOT ***Model Deployment Initiatives*** in 1996, the project has been expanded into three interrelated ATMS: a north; east; and south. These systems will be controlled from WSDOT's Traffic Systems Management Center in North Seattle. New software will fuse information from the three traffic regions and provide the platform for cross-agency data sharing. For example, the ATMS network will be able to communicate with King County Metro's operations center and other local transit operators to improve both traffic and transit operations.[185]

The WSDOT ATMS computer system will consist of one to three servers operating with an open architecture that will integrate the ATMS information with data collected from participating agencies. WSDOT will make available most of its traffic data including incident information, travel speeds, video feeds from its 150+ closed-circuit television cameras, and general traffic conditions. Those agencies that have a fiber optic cable connection to WSDOT will be able to access full motion video and request (under special circumstances) that the TMC use the pan/tilt/zoom capabilities of its video network to relay more exacting visual data. As of September 1997, the municipalities of Seattle and Bellevue are connected to the video network and are also able to share their video feeds with the TMC for distribution over the ATMS network.

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[182] **Real-time Area Wide Travel Data Base**, Texas Department of Transportation fact sheet on TransGuide.

[183] Brian Fariello, Texas Department of Transportation.

[184] Tom Carter, VIA, San Antonio, Texas.

[185] Dave Berg, Washington Department of Transportation Northwest Region, Seattle, Washington.

The ATMS network will interface with King County Metro's automatic vehicle identification and automatic vehicle location systems to keep track of where bus signal priority is being granted. WSDOT will rely on information from the AVI system to maintain a current snapshot of signal priority activities in the field and to accurately evaluate their impact on traffic flow.

WSDOT also expects during 1998 to start using Metro Transit's AVI and AVL data to calculate and/or verify roadway travel times, especially with data from express buses traveling on limited access roads. It hopes that the 1,000 bus Metro Transit fleet will augment its own incident detection and management capabilities.

A major improvement that WSDOT expects to implement during the Winter of 1998 is integration of existing traffic surveillance equipment on major arterials. The data collected from this now centralized detection network will provide surface street traffic conditions that will be much more useful to Metro Transit than the limited access roadway information that is currently available.

Atlanta, Georgia

The Georgia Department of Transportation's Atlanta Transportation Management Center opened in April 1996. It covers surveillance and management of highways throughout the metropolitan Atlanta area, and is connected to six satellite traffic centers operated by other jurisdictions. The TMC is connected to MARTA's operations center via a fiber optic communications network that permits sharing of traffic and transit data between the two agencies. MARTA currently has access to all traffic condition information collected and processed by the TMC using 317 Autoscope visual image processing cameras. It also has access to video feeds from the DOT's 70 highway mounted cameras.[186]

Although MARTA tracks its own vehicles that are equipped with AVL, the TMC is planning to equip its Highway Emergency Response Operator vehicles with automatic vehicle location technology and install computer-aided dispatch software to improve incident detection and management. The TMC foresees using information from MARTA's bus operators as another source of incident detection.

[186] Sam Ziegler, Georgia Department of Transportation, Atlanta, Georgia.

5.4 HIGH-OCCUPANCY VEHICLE FACILITY MONITORING

With traffic and congestion growing year by year, an increasing number of lanes are being set aside on roadways in and around large cities for vehicles carrying more than one occupant. The objective of creating high occupancy vehicle facilities is to encourage carpooling and reduce the number of vehicles on the road. In addition to a faster trip, some HOV facilities, such as toll roads or bridges, also give reduced tolls or free passage to HOVs. However, illegal use can slow traffic flow on the lanes and decrease their advantage over adjacent lanes, thereby diminishing the incentive to carpool or use public transit. In order to ensure that these lanes are accomplishing the desired objective, and not being improperly used by drivers to bypass congested sections of highway or avoid tolls, these lanes are usually monitored for compliance with specified minimum vehicle occupancy requirements.

State-of-the-Art Summary

The process by which HOV lanes are monitored normally consists of police stationed by the side of the facility to observe the number of occupants in each vehicle and to stop and issue citations to drivers carrying less than the minimum number of passengers. Most often, two police locations are required to adequately enforce the occupancy requirements. At one location, the occupancy is observed; at the other location, an alleged violator is pulled over for verification of the violation and issued a ticket if found to be guilty. (At some sites, more than one police officer may be stationed at each police location.) Some jurisdictions may perform both the observation and apprehension at one location, but this will still require more than one police officer in most circumstances to do the job well. Some jurisdictions allow the issuance of tickets through the mail. In this case, police presence could be reduced as the violator would be issued the ticket by mail rather than pulled over at the scene. However, this requires a more accurate method of occupant (and license plate) identification than has been found to date.

The manual enforcement process is labor intensive and costly, as well as a potential safety hazard. Even though fines for violations in some jurisdictions can be in the hundreds of dollars (more than $100 in Texas, $271 in California[187]), the fine revenue collected may not be sufficient to cover the cost of enforcement. In addition, it requires the presence of police officers who otherwise could be performing more useful functions. For these reasons, some jurisdictions have sought an automated means of enforcing the HOV lanes.

In **Update '96**, potential technologies and their limitations were described. Technologies discussed included video, near infrared, millimeter wave, thermal infrared, and transponders. All have some deficiencies, whether they be heavily tinted windows which are difficult if not impossible to see through, the difficulty of processing images, or too easy to deceive. The only method which would have no technical implementation obstacles at this time is the issuance of transponders to carpool members. However, the potential for fraudulent use of transponders makes this approach suspect. A test of video cameras by Caltrans in 1990 concluded that the occupant count was not sufficiently accurate to support mailed citations. The use of millimeter wave technology (radiometry) is believed to have potential by one researcher but would require a substantial research effort to test its suitability.[188] No funding for this approach seems forthcoming.

All except the transponder approach will require an image-acquisition subsystem, a central processing unit for image processing and control, a hardware- or software-based image recognition engine, and a storage or transmission subsystem for data. The technology approaches found to be undergoing testing at this time are video and near infrared.

The video approach uses video cameras to take pictures of the inside of the vehicle and the license plate. The vehicle compartment video images are processed to determine the number of vehicle occupants. License plate numbers are identified by optical character recognition. While video cameras have not previously been used in other than test situations to determine the number of occupants in a vehicle, they have been applied successfully to other traffic enforcement operations. For example, in London, United Kingdom, video cameras on buses are used to identify violations of bus-only lanes. In San Francisco (four intersections), Howard County, Maryland (two intersections), and New York City (18 intersections), video cameras have been used to identify red

[187] Shawn Turner, Texas Transportation Institute, College Station, Texas.

[188] Eugene Greneker, Georgia Tech Research Institute, Atlanta, Georgia.

light running violators. Except in Maryland, violators are sent citations through the mail. During a three-year period, revenues collected in New York ($18 million at $50 per violation with a $25 late payment penalty) exceeded the cost of project implementation. These applications have achieved a reduction in the rate of violations of 20 to 30 percent. All three sites are planning to expand the number of intersections covered.[189] The percent of accurate identification of license plates at these three sites is unknown. It is anticipated that the accuracy level in that type of application would be higher than on an HOV lane with traffic passing the cameras at 50 miles per hour or higher. At this time, a correct license plate identification rate of 60 to 70 percent would be expected on general flow lanes during most periods of the day, but this might reduce to about 50 percent during rush hours. The percentage of valid license plate identifications is affected by weather, lighting conditions, and vehicle position within the lanes.[190]

Automated license plate identification has also been used in the measurement of travel times and congestion in the Tampa, Florida area and truck diversion after new toll imposition in South Florida.[191] This technology could be effective in congestion pricing applications, as well.

The use of digital cameras is being considered by some cities. These would provide better images, but would be more expensive. A German firm has launched a product for identifying drivers who were speeding or running a red light. The system records and displays digital images of the car, the license plate number, and the driver.[192]

The other approach being tried uses an infrared camera to capture images which are then processed to generate a "picture" of the inside of a passing vehicle. Another camera simultaneously takes a picture of the vehicle's license plate. Near infrared can be used throughout the entire day as it is not dependent on external lighting. However, inclement weather is likely to cause deterioration

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[189] "Cameras Reduce Red Light Running Violations by 20-30%," *The Urban Transportation Monitor*, May 23, 1997.

[190] Jeffrey Woodson, Transformation Systems, Inc., Dallas, Texas.

[191] Mark Burris, Center for Transportation Research, University of South Florida, Tampa, Florida.

[192] *ITS: Intelligent Transport Systems*, May/June, 1997.

in picture quality.[193] This approach has not been previously used or tested in any traffic observation situation.

Application Examples

Dallas, Texas

The Texas Transportation Institute is conducting a study to identify and test advanced technology to improve the safety and cost-effectiveness of HOV lane enforcement. As part of this study, video technology is being evaluated in an operational test on the East R.L. Thornton (I-30) HOV lane in Dallas. Several agencies are involved in sponsoring or supporting the operational test and evaluation: TxDOT; Dallas Area Rapid Transit (DART); the Federal Highway Administration; and the Federal Transit Administration. This test was developed following a small-scale proof of concept demonstration of HOV lane video technology use in Houston in 1995.

The enforcement system performs these basic functions:

- Collect and transmit video images of vehicle license plates and vehicle compartments for all HOV lane users to a remote computer workstation;
- Perform automatic license plate character recognition on the license plate video image;
- Synchronize the captured video images of vehicle occupants with license plate numbers; and
- Search a license plate data base containing vehicle occupancy histories and, based upon failure to meet set criteria, display the vehicle license plate number and vehicle compartment images on a computer monitor for review and enforcement purposes.[194]

Three cameras are being used in the test. Two cameras capture front and side images of vehicle compartments; the third collects images of the rear license plates. The vehicle interior video images, automatic license plate recognition, license plate/vehicle occupancy history data base searching, and display of license plate records are integrated into a single computer workstation interface. In two to three seconds, the video images for each vehicle can be processed and is

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[193] Gary Gimmestead, Georgia Tech Research Institute, Atlanta, Georgia.

[194] Shawn M. Turner and Jeffrey B. Woodson, "Video Enforcement Testing on the I-30 Contraflow Lane in Dallas, Texas," paper presented at the Institute of Transportation Engineers Annual Meeting, Boston, Massachusetts, August 1997.

displayed on the workstation screen if the vehicle does not have a carpool history. This could be reduced to one second with a faster processor.

The test system requires two people: one at the computer workstation and one DART police officer downstream of the video cameras. If a vehicle is not in the carpool data base and the workstation operator's manual review of the displayed images cannot confirm that the vehicle meets minimum occupancy requirements, the DART officer is radioed the license plate number and vehicle description for observation and potential citation. A police presence is necessary since, in Texas, tickets for moving violations must be presented in person. [195]

A potential system enhancement would be to send the processed, integrated images directly to the DART enforcement officer, thereby eliminating the workstation operator.

The six-month test will end in February 1998. Results should be available soon thereafter.

Atlanta, Georgia

The Georgia Tech Research Institute will test the near infrared approach on I-285 in Atlanta in January 1998. This test is being funded with $317,000 of research money by the Georgia Department of Transportation. Georgia DOT's objective is to determine if this technology is usable for highway planning purposes.

A single near infrared camera will be used to take pictures of the interiors of passing vehicles. The camera will be placed at the side of the road at an angle to the lane being observed. A short duration infrared strobe flash will be directed toward the vehicle, thereby providing its own illumination. The flash will be invisible to the driver, so he/she will not be affected. It will also conform to eye safety standards. This technology has an advantage over video cameras, which need sufficient natural or artificial illumination in order to see into the vehicle compartment. An infrared camera will be linked to the demonstration site to take a picture of the vehicle's license plate at the same time. The trigger for the cameras will be a separate system being used to detect the presence of a vehicle at a particular spot in the lane as well as to collect other vehicle and traffic data. All data will be stored on the same disk and ultimately integrated for processing and further review purposes.

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[195] Jeffrey Woodson, Transformation Systems, Inc., Dallas, Texas.

Testing will occur at several times over a 24-hour period. The test specification is for the system to be able to obtain pictures of vehicles traveling at speeds up to 80 miles per hour at 0.4 second intervals. Images will be taken of thousands of vehicles spaced around the clock. For this test, the reflected infrared images will be post-processed by rudimentary machine vision software in the laboratory.

Since the purpose of the test is to determine whether this technology can be used for planning purposes, not for HOV lane enforcement, there is no need for rapid processing. However, if near infrared technology proves successful, with faster processing and improved image recognition software, it would clearly be applicable for real-time HOV lane enforcement. [196, 197]

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[196] Gary Gimmestead, Georgia Tech Research Institute, Atlanta, Georgia.

[197] Rick Deaver, Georgia Department of Transportation, Atlanta, Georgia.

6. FTA-SPONSORED FIELD OPERATIONAL TESTS

Testing in a real-world environment is essential for a complete and proper evaluation of any technology, system, or innovation. It is only in this environment that the system will be subjected to the challenges that it will experience in regular operation. As part of the Advanced Public Transportation Systems program, the Federal Transit Administration is sponsoring several Field Operational Tests of various innovative technologies throughout the country. These tests will include a full assessment of each promising technology with test results widely disseminated. This will allow service providers interested in implementing APTS technologies and innovations to benefit from the FOT information generated by others. It should reduce trial-and-error inefficiencies and may eliminate wasteful implementation of systems that are inappropriate.

Representative Projects

There are several FTA-sponsored FOTs planned or in progress. [198] They are listed in Table 6.1. Further details regarding many of the projects, including status and findings-to-date, are given earlier in this report. More information also is available from the appropriate FTA contact or:

Walter Kulyk
Director, Office of Mobility Innovation, TRI-10
U.S. Department of Transportation
Federal Transit Administration
400 Seventh Street, SW
Washington, DC 20590
(202) 366-4991

[198] W. Raymond Keng, Federal Transit Administration, Washington, D.C.

Table 6.1 Current FTA-Sponsored APTS Field Operational Tests[199]

Title	FTA Contact	Status	Date	Contact Agency // Location	Contact Person
FLEET MANAGEMENT					
Santa Clara County Smart Paratransit	Ron Boenau (202) 366-0195	Evalu- ation	8/98	Caltrans San Jose, California	Clif Loveland (916) 654-9970
Denver Smart Vehicle	Denis Symes (202) 366-0232	Evalu- ation	8/98	Regional Transportation District Denver, Colorado	Lou Ha (303) 299-6265
North Florida Transit ITS	Ron Boenau (202) 366-0195	Project Develop.	4/00	Florida Comm. For the Transp. Disad. Florida	Jennifer Bowers (940) 488-6036
CTA (Chicago) Smart Bus (See also Traveler Information)	W. Raymond Keng (202) 366-6667	Imple- mentation	12/98	Chicago Transit Authority Chicago, Illinois	Ron Baker (312) 733-7000
Ann Arbor Smart Intermodal (See also Electronic Fare Payment)	Sean Ricketson (202) 366-6678	Evalu- ation	2/98	Ann Arbor Transit Authority Ann Arbor, Michigan	Bill Hiller (313) 973-6500
Winston-Salem Mobility Management - Phase II	Ron Boenau (202) 366-0195	Project Develop.	9/97	North Carolina State University Winston-Salem, North Carolina	John Stone (919) 515-7732
Dallas Area Rapid Transit Personalized Public Transit	W. Raymond Keng (202) 366-6667	Project Develop.	4/00	Dallas Area Rapid Transit Dallas, Texas	Koorosh Olyai (214) 749-2866
Smart Flexroute Integrated Real-Time Enhncmnt Sys. (SAFIRES)	Irv Chambers (202) 366-0238	Evalu- ation	6/98	Potomac-Rappahanock Reg. Transp. Comm Northern Virginia	Eric Marx (703) 490-4811
TRAVELER INFORMATION					
Orange County (California) Smart Traveler	Ron Boenau (202) 366-0195	Project Develop.		Orange County Transit Authority Orange County, California	
Denver RTD Passenger Information Display System	W. Raymond Keng (202) 366-6667	Project Develop.	9/98	Denver RTD Denver, Colorado	Dave Shelley (303) 299-2408
LYNX Passenger Travel Planning	W. Raymond Keng	Project	6/98	Central Florida Regional Transp. Authority	Rob Gregg

[199] Based on information provided by FTA, Office of Mobility Innovat ion.

Title	FTA Contact	Status	Date	Contact Agency // Location	Contact Person
System	(202) 366-6667	Develop.		Orlando, Florida	(407) 841-2279 x3212
Miami Real-Time Passenger Information System	W. Raymond Keng (202) 366-6667	Project Develop.	7/99	Metro-Dade Transit Agency Miami, Florida	Maria Elena Salazar (305) 375-2139
CTA (Chicago) Smart Bus (See also Fleet Management)	W. Raymond Keng (202) 366-6667	Imple-mentation	12/98	Chicago Transit Authority Chicago, Illinois	Ron Baker (312) 733-7000
Cape Cod Advanced Intermodal Transportation System	William Wiggins (202) 366-0255	Project Develop.	6/99	Cape Cod Regional Transit Authority Cape Cod, Massachusetts	Dennis Walsh (508) 385-8311
NYC Metro. Transp. Authority Travel Information System	W. Raymond Keng (202) 366-6667	Project Develop.	4/00	New York City Transit New York, New York	Isaac Takyi (718) 694-3652
Houston Smart Commuter (See also TDM Technologies)	W. Raymond Keng (202) 366-6667	Evalu-ation	7/98	Houston Metro Houston, Texas	Susan Beaty (713) 881-3029
Blacksburg Traveler Information System	Ron Boenau (202) 366-0195	Project Develop.	12/98	Town of Blacksburg Blacksburg, Virginia	Mike Connely (540) 961-1185
ELECTRONIC FARE PAYMENT					
Wilmington, Delaware Smart DART	Sean Ricketson (202) 366-6678	Under Review	12/99	Delaware DOT Wilmington, Delaware	Gene Donaldson (302) 739-4301
Ann Arbor Smart Intermodal (See also Fleet Management)	Sean Ricketson (202) 366-6678	Evalu-ation	2/98	Ann Arbor Transit Authority Ann Arbor, Michigan	Bill Hiller (313) 973-6500
Delaware County Ridetracking	Sean Ricketson (202) 366-6678	Operation	9/97	Community Transit Delaware County, Pennsylvania	Judy McGrane (610) 532-2900
Northern Virginia Regional Fare System	Sean Ricketson (202) 366-6678	Project Develop.	9/98	Northern Virginia Transportation Comm Northern Virginia	Heather Wallenstrom (703) 524-3322
TDM TECHNOLOGIES					
Montgomery County Parking Management System	W. Raymond Keng (202) 366-6667	Project Develop.	12/99	Montgomery County DPW Montgomery County, Maryland	Marc Atz (301) 217-2097
Houston Smart Commuter (See also Traveler Information)	W. Raymond Keng (202) 366-6667	Evalu-ation	7/98	Houston Metro Houston, Texas	Susan Beaty (713) 881-3029

APPENDIX A

CONTACTS

Table A.1 List of Contacts - By City and State [A-1]

Organization City, State	Contact e-mail	Phone # FAX #
AzTech Phoenix, AZ	Yogesh Mantri	(602) 506-8689 (602) 506-5969
City of Phoenix Public Transit Department Phoenix, AZ	Mike Nevarez	(602) 262-7242
Anaheim Traffic Management Center Anaheim, CA	John Thai	(714) 254-5183 (714) 254-5225
Systan, Inc. Los Altos, CA	Roy Lave	(415) 941-3311
Bay Area Rapid Transit District Oakland, CA	Rocky Green	(510) 464-6712 (510) 464-6735
Bay Area Rapid Transit District Oakland, CA	Betty Soo Hoo	(510) 464-6712 (510) 464-6735
Metropolitan Transportation Commission Oakland, CA	Emilio Escudero eescud@mtc.dst.ca.us	(510) 464-7700 (510) 464-7847
Metropolitan Transportation Commission Oakland, CA	Michael Berman	(510) 464-7700 (510) 464-7847
Metropolitan Transportation Commission Oakland, CA	Russell Driver	(510) 464-7808
Orange County Transit Authority Orange County, CA	Vicki Cobbs	(916) 654-9390
Central Contra Costa County Transportation Pleasant Hill, CA	Lynn Osborn	(510) 671-5249 (510) 609-8853
TransAction Network Riverside County, CA	Doris Henry	(619) 343-3456 x162
Caltrans New Technology Programs Sacramento, CA	Elaine Houmani	(916) 657-3957
Caltrans New Technology Programs Sacramento, CA	Bill Tournay btournay@trmx3.dot.ca.gov	(916) 654-9878
Outreach San Jose, CA	Kathryn Heatley	(408) 436-2865
City of Santa Ana, TransitProbe Santa Ana, CA	T.C. Sutaria	(714) 647-5604
Santa Monica Municipal Bus Lines Santa Monica, CA	Janet Shelton	(310) 451-5444 (310) 451-3163

[A-1] The following provided input for the report

Contacts are listed alphabetically by state abbreviations, then by city within each state. U.S. organizations are listed first, followed by Canadian. An additional list, which is ordered by the contacts' last names is included as table A-2.

Table A.1 List of Contacts - By City and State (continued)

Organization City, State	Contact e-mail	Phone # FAX #
City of Torrance Torrance, CA	Bob Meyers	(310) 781-6924 (310) 618-6229
Regional Transportation District Denver, CO	Lou Ha	(303) 299-6265 (303) 299-6060
ITS Joint Program Office (HVH-1) Washington, DC	Mac Lister	(202) 366-9292 (202) 366-8712
Federal Transit Administration (TRI-11) Washington, DC	W. Raymond Keng	(202) 366-6667 (202) 366-3765
University of South Florida Tampa, FL	Mark Burris	(813) 974-3120 (813) 974-5168
Georgia Department of Transportation Atlanta, GA	Rick Deaver deaver_r@dot.state.ga.us	(404) 363-7584 (404) 363-7684
Georgia Department of Transportation Atlanta, GA	Sam Ziegler	(404) 635-8014 (404) 635-8001
Georgia Tech Research Institute Atlanta, GA	Gary Gimmestead	(404) 894-3419
Georgia Tech Research Institute Atlanta, GA	Eugene Greneker	(404) 528-7744 (404) 528-7749
Metropolitan Atlanta Rapid Transit Authority Atlanta, GA	Ralph Martin	(404) 848-5430
Metropolitan Atlanta Rapid Transit Authority Atlanta, GA	James Young	(404) 848-4204
TheBus Honolulu, HI	William Haig	(808) 848-4501
Chicago Transit Authority Chicago, IL	Ronald Baker	(312) 664-6200 x4105
Chicago Transit Authority Chicago, IL	Ross Petronsky	(312) 432-7043
Chicago Transit Authority Chicago, IL	David Phillips	(312) 432-8005
Talking Signs Baton Rouge, LA	C. Ward Bond ward@talkingsigns.com	(504) 344-2812 (504) 344-2811
Massachusetts Bay Transportation Authority Boston, MA	Jeffrey Parker	(617) 222-5621 (617) 222-3928
Dial-A-Bat Brockton, MA	Dee Luddy	(508) 584-5530
U.S. DOT/Volpe Center (DTS-38) Cambridge, MA	Michael Dinning	(617) 494-2422
U.S. DOT/Volpe Center (DTS-49) Cambridge, MA	Robert Dial	(516) 952-6113

Table A.1 List of Contacts - By City and State (continued)

Organization City, State	Contact e-mail	Phone # FAX #
Global Exchange, Inc., SmarTraveler Info. Sys. Maryland	Jennifer Garfinkel	(301) 656-3100
Metropolitan Transit Authority Baltimore, MD	David Hill	(410) 767-3316
Montgomery County Transportation Mgmt. Sect. Rockville, MD	Mark Atz	(301) 217-2097
Montgomery County Transportation Mgmt. Sect. Rockville, MD	Bill Corder	(301) 217-2190 (301) 217-2637
Montgomery County Transportation Mgmt. Sect. Rockville, MD	Alfie Steele	(301) 217-2783 (301) 217-2637
Ann Arbor Transportation Authority Ann Arbor, MI	William Hiller	(313) 973-6500 (313) 677-3944
Suburban Mobility Auth. for Regional Transport. Troy, MI	Ronald R. Ristau	(810) 362-0925 x7060 (810) 362-0889
Minnesota DOT - Transportation Mgmt. Ctr. Minneapolis, MN	Glen Carlson gcc000@dot.state.mn.us	(612) 341-7500 (612) 341-7239
Minnesota DOT St. Paul, MN	Marilyn Remer marilyn.remer@dot.state.mn.us	(612) 582-1302
MetroLink St. Louis, MO	Anthony Webb	(314) 982-1435 (314) 923-3025
Missoula Ravalli Transportation Mgmt. Assoc. Missoula, MT	Noel Larrivee mrtma@montana.com www.mrtma.org	(406) 523-4944 (406) 523-4944
Winston-Salem Transit Authority Winston-Salem, NC	Suzanne Tellechea	(910) 727-2648
Winston-Salem Transit Authority Winston-Salem, NC	Nedra Woodyatt	(910) 727-8131
TRANSCOM Jersey City, NJ	Tom Batz	(201) 963-4033 (201) 963-8376
TRANSCOM Jersey City, NJ	Pete Dwyer	(201) 963-4033 (201) 963-8376
TRANSCOM Jersey City, NJ	Martha Morecock	(201) 963-4033 (201) 963-8376
TRANSCOM Jersey City, NJ	Shelley Prettyman	(201) 963-4033 (201) 963-8376
New Jersey Transit Newark, NJ	Jim Kemp	(201) 491-7861 (201) 491-7837
New Jersey Transit Newark, NJ	Lou Wassong	(973) 378-6906

Table A.1 List of Contacts - By City and State (continued)

Organization City, State	Contact e-mail	Phone # FAX #
New York City Transit Brooklyn, NY	Isaac Takyi	(718) 694-3652 (718) 488-6468
New York City Transit Brooklyn, NY	Andrew Bata	(718) 694-3652 (718) 488-6468
New York City Transit Brooklyn, NY	Tarik Hussain	(718) 694-3231 (718) 488-6468
Long Island Rail Road Jamaica, NY	Frank Rizzo	(718) 558-3090
City University of New York New York, NY	Karen Luxton-Gourgey klgbb@cunyum.cuny.edu	(212) 802-2146 (212) 802-2050
Rochester-Genesee Regional Transp. Authority Rochester, NY	Lisa Hennik	(716) 654-0244
Rochester-Genessee Regional Transp. Authority Rochester, NY	Chip Walker	(716) 654-0247
Westchester County DOT White Plains, NY	Richard Stiller	(914) 285-5118 (914) 682-2987
SW Ohio Regional Transportation Authority Cincinnati, OH	Greg Lind	(513) 632-7571 (513) 242-3576
Greater Cleveland Regional Transit Authority Cleveland, OH	Joel Frielich	(216) 566-5120 (216) 781-4488
Central Ohio Transit Authority Columbus, OH	Khaled Shammout	(614) 275-5837 (614) 275-5933
Tri-County Metropolitan Transp. Dist. of Oregon Portland, OR	John Lutterman	(503) 238-4922 (503) 239-3088
Tri-County Metropolitan Transp. Dist. of Oregon Portland, OR	Ken Turner kturne01@reach.com	(503) 238-4918 (503) 239-3088
Community Transit of Delaware County Folsom, PA	Judith McGrane	(610) 532-2900
Southeastern Pennsylvania Transportation Auth. Philadelphia, PA	John Bukowski	(215) 580-7619 (215) 580-3780
Southeastern Pennsylvania Transportation Auth. Philadelphia, PA	Michael Monastero	(215) 580-7619 (215) 580-3780
Southeastern Pennsylvania Transportation Auth. Philadelphia, PA	Jim Polka	(215) 580-5700 (215) 580-5714
Beaver County Transit Authority Rochester, PA	Bruce Ahern	(412) 728-4255 (412) 728-8333
Texas Transportation Institute College Station, TX	Katherine Turnbull	(409) 845-1535 (409) 845-6008
Texas Transportation Institute College Station, TX	Shawn Turner shawn-turner@tamu.edu	(409) 845-8829 (409) 845-6008

Table A.1 List of Contacts - By City and State (continued)

Organization City, State	Contact e-mail	Phone # FAX #
Houston Metro, MetroLift Houston, TX	Jim Laughlin	(713) 739-4986
Houston TranStar Houston, TX	Gloria Stoppenhagen gstop@sprynet.com	(713) 881-3310 (713) 881-3028
Houston TranStar Houston, TX	Doug Weirsig	(713) 613-0315
Transfomation Systems, Inc. Houston, TX	Jeffrey Woodson	(713) 952-7494 (713) 952-7497
Metropolitan Transit Authority of Harris County Houston, TX	Lloyd Smith	(713) 739-3870
Texas DOT San Antonio, TX	Betty Taylor	(210) 731-5223 (210) 731-5310
Texas DOT San Antonio, TX	Brian Fariello	(210) 731-5223 (210) 731-5310
VIA Metropolitan Transit San Antonio, TX	Tom Carter tomascarter@compuserv.com	(210) 277-2276 (210) 362-2588
Potomac & Rappahannock Transportation Comm Woodbridge, VA	Eric Marx	(703) 490-4811
King County DOT - Metro Transit Seattle, WA	Catherine Bradshaw Catherine.Bradshaw@metrokc.gov	(206) 684-1516 (206) 684-2059
King County DOT - Metro Transit Seattle, WA	Robert Wade	(206) 684-1516 (206) 684-2059
King County DOT - Metro Transit Seattle, Washington	Candace Carlson	(206) 684-1562
King County DOT - Metro Transit Seattle, WA	Carol Douglas	(206) 684-1571
King County DOT - Metro Transit Seattle, WA	Dan Overgaard dan.overgaard@metrokc.gov	(206) 684-1415 (206) 684-1860
Washington State DOT - Northwest Region Seattle, WA	Dave Berg bergd@wsdot.wa.gov	(206) 440-4485 (206) 440-4804
Spokane Transit Authority Spokane, WA	Jill Lamb jlamb@spokanetransit.com	(509) 325-6000 (509) 325-6050
Milwaukee County Transit System Milwaukee, WI	Michael Giugno	(414) 937-3214
Milwaukee County Transit System Milwaukee, WI	Ron Rutkowski	(414) 278-4888
City of Calgary Transportation Department Calgary, AB CANADA	Neil McKendrick tpctnm@gov.calgary.ab.ca	(403) 277-9727 (403) 230-1155

Table A.1 List of Contacts - By City and State (continued)

Organization City, State	Contact e-mail	Phone # FAX #
BC Transit Surrey, BC CANADA	Stephen Rees stephen_rees@bctinet.bctransit.com	(604) 540-3374 (604) 540-3380
BC Transit Surrey, BC CANADA	Wayne Dale	(604) 540-3528
Hamilton Street Railway Company Hamilton, ON CANADA	Bob Krbvak	(905) 528-4200 x418 (905) 528-5410
Hamilton Street Railway Company Hamilton, ON CANADA	Kevin Smith	(905) 528-4200 (905) 528-5410
London Transit London, ON CANADA	Bill Brock	(519) 451-1340
Trapeze Software, Online Data Products Mississauga, ON CANADA	Andrea Potter	(905) 629-8727
Societe de Transport L' Outaouais Hull, QC CANADA	Sallah Barj	(819) 770-7900 (819) 770-5987

Table A.2 List of Contacts - By Contact Name

Organization City, State	Contact e-mail	Phone # FAX #
Beaver County Transit Authority Rochester, PA	Bruce Ahern	(412) 728-4255 (412) 728-8333
Montgomery County Transportation Mgmt. Sect. Rockville, MD	Mark Atz	(301) 217-2097
Chicago Transit Authority Chicago, IL	Ronald Baker	(312) 664-6200 x4105 (312) 664-2748
Societe de Transport L' Outaouais Hull, QC CANADA	Sallah Barj	(819) 770-7900 (819) 770-5987
New York City Transit Brooklyn, NY	Andrew Bata	(718) 694-3652 (718) 488-6468
TRANSCOM Jersey City, NJ	Tom Batz	(201) 963-4033 (201) 963-8376
Washington State DOT - Northwest Region Seattle, WA	Dave Berg bergd@wsdot.wa.gov	(206) 440-4485 (206) 440-4804
Metropolitan Transportation Commission Oakland, CA	Michael Berman	(510) 464-7700 (510) 464-7847
Talking Signs Baton Rouge, LA	C. Ward Bond ward@talkingsigns.com	(504) 344-2812 (504) 344-2811
King County DOT - Metro Transit Seattle, WA	Catherine Bradshaw Catherine.Bradshaw@metrokc.gov	(206) 684-1516 (206) 684-2059
London Transit London, ON CANADA	Bill Brock	(519) 451-1340
Southeastern Pennsylvania Transportation Auth. Philadelphia, PA	John Bukowski	(215) 580-7619 (215) 580-3780
University of South Florida Tampa, FL	Mark Burris	(813) 974-3120 (813) 974-5168
King County DOT - Metro Transit Seattle, Washington	Candace Carlson	(206) 684-1562
Minnesota DOT - Transportation Mgmt. Ctr. Minneapolis, MN	Glen Carlson gcc000@dot.state.mn.us	(612) 341-7500 (612) 341-7239
VIA Metropolitan Transit San Antonio, TX	Tom Carter tomascarter@compuserv.com	(210) 277-2276 (210) 362-2588
Orange County Transit Authority Orange County, CA	Vicki Cobbs	(916) 654-9390
Montgomery County Transportation Mgmt. Sect. Rockville, MD	Bill Corder	(301) 217-2190 (301) 217-2637
BC Transit Surrey, BC CANADA	Wayne Dale	(604) 540-3528

Table A.2 List of Contacts - By Contact Name (continued)

Organization City, State	Contact e-mail	Phone # FAX #
Georgia Department of Transportation Atlanta, GA	Rick Deaver deaver_r@dot.state.ga.us	(404) 363-7584 (404) 363-7684
U.S. DOT/Volpe Center (DTS-49) Cambridge, MA	Robert Dial	(516) 952-6113
U.S. DOT/Volpe Center (DTS-38) Cambridge, MA	Michael Dinning	(617) 494-2422
King County DOT - Metro Transit Seattle, WA	Carol Douglas	(206) 684-1571
Metropolitan Transportation Commission Oakland, CA	Russell Driver	(510) 464-7808
TRANSCOM Jersey City, NJ	Pete Dwyer	(201) 963-4033 (201) 963-8376
Metropolitan Transportation Commission Oakland, CA	Emilio Escudero eescud@mtc.dst.ca.us	(510) 464-7700 (510) 464-7847
Texas DOT San Antonio, TX	Brian Fariello	(210) 731-5223 (210) 731-5310
Greater Cleveland Regional Transit Authority Cleveland, OH	Joel Frielich	(216) 566-5120 (216) 781-4488
Global Exchange, Inc., SmarTraveler Info. Sys. Maryland	Jennifer Garfinkel	(301) 656-3100
Georgia Tech Research Institute Atlanta, GA	Gary Gimmestead	(404) 894-3419
Milwaukee County Transit System Milwaukee, WI	Michael Giugno	(414) 937-3214
Bay Area Rapid Transit District Oakland, CA	Rocky Green	(510) 464-6712 (510) 464-6735
Georgia Tech Research Institute Atlanta, GA	Eugene Greneker	(404) 528-7744 (404) 528-7749
Regional Transportation District Denver, CO	Lou Ha	(303) 299-6265 (303) 299-6060
TheBus Honolulu, HI	William Haig	(808) 848-4501
Outreach San Jose, CA	Kathryn Heatley	(408) 436-2865
Rochester-Genesee Regional Transp. Authority Rochester, NY	Lisa Hennik	(716) 654-0244
TransAction Network Riverside County, CA	Doris Henry	(619) 343-3456 x162
Metropolitan Transit Authority Baltimore, MD	David Hill	(410) 767-3316

Table A.2 List of Contacts - By Contact Name (continued)

Organization City, State	Contact e-mail	Phone # FAX #
Ann Arbor Transportation Authority Ann Arbor, MI	William Hiller	(313) 973-6500 (313) 677-3944
Caltrans New Technology Programs Sacramento, CA	Elaine Houmani	(916) 657-3957
New York City Transit Brooklyn, NY	Tarik Hussain	(718) 694-3231 (718) 488-6468
New Jersey Transit Newark, NJ	Jim Kemp	(201) 491-7861 (201) 491-7837
Federal Transit Administration (TRI-11) Washington, DC	W. Raymond Keng	(202) 366-6667 (202) 366-3765
Hamilton Street Railway Company Hamilton, ON CANADA	Bob Krbvak	(905) 528-4200 x418 (905) 528-5410
Spokane Transit Authority Spokane, WA	Jill Lamb jlamb@spokanetransit.com	(509) 325-6000 (509) 325-6050
Missoula Ravalli Transportation Mgmt. Assoc. Missoula, MT	Noel Larrivee mrtma@montana.com www.mrtma.org	(406) 523-4944 (406) 523-4944
Houston Metro, MetroLift Houston, TX	Jim Laughlin	(713) 739-4986
Systan, Inc. Los Altos, CA	Roy Lave	(415) 941-3311
SW Ohio Regional Transportation Authority Cincinnati, OH	Greg Lind	(513) 632-7571 (513) 242-3576
U.S. DOT/ITS Joint Program Office (HVH-1) Washington, DC	Mac Lister	(202) 366-9292 (202) 366-8712
Dial-A-Bat Brockton, MA	Dee Luddy	(508) 584-5530
Tri-County Metropolitan Transp. Dist. of Oregon Portland, OR	John Lutterman	(503) 238-4922 (503) 239-3088
City University of New York New York, NY	Karen Luxton-Gourgey klgbb@cunyum.cuny.edu	(212) 802-2146 (212) 802-2050
AzTech Phoenix, AZ	Yogesh Mantri	(602) 506-8689 (602) 506-5969
Metropolitan Atlanta Rapid Transit Authority Atlanta, GA	Ralph Martin	(404) 848-5430
Potomac & Rappahannock Transportation Comm Woodbridge, VA	Eric Marx	(703) 490-4811
Community Transit of Delaware County Folsom, Pennsylvania	Judith McGrane	(610) 532-2900

Table A.2 List of Contacts - By Contact Name (continued)

Organization City, State	Contact e-mail	Phone # FAX #
City of Calgary Transportation Department Calgary, AB CANADA	Neil McKendrick tpctnm@gov.calgary.ab.ca	(403) 277-9727 (403) 230-1155
City of Torrance Torrance, CA	Bob Meyers	(310) 781-6924 (310) 618-6229
Southeastern Pennsylvania Transportation Auth. Philadelphia, PA	Michael Monastero	(215) 580-7619 (215) 580-3780
TRANSCOM Jersey City, NJ	Martha Morecock	(201) 963-4033
City of Phoenix Public Transit Department Phoenix, AZ	Mike Nevarez	(602) 262-7242
Central Contra Costa County Transportation Pleasant Hill, CA	Lynn Osborn	(510) 671-5249 (510) 609-8853
King County DOT - Metro Transit Seattle, WA	Dan Overgaard dan.overgaard@metrokc.gov	(206) 684-1415 (206) 684-1860
Massachusetts Bay Transportation Authority Boston, MA	Jeffrey Parker	(617) 222-5621 (617) 222-3928
Chicago Transit Authority Chicago, IL	Ross Petronsky	(312) 432-7043
Chicago Transit Authority Chicago, IL	David Phillips	(312) 432-8005
Southeastern Pennsylvania Transportation Auth. Philadelphia, PA	Jim Polka	(215) 580-5700 (215) 580-5714
Trapeze Software, Online Data Products Ontario CANADA	Andrea Potter	(905) 629-8727
TRANSCOM Jersey City, NJ	Shelley Prettyman	(201) 963-4033 (201) 963-8376
BC Transit Surrey, BC CANADA	Stephen Rees stephen_rees@bctinet.bctransit.com	(604) 540-3374 (604) 540-3380
Minnesota DOT St. Paul, MN	Marilyn Remer marilyn.remer@dot.state.mn.us	(612)582-1302
Suburban Mobility Auth. for Regional Transport. Troy, MI	Ronald R. Ristau	(810) 362-0925 x7060 (810) 362-0889
Long Island Rail Road Jamaica, NY	Frank Rizzo	(718) 558-3090
Milwaukee County Transit System Milwaukee, WI	Ron Rutkowski	(414) 278-4888
Central Ohio Transit Authority Columbus, OH	Khaled Shammout	(614) 275-5837 (614) 275-5933
Santa Monica Municipal Bus Lines Santa Monica, CA	Janet Shelton	(310) 451-5444 (310) 451-3163

Table A.2 List of Contacts - By Contact Name (continued)

Organization City, State	Contact e-mail	Phone # FAX #
Hamilton Street Railway Company Hamilton, ON CANADA	Kevin Smith	(905) 528-4200 (905) 528-5410
Metropolitan Transit Authority of Harris County Houston, TX	Lloyd Smith	(713) 739-3870
Bay Area Rapid Transit District Oakland, CA	Betty Soo Hoo	(510) 464-6712 (510) 464-6735
Westchester County DOT White Plains, NY	Richard Stiller	(914) 285-5118 (914) 682-2987
Montgomery County Transportation Mgmt. Sect. Rockville, MD	Alfie Steele	(301) 217-2783 (301) 217-2637
Houston TranStar Houston, TX	Gloria Stoppenhagen gstop@sprynet.com	(713) 881-3310 (713) 881-3028
City of Santa Ana, TransitProbe Santa Ana, CA	T.C. Sutaria	(714) 647-5604
New York City Transit Brooklyn, NY	Isaac Takyi	(718) 694-3652 (718) 488-6468
Texas DOT San Antonio, TX	Betty Taylor	(210) 731-5223 (210) 731-5310
Winston-Salem Transit Authority Winston-Salem, NC	Suzanne Tellechea	(910) 727-2648
Anaheim Traffic Management Center Anaheim, CA	John Thai	(714) 254-5183 (714) 254-5225
Caltrans New Technology Programs Sacramento, CA	Bill Tournay btournay@trmx3.dot.ca.gov	(916) 654-9878
Texas Transportation Institute College Station, TX	Katherine Turnbull	(409) 845-1535 (409) 845-6008
Texas Transportation Institute College Station, TX	Shawn Turner shawn-turner@tamu.edu	(409) 845-8829 (409) 845-6008
Tri-County Metropolitan Transp. Dist. of Oregon Portland, OR	Ken Turner kturne01@reach.com	(503) 238-4918 (503) 239-3088
King County DOT - Metro Transit Seattle, WA	Robert Wade	(206) 684-1516 (206) 684-2059
Rochester-Genessee Regional Transp. Authority Rochester, NY	Chip Walker	(716) 654-0247
New Jersey Transit Newark, NJ	Lou Wassong	(973) 378-6906
MetroLink St. Louis, MO	Anthony Webb	(314) 982-1435 (314) 923-3025
Houston TranStar Houston, TX	Doug Weirsig	(713) 613-0315

Table A.2 List of Contacts - By Contact Name (continued)

Organization City, State	Contact e-mail	Phone # FAX #
Transfomation Systems, Inc. Houston, TX	Jeffrey Woodson	(713) 952-7494 (713) 952-7497
Winston-Salem Transit Authority Winston-Salem, NC	Nedra Woodyatt	(910) 727-8131
Metropolitan Atlanta Rapid Transit Authority Atlanta, GA	James Young	(404) 848-4204
Georgia Department of Transportation Atlanta, GA	Sam Ziegler	(404) 635-8014 (404) 635-8001

APPENDIX B

ITS SYSTEM ARCHITECTURE AND STANDARDS

This appendix provides a definition and objectives of a "system architecture," discusses the National Intelligent Transportation Systems Architecture, and reviews the public transportation involvement in the system architecture and standards areas.[B-1]

What Is a System Architecture?

A system architecture is simply a description of how system components interact to achieve system goals. A system architecture defines:

- Complete system operation;
- What each component does; and
- What information is exchanged among components.

For simple systems, an architecture may provide little benefit, but for a large complex system, a system architecture is tremendously helpful. Meeting the first objective assures that everyone agrees on the finished system operation and that no major functions are overlooked. The second objective is the embodiment of the "divide and conquer" methodology with the additional aspect of looking for opportunities for shared use of components. The third objective is a definition of which components need to communicate and what information is passed among components; this is necessary to allow independent development of components.

A system architecture, however, is not a system design. It does not specify how each component accomplishes its task or a component's "look and feel." It is an organization of functions, not a specification of equipment. Nevertheless, it does have a strong influence on the design. For example, the architecture facilitates the development of standards which can flow directly from the specification of communication pathways. The resulting standards ensure equipment compatibility and inter-operation, resulting in larger, more stable equipment markets and the accompanying reduction in component costs. The architecture also minimizes system costs by assuring that the system is sensibly deployed with a minimum of redundant equipment.

The National ITS System Architecture Development

[B-1] Information contained in this appendix on the national ITS system architecture was summarized or extracted from "ITS Architecture Executive Summary," prepared by the Joint Architecture Team (Lockheed Martin and Rockwell International) for the U. S. DOT - Federal Highway Administration, January 1997.

Central to the successful realization of a national ITS is the establishment of a unifying national architecture. It will ensure that a nationally compatible system is developed, linking all modes of transportation. The architecture will promote national standards to accommodate intercity travel and cross country goods movements, while discouraging local or regional areas from developing incompatible ITS implementations.

The U. S. Department of Transportation, in June 1996, completed its development of a National ITS Architecture. This comprehensive program began in September 1993, with four teams led by Hughes Aircraft, IBM-Loral, Rockwell International, and Westinghouse Electric competing to develop the best architectures (Phase I). In February 1995, two selected teams, Loral and Rockwell International, began working together to merge and their architectures into a national standard (Phase II).

The foundation of the National ITS Architecture is a collection of interrelated user services for application to the Nation's surface transportation problems. To date, 30 user services have been identified. The user services address a broad spectrum of services including travel management, public transportation operations, emergency management, etc. The goal of the National ITS System Architecture Program is to unify and organize user services and promote standards that assure seamless operation of the system from coast-to-coast. The 30 user services have been bundled into six categories as shown in Table B-1.

As part of the ITS architecture development, models of the ITS functions and physical entities were developed. The *logical architecture* presents a functional view of ITS services. This representation is intentionally divorced from likely implementations and physical interface requirements. The logical architecture defines and describes the functions or process specifications that are required to perform ITS user services, and the information or data flows that need to occur among these functions. *The physical architecture* partitions the functions defined by the logical architecture into systems and subsystems based on the functional similarity of the process specifications and the location where the functions are being performed. The ITS physical architecture defines four systems (Traveler, Center, Roadside, and Vehicle) and 19 subsystems. Subsystems are composed of equipment packages with specific functional attributes.

TABLE B-1. USER SERVICES

USER SERVICES BUNDLE	USER SERVICES
Travel and Transportation Management	En-Route Driver Information Route Guidance Traveler Services Information Traffic Control Incident Management Emissions Testing and Mitigation Demand Management and Operations Pre-Trip Travel Information Ride Matching and Reservation Highway Rail Intersection
Public Transportation Operations	Public Transportation Management En-Route Transit Information Personalized Public Transit Public Travel Security
Electronic Payment	Electronic Payment Services
Commercial Vehicle Operations	Commercial Vehicle Electronic Clearance Automated Roadside Safety Inspection On-board Safety Monitoring Commercial Vehicle Administration Processes Hazardous Materials Incident Response Freight Mobility
Emergency Management	Emergency Notification and Personal Security Emergency Vehicle Management
Advanced Vehicle Control and Safety Systems	Longitudinal Collision Avoidance Lateral Collision Avoidance Intersection Collision Avoidance Vision Enhancement for Crash Avoidance Safety Readiness Pre-Crash Restraint Deployment Automated Highway System

The National ITS Architecture provides a framework for the development of national standards to ensure national interoperability, a major goal of the ITS program. Standards are crucial to guide deployment at the local level and for ITS to maintain consistency across the country. Figure B-1, the Systems Architecture Interconnect Diagram, which was developed by the U.S. Architecture Team, depicts the 19 subsystems for the fully-deployed ITS and shows the basic communications channels among them. These channels and their underlying detailed architecture provide the basis for most of the ITS standards currently in development, particularly the message sets.

Development of national standards is typically a time-consuming and cumbersome process. In 1996, under a Federal initiative to speed development of ITS standards, DOT signed cooperative agreements with five standards development organizations to accelerate the development and acceptance of standards. These organizations are the American Association of State Highway and Transportation Officials; American Society for Testing and Materials; Institute of Electrical and Electronics Engineers; the Institute of Transportation Engineers; and the Society of Automotive Engineers. These agreements are meant to accelerate the inherently slow process of establishing standards for ITS technologies needed to ensure national interoperability.

Transit Involvement in the System Architecture Development Program

The Federal Transit Administration participated in the ITS system architecture development process through an effort to identify transit-specific requirements. In support of FTA, the DOT Volpe National Transportation Systems Center and Sandia National Laboratories developed a set of information flow charts which represent the logical information flows necessary to satisfy the needs of the APTS user services. These flow charts along with a narrative description were provided to the architecture teams as well as the transit community.

FIGURE B-1. SYSTEMS ARCHITECTURE INTERCONNECT DIAGRAM

(Source: *ITS America Standards Quarterly*, Fall 1997.)

In an effort to assist the public transportation community to better understand and use the ITS system architecture, a report "ITS Deployment Guidance for Transit Systems," April 1997, has been developed by the U. S. DOT ITS Joint Program Office. An Executive Edition and Technical Edition of this report are available from the APTS Division of the Federal Transit Administration, 400 7th Street, SW, Washington, DC 20590.

The "ITS Deployment Guidance for Transit Systems" provides guidance for the transit community on developing and implementing ITS and using the National ITS Architecture. It focuses on transit applications and provides practical assistance based on real-life experiences with developing and implementing transit ITS systems. The document includes definitions of ITS and the National ITS Architecture; applications of ITS using a systems engineering approach; alignment with the National ITS Architecture; and best practices and lessons learned for developing and implementing ITS. The document is intended for those performing the following functions within transit agencies; planning and development, project definition, project approval, funds identification and allocation, design, project management, procurement, and project implementation.

Standards Development

As indicated above, a national architecture facilitates the development of necessary ITS and APTS standards in the U.S. Several transit standards activities are currently actively underway.

Vehicle Area Network Standard

One of the first ITS standards was an APTS standard for public transit vehicle area networks, developed through the efforts of ITS America's APTS Committee/Bus Vehicle Area Network Working Group. The standard was based on Society of Automotive Engineers standard SAE J1708 (hardware and communications format), and related standards, SAE J1587 (protocols) and SAE J1455 (environmental requirements). Work is currently underway to convert a "de facto" standard cable and connector to a SAE standard; this is expected to be completed in

1998. (SAE was one of the five standards development organizations selected by DOT to accelerate ITS standards development)

Acceptance of the modular non-proprietary concept embodied by J1708 and its related standards has been widespread. Transit agencies can now specify and procure a given electronic device from multiple sources with the resulting devices able to interchangeably communicate with the rest of the vehicle's devices. Manufacturers now have the opportunity to market commodity building block devices while competing on pure performance issues (speed, accuracy, power demands, etc.) Agencies can assemble a system meeting their special needs and budgets by selecting functions and performance requirements afforded by an open architecture marketplace. Because of the modular nature of the device standards, additional device and functional expansions could occur without discarding previous investments. Through standardization of communications and hardware interfaces, the entire on-vehicle system becomes transparent to the vehicle on which it is installed. This enables a single implementation solution to be transportable to various types of transit vehicles.

The vehicle area network (VAN) standard is a fundamental component of other transit standards development activities. In the Transit Communications Interface Profiles development activity (described below), TCIP will map the data from the vehicle into a target database schema which allows multiple vendors to access the data in a non-proprietary and standardized manner. The VAN standard has also been accepted as a work item in ISO/TC 204 Working Group 8 for Public Transport and Emergency Services (see discussion below).

Transit Communications Interface Profiles

A second major standards development project, initiated in November 1996, is for Transit Communications Interface Profiles. This project is led by the Institute for Transportation Engineers, one of the five standards development organizations chosen by DOT to accelerate development of ITS standards, and funded by the U.S. Department of Transportation's Intelligent Transportation Systems Joint Program Office. TCIP will define the data interface structures that will allow the different transit components to exchange data, and allow data exchange between transit authorities and external entities such as traffic management centers and emergency management centers.

The TCIP draft specification document was filed with the Institute for Transportation Engineers on September 2, 1997. The draft specification includes data definitions and message sets for seven key transit object areas: fare collection, incident management, onboard/control center, passenger information, scheduling and runcutting, spatial representation, and traffic management.The standards were not designed to replace existing interfaces, but to extend them. The profiles will act as a layer between proprietary systems; with TCIP, rather than writing an interface between each system, agencies can specify just one.

The public comment period on the draft standards closed on November 14, 1997; the final draft specifications are targeted for completion on February 20, 1997. At that time, they will be passed to the National Transportation Communications for ITS Protocols project for further review and balloting. Officially sanctioned standards are expected to be available by summer 1998.

The TCIP effort is remarkable for its high level of participation by transit authorities and industry, through its many workshops and working meetings. The project established a user-driven framework within the transit industry for a "business enterprise" approach to transit standards development, testing, training, and maintenance.

International Standards Organization Technical Committee 204 Working Group 8 - Public Transport and Emergency Services

On the international front, the International Standards Organization has established Technical Committee (TC) 204, composed of 16 international Working Groups (WG), to develop ITS standards. There are currently 18 participating countries and 27 observing countries in ISO/TC 204. The U.S. is the International Secretariat of ISO/TC 204 and also convenes five of the 16 WGs. ISO/TC 204's WG 8, convened by the U.S., is chartered with developing international ITS standards in the areas of public transport and emergency services.

The U.S., in support of ISO/TC 204 activities, established a parallel structure within the U.S. to provide technical expertise in the development of U.S. input to the ISO/TC 204 working groups. The counterpart of ISO/TC 204 WG 8 is the U.S. Working Advisory Group (WAG) 8 for public transport and emergency services, which is responsible for developing U.S. positions on international standards and for initiation of international standards based on U.S. standards. The U.S. WAG 8 is currently administered by the U.S. Department of Transportation's Volpe National Transportation Systems Center. WAG 8 has approximately 40 members supporting four U.S. experts nominated by the WAG and confirmed by the American National Standards Institute. The membership includes representatives from U.S. industry, transit authorities, emergency services, academia, standards development organizations, transit associations, and government.

U.S. WAG 8 has carried both the VAN standard and TCIP forward for consideration in ISO/TC 204 WG 8. The vehicle area network standard (SAE J1708) has been approved as a new item of work for the WG 8 program. TCIP was approved by ISO/TC 204 as a preliminary work item, allowing time for the standards to be developed and approved in the U.S.