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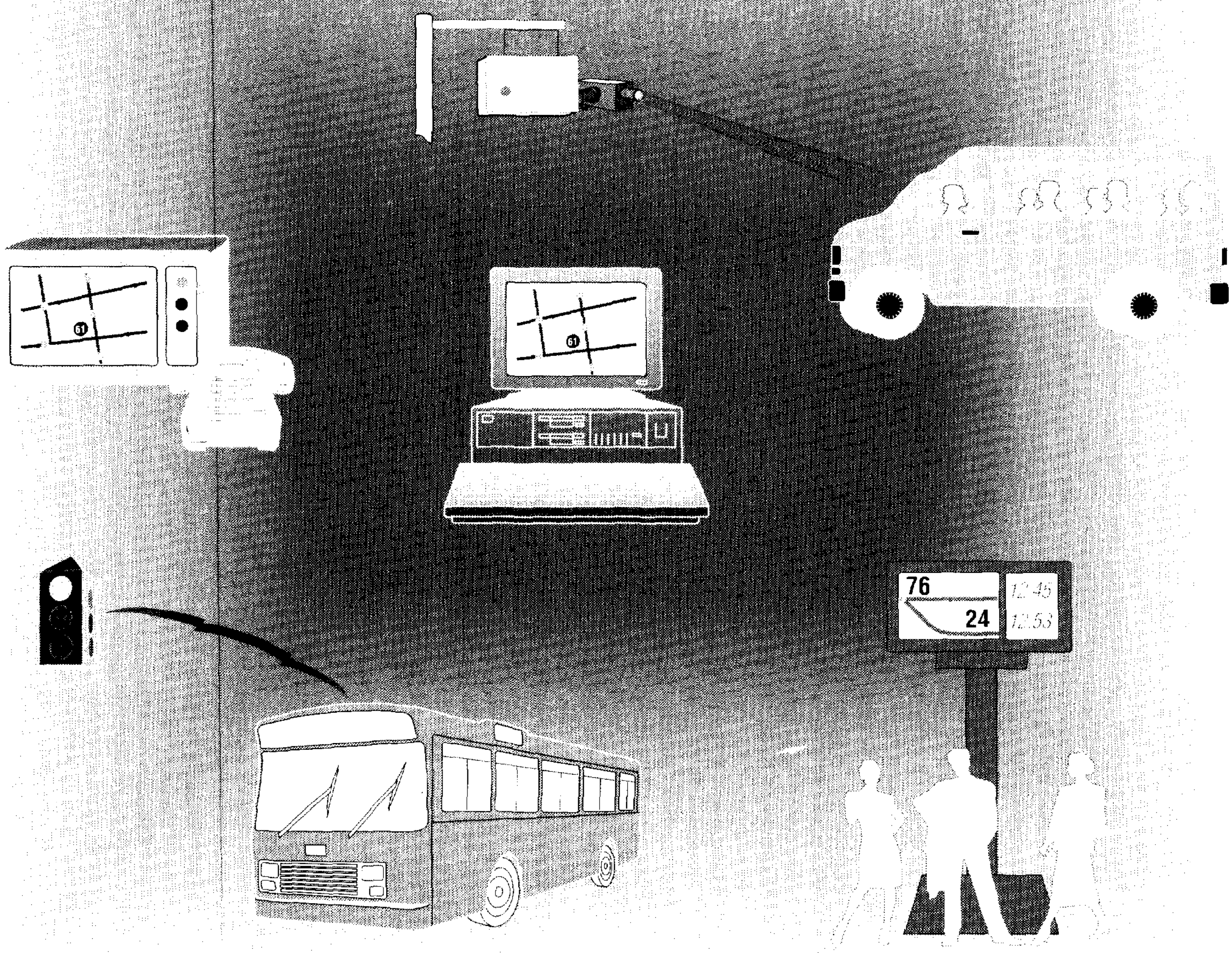
U. S. Department
of Transportation
**Federal Transit
Administration**

Federal Transit
Administration

Advanced Public Transportation Systems: The State of the Art

Update '96



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13. ABSTRACT (Maximum 200 words)

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, 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 1994. 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 tghe 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, and January 1994. 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.

METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectare (ha) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gm)
1 pound (lb) = .45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x - 32)(5/9)]°F = y°C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2) = 1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

[(9/5)(y + 32)]°C = x°F

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES	0	1	2	3	4	5

CENTIMETERS	0	1	2	3	4	5	6	7	8	9	10	11	12	13

QUICK FAHRENHEIT-CELSIUS TEMPERATURE CONVERSION

°F	-40°	-22°	-4°	14°	32°	50°	68°	86°	104°	122°	140°	158°	176°	194°	212°
°C	-40°	-30°	-20°	-10°	0°	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°

For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10286.

Updated 9/29/95

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LIST OF ACRONYMS AND ABBREVIATIONS USED IN THIS REPORT

AATA	Ann Arbor Transportation Authority (Michigan)
AC Transit	Alameda-Contra Costa Transit (Oakland, California)
ADA	Americans with Disabilities Act
APC	Automatic Passenger Counter
APTS	Advanced Public Transportation Systems
ATIS	Advanced Traveler Information System
ATM	Automated Teller Machine
ATMS	Advanced Transportation Management System
ATN	Anaheim Transportation Network (California)
ATS	Automatic Train Supervision
AVAS	Automated Voice Annunciator Systems
AVI	Automatic Vehicle Identification
AVL	Automatic Vehicle Location
AVM	Automatic Vehicle Monitoring
BCTA	Beaver County Transit Authority (Rochester, Pennsylvania)
BST	Bellevue Smart Traveler (Washington)
BSMS	Bus Service Management System
BART	Bay Area Rapid Transit District (Oakland, California)
CAD	Computer-Aided Dispatch
Caltrans	California Department of Transportation
CCCTA	Central Contra Costa County Transit Authority (California)
CCMP	Control Center Modernization Program
CCRTA	Corpus Christi Regional Transportation Authority (Texas)
CCTV	Closed-Circuit Television
CDPD	Cellular Digital Packet Data
COLTS	County of Lakawanna Transit System (Scranton, Pennsylvania)
COTA	Central Ohio Transit Authority (Columbus)
CTA	Chicago Transit Authority
DART	Delaware Authority for Regional Transportation (Wilmington)
DGPS	Differential Global Positioning System
DOT	Department of Transportation
EEPROM	Electronically Erasable Programmable Read-Only Memory
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
FOT	Field Operational Test
GDOT	Georgia Department of Transportation
GIS	Geographic Information Systems
GPS	Global Positioning System
HOV	High Occupancy Vehicle
HSRC	Hamilton Street Railway Company (Ontario)

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

IC	Integrated Circuit
ID	Identification
ISO	International Standards Organization
ITS	Intelligent Transportation Systems
I^2TS	Integrated Intelligent Transportation System
IVLU	Intelligent Vehicle Logic Unit
LACMTA	Los Angeles County Metropolitan Transportation Authority
LCMTD	Lane County Mass Transit District (Eugene, Oregon)
LIRR	Long Island Rail Road (New York)
Loran-C	Long Range Aid to Navigation
MARTA	Metropolitan Atlanta Rapid Transit Authority
MBTA	Massachusetts Bay Transportation Authority (Boston)
MCTS	Milwaukee County Transit System
MDT	Mobile Data Terminal
Metro	Metropolitan Transit Authority (Houston)
MTA	Metropolitan Transportation Authority (New York City)
MTACC	MTA Card Company (New York)
MTC	Metropolitan Council of Transit Operations (Minneapolis/St. Paul, Minnesota)
MTDB	Metropolitan Transit Development Board (San Diego)
MTIS	Multimodal Traveler Information Systems
MTS	Metropolitan Transit System (San Diego)
NDS	Navigation Data Systems
NJT	New Jersey Transit
NTIA	National Telecommunications Information Agency
NYCT	New York City Transit
OCC	Operations Control Center
OCTA	Orange County Transportation Authority (California)
PARIS	Passenger Routing and Information System
PATH	Port Authority Trans-Hudson (New York City/New Jersey)
PC	Personal Computer
PCD	Personal Communications Device
PRTC	Potomac and Rappahannock Transportation Commission (Virginia)
R-GRTA	Rochester-Genesee Regional Transportation Authority (New York)
RCTIS	Regional Customer Telephone Information System
RDS	Radio Data System
RF	Radio Frequency
RFP	Request for Proposals
ROCSIM	Railroad Operations Computer Simulation
ROM	Read-Only Memory
RTD	Regional Transportation District (Denver)
SBIR	Small Business Innovative Research

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

SCADA	Supervisory Control and Data Acquisition
SEPTA	Southeastern Philadelphia Transit Authority (Philadelphia)
SMART	Suburban Mobility Authority for Regional Transportation (Detroit)
SONET	Synchronous Optical Network
SST	Seattle Smart Traveler
STO	Societe' de Transport de l'Outaouais (Hull, Quebec)
SWIFT	Seattle Wide-area Information for Travelers
TCC	Transportation Control Center
TCRP	Transit Cooperative Research Program
TDDS	Talking Directory Display System
TDM	Transportation Demand Management
TheBUS	Oahu Transit Services (Hawaii)
TIC	Traveler Information Center
TMA	Transportation Management Association
TMC	Traffic Management Center
TMS	Transportation Management Solutions
TOS	Transit Operating System
Tri-Met	Tri-County Metropolitan Transportation District of Oregon (Portland)
TRT	Tidewater Regional Transit (Norfolk, Virginia)
TTC	The Toronto Transit Commission
TTI	Texas Transportation Institute
UTA	Urban Transportation Associates
UW	University of Washington
VCTC	Ventura County Transit Commission (California)
VLU	Vehicle Location Unit
VMS	Variable Message Sign
Volpe Center	Volpe National Transportation Systems Center
VRE	Virginia Railway Express (Metro DC)
WSDOT	Washington State DOT
WSTA	Winston-Salem Transit Authority
WWW	World Wide Web

EXECUTIVE SUMMARY

This report examines the implementation status of advances in technology in the public transportation industry. The Federal Transit Administration (FTA) established the Advanced Public Transportation Systems (APTS) Program as part of the U.S. Department of Transportation's initiative in Intelligent Transportation Systems (ITS). ITS, the integration of several information and control technologies, is a tool to enhance mobility, energy efficiency, and environmental protection. The APTS program was established to encourage innovation and to develop worthwhile apporaches that use advanced technology to improve public transportation and ridesharing.

This report documents an investigation of the extent of adoption of advanced technology in the provision of public transportation service in the U.S. and Canada. It is an update to three similar reports published in 1991, 1992, and 1994. It was not an exhaustive search of every city or transit authority which has tested, planned, or implemented an advanced technology concept. Rather, it focused on some of the most innovative or comprehensive implementations, categorized broadly under four different sets of services/technologies: Fleet Management, Traveler Information, Electronic Fare Payment, and Transportation Demand Management.

FLEET MANAGEMENT

Fleet Management focuses directly on vehicles and operations, improving the efficiency and effectiveness of the services provided, and passenger safety. By making transit more efficient and reliable, it should be more attractive to prospective riders, transit operators, and the municipalities they serve.

Communications Systems

Telecommunications technology is growing and changing, stimulated largely by both a need to make better use of the limited electromagnetic spectrum to accommodate growing communication needs and spectrum allocation actions by the Federal regulating agencies. APTS technologies introduce new communications requirements. Currently, transit mainly uses conventional land mobile communication services, but it is unlikely these services alone will meet the needs of full-fledged

APTS technologies. Innovative strategies, such as trunked radio, overlaying on transmissions by conventional commercial FM radio stations, low earth orbit satellite services, or cellular phone, are potential solutions. The main benefit is an easing of the strain on the communications network and better utilization of frequency spectrum.

Geographic Information Systems

A geographic information system (GIS) combines an electronic map and a relational database and allows users to visualize and analyze relationships between non-related data whose only common feature is that they are in the same basic location. A GIS has four necessary components: computer hardware, a software package, data, and people to design and use it. There are many uses for GIS in transit, including display and analysis of: bus routes, facilities, shelters, emergency call location, trip planning route choices, on-time perfromance data, and origin and destination of ridesharing and paratransit clients.

Automatic Vehicle Location Systems

Computer-based vehicle tracking systems are being used extensively by transit agencies to monitor their vehicles. Over the last four years, their use by transit systems in the U.S. has increased more than 200 percent, and there are now at least 58 AVL systems in operation, under installation, or planned. The (real-time) location of each vehicle is determined and is transmitted to dispatch. This information may be used for a number of purposes, including taking corrective action to deviations in service, input to passenger information systems, and emergency location of vehicles in times of crises (e.g., crimes in progress, medical emergencies). Additionally, data generated over a period of time can be used for planning and management activities.

The benefits of AVL are numerous and varied. Most systems experience more efficient and on-time operations as their schedules are improved, they are better able to respond to disruptions, (e.g., a disabled vehicle), and bus operators are aware of their schedule adherence. Safety and security typically increase, since the dispatcher knows immediately where to send help. AVL information also provides very useful inputs to passenger information and traffic signal preferential treatment systems.

Automatic Passenger Counters

Automatic Passenger Counters (APCs) are an automated means for collecting data on passenger boardings and alightings by time and location. These data may be used as additions to location data for passenger information or decisions on corrective action, future planning and scheduling, or National Transit Database reporting. Most agencies currently planning to acquire APCs are including them in their AVL systems, in order to take advantage of the location information. Older APC installations are primarily stand-alone applications, although some agencies with older APC installations are linking them to their new AVL systems. Though, in some cases, APCs can be used for real-time application, they are used almost exclusively for planning, scheduling, and reporting purposes. APCs provide much more complete data at a much lower cost than is possible using manual checkers.

Transit Operations Software

Until recently, software use was usually limited to run-cutting for fixed-route operations. Now, as technology has advanced, the focus is on increasing customer satisfaction and enhancing operations. In conjunction with other APTS components, especially AVL, transportation operations software (TOS) now performs many advanced functions. Some of these are: real-time dispatching, quicker response to disruptions in service, and coordination between modes (e.g., fixed-route bus with paratransit). Additionally, TOS, combined with the appropriate hardware, allows a smaller number of operator interfaces for many functions, making the operator's job easier to perform.

TOS is especially useful in paratransit operations and management in the area of scheduling and dispatching. Vehicles may now be dispatched much more quickly after a request. Further, with TOS, agencies may now dynamically reschedule and re-route paratransit vehicles in real time, based on changes in schedules such as cancellations. Not only does this help with customer satisfaction and overall efficiency, it helps operators meet requirements of the Americans with Disabilities Act (ADA).

TRAVELER INFORMATION

Information on multiple transportation modes is provided to travelers to facilitate decision-making. Travelers can access this information through a variety of media, including telephones, monitors, cable television, variable message signs, kiosks and personal computers (PCs). 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.

Pre-Trip Information

Information provided includes transit routes, schedules, fares, and other pertinent information. The most common media employed are touch-tone telephones and human operators, but some newer systems also utilize PCs, the Internet (and World-Wide Web), pagers, personal communications devices, kiosks, or voice synthesizers. Originally directed primarily towards riders who knew the transit system, information systems now also provide easy-to-obtain information to the novice.

These systems have enabled transit agencies to reduce the time and the cost of a customer's request for information. Information access is quicker, and many calls do not even require human intervention. Many automated information systems have been implemented throughout the U.S.

In-Terminal and Wayside Information Systems

Schedule updates and transfer information are provided for passengers enroute via a number of technologies, including: electronic signs, kiosks, and television monitors. Data from technologies such as AVL help transit agencies provide information in real time. Automated in-terminal and wayside information systems are in their infancy in North America, primarily because supporting APTS technologies are only now being implemented. A few of these systems are in operation now, and many more are planned. When fully functional, these systems enable riders to make intelligent decisions enroute and should increase their confidence in and use of the transit system.

In-Vehicle Information Systems

Transit riders are provided with displays and communication devices on-board vehicles that provide information on stops, routes, schedules, and connections. The displays make transit easier for the novice to use. Further, these systems aid transit agencies in complying with ADA requirements. In-vehicle information is more common on rail modes because of the limited, exclusive rights-of-way on which they operate. Bus systems are beginning to provide automated information, often aided by data from AVL systems.

Multimodal Traveler Information Systems

These systems provide information (typically pre-trip) on several modes, including transit and traffic, via various technologies including, phones, personal computers, and the Internet. The goal of multimodal traveler information systems is reduced congestion through increased use of higher occupancy modes. A number of these systems are planned or recently have been implemented.

ELECTRONIC FARE PAYMENT

Electronic and automated fare payment systems employ electronic communication, data processing, and data storage techniques. Electronic fare media are capable of storing information in readable, writable form.

Automated Fare Payment Systems

There has been rapid growth in advanced fare payment systems, making possible: more sophisticated fare pricing systems, based on factors such as distance traveled and time of day; elimination of cash and coin handling; improved security; lowered cash handling costs; automation of the accounting and financial settlement process; improved reliability and maintainability of fare boxes; more equitable fare structures; and creation of multimodal and multi-provider transportation networks that are seamless for the rider but operationally and organizationally sound for the multiple providers.

Multi-Carrier Fare Integration Systems

Multimodal automated payment systems are fare media that can be used for more than one transit mode, such as magnetic stripe cards usable for subway, bus, and passenger ferry. The development of multimodal automated payment systems has been made possible by advancements in recent decades in electronic data processing and storage, magnetic recording technology, microcomputers, and in data communication. These systems are more convenient for the passenger and will encourage transit use.

TRANSPORTATION DEMAND MANAGEMENT TECHNOLOGIES

These technologies combine innovative approaches and advanced technologies to better utilize existing infrastructure. The goal of these technologies is to maximize the ability of the current transportation network to serve the increase in demand for transportation, through a combination of strategies, including: increased incentives towards shared rides, coordination of transportation service providers, and enhanced incident management.

Real-Time Ridesharing

Unlike regular carpooling, real-time ridesharing (also called dynamic ridesharing and single-trip ridesharing) calls for individual trips to be arranged close to the time when they are requested. A person wishing to obtain a ride initiates a request to a central clearinghouse and is then matched (if possible) with a driver who has registered for this program. Arrangements are then made by direct contact between both parties. The potential for real-time ridesharing is evident from the casual carpooling which exists in a few cities, wherein passengers waiting by the roadside are picked up by drivers wishing to form carpools in order to take advantage of the time savings offered by use of HOV lanes. There are a number of organizational, logistical, legal, insurance, and safety issues associated with real-time ridesharing that will be addressed in upcoming operational tests. If successful, organized real-time ridesharing has the potential to increase HOV use.

Mobility Manager

Mobility manager is a mechanism to integrate and coordinate transportation services offered by multiple providers. A central clearinghouse handles requests for information and services and client billing for each subscribing provider. Prospective riders need only call the clearinghouse for rides on any of the subscribing providers' vehicles and will receive a single bill (if applicable), issued and collected by the clearinghouse. Funding for the clearinghouse is provided by the subscribing agencies from part of the savings achieved through the process.

An increasing number of transportation agencies are embracing this concept. Also, critical research and practical applications of mobility management are being examined in a Transportation Research Board Transit Cooperative Research Program project entitled Strategies to Assist Local Transportation Agencies in Becoming Mobility Managers (project B-7).

Transportation Management Centers

A Transportation Management Center (TMC) employs advanced technologies to provide multimodal transportation information and/or to manage and control transportation networks. A wide range of technologies is used to collect information, including: AVL, geographic information systems, closed-circuit television, roadside-mounted radar detectors, and automatic vehicle identification. Technologies that are used to distribute traffic and transit information from a TMC include: cable TV, radio broadcasts, personal computers (with modems), information kiosks, telephone, electronic signs on-board vehicles and on highways, and highway advisory radio. The increase in coordination and information dissemination allows both for more intelligent decisions to be made on the part of trip-makers and more appropriate and timely response to incidents by transportation and emergency personnel, when they arise.

High Occupancy Vehicle Facility Monitoring

Some drivers use high-occupancy vehicle lanes with less than the minimum number of passengers required in order to take advantage of the travel time savings the lanes offer. There are a number of "manual" enforcement approaches to deter violators which vary in cost, safety and effectiveness. A number of automated methods have been considered, and a few have been the subject of limited testing. Video camera, near infrared, millimeter wave, and thermal infrared are hypothesized means to automatically identify violators, but need to be complemented with image processing and pattern recognition in order to function. The easiest technique is still at least a year away from deployment. If successful, however, automated monitoring will enable more thorough enforcement with fewer resources.

1. INTRODUCTION

Purpose of Report

This report describes the implementation status 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 adoption.

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 involves the integration of electronics, communications, navigation, passenger information, computer, and control technologies into the transportation system. It is a tool to enhance transportation mobility, energy efficiency, and environmental protection. The APTS program was established to encourage innovation and to develop worthwhile approaches that use advanced technology to improve public transportation and ridesharing. Various technologies are being tested in the APTS program, with many projects involving the integration of several different systems.

The APTS program has four major objectives. The first objective, "Enhance the Quality of On-Street Service to Customers," focuses on service to the customer. The second, "Improve System Productivity and Job Satisfaction," focuses on the system and its workers. The third, "Enhance the Contribution of Public Transportation Systems to Overall Community Goals," focuses on the community. The fourth objective, "Expand the Knowledge Base of Professionals Concerned with APTS Innovations," focuses on dissemination of information developed in the APTS program. This state-of-the-art update is one of the initiatives under the fourth objective.

Scope

This effort was a short-term investigation of the status of developments and advancements in the adoption of new technology in public transportation services in North America. It was not an exhaustive search of every city or transit authority which has tested, planned, or implemented an advanced technology concept. Rather, it focused on some of the most innovative or comprehensive implementations 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 FTA-sponsored projects and Appendices containing a comprehensive list of the individuals contacted during this study, a summary listing of APTS applications by implementing agency mentioned in this document, 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, transit operators, and the municipalities they serve. The technologies and innovations described in this chapter are:

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

2.1 COMMUNICATIONS SYSTEMS

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

- Making better use of the crowded electromagnetic spectrum;
- More fully accommodating increasing telecommunication needs; and
- Responding to spectrum allocation actions by the Federal Communications Commission (FCC) and the National Telecommunications Information Agency (NTIA).

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

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

- Bus and control center communications
    - voice
    - data
    - emergency;

- Fare payment;
- Park-and-ride operations;
- HOV/express bus lane access;
- Adaptive signal systems;
- Intermodal communications;
- Workplace/home transit and intermodal information;
- Wayside/transfer center transit and intermodal information; and
- On-board information.[1]

Of all the APTS functions requiring communications, by far the most critical is the bus/control center link. Most 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 devices. 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 bus/control center communication requirement may be satisfied by broadcast services instead of direct dedicated communications links. The spectrum allocated to FM broadcast stations 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.

State-of-the-Art Summary

The additional requirements brought about by the introduction of ITS technology to public transportation make it questionable whether utilized communications and spectrum capability will

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[1] Internal working document of the Communication Spectrum Working Group of the Intelligent Transportation Society of America APTS Committee.

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 may be necessary for the transit functions previously noted. Some of these alternatives include:

- Low earth orbit satellite services: satellite communication services under development, i.e., IRIDIUM system;
- 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;
- Wireless data services: utilization of wireless data services such as Cellular Digital Packet Data (CDPD), and commercial services such as ARDIS;
- Commercial mobile radio: for some transit services; and
- Integrated communications system: making use of a combination of mobile radio and other services such as those outlined above.

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

An alternative to using dedicated spectrum for vehicle communications is to seek status as a secondary user, where permission to operate on a non-interfering basis to primary users may be possible. "Spread spectrum" techniques (see above) lend themselves to such 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 of using spectrum-efficient signal processing techniques.) Analog cellular systems have approached a saturation level, and the application of spread spectrum techniques will allow an improvement in spectrum utilization efficiency of from three to 15 times for digital cellular systems.[2]

Applications

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. In a trunked system, the available spectrum is partitioned into a number of channels and received or transmitted signals are automatically directed to whatever channel is currently unused.

Many properties that have updated their communications systems have done so in conjunction with introduction of APTS functions such as Automatic Vehicle Location (AVL) capabilities.

Some 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 (CTA) - trunked system
- Denver Regional Transportation District (RTD) - digital system, mobile data terminals (MDTs)
- Milwaukee County Transit System (MCTS) - updated trunked system
- New Jersey Transit (NJT) - trunked analog system
- Southeastern Philadelphia Transit Authority (SEPTA) - updated system, unlicensed 900 MHz
- Bi-State Development Agency (St. Louis) - digital, MTDs
- Pierce Transit (Tacoma) - trunked 900 MHz system, MTDs
- Washington Metropolitan Area Transit Authority - trunked analog, MTDs[3, 4]

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

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

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

Telecommunications Spectrum Issues

A number of current spectrum issues may impact transit telecommunications. An important consideration in the application of telecommunication technologies to transit is 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. This issue is the subject of a current Transit Cooperative Research Program. A report, Impact of Radio Frequency Refarming on Transit Communications, documenting the results of the study, will be published by the Transportation Research Board in December 1995.[5]

Another issue concerns the spectrum formerly controlled by Federal government agencies which is being turned over to the FCC for reallocation to private sector use. 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.

This situation 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.

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[5] Instructions on how to obtain copies of the report can be obtained from the TCRP office at (202) 334-3886, or the Volpe Center at (617) 494-2131.

2.2 GEOGRAPHIC INFORMATION SYSTEMS

A geographic information system (GIS) has been described as "A system of computer hardware, software, and procedures designed to support the capture, management, manipulation, analysis, modularity and display of spatially referenced data..."[6] In the transit environment, GIS can be used for solving complex planning problems, operations planning, and other management and operational needs, including AVL operations.

GIS is a combination of an electronic map and a relational database that allows a user to visualize and analyze the relationship between non-related data whose only common feature is that the information shares similar geographic location. An example is a database containing the location of the bus stops in a city's transit system and the 1990 Census population data by geographic area. By using their common geography to determine how many people live within a certain distance of a bus stop, together with commute patterns and income levels, a transit planner can make better decisions regarding service needs.

A GIS has four necessary components: computer hardware (a personal computer or a workstation), a software package (for analysis of relationships and interfaces with databases), data (from various Government, commercial and internal sources), and people to design it and use it.[7] The number of different uses for GIS in transit are numerous. Among its many applications, a GIS can be used for the display and/or analysis of the following:

- bus routes, streets, parking lots, facilities, shelter locations, ridership loadings, running times, scheduling, bus assignments, dead-head routings, accidents, and customer complaints - for service and facilities planning;
- street and route maps, service performance monitoring, vandalism location and history, and emergency call location identification - for operations purposes;
- land uses, employer sites, demographic data, and travel patterns - for market development;
- bus route maps, trip planning route choices, on-time performance data, multi-media displays, pass sales outlet planning, and customer complaint data - for customer information/service purposes;
- customer address location, service qualification determination, and service performance statistics - for Americans with Disabilities Act service operations; and

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[6] Federal Interagency Coordinating Committee Technology Working Group, **A Process for Evaluating Geographic Information Systems, Technical Report 1**, U.S. Geological Survey Open-File Report 88-105.

[7] Rabkin, Matthew D. and Dmitri S. Slavnov, **Analysis of the Need for GIS in the City of the Boston Transportation Department**, April 20, 1994.

- origin and destination of ridesharing applicants, custom bus service requests, and HOV lane violations - for other transportation service analyses.[8]

Since information on GIS systems was not solicited during the data collection effort for this report, it is not possible to judge the extent of GIS deployment. However, transit operators with global positioning system AVL systems, as well as newer signpost systems usually also have a GIS.

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 trucking fleets, police cars, and ambulances. Further, their use in transit applications is growing, driven by the following expected benefits:

- Increased overall dispatching and operating efficiency;
- More reliable service, promoting increased ridership;
- 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, reducing maintenance costs;
- Inputs to traffic signal preferential treatment actuators; and
- More extensive planning information collected at a lower cost than manual methods.

Over the last four years, AVL use in U.S. transit systems has increased more than 100 percent.

The system operates 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. Typically, position information is stored on the vehicle for a time, which can be as short as a few seconds or be as long as several minutes or can depend on an outside trigger (passing a specified location or being polled). Sometimes the information is relayed to the central location in raw form, and sometimes it is processed on-board the vehicle.

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[8] Neuerburg, Nancy, Wayne Watanabe, Bob Peterson, Lisa Landkamer Yale, and Eddie Speer, **Geographic Information Systems Project Phase 1 Feasibility Study, User Needs Assessment Document**, Metro, Seattle, Washington, July 1992.

Other APTS applications which can be (and often are) linked to the AVL include:

- 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 (see Section 2.4);
- Computer aided dispatch (see Section 2.5);
- Traffic Signal Preferential Treatment - avoiding the need for driver intervention; and
- Automated fare payment systems (see Chapter 5).

State-of-the-Art Summary

There are at least 58 AVL systems in operation, under installation, or planned in the U.S. and at least six in Canada. At a minimum, each includes a specific location technology (or technologies) and a method of transmitting the location data from the bus to dispatch. Usually, each system has one or more tie-ins to other features, such as passenger information systems, automated passenger counters, or silent alarms.

Location Technology

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

- Signpost and odometer
- Global Positioning System (GPS) (Satellite Location)
- Radio navigation/location
- Dead-reckoning

In some cases, a single location technology is sufficient for position determination. Often, however, the primary location technology must be supplemented with another, due either to the environment in which the system operates (e.g., the topography) or the demands of the agency's application of the AVL system.

Table 2.1 lists current statistics on AVL systems. Until two years ago, the most common form of AVL chosen by transit agencies was the signpost and odometer system. A series of radio beacons are placed along the bus routes, normally mounted on utility poles. Typically, the beacons each have a unique ID and send out a low-powered signal which can be detected by a vehicle fitted with a receiver. When it is time for the vehicle to report, it relays the ID of the last signpost it passed to the control center, along with a measure (from the odometer) of the distance it traveled since passing the signpost. Under an alternate strategy, each bus has a unique ID, and the signposts receive signals from the buses. The signpost then relays the bus' location to the control center as it passes. The alternate method reduces radio traffic and the need for many reserved radio frequencies, since stationary signposts may by wired into the communication system. The traditional method, however, since the bus may report its location at any point, and not just when a signpost is passed, offers a greater range of positions from which the bus may be located.

Signpost and odometer technology is well tested, having been employed by transit systems for a number of years. However, it is limited due to the requirement that signposts be placed at known locations, and it requires high levels of maintenance. It can only operate where signposts are located. Thus, changes in bus routes could require the installation of additional signposts. Additionally, the system is incapable of tracking vehicles which stray off-route. Some major bus systems are in the process of installing new signpost and odometer systems, although most agencies installing new systems are choosing GPS-based systems.

GPS technology uses signals transmitted from a network of 24 satellites in orbit, and receivers placed on the roof of each bus. The bus reads the signals from a few satellites and transmits the location to dispatch. GPS works anywhere the satellites will reach - the coverage area includes all of North America - so it is far more robust than signpost and odometer. Additionally, since the satellites are already in orbit, the only cost of the location technology is the receivers. However, satellite signals do not reach underground and can be interrupted by the presence of tall buildings on

Table 2.1 North American AVL Systems - Location Technology Summary

	Operation	Installation/Plan	Total
Signpost and Odometer	14	3	17
Global Positioning System	10	30	40
Other	4	3	7
Total	28	36	64

"Other" refers to dead-reckoning, ground-based radio, or one of these supplemented by signposts or GPS.

either side of the street ("urban canyons") 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 employing selective availability of the satellites, which results in decreased position accuracy, a number of transit operations are installing "differential GPS" (DGPS) which can correct for this inaccuracy. Under DGPS, a GPS receiver is placed at a stationary site whose location has been precisely determined. The difference in the known location and the GPS-measured location is used to improve the accuracy of the position determination of the vehicles.

Ground-based radio includes 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. It determines location, based on the reception of transmissions and associated timing. Drawbacks for land vehicle location is its susceptibility to radio-frequency and electromagnetic interference. Interference from close proximity to overhead power lines and substations in urban and industrial areas can cause significant errors (as much as 1,000 meters) in time difference calculations. There are also problems with signal reception in urban canyons. As a result, Loran-C is no longer widely used for intensive real-time vehicle tracking.

There is, however, a form of ground based radio system which is proving to be effective in generalized vehicle tracking. In the Los Angeles area, for example, a private vendor, PacTel Teletrac, serves a variety of clients in several different businesses including: package delivery, an ambulance service, a sanitation service and a transit system. PacTel Teletrac services are supported by a radio location system that operates on radio frequencies in the 900 MHz band. Transmitting and receiving towers are placed strategically throughout the metropolitan region. By triangulating the signal at its receiving towers, PacTel is able to locate a vehicle within 150 feet. Positions of vehicles are relayed back to subscribers' base stations where they are shown on display maps. Multiple users of the radio towers leads to a relatively low subscriber's rate.

Data Transmission to Dispatch

The two most common methods of getting the location data to dispatch are polling and exception reporting. Under polling, the computer at dispatch polls each bus, in turn, asking it for its location. This requires the bus to be able to read and/or calculate its position from the signpost, satellite, or radio signals and its own odometer (if applicable). Once all the buses have been polled, the computer starts again with the first bus and repeats the cycle. The amount of time it takes to complete a cycle will increase as the number of buses to be polled increases. However, since the computer can poll different buses simultaneously over different radio channels, the time to complete a polling cycle will depend on the number of channels which are available. The agencies which employ polling have cycles as short as a few seconds, or as long as several minutes.

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 (e.g., more than one minute early or more than five minutes late). Barring a location report, dispatch assumes that the bus is on schedule. Exception reporting requires each bus to know not only its position, but also its scheduled position. The additional hardware and software complexity required increases per vehicle costs, but makes more efficient use of available radio channels. Many agencies use a combination of polling and exception reporting.

Applications

Table 2.2 contains a listing of known existing or planned transit AVL systems in North America, as of September 30, 1995. An effort was made to make this list as complete as possible. A representative sample of applications using the various technologies follows.

Table 2.2 North American Transit AVL Systems

City System	Location	Vehicles	Vendor	Cost	Status (as of 9/30/95)	Report	Extras	Comment
Phoenix, AZ PTS	GPS	all 450			Bids due 12/95, Demand Response implemented first		CAD, SA	
Tucson, AZ SunTran	GPS	all ~200 fr	Rockwell Int'l	3.5	Installation began 12/95, 18-24 month implementation	p 40	CAD, PIkv (40 veh), APC, EP, SA, (SP)	
Alameda, CA Ferry Svcs.	GPS	all 2 ferry boats			RFP out - expected implementation during 1996		PIpk, PIv (one boat)	Major goal: enhance safety in fog and times of high boat traffic in harbor
Los Angeles, CA LAMTA	SO	all 2085 fr (ph)	Gen. R'way Signal	~12	36 buses equipped now, install. on next 1000 began Oct/Nov	p 120	CAD, (PI), (SC), EP, SA, SP*	location accuracy "very good" in early test; minor software giltches
Napa, CA The Vine	GPS	all 18	3M Corp	0.13	prototype test began 3/95		CAD, PIp, SA, SP	
Oakland, CA AC Transit	GPS	all 702			RFP out Oct 1995	e	CAD, PIk, APC, EP, SA	
San Francisco, CA Muni	SO	all 1000	Motorolla		implemented 1985, used mainly for emergency response	"line poll"	SA	"not very accurate" due to low poll rate and SF hills; great for emergency resp.
San Jose, CA Outreach	GPS	15 bus, 55 van & taxi	UMA, Trimble		expected implementation early 1996		CAD, SA	paratransit system
San Mateo, CA SamTrans	SO	all 320	Motorolla		Operatonal Since 1994			

Key:

Shaded rows indicate systems in operation.

Location - Principle location technologies employed. "SO" - signpost & odometer, "GPS" - Global Positioning System, "DR" - dead-reckoning, "LC" - Loran-C, "GBR" - other ground-based radio

Vehicles - (ph) - phased implementation, "fr" - fixed route, "dr" - demand response, "rl" - rail, "sv" - supervisory, number is the number equipped when complete

Vendor - the primary vendor/system integrator

Cost - in millions of dollars, when purchased (Canadian systems costs are in Canadian dollars.)

Report - reporting strategy employed (bus to dispatch). "p" - polling, "e" - exception reporting, "vi" - vehicle-initiated, "st" - signpost transmitted, "sp" - at signpost passage, number is time in seconds. "line poll" uses three base stations, and moves on if a bus is temporarily out of range. * - data not received in real time

Extras - other aspects of the system (see text). CAD = Computer-Aided Dispatch, PI = Real-Time Passenger Information (followed by a "k" indicates en route displays or kiosks, followed by a "p" indicates phone information, followed by a "v" indicates automated in-vehicle information), SC = Smart Cards, APC = Automatic Passenger Counters, EP = Engine Component Probes, SA = Silent Alarm, SP = Signal Pre-Emption. Parentheses indicate that the item is a future possibility, and not part of the current project. An asterisk indicates that the item is part of a separate project.

Table 2.2 North American Transit AVL Systems (continued)

City System	Location	Vehicles	Vendor	Cost	Status (as of 9/30/95)	Report	Extras	Comment
Santa Monica, CA SMMBL	GBR (leased)	all 135	Teletrac	0.13	in regular use since 1992	*		system is leased - data is transferred on request but is not used in real-time
Stockton, CA RTD	GPS	all 106			RFP out 9/95, installed by early to mid 1996		CAD, PIp, (SC), EP, SA, SP	
Denver, CO RTD	GPS	all 900	TMS	11	Final acceptance anticipated 12/95	e/p 120	CAD, PIk, (SC), SA	some software difficulties early in the installation process
Cocoa, FL SCAT	GPS	12-13 of 28 fr	Harris Corp.		Demonstration Project, anticipated on-line spring 96		CAD, PIv, EP, SA	some difficulty obtaining dedicated radio frequency
Ft. Lauderdale, FL BCT	GPS	all 200 fr, all 30 sv			RFP out 7/95, contract 11/95-1/96	p ~60	CAD, (PIp), (APC), SA	
Miami, FL MDTA	GPS	all 610	Ericson, GE, Harris Corp.	14.5	Installing, testing system; expected complete 12/95	p 120	CAD, (PI), EP, SA	
Palatka, FL Arc Transit	GPS	all 14 fr all 6 dr	Management Analysts	0.44	Installing, testing system	p 3	CAD, (PIcable?), SC	Fully integrated card readers and medicaid billing system
Palm Beach, FL CoTran	SO	*none*	Motorolla		System abandoned			Interfered w/reg. comm.-possible future system w/new tech (GPS?)
Tampa, FL Hartline	SO	all 175	Motorolla		Regular operation since 1993	vi 120	(SC), SA	
Atlanta, GA MARTA	GPS	250 of 750 bus	TMS	7	Contractor on-board, operational by 3/31/96	vi 120	CAD, (PIk), PIv, APC, SA, (SP)	linked to state-wide multi-modal, multi-jusidictional ATMS

Key:

Shaded rows indicate systems in operation.

Location - Principle location technologies employed. "SO" - signpost & odometer, "GPS" - Global Positioning System, "DR" - dead-reckoning, "LC" - Loran-C, "GBR" - other ground-based radio

Vehicles - (ph) - phased implementation, "fr" - fixed route, "dr" - demand response, "rl" - rail, "sv" - supervisory, number is the number equipped when complete

Vendor - the primary vendor/system integrator

Cost - in millions of dollars, when purchased (Canadian systems costs are in Canadian dollars.)

Report - reporting strategy employed (bus to dispatch). "p" - polling, "e" - exception reporting, "vi" - vehicle-initiated, "st" - signpost transmitted, "sp" - at signpost passage, number is time in seconds. "line poll" uses three base stations, and moves on if a bus is temporarily out of range. * - data not received in real time

Extras - other aspects of the system (see text). CAD = Computer-Aided Dispatch, PI = Real-Time Passenger Information (followed by a "k" indicates en route displays or kiosks, followed by a "p" indicates phone information, followed by a "v" indicates automated in-vehicle information), SC = Smart Cards, APC = Automatic Passenger Counters, EP = Engine Component Probes, SA = Silent Alarm, SP = Signal Pre-Emption. Parentheses indicate that the item is a future possibility, and not part of the current project. An asterisk indicates that the item is part of a separate project.

Table 2.2 North American Transit AVL Systems (continued)

City System	Loca-tion	Vehicles	Vendor	Cost	Status (as of 9/30/95)	Re-port	Extras	Comment
Sioux City, IA Sioux City TS	GPS	14 of 32			Funding approved, preparing RFP		CAD	
Chicago, IL CTA	DR, GPS	all 2080 bus (ph)			Installation to begin early 1996	vi e	CAD, SC*, APC*, EP, SA*, SP	1st RFP out 94, not enough $ available, re-issued in 1995
Chicago, IL PACE	prob. GPS	all 600 bus			RFP out 8/95, due 12/1/95		CAD, PI?, APC*, EP, SA, SP	
Rock Island, IL RICMT	GPS	all 58 bus			expected implementation spring 1996		CAD, PIcomputer, PIk, SA	
Gary, IN GPTC	GPS	all 32 (dr)		0.14	In bid process		CAD	
Louisville, KY TARC	SO	all 257 bus	Glenayre	2.5	Operational since 1994, resolving some issues	p 40	CAD, (SC), APC, EP, SA	insufficient accuracy in sched. database, had contractor problems
New Orleans, LA RTA	GPS	all 500+			Doing feasibility study		CAD, PIpv, EP, SA, SP	Previous test of kiosks - kiosks failed, mostly due to vandalism
Baltimore, MD MTA	GPS	all 935 (ph)	TMS	8.9	Bus install. proceeding, all rail done - complete 12/96	p 120	CAD, (PIv), (APC), SA	former sucessful test of Westinghouse Loran-C system on 50 buses
Montgomery, MD Ride-On	GPS	all 250	Orbital Sciences		Installation proceeding, expected complete by 10/96		CAD, EP, SA, SP	signal pre-emption a major component of system
Ann Arbor, MI AATA	GPS	all 70 fr all 10 dr			RFI out 7/95; expected to be installed by 3/96		CAD, PIcableTV, (PIk) SC*, EP, SA	agency terminated prior contract in late 1994

Key:

Shaded rows indicate systems in operation.

Location - Principle location technologies employed. "SO" - signpost & odometer, "GPS" - Global Positioning System, "DR" - dead-reckoning, "LC" - Loran-C, "GBR" - other ground-based radio

Vehicles - (ph) - phased implementation, "fr" - fixed route, "dr" - demand response, "rl" - rail, "sv" - supervisory, number is the number equipped when complete

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Table 2.2 North American Transit AVL Systems (continued)

City System	Location	Vehicles	Vendor	Cost	Status (as of 9/30/95)	Report	Extras	Comment
Detroit, MI SMART	GPS	all 250 fr all 150 dr	TMS	2.7 - 8	Installation began 7/95, to finish 7/96	p 120	CAD, (PIkp), (APC), EP, SA, SP?	Buses used as probes for MDOT freeway monitoring
Minneapolis, MN MTC	GPS	80 of 810 bus	TMS	6.5	1 year operational test, 12/94 to 12/95		CAD, PIk, APC* PImodem	Huge benefit to security in knowing bus' exact location
Kansas City, MO KCATA	SO	all 250 bus			Developing Specs for signpost upgrade, bid out 8 or 9/95	prob p	(APC), SA	Old signposts began malfunctioning 18months after installation
Raleigh, NC CAT	GPS	all 40 fr all 12 dr			Solicitation for Letters of Interest out 9/95		CAD, PIp, PIcableTV, SA	"Seemless (transit) system" with guaranteed, timed transfers
Winston-Salem, NC WSTA	GPS	3 of 17 dr	GMSI		Operational 5/95, to be expanded to all 17 vehicles	p	CAD, PIp, SC, SA	Part of CAD for dr system, focus of project was not on AVL
Newark, NJ NJT	SO	all 800 bs Essex Co.	Motorolla		2 lines done, installation of rest over next 2 years	sp, 600	CAD, SA, PIkp-disrupt'ns only	To use GPS for rail; investigating cellular tri-angulation
Albuquerque, NM Sun Tran	GPS	all 40 dr	On-line (software)		Software installed, RFP on MDTs due 9/95, AVL done 3/96	prob p	EP?, SA	Demand-response system
Albany, NY CDTA	SO	all 232 bus	Motorolla		Operational since 1994	p 240	CAD, EP, SA	
Buffalo, NY Metro	GPS	all 355fr, 35dr,25sv	Harris Corp.	9.6	Contract awarded 7/95, installation 8/95-1/97	e, p 120	CAD, PIv, (PIp), (APC), EP, SA	
Long Island, NY MTA LI Bus	GPS	all 318 bus			RFP out 9/95, 12-18 month implementation	e	CAD, PIv, SA	

Key:

Shaded rows indicate systems in operation.

Location - Principle location technologies employed. "SO" - signpost & odometer, "GPS" - Global Positioning System, "DR" - dead-reckoning, "LC" - Loran-C, "GBR" - other ground-based radio

Vehicles - (ph) - phased implementation, "fr" - fixed route, "dr" - demand response, "rl" - rail, "sv" - supervisory, number is the number equipped when complete

Vendor - the primary vendor/system integrator

Cost - in millions of dollars, when purchased (Canadian systems costs are in Canadian dollars.)

Report - reporting strategy employed (bus to dispatch). "p" - polling, "e" - exception reporting, "vi" - vehicle-initiated, "st" - signpost transmitted, "sp" - at signpost passage, number is time in seconds. "line poll" uses three base stations, and moves on if a bus is temporarily out of range. * - data not received in real time

Extras - other aspects of the system (see text). CAD = Computer-Aided Dispatch, PI = Real-Time Passenger Information (followed by a "k" indicates en route displays or kiosks, followed by a "p" indicates phone information, followed by a "v" indicates automated in-vehicle information), SC = Smart Cards, APC = Automatic Passenger Counters, EP = Engine Component Probes, SA = Silent Alarm, SP = Signal Pre-Emption. Parentheses indicate that the item is a future possibility, and not part of the current project. An asterisk indicates that the item is part of a separate project.

Table 2.2 North American Transit AVL Systems (continued)

City System	Location	Vehicles	Vendor	Cost	Status (as of 9/30/95)	Report	Extras	Comment
New York, NY NYCT	GPS, DR	all 170 bs on 4 rtes			RFP due 8/95, Installation expected complete 7/97	e	CAD, PIk, (PIp), EP, SA	Also 30 non-revenue vehicles
Rochester, NY RGRTA	GPS?	all 215 fr all 21 pt?			RFP out 1/96 for new radio system, possibly to include AVL		CAD?, PIv*, EP*, SA*	Existing test of 10 GPS actuated on-board enunciators on 2 routes
Syracuse, NY RTA	GPS	all 180 bs in core sys			Spec Development - no set schedule	prob e	PIv, APC?, EP, SA	Goal: 95% schedule adherence
White Plains, NY Bee-Line	SO	95% of 332 fr	Motorolla		Regular operation since 1983, upgrading to GPS in 1½ years		SA	SO system reliable, but limited. GPS will have more options and include dr
Cincinnati, OH SORTA	GPS	all 380 fr opt 33 dr			RFP out 7/95, due 10/95		CAD, PIv, (PIk), (APC), EP, SA	had demo GM SO AVL in late 70s, early 80s. Very positive results.
Grand River, OH Laketran	GPS	all 64 dr all 14 fr			Best and Final Offer due 12/15/95		CAP, PI, SA	
Portland, OR Tri-Met	GPS	all 630 fr all 140 dr	Orbital Sciences	5.2	Final design review complete, installation began 11/95	e 300	CAD, (PI), APC, SP?, SA	engine probes gave false alarms
Rochester, PA Beaver County TA	LC	13 of 36 fr	Motorola	0.05	Regular operation since 1991, working on "next generation"	p	PI, SA	"valuable tool", on-time performance up, complaints are down
Scranton, PA COLTS	GPS	all 32 fr	AutoTrac	0.3	Regular operation since 10/94		CAD, PIv, SA	great record-keeping tool; "buses on time;" easier ADA compliance
Corpus Christi, TX CCTS	GPS	all 110 bus			RFP out in Fall 95		CAD, PIkv, APC, EP, SA, SP*	fully integrated system with police, fire, emergency response

Key:

Shaded rows indicate systems in operation.

Location - Principle location technologies employed. "SO" - signpost & odometer, "GPS" - Global Positioning System, "DR" - dead-reckoning, "LC" - Loran-C, "GBR" - other ground-based radio

Vehicles - (ph) - phased implementation, "fr" - fixed route, "dr" - demand response, "rl" - rail, "sv" - supervisory, number is the number equipped when complete

Vendor - the primary vendor/system integrator

Cost - in millions of dollars, when purchased (Canadian systems costs are in Canadian dollars.)

Report - reporting strategy employed (bus to dispatch). "p" - polling, "e" - exception reporting, "vi" - vehicle-initiated, "st" - signpost transmitted, "sp" - at signpost passage, number is time in seconds. "line poll" uses three base stations, and moves on if a bus is temporarily out of range. * - data not received in real time

Extras - other aspects of the system (see text). CAD = Computer-Aided Dispatch, PI = Real-Time Passenger Information (followed by a "k" indicates en route displays or kiosks, followed by a "p" indicates phone information, followed by a "v" indicates automated in-vehicle information), SC = Smart Cards, APC = Automatic Passenger Counters, EP = Engine Component Probes, SA = Silent Alarm, SP = Signal Pre-Emption. Parentheses indicate that the item is a future possibility, and not part of the current project. An asterisk indicates that the item is part of a separate project.

Table 2.2 North American Transit AVL Systems (continued)

City System	Location	Vehicles	Vendor	Cost	Status (as of 9/30/95)	Report	Extras	Comment
Dallas, TX DART	GPS	1200 of 1300 fr,sv	ElectroCom	16.4	Last glitches expected to be resolved by the end of 11/95	p 120	CAD, EP, SA	reliability problems in 1994, worked out
El Paso, TX Sun Metro	GPS	all 160 fr all 62 dr			Specs complete - project on hold for funding		CAD, (PI), APC, SA	
Houston, TX Metro	DR+ ???	all 1750 veh		22 + 6	radio/comm backbone procured, RFP for AVL released late 95		CAD, PIk, PIv?, (APC), EP, SA, (SP)	additional location rechnology will be determined in the bid process
San Antonio, TX VIA	SO	all 531 veh	Gen R'way Signal	3.7	Regular use since 1987; examining potential upgrades	p 60		
Norfolk, VA TRT	SO	all 151 veh	F&M Global	2	Regular use since 1991	p 40	EP, SA	allows tighter scheduling, functioning very well, reduced pass. complaints
Woodbridge, VA PRTC	GPS	all flex-route	Gandalf		Installing AVL, expected compete by mid-1996		CAD, SA	new transit operation, major purpose of AVL to assist flexible routing of buses
Bremerton, WA Kitsap Transit	GPS	all 155 veh	3M Corp	0.6	Phase I testing (buses in central area) expected complete early 96	e	CAD, PIk, (PIpv), SA, SP	Phased project: II - outlying area buses; III - paratransit veh.; IV - ferries
Seattle, WA KC Metro	SO	all 1250 revenue	Harris Corp.	15	Regular use since 1993	p 90	CAD, PIradio*, APC, SA, SP*	operators rely on increased security
Milwaukee, WI MCTS	GPS	all 550 fr all 50 sv	TMS, Trimble, Motor	7.8	Final acceptance anticipated 12/95	p 45	CAD, (PI), (APC), SA	
Sheboygen, WI STS	LC	20 of 33 bus	II Morrow	0.1	Regular use since 1991			

Key:

Shaded rows indicate systems in operation.

Location - Principle location technologies employed. "SO" - signpost & odometer, "GPS" - Global Positioning System, "DR" - dead-reckoning, "LC" - Loran-C, "GBR" - other ground-based radio

Vehicles - (ph) - phased implementation, "fr" - fixed route, "dr" - demand response, "rl" - rail, "sv" - supervisory, number is the number equipped when complete

Vendor - the primary vendor/system integrator

Cost - in millions of dollars, when purchased (Canadian systems costs are in Canadian dollars.)

Report - reporting strategy employed (bus to dispatch). "p" - polling, "e" - exception reporting, "vi" - vehicle-initiated, "st" - signpost transmitted, "sp" - at signpost passage, number is time in seconds. "line poll" uses three base stations, and moves on if a bus is temporarily out of range. * - data not received in real time

Extras - other aspects of the system (see text). CAD = Computer-Aided Dispatch, PI = Real-Time Passenger Information (followed by a "k" indicates en route displays or kiosks, followed by a "p" indicates phone information, followed by a "v" indicates automated in-vehicle information), SC = Smart Cards, APC = Automatic Passenger Counters, EP = Engine Component Probes, SA = Silent Alarm, SP = Signal Pre-Emption. Parentheses indicate that the item is a future possibility, and not part of the current project. An asterisk indicates that the item is part of a separate project.

Table 2.2 North American Transit AVL Systems (continued)

City System	Location	Vehicles	Vendor	Cost	Status (as of 9/30/95)	Report	Extras	Comment
Halifax, NS MTD	SO	all 168 bus	(agency did integration)	1	Regular use since 1987, upgrades in progress, esp to software	p 30	CAD, PIpk, SA	more accurate info to public; had APC-not reliable; had EP-false alarms
Hamilton, ON HSR	DR	all 240 veh	RMS Industrial	6	Regular use since 1991	p 30	CAD, APC*, SA	on time perfomance went from 82-89% in last year
London, ON LTC	SO	all 160 veh	Siemens	2	Pilot install. on 1 vehicle of each type; operational early 1997	p 30	CAD, (PIp), (APC), EP, SA, (SP?)	Primarily for communication, holding buses for passenger transfers
Ottawa, ON OC Transpo	SO	all 825 veh	Amtech		Operational 3/95	st	CAD, APC*, SA	system to be evaluated over the next year
Toronto, ON TTC	SO	all 2300 veh	Bell Radio	38	Fully operational since 1992 (1st division on line in 1985)	poll 6	CAD, PIv, SA, SP	APC tried, double-counted; AVL gives much greater safety; 42 radio channels
Hull, QC STO	SO	all 183 veh	Fishbck & Mre, Gndlf		Operational since 1984, upgrading dispatch/PI software	sp	CAD, PIp, SC*, (APC), EP, SA, SP*	Many benefits (see text)

Key:
Shaded rows indicate systems in operation.
Location - Principle location technologies employed. "SO" - signpost & odometer, "GPS" - Global Positioning System, "DR" - dead-reckoning, "LC" - Loran-C, "GBR" - other ground-based radio
Vehicles - (ph) - phased implementation, "fr" - fixed route, "dr" - demand response, "rl" - rail, "sv" - supervisory, number is the number equipped when complete
Vendor - the primary vendor/system integrator
Cost - in millions of dollars, when purchased (Canadian systems costs are in Canadian dollars.)
Report - reporting strategy employed (bus to dispatch). "p" - polling, "e" - exception reporting, "vi" - vehicle-initiated, "st" - signpost transmitted, "sp" - at signpost passage, number is time in seconds. "line poll" uses three base stations, and moves on if a bus is temporarily out of range. * - data not received in real time
Extras - other aspects of the system (see text). CAD = Computer-Aided Dispatch, PI = Real-Time Passenger Information (followed by a "k" indicates en route displays or kiosks, followed by a "p" indicates phone information, followed by a "v" indicates automated in-vehicle information), SC = Smart Cards, APC = Automatic Passenger Counters, EP = Engine Component Probes, SA = Silent Alarm, SP = Signal Pre-Emption. Parentheses indicate that the item is a future possibility, and not part of the current project. An asterisk indicates that the item is part of a separate project.

A. Signpost and Odometer

Halifax, Nova Scotia

Metro Transit's AVL system has been in operation since 1987. All of the agency's 168 buses are equipped with signpost receivers and magnetic wheel sensors. The central computer at dispatch polls the buses approximately every 30 seconds to update its record of bus positions. Metro Transit is in the process of adding computer-aided dispatch (CAD) software (see Section 2.5.1), to aid the dispatcher. The AVL system already provides passengers real-time bus location information both over the phone and via kiosks. Each bus is equipped with a silent alarm which the driver may activate in an emergency. The AVL system once included engine component probes, which were abandoned because they were too sensitive, often sounding the alarm for problems that could have waited. Automatic Passenger Counters (APCs) were also once part of the system, but were also abandoned, because they were found to be unreliable.

Metro Transit is enthusiastic about the system. With the system, they are better able to manage the fleet. This includes both designing schedules that are easier to keep and better serve the public, and responding to situations in real-time (e.g., bus bunching, a bus ahead of schedule). Further, the AVL system enables them to provide the public with more accurate, real-time information.[9]

Norfolk, Virginia

Tidewater Regional Transit (TRT) has been operating a signpost and odometer system procured from F & M Global since 1991 on all of its 151 vehicles. The computer at dispatch polls the vehicles every 40 seconds. There is no grand map display, since the system was developed before the recent advances in computer technology and software. TRT uses the system for real-time corrections to service, and to produce "tighter" schedules. According to TRT, the system is functioning very well in both of those roles. In addition, they note a reduction in passenger

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[9] **Moss Mombourquette, Metropolitan Transit Division of the Metropolitan Authority, Halifax, Nova Scotia, Canada.**

complaints since the system was implemented and a better ability to respond to complaints in general. The system also includes engine component probes, and a driver silent alarm.[10]

Seattle, Washington

Metro has equipped all of its 1,250 revenue vehicles with a signpost and odometer AVL system. The AVL, provided by Harris Corporation, has been operational since 1993 and is linked with numerous other projects. The system includes a silent alarm for the driver and CAD. Each dispatch station includes two computer screens with a digital map of the service area (or a user-specified subset of the area) and several automated dispatch functions, such as communications with the drivers and incident logging. In addition, the system will provide input to an FM radio station which will include real-time information on all relevant commute modes.

Metro is quite pleased with the system. They are especially happy with the increased safety and security the silent alarm and knowledge of a vehicle's exact location in real time provides. According to the agency, the vehicle operators have come to rely on this feature. Additionally, the AVL system has been used to assist the agency in responding to customers' complaints, when they arise. With a record of exactly what happened, it is much easier either to give upset riders a response that will satisfy them, or, if the complaint is unwarranted, to feel confident in dismissing it.[11]

Toronto, Ontario

The Toronto Transit Commission (TTC) has a very large and well-established signpost and odometer system. TTC operates 2,300 buses in several divisions. The first division was outfitted with AVL in 1985, and installation in the last division was complete in 1992. Buses are polled every six seconds, made possible by the large number of dedicated radio frequencies the agency has for this purpose. The system is equipped with CAD and a silent alarm for the driver. Additionally, the system inputs to on-board enunciators, which provide audible next-stop announcements en route.

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[10] Milt Woodhouse, Tidewater Regional Transit, Norfolk, Virginia.

[11] Dan Overgaard, King County Metro, Seattle, Washington.

As do many other systems, TTC cites an increase in safety and security as a major benefit of the system.[12]

Westchester County, New York

The Westchester County DOT (White Plains area) has been operating a Motorola signpost and odometer AVL system on most of their 332 buses since 1983. The agency finds the AVL system performs quite well, and uses it for complaint investigation and some real-time adjustments to schedules. However, since the system has not been updated and still uses 1983 state-of-the-art computers, it is in need of replacement. The agency is doing a feasibility study to determine which location technology would be most appropriate for the new system, and what additional features to include in the new system.[13]

Newark, New Jersey

New Jersey Transit is in the process of installing a signpost and odometer system on 800 buses serving all their routes in Essex County (Newark), New Jersey. Nearly 2,000 more buses in the state will be equipped with a more limited form of the system. Two of the lines are already equipped, and the rest will be complete within the next two years. Buses report their location over an 800 MHz trunked radio channel every ten minutes or when a signpost is passed. The system will include silent alarms for the drivers and automated on-board vehicle "next-stop" announcement by means of verbal enunciators. The system also will provide input to the telephone information system when there is a major service disruption. The goals the agency has for AVL are to improve vehicle performance, reduce vehicle maintenance, be able to perform appropriate real-time service adjustments, and to improve service planning.[14]

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[12] **Adelgard vonZittwitz, Toronto Transit Commission, Toronto, Ontario, Canada.**

[13] **Carol Schweiger, EG&G Dynatrend, Burlington, Massachusetts.**

[14] **Jim Kemp, New Jersey Transit, Newark, New Jersey.**

Hull, Quebec

The Societe' de Transport de l'Outaouais (STO) has had a signpost and odometer system on all 183 of its buses since 1984. The system includes an extensive telephone passenger information system ("Infobus"), CAD, driver silent alarm, and engine condition monitoring. STO is very happy with the system citing several benefits, including: better control of service, real-time maintenance information for reducing maintenance costs and service disruptions, better planning information, and especially an increase in security.[15]

B. Global Positioning System

Denver, Colorado

The Regional Transportation District recently has completed installation of a Transportation Management Solutions (TMS) GPS-based system on all of its 900 buses. Each dispatcher is provided with two large monitors, one of which shows a digital map of Denver (or a user-defined enlargement of part of the area) along with the location of each bus with which he or she is concerned. The buses are color-coded, based on status: on-time, early, late, or emergency-alarm-activated. The other dispatcher screen includes a number of utilities, including a record of radio traffic, and incident reports. Drivers are provided with a small control "head," through which they may send and receive messages, including automatic reports on their on-time status.

The AVL is principally used for ensuring schedule adherence, making real-time adjustments in response to service disruptions, response to emergencies, and scheduling. In addition, the AVL will be used to update in real time the departure-time monitors at the downtown terminals. There also are future plans to feed AVL information directly into the telephone information system.[16]

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

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

Atlanta, Georgia

In preparation for the 1996 Summer Olympics, the Metropolitan Atlanta Rapid Transit Authority (MARTA) is installing a TMS GPS-based system on 250 of its approximately 750 buses. The AVL will hook into both their existing CAD system and bus information kiosks located at MARTA rail transit stations. In addition to kiosks, AVL information will be sent to 15 new passenger information devices at busy bus stops (which will tell passengers whether each bus is on-time or delayed), and 100 vehicles will be equipped with audible "next-stop" enunciators and visual, digital "next-stop" signs. There will be APCs on 15 of the buses, although the passenger load information will be used for planning purposes only, and will not be available in real time. MARTA is also hoping to link the AVL into a separate signal pre-emption project. Finally, the system will include a fiber-optic link to the Georgia DOT's advanced transportation management system, a multi-modal, multi-jurisdictional system, including complete transit and traffic information, video feeds, and trip itinerary planning.[17]

Portland, Oregon

The Tri-County Metropolitan Transportation District of Oregon (Tri-Met) recently began installation (in November 1995) of an Orbital Sciences Corporation GPS-based AVL system on its entire fleet, which includes 630 fixed-route buses and 140 demand-response vehicles. The system includes CAD, automatic feedback to the driver regarding on-time performance, and APCs on 10 percent (later to increase to 20 percent) of the buses.

Tri-Met's uses for the system vary somewhat between the two modes. On the fixed-route fleet, it will be used for route and schedule adherence monitoring. On demand-response vehicles, it will be used to increase the efficiency of dispatching and to help meet ADA-mandated advance trip reservation criteria.

Future plans include extensive passenger information systems and perhaps signal pre-emption. The passenger information systems would include monitors with real-time information in the transit mall, "next-bus" displays at ten bus stops, and on-board digital signs and audible enunciators on 30

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[17] Harriet Robbins-Smith, Metropolitan Atlanta Rapid Transit Authority, Atlanta, Georgia.

new vehicles. Tri-Met is experimenting with different signal pre-emption technologies, all working on a "smart pre-emption" model, giving preferential treatment only when certain conditions are met (e.g., late-running bus).[18]

Scranton, Pennsylvania

The County of Lakawanna Transit System (COLTS) has had their AutoTrac GPS-based system in operation since October 1994. COLTS uses the system to coordinate their routes and passenger transfers between buses. All 32 of their buses are equipped with AVL and verbal enunciators, which give audible "next-stop" announcements. The agency is very enthusiastic about the system, citing that on-time performance has increased dramatically, that the enunciators help with ADA compliance, and that AVL aids record-keeping.[19]

Corpus Christi, Texas

The Corpus Christi Transit System released a Request for Proposals (RFP) in the Fall of 1995 for a GPS-based AVL system including mobile data terminals and voice enunciators on all 110 of its buses, kiosks at transfer centers, and CAD. The system will be fully integrated with county safety operations, including a joint communication center with police and fire departments. Thus, in addition to the planning and operational benefits of AVL, the agency hopes to greatly improve emergency response, not only in the case of crimes, but also in response to natural disasters (i.e., hurricanes) and man-made crises (i.e., oil refinery accidents).[20]

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

[19] Kurt Kempter, County of Lakawanna Transit System, Scranton, Pennsylvania.

[20] Len Brandrup, Corpus Christi Transit System, Corpus Christi, Texas.

C. Dead Reckoning (Combined With Another Technology)

Chicago, Illinois

CTA is about to award a contract for an AVL system which will eventually cover all 2,080 of their buses. To determine location, the system will use a combination of GPS and dead-reckoning techniques. Because of the tall buildings lining downtown streets and underpasses (both of which interfere with the bus attaining GPS signals), this combination will provide the most accurate location information. When fully implemented, the system will include MDTs on the buses, digital passenger information signs in two bus shelters (one downtown shelter, and one suburban shelter), and engine condition monitors on its new buses, and at dispatch, a Computer-Aided Service Restoration system (see Section 2.5.1).

CTA's AVL system will also include bus preferential treatment at five consecutive traffic signals covering one-half mile in the downtown area. These will be "smartly" activated to facilitate maintaining even headways, a challenge during the peak, when the headways downtown are only 90 seconds.[21]

New York City, New York

New York City Transit (NYCT) will soon be installing a combination GPS and dead-reckoning AVL system on four of its routes operating out of its 126th Street garage in Manhattan. One hundred-seventy buses and 30 non-revenue vehicles will be AVL-equipped. Although the system will be used for restoring service and ensuring on-time performance, AVL is designed primarily for inputs to the passenger information system - kiosks at transfer locations and tourist attractions and monitors and signs at selected bus stop shelters.[22]

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

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

Houston, Texas

The Metropolitan Transit Authority (Metro) tested a credit card-sized transponder which emits a low power radio frequency which buses detect. The transponder costs about $10 and has a battery rated to last ten years. Metro mounted several of these transponders on traffic signals along a street and recorded bus position data. The test produced very accurate location data, according to the agency.

Metro now is procuring a full AVL system, for all the vehicles it operates - 1,200 buses, 153 demand-response, 154 police cars, 4 motorcycles, and 263 support. They have awarded a $22 million contract to TMS for the communications backbone, complete with new radio system, and the J1708 vehicle area network standard for their buses. They are about to release an RFP for the location component of the system, which they have specified as dead-reckoning, supplemented with another location technology. The "other" location technology is not specified, and will depend on who wins the bid. Possibilities include GPS, signposts, and the credit card-sized transponders which the agency tested.

The system will include all of the more common extras, including a silent alarm for the driver, engine component monitoring, kiosks, and CAD. Metro will soon perform a pilot test of on-vehicle enunciators to determine public acceptance, before possibly equipping the whole fleet. Metro is also working with local traffic authorities to implement selective signal pre-emption.[23]

Hamilton, Ontario

The Hamilton Street Railway has had an RMS Industrial Controls dead-reckoning AVL system in operation on all 240 of its buses since 1991. Buses determine their location from a known starting point by measuring the distance they travel and using an integrated compass. Periodic corrections are provided from two signposts placed along each route. The agency uses the system for planning purposes, response to emergencies, improving on-time performance, and facilitating

[23] Bill Kronenberger, Metropolitan Authority of Harris County, Houston, Texas.

passenger transfers between buses. The agency cites an increase in on-time performance from 82 to 89 percent in the last twelve months.[24]

D. Ground-Based Radio

Rochester, Pennsylvania

The Beaver County Transit Authority has been operating a Motorola Loran-C system on 13 of its 36 fixed-route fleet since 1991. The agency feels the system has been a valuable tool, and has noted that on-time performance has increased noticeably since the system's installation, and that passenger complaints have decreased. The Loran-C is scheduled to be replaced. Rochester is a National Pilot Site for a Mobility Manager system (see section 5.2), which will include an updated AVL system. A performance-based specification for a GPS system was to be completed by the end of 1995.[25]

Santa Monica, California

The Santa Monica Municipal Bus Lines is employing an alternative form of fleet location. Their system, in regular operation since October 1992, uses Teletrac's network of transmitting and receiving antennas. The agency owns a PC-based workstation equipped with a modem, an Etak Map with a detailed database of the streets and addresses in the Los Angeles area, and communications and control software. The workstation communicates with the Teletrac control center through standard telephone lines, and the agency pays for the time its workstation is connected to the central computer. Thus, the agency does not request location information in real time, since it uses the information for planning and problem investigation only, and the cost of full-time connection would be prohibitive.[26]

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[24] Gord Heidman, Hamilton Street Railway, Hamilton, Ontario, Canada.

[25] Bruce Ahern, Beaver County Transit Authority, Rochester, Pennsylvania.

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

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. These 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.

To operate, an APC installation requires means to perform the following:

- Register each boarding and alighting (and be able to distinguish between the two);
- Determine the location of the vehicle when each boarding/alighting occurred; and
- Store the information and transmit it to a central computer so that it can be used.

The two most common technologies used to register boardings and alightings are infrared beams and treadle mats. Two infrared beams are typically placed across the passengers' path as they board or alight the vehicle. As a passenger boards, he or she interrupts the beams in a particular order, and the APC registers the boarding. Likewise, as a passenger alights, he or she interrupts the beams in the reverse order, and the APC registers the alighting. Treadle mats operate on the same principle, but these are placed on the steps (two for each doorway). The pressure of a passenger walking on them activates the APC.

The APC may be part of an AVL installation (see section 2.3) and simply use the location information already being recorded. If there is no AVL system or if the APCs are a separate system from the AVL, location will be determined using one of the options described in the previous section: signpost and odometer, GPS, ground-based radio, dead-reckoning, or a combination of these strategies.

Options for data transmission fall into two categories: real-time (at least once every 10 minutes), and off-line. The type of data transmission chosen will depend largely on the desired applications of the APC data. If the data is needed for input into real-time computer-aided service restoration, or real-time passenger information, then real-time transmission is required. If the data is only to be used for planning, schedule-building, and other uses which do not use the data until well after it is collected, most agencies find it more cost-effective to use a delayed collection method.

The most common real-time transmission method is via radio channel and works as described in the previous two sections. With an off-line technique, the data is down-loaded while the vehicle is in the garage, typically once every one to three days. Either a short distance radio link (like a cordless phone) is established with the APC on the bus, a cable is physically connected between the APC and a lap-top computer or mini base station, or a cassette is taken from the APC and brought to the main computer.

State-of-the-Art Summary

APCs were first deployed in the 1970s. These older systems pre-date real-time AVL systems and much of the computer and digital radio technology now utilized. Thus, the data collected by these systems was (and still is) used exclusively for delayed-type applications, such as scheduling and planning. Although there were numerous difficulties, most of these old systems proved to provide accurate data more quickly and at a lower cost than could be achieved with manual data collection by human checkers. Many are still in use, sometimes with updated equipment.

Currently planned APC installations are most commonly implemented in conjunction with AVL systems, in order to take advantage of the available location information.

Regardless of the manner in which it is collected, APC data is almost universally applied to delayed applications, such as planning and scheduling. The main reason for this is that most agencies do not feel there is sufficient benefit in the real-time applications of APC data to merit the additional expenses involved. Real-time application of the data would require equipping every vehicle (or a large percentage) in the fleet. Conversely, delayed applications can do very well if only a small sample (usually about 10 percent) of the fleet is equipped and the equipped vehicles rotated throughout the system.

In addition, many agencies have barely enough radio capacity to transmit the location information in real time. Adding passenger count data would put a further strain on the system and create greater delays in getting the location information to dispatch.

Applications

Known North American applications of APCs are detailed in Table 2.3. A representative sample of these applications is described in detail.

Columbus, Ohio

The Central Ohio Transit Authority (COTA) has had operational APCs since 1984, and is now upgrading its software and hardware. The original system, procured from Urban Transportation Associates (UTA) for $171,000, included the installation of infrared beam APCs on 37 vehicles (of COTA's 310) and about 105 signposts - some solar-powered, and some electric. Data is currently removed from the bus every few days by replacing a full data storage cassette tape with an empty one. As part of the upgrade, however, the cassette drives will be replaced with diskette drives, which COTA hopes will inprove the reliability of the data transfer.

COTA is pleased with its APCs, citing 95 percent accuracy of the counts. The agency likes the fact that the system is fully automated, requiring no driver input. The data they collect is used for COTA's annual National Transit Database report, system planning, schedule adherence (though not in real time), and measuring ridership on each route and run.[27]

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[27] Mike McCann, Central Ohio Transit Authority, Columbus, Ohio.

Table 2.3 North American Automatic Passenger Counter Applications

City System	Location	Counts	Vehicles	Vendor	Cost	Status (as of 9/30/95)	AVL Link	Xfer Freq
Tucson, AZ Sun Tran	GPS	ir beams	40/ 200			Bids returned 8/95, 12-15 month implementation	Yes	Daily
Oakland, CA AC Transit	GPS		100/ 702			RFP 10/95	Yes	Daily
Atlanta, GA MARTA	GPS	ir beams	15/ 250	Urban Transportation Associates		Installation proceeding, finish date 3/31/96	Yes	Daily
Chicago, IL CTA	SO	treadle mats	120/ 2000			Working out some bugs	No	
Chicago, IL PACE		ir beams	70/ 758	Urban Transportation Associates	~$1.5K/bus	Up since '87, plan: upgrade & link w/new AVL system	Linking	Daily
Louisville, KY TARC	SO	ir beams	68/ 257					Daily
Baltimore, MD MTA	GPS		25/ 900	Urban Transportation Associates		Planning as future addition to AVL	Yes	Daily
Minneapolis, MN MTC	SO	ir beams	10/ 830	Urban Transportation Associates	$150K (total)	Operational since 8/94, plan to expand to 50 equipped	No	Weekly
Columbus, OH COTA	SO	ir beams	30/ 310	Urban Transportation Associates	$171K (total)	Oper. since '84, upgrading software and hardware	No	a few days
Eugene, OR LCMTD	SO	treadle mats	12/ 95	Microtronics	$95K 1st 8, $16K new 4	Operational since 1986	No	Daily

Key:
Shaded columns indicate operational APC installations.
Location - technology used: SO = signpost and odometer, GPS = Global Positioning System, OS = odometer readings vs. scheduled position (post processing method)
Counts - method by which the system counts passengers (e.g., treadle mats or infrared ("ir") beams)
Vehicles - number equipped vs. number operated
Cost - total cost of system when the system was purchased (U.S. systems - U.S. $; Canadian systems - Canadian $)
(Cost variations may be due to varied capabilities and features.)
AVL Link - "Yes" - system is linked (or will be when installed) with an AVL system; "No" - not linked, no plans to link "Linking" - an existing, independent APC system will be linked to an existing or new AVL system
Xfer Freq. - indicates how often the data is transferred from the bus either to the central computer or to a temporary storage device.

Table 2.3 North American Automatic Passenger Counter Applications (continued)

City System	Location	Counts	Vehicles	Vendor	Cost	Status (as of 9/30/95)	AVL Link	Xfer Freq
Portland, OR Tri-Met	OS	ir beams	80/ 635	Red Pine	$4.5K/bus, $5K/retrieval unit	Oper. since 1982, plan to link with new AVL system	Linking	Daily
Corpus Christi, TX CCTS						Part of AVL System - RFP out Fall 1995	Yes	Real-Time?
Seattle, WA KC Metro	SO	treadle mats	150/ 1000	Pachena; London Mat	$10K-$12K/bus	Operational since 1980, linking to (SO) AVL system	Linking	Weekly
Milwaukee, WI MCTS	GPS		50/ 550			RFP by end of 1995	Yes	Real-Time
Calgary, AB Transport Dep't	SO, GPS	mats, prox. sensors	30/ 580	Crayfield Digital	$280K 1st 25 $30K new 5	Operational since 1990	No	Real-Time
Winnipeg, MB Transit System	GPS	treadle mats?	35/ 530			RFP 10/95	No	Daily
Hamilton, ON HSRC	SO	vertical ir beams	32/ 240	London Mat - original system; updates in house	$6K/bus	Oper. since '86 with mats, changeover to beams 12/95	No	Daily
Montreal, QC STCUM	SO	treadle mats	175/ 1650	Wardrup	$2.5 million (total)	Under Installation		Daily

Key:

Shaded columns indicate operational APC installations.

Location - technology used: SO = signpost and odometer, GPS = Global Positioning System, OS = odometer readings vs. scheduled position (post processing method)

Counts - method by which the system counts passengers (e.g., treadle mats or infrared ("ir") beams)

Vehicles - number equipped vs. number operated

Cost - total cost of system when the system was purchased (U.S. systems - U.S. $; Canadian systems - Canadian $)
(Cost variations may be due to varied capabilities and features.)

AVL Link - "Yes" - system is linked (or will be when installed) with an AVL system; "No" - not linked, no plans to link "Linking" - an existing, independent APC system will be linked to an existing or new AVL system

Xfer Freq. - indicates how often the data is transferred from the bus either to the central computer or to a temporary storage device.

Eugene, Oregon

Lane County Mass Transit District (LCMTD) has been operating their APCs since 1986. Like COTA, LCMTD measures location with signposts and odometer readings, but LCMTD uses treadle mats for counting. The original system was procured from a company now called Microtronics for $95,000 and included 30 signposts and mats for eight (of the agency's 95) buses. The agency recently bought APCs for an additional four buses for $4,000 each. Data is transferred daily when the bus returns to the garage. At the bus fueling station, the data is transmitted over an infrared link.

The agency uses the data for a number of purposes, including route and schedule planning, analysis of passenger loads on vehicles, and deciding where to locate bus shelters. LCMTD is pleased with the system, saying it reduces their reliance on manual (human) checkers (which are more expensive), and provides more detailed information on boardings and alightings than is possible with registering fareboxes.[28]

Portland, Oregon

Tri-Met currently uses a unique form of position determination. Bus odometer readings are recorded and later combined with knowledge of the schedule and layover points to determine position. This location method saves the capital cost of an AVL system, but might sacrifice some accuracy. The system originally became operational in 1982 (manufactured by Red Pine), costing $4,500 per APC on 80 of Tri-Met's 635 buses. The data retrieval units (also $4,500 each) collect the data automatically from each APC-equipped bus via infrared link when the bus returns to the garage.

Tri-Met states that the APCs provide easier and quicker access to passenger data and cheaper data collection than manual counting. Future plans include linking the APCs to the AVL system that Tri-Met is procuring. The old location technology will therefore be replaced by GPS. Tri-Met is also considering equipping its demand-responsive vehicles with APCs.[29]

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[28] Mike Northup, Lane County Mass Transit District, Eugene, Oregon.

[29] John Lutterman, Tri-County Metropolitan Transportation District of Oregon, Portland, Oregon.

Calgary, Alberta

The City of Calgary, Alberta, Canada operates a relatively new APC system. Originally brought on-line in 1990, the system was manufactured by a company now called Crayfield Digital. Total system cost (approximately $310,000 Canadian) includes 70 signposts, 25 APC units acquired as part of the original system (which locate by signpost), five newly acquired APC units (which locate by GPS), and all base station and data transfer equipment. Counts are obtained by treadle mats except on low-floor buses which use proximity sensors. Data is transferred from the vehicle via a dedicated radio channel to a repeater, and via a land line from the repeater to the central computer. Transfer occurs every time one of the following conditions are met: a signpost APC bus passes a signpost, a GPS APC bus passes a pre-specified location, or when on-board data storage is full.

Although the data are collected in real time, the agency has no real-time uses for them. Instead, the agency uses the data for the same planning and scheduling applications employed by most transit systems with APCs.

The benefits the agency has gleaned from the APCs are extensive. 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 cite 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.[30]

Winnipeg, Manitoba

In another application of GPS, the transit system in Winnipeg plans to implement APCs on 30 to 40 of its approximately 530 buses. The RFP was to be released in September 1995, and the agency expects to procure a GPS, treadle mat system. Data will probably be transferred daily and will be used for schedule-making, deciding the locations of bus shelters, and for some planning and route re-design.[31]

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

[31] Bill Menzies, City of Winnipeg Transit System, Winnipeg, Manitoba, Canada.

Hamilton, Ontario

The Hamilton Street Railway Company (HSRC) has operated an APC system since 1987 and is now implementing significant upgrades to it. The original system was a signpost, treadle mat system on 32 of its 240 buses. However, HSRC is equipping their new, low-floor buses with vertical infrared beams, which point downward across the path of boarding and alighting passengers, rather than pointing horizontally. The agency is also looking at making changes to its on-board storage and data transfer methods. Vibration creates some problems with the on-board storage, and the current data off-load method of attaching a cable to the unit in the garage at the end of each day is somewhat cumbersome.

HSRC also operates an AVL system, but it is completely separate from the APC system, and there are currently no plans to integrate them.

While the agency feels that APC technology is not keeping up with general advances in the state of the art, they do note the significant benefit of quicker data availability compared to manual checkers. With APCs it takes about a week. Manually, it would take about a month.[32]

Atlanta, Georgia

As part of their new GPS AVL system, MARTA is including 15 infrared beam APCs, manufactured by UTA. Although location information will be transmitted and used in real time (see description in Section 2.3), the passenger count data will be transferred once a day in the garage via radio link.[33]

2.5 TRANSIT OPERATIONS SOFTWARE

Transit operations software has the capability to perform and integrate many transit operations functions, such as computer-aided dispatching, computer-aided service restoration, and service monitoring. Integration of service components like fixed-route services with paratransit and demand-responsive services is still in early development. Service restoration involves the adjustment of

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

[33] Harriet Robbins-Smith, Metropolitan Atlanta Rapid Transit Authority, Atlanta, Georgia.

vehicle operations based on schedule adherence or scheduled headways, the replacement of a disabled revenue vehicle, and the activities necessary to restore the schedule disrupted by a disabled revenue vehicle. With the use of an AVL and communications system, service restoration can be accomplished by:

- Adjusting vehicle dwell time at particular stops/locations (e.g., transfer points);
- Adjusting vehicle schedule/headway;
- Performing traffic signal priority;
- Rerouting the vehicle;
- Adding a vehicle to a route; and/or
- Dispatching a vehicle to replace a disabled vehicle.

Service monitoring involves collecting data on such operational details as vehicle position, schedule adherence, route adherence, headway adherence, passenger data (e.g., passenger counts), status of vehicle components, and traffic and weather conditions. Service monitoring also involves analyses such as determining vehicle performance and loading, driver performance, estimated time or arrival at a specific point or stop, passenger statistics (e.g., passengers per vehicle, per stop, etc.), and system-wide statistics (e.g., overall on-time performance).

2.5.1 Fixed-Route Bus

Over the years, software for fixed-route operations generally revolved around run cutting activities. As buses have evolved into technically-advanced vehicles, the transit industry is focusing on technology that will help increase customer satisfaction and enhance their overall operation. With the advent of AVL systems, transportation operations software has evolved to functions such as computer-aided dispatch, adaptive signal control to give preference to transit vehicles, and rapid response to emergency situations. The key to AVL systems is software that can synthesize data inputs and outputs into meaningful information for transit operations and management.

State-of-the-Art Summary

The industry is realizing the need to utilize AVL systems for safe and efficient fleet management. In recent AVL implementations, fleet management is typically performed in a control center which usually includes a pair of high-speed personal computers (PCs) for each dispatch position, a GPS base station, modems, printers, appropriate communications equipment, and mapping software. In each pair of PCs, one usually functions as a mapping station utilizing software to display geographic areas and the location of the buses. This provides the control center staff with the capability to view all buses and paratransit vehicles as they move along their routes. The other PC normally functions as a communications controller and uses sophisticated software to manage a host of data transmissions and messages to and from the vehicles as well as keeping track of a number of bus and bus operator data items. In addition, software programs facilitate the response to emergency situations on-board the buses, assist in the evaluation of route efficiency, and provide location-triggered audio and visual announcements to comply with ADA requirements. Today's software is also designed to be adaptable to a myriad of hardware applications and to facilitate system expansion.

Applications

The following is a sample of transit operators employing fleet management software.

Denver, Colorado

The Regional Transportation District has installed a GPS-based AVL system on 857 buses, 11 light rail vehicles, and 28 supervisory vehicles. Transportation Management Solutions, Inc. provided SmartTrack, the AVL/CAD system. On board each vehicle is an Intelligent Vehicle Logic Unit (IVLU). As Global Positioning Satellites orbit overhead, the IVLU takes in signals through an antenna on top of the bus which, through a software algorithm, are decoded to let the IVLU know the longitude and latitude position of the vehicle. This information is transmitted on a 400 MHz radio frequency to the operations center. At the center, the dispatcher will have an icon displayed on a computer screen signifying the vehicle, along with an overlay of the route and its schedule adherence condition.

Two key benefits of this system are information for route and schedule adherence and for quickly addressing and resolving emergency situations. To accurately obtain this information, correct software code must be in place to gather and process information in an orderly fashion. Each vehicle sends its unique information in a fraction of a second through what is called a contention slot. At the control center, this information is gathered and disseminated to a minicomputer and back to the dispatcher's CPU. Ultimately, dispatchers can have updated information every two minutes for a bus, every one minute for a light rail vehicle and every 30 seconds for a vehicle experiencing an emergency situation. Also, information is received regarding bus engine idling. In Denver, it is unlawful for buses to idle their engines for over 10 minutes. Dispatchers and/or street supervisors, who have lap-top computers that receive the same information as the dispatchers, can contact the operator to shut down the engine. To achieve this level of precision, extensive testing was conducted over the past two years that ultimately resulted in over 20 versions of software upgrades.

Milwaukee, Wisconsin

A new GPS-based AVL system should be fully operational in all Milwaukee County Transit System buses by the time of publication of this report. Transportation Management Solutions, Inc. provided SmartTrack, the AVL/CAD system. The system provides two-way radio communications and enables MCTS central dispatchers to identify within 40 feet the location of any on-duty bus and to determine whether or not individual buses are on schedule. Buses are identified on dispatcher's computer screens with icons that change colors indicating the number of minutes the bus is ahead or behind schedule.

SmartTrack includes location software which can assist dispatchers in determining if a bus stop is missed and if a driver has gone off route (e.g., because of a detour or an emergency). This also serves an important role in helping dispatchers identify exactly where to send assistance to a bus in cases where a bus breaks down, or there are medical or security concerns. Also, SmartTrack software generates on-time performance and mean-miles between breakdown reports for the scheduling and maintenance departments.

Montgomery County, Maryland

Montgomery County is the site of the pilot program for the nation's first fully integrated transit and traffic management system for its Ride-On buses and traffic operations. All 250 public transit buses are being equipped with GPS-based AVL technology from the Orbital Sciences Corporation. Using this technology, Montgomery County DOT officials are able to track these buses as they move through the County, and integrate that information with traffic signal operations to give buses priority treatment when necessary.

The vehicle location data are transmitted from the buses by radio transmission to the Advanced Transportation Management Systems Control Center, where it is received by a computer. Using control software, the received information is translated and displayed graphically on a monitor, indicating the location of each vehicle at the time of data transmission. Data transmission will occur on a regular cycle. From the graphic display, traffic management staff can manually adjust signal timing, if necessary. If a bus is running late, the software algorithm in the bus computer requests priority movement as it approaches an intersection with a traffic signal. The traffic manager reviews the scenario to see if the traffic flow can be adjusted. Once the bus is through the intersection, it will send a message saying "intersection clear," so that the traffic manager can stop the signal cycle lengthening.

Presently, 15 percent of Montgomery County commuters use Ride-On buses. As the vehicle tracking and management software systems are perfected, improving reliability and convenience of service, the County hopes to increase the number of bus commuters to 20 percent.

Miami, Florida

Metro-Dade County Transit Agency in Southern Florida is installing a GPS-based AVL and mobile data system. Navigation Data Systems (NDS) is developing and installing the software for the AVL equipment along with Harris Corporation. The NDS FLEET-TRAK 1000 mobile equipment system is being installed on over 800 transit vehicles. It features an advanced Transit Control Head which includes the display of dispatcher-originated messages and operator-entered data including route/run and status information.

As the transit vehicle goes into service, its schedule is downloaded from the central Transit Operating System (TOS) computer to the on-board computer. As the vehicle progresses along the route, the software calculates schedule adherence and sends this information to central control every two minutes. At central control, there is a large electronic map of Dade County which displays the vehicle, its route number and direction of travel, as well as its position in terms of longitude and latitude. As schedule adherence information is received, the vehicle route number is assigned colors on the map to denote if the vehicle is ahead, behind or on schedule, or if an emergency alarm condition is occurring. Dispatchers can contact the operator to give direction on schedule adherence, or law enforcement authorities in the case of an incident. Throughout the route, the radio on board stays on 'data-mode' unless there's a voice call from either the operator or dispatcher. When there is a voice call, the TOS tells the on-board computer to switch from data mode to voice mode. When the conversation is completed, the software algorithm resets the radio to the data mode, and updates the location of the vehicle.

Chicago, Illinois

The Chicago Transit Authority is presently reviewing proposals for its Bus Emergency Communications System and Bus Service Management System (BSMS). The CTA has sought the use of "off-the-shelf" or production hardware elements for the BSMS employing modular components and industry-standard interfaces. Software components will be standards based and follow well-documented, modular coding. These software components will be flexible for future enhancements including Computer-Aided Service Restoration and on-board active signs and audio announcements.

2.5.2 Rail

A number of large, urban transit agencies are replacing their aging control centers with state-of-the-art facilities. For some, the replacement not only includes advanced computer hardware, software, and ergonomics, but also a new building to house the equipment. A key to success for these new facilities is employing open system design concepts. The use of open system design standards allows a transit agency to upgrade systems in the future without making significant changes to the software.

State-of-the-Art Summary

Operations software for rail transit systems are helping perform many different functions in newer operations control centers. Custom designed software is the tool that allows controllers to see the status of many elements of the system displayed on large panels or screens. These displays can include rail vehicle location, switch positions, signal settings, electronic fare collection status, platform conditions, and messages being shown to passengers. The software also can automatically control, or assist the center staff in controlling, vehicle dispatching and routing and voice and digital communications. Other functions the software facilitates is identification of abnormal situations. data retrieval and storage, and provision of information to customers..

Today's control centers, using open software architecture and interface standards, allow a smaller number of operator interfaces for many functions, making the operator's job easier to perform. Because of the higher level of automation, the operator has less interaction with the system. The ability to understand the needs of the operator, as well as to provide the functionality required for efficient transit operations, are crucial to the design and implementation of today's rail operations software.

Applications

Oakland, California

The Bay Area Rapid Transit District (BART) opened its new Operations Control Center (OCC) beneath its Lake Merritt Administration building in March 1994. The futuristic, $2.9 million system with computer-driven color graphics measures 90 feet across two 12-foot high walls. It replaces the 22 year-old train monitoring system. Funding for the project came from the FTA, California DOT, and BART. Three years in design and development, the OCC functions as the nerve center of BART, performing supervisory control of train operations and remote control of electrification, ventilation and emergency response systems across BART's 34 stations, four maintenance yards and 71.5 miles of double track (including the 3.6 mile TransBay tube beneath San Francisco Bay).

With the completion of the building, BART has launched a five year program to replace three computer systems with a single state-of-the-art system handling train control, fare collection and station message signs. This next generation project, referred to as NXTGEN, will allow BART to incorporate software driven command and control routines with its hardware. When completed, NXTGEN will allow trains to operate over the 115 km network at closer headways, while allowing for the control of several lengthy extensions now being planned. Already, new display boards in the OCC use computer imaging and video projections to display the entire BART system, including system extensions as they are completed in the near future. The two boards combine information formerly displayed on three boards - one for track and train positions, and the other for maintenance and electrification. The software-driven displays can be updated with virtually no limit to the miles of track or number of stations shown on the boards. Changes to the display are made by modifications to the software, which can be accomplished by BART personnel. Additionally, the dispatch center for the BART police department is located in an adjacent room with a view of the display boards so that officers can spot precisely where calls are coming from and interact with train controllers to coordinate the response by police and emergency personnel.

The original control center in operation since BART began service in 1972 had 87 feet of display boards with more than 35,000 tiny blinking light bulbs. BART had to replace more than 26,000 of the colored bulbs each year at an annual cost of approximately $16,000. The new computer imaging, video-projected OCC is expected to improve efficiency and lower costs by eliminating the bulbs and the need to replace them.

New York City, New York

A new facility that gives Amtrak and the Long Island Rail Road (LIRR) joint control of rail operations through Penn Station in New York City was dedicated in June 1994. The opening of the new six-story Clayton-Scannell Control Center contained two breakthrough developments. LIRR and Amtrak jointly funded the planning and construction of the $110 million modern, centralized control facility for Penn Station, which replaced the 80-year old system. Both railroads will share equally in the dispatching operations of all trains through Penn Station, resulting in an increased role for the LIRR in controlling trains.

In October 1994, the new control center took the place of four antiquated control towers built in 1910. At present, Penn Station is the busiest railroad station in the United States, with over 600,000 passengers arriving and departing daily on over 1,000 trains. The facility controls rail operations from Morrisville, PA, through New Jersey into Penn Station, north to the Bronx, and east to Harold Tower on Long Island City, Queens. A chief element of the project is the completion of the Central Control "Operating Theater," in which the locations of all trains will be displayed on a bank of rear projection screens, giving operators a complete overview of the operating territory at all times.

The Central Control facility will integrate the latest in computer-aided, centralized signaling technology and all-relay control for efficient and fail-safe train traffic management. At present, the computerized traffic control software is under development. When it becomes operational in late-1996, it will serve as the primary means for monitoring and controlling train movements. Until that time, the overall operating scheme is a modular, "mosaic" human/machine interface. This progressive, hardwired, unit-lever mosaic control panel allows operators to manually control the rail territory. When the software becomes operational, the mosaic controls will provide a fail-safe backup to keep the trains moving in the event that computer controls are unavailable. This console is believed to have the highest density wire interface ever designed and manufactured for the rail industry, with some mosaic panels having over 300 signal wires per square foot.

Red, green, and blue LEDs incorporated into the mosaic tiles correspond to occupied or blocked tracks, interlockings, and junctions. By turning small, ergonomically-designed switch devices protruding from the tiles, command signals are sent, via the electronic logic system, to the relay operating room controlling the four Penn Station interlockings. What was once a physical operation is now a push-button operation, and when the software integration is completed, will become a "click-and-shoot" operation. "The mosaic system enhances the centralization of our operation and provides a more user-friendly operator interface. Working with large lever machines and switching devices was a way of life for our dispatchers since 1910. The '90s technology we've instituted now offers our operators greater operating efficiency."[34]

Boston, Massachusetts

The Massachusetts Bay Transportation Authority (MBTA) is set to open its 10-story Operations Control Center in May 1996 in downtown Boston. Revenue operations are set to commence later that year. It will be one of the most automated rail transit control centers in the

[34] Gary Suchy, "On the Move with Mosaic Technology," *Mass Transit,* November/December 1994, Volume XX, No. 6, p. 54.

world. It is designed to permit real-time monitoring and control of the MBTA rail system, to provide operations personnel and management with up-to-date information, and to identify abnormal situations as they occur. The software and hardware systems are modular, making the system easily expandable or enhanced. The control system will feature console workstations and an overview display. It will provide complete coverage for monitoring all four of the MBTA's rail transit lines, including direct control of the three heavy rail lines.

The OCC will include an amphitheater style control center with seven rail dispatch positions, two manager consoles and a public address console. Forty-two rear projection, large screen displays will provide an overview of the entire system. Personnel will be provided with detailed displays of the rail network, station facilities, station functions, fare collection, signage, emergency and auxiliary response systems in real time. Besides real-time control, the software will provide for on-line retrieval of archival information. This expanded data handling and reporting will provide managers with the tools to optimize operations.

The MBTA currently operates separate supervisory control and data acquisition (SCADA) systems. The new control center will integrate a new SCADA Power Distribution Management System and an improved System-wide Supervisory Control System. Besides providing for information exchange, this integration will permit OCC personnel to de-energize traction power under emergency conditions. They can monitor and/or control emergency fan ventilation systems, exit doors and emergency devices, and system support functions such as high-pressure water pumps and escalators. The completed project will also have a fully integrated voice communication system including radio, telephone, public address and intercom. The operator will have access to all voice systems from a single display using a single headset. Included in the software will be expert algorithms to provide operational suggestion aids to dispatchers.

The new control center will also provide for dispatching the MBTA's 1,000 buses. Three bus dispatch consoles will be provided along with geographic maps of service areas. The bus operations software module will provide bus dispatchers with digitized maps, showing route and address location information, which can be enhanced with satellite-based communications and locations systems. Future expansion capabilities include integration of computer-aided dispatch, AVL, and monitoring.

New York City, New York

The New York City Transit Subway Department is proceeding with their Control Center Modernization Program (CCMP). The CCMP program will provide a new Rail Control Center building, Automatic Train Supervision (ATS), and upgrades to the communications and information systems. Total project cost is estimated to be $200 million. This ranges from technology demonstration and testing to new train control initiatives, some of which may take 30 years to introduce.

The CCMP consists of train control, communications, and decision support. SCADA systems will incorporate dedicated software to indicate the status of devices and trains, which are connected to Central Control through remote terminal units. Communications (fiber or radio) will bring data back to Central Control where it will be processed and analyzed using decision support systems, and displayed. Central operators will then send instructions back to the field. To achieve all of these capabilities, the following projects will be implemented:

- *ATS* - This is the centerpiece of the program. The ATS software will provide the following capabilities: automatic vehicle identification, central train tracking and control, automatic dispatching and routing, service monitoring and control, transportation rule monitoring, console communications, and a customer information system. Due to the size of NYCT, ATS is being implemented in stages. Functional specifications for the first stage, the Interborough Rapid Transit are being completed now. In 1996, planning will commence for the second ATS project, the former Brooklyn-Manhattan Transit. These two phases are expected to form the foundation for the remaining portions of the system.
- *Communications* - These projects will improve the ability to inform all operators of current conditions and actions to be taken. Staff will be connected by voice and data. Trunk radio systems will employ software controls to determine trunk communication channels. Communications facilities will become networked using current fiber optic and PBX projects, rather than the present pattern of connections in localized loops.
- *Decision Support Systems* - Software will provide the following capabilities:
  - Evaluation of on-time performance/headway regularity;
  - Emergency response dispatching activities (logging, classification, notification, and reporting of incidents); and
  - General order planning and, preparation of train schedules for ATS.

  At present, the LIRR's TIMACS system is being tested to improve train monitoring capabilities until the ATS is fully deployed.
- *Facilities* - The new rail control center will be built on the site of the 54th Street Bus Depot. Preliminary design and engineering for the new building is complete, and MTA will soon be

awarding demolition contracts for the present site. It is estimated that demolition will be complete in early 1996 and the building will be completed sometime in 1997.

Philadelphia, Pennsylvania

The Southeastern Pennsylvania Transportation Authority awarded a contract to LS Transit Systems, Inc. for development of the new Railroad Operations Computer Simulation (ROCSIM), including development of a PC-based operations software simulation model of the entire SEPTA Regional Rail system. The project will include extensive integration of GIS and Computer Aided Design systems. Tracks, switches, signals, platforms, structures, and line side equipment will be displayed using true geographic coordinates, allowing seamless integration with GIS software. In addition, the system's CAD capabilities will be used to generate SEPTA system-wide track and signal drawings, including information on grades, curves, signal aspects and signal control lines.

Other facets include simulation of grade crossing gate down times, system-wide power consumption, and passenger flow modeling. The ROCSIM project will incorporate SEPTA's regional trip table of origins and destinations, with automatic calculation of train dwells and ridership throughout the system.

The system is designed to allow SEPTA engineers, operators, schedulers and planners to answer innumerable "what if" questions. These answers will help optimize existing operations, respond to unforeseen operating problems, and plan the next generation of capital improvements. The project is slated for completion in early 1996.

2.5.3 Paratransit

Automation for paratransit has made tremendous advancements over the last five years. More paratransit systems than ever are implementing automated scheduling and dispatching software, in addition to other technologies. This software assigns customers to demand-responsive vehicles that are operating in shared-ride mode. The scheduling components accommodate advanced trip reservations, standing orders, and immediate requests. Immediate trip requests, or real-time dispatching, can be accommodated through the use of radio frequency (RF) communications with on-board mobile data terminals. Information from scheduling and dispatching can be integrated into management information, billing and accounting functions of the paratransit agency.

State-of-the-Art Summary

Advanced technology has been applied to paratransit operations and management mostly in the area of scheduling and dispatching. Increasingly more automation is available for paratransit systems in addition to the automated scheduling and dispatching. Several systems are in the process of integrating AVL and advanced communications technologies with automated scheduling and dispatching.

Another innovation in scheduling and dispatching systems is the ability to dynamically reschedule and re-route paratransit vehicles in real time, based on changes in schedules such as trip additions and trip cancellations. These systems can operate with or without the use of advanced hardware.

As a result of the ADA, many paratransit operations have chosen to automate scheduling and dispatching in order to comply with several of the complementary paratransit service criteria of the ADA. The ADA has stimulated the vendors of scheduling and dispatching software to incorporate new features into their software, such as mapping or GIS software, to assist in the determination of whether an individual's origin or destination is located within ¾-mile on either side of a fixed route, and the scheduling of trip requests within one hour of the requested pick-up time.

The level of automation in scheduling and dispatch systems ranges from minimal to fully automated scheduling and dispatch with the use of advanced communications and/or location technology. The lowest level of automation, computer-assisted scheduling and dispatch, involves the use of specialized software to develop schedules for paratransit vehicles. The vehicles are then dispatched manually. If any changes in schedule and/or routing are required due to trip cancellations or additions, the vehicles' schedules and routes must be modified manually.

The next level of automation is the capability of the software to dynamically modify the schedules and routes of paratransit vehicles in real time, based upon trip cancellations and additions. These modifications are then communicated to the vehicles manually (by voice over the radio) by the dispatcher. A more automated system includes this same type of software with a capability to automatically communicate, in real time, changes in schedules and routes to the drivers. This communication is accomplished through technology such as on-board computers/displays that can receive data from scheduling and dispatching software.

The highest level of automated scheduling and dispatching systems incorporates AVL in the decision-making process.

Applications

This section includes information on automated or computer-assisted scheduling and dispatching systems, and in a few cases, the integration of these systems with AVL or other technologies. Appendix A - Table A.2 shows a list of users of automated or computer-assisted scheduling and dispatching systems. This is not an exhaustive list of users and is presented to illustrate how widespread is the use of automated scheduling and dispatching systems. Table 2.4 lists the manufacturers of each system, as further reference. This is not an exhaustive list of all vendors.

Even though there are many automated scheduling and dispatching systems available for paratransit operators, not all of these systems have been successfully implemented. It is important for prospective buyers of these systems to carefully evaluate any software and/or hardware before considering its installation. This evaluation should include an investigation of the experience of paratransit operators who are using this software and/or hardware.

Detroit, Michigan

Suburban Mobility Authority for Regional Transportation (SMART) in Southeastern Michigan is implementing automated scheduling and dispatching, and AVL technologies to manage its paratransit services. (AVL will be implemented in the future on the fixed-route system.) SMART is nearing full implementation of Trapeze Software's (formerly UMA Systems) TRAPEZE™-QV, a paratransit computerized scheduling and dispatch system, to better automate the reservations, scheduling and dispatch at SMART and remotely at other regional paratransit providers. The AVL implementation began in July 1995, and is expected to be completed one year later (including integration with *TRAPEZE*™-QV).

Table 2.4 Paratransit Scheduling and Dispatching System Vendors

AUTOMATED SYSTEM	VENDOR
CADMOS Pro+	Micro Dynamics Corporation
DISPATCH-A-RIDE	Multisystems
Dispatch Manager	Innovative Software Designers, Inc.
Easy Lift™	Easy Lift Solutions
FAS (Fully Automated Scheduler)	Automated Business Solutions, Inc.
GIRO/ACCES	GIRO
MIDAS	Multisystems
PARRAS® (Paratransit Advance Reservation Routing and Scheduling)	Paratransit Software
PASS™ (Paratransit Automation Scheduling System)	On-Line Data Products, Inc.
PtMS (Paratransit Management and Scheduling)	Automated Business Solutions, Inc.
Rides Unlimited™	Paratransit Systems International Inc.
TRAPEZE™-QV	Trapeze Software Inc. (formerly UMA Systems Inc.)
TRIPS (Transportation Reservation Information Processing System)	Micro Dynamics Corporation

With the AVL system integrated with the scheduling and dispatch, "it will enable [SMART] to provide efficient, cost-effective service to its current paratransit riders as well as maximum flexibility to plan for new service within the region. Beside the expansion allowed by more efficient fleet control, SMART also plans to offer these dispatching capabilities to other service providers in the region. Agencies using SMART service will be able to remotely book their own trips, coordinate service they provide with SMART service, or simply inform their customers about SMART service based on real-time input."[35]

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[35] **Lister, Mac, Carol L. Schweiger and Ian Keaveny, "Getting SMARTer with ITS: Improved Paratransit Operations at SMART Using Integrated Scheduling/Dispatch and AVL,"** ***Proceedings of the 1995 Annual Meeting of ITS America*****, Volume 2, March 15-17, 1995, Washington, DC, ©1995, pp. 742 and 747.**

Folsom, Pennsylvania

Community Transit of Delaware County is implementing a sophisticated automated system that includes sophisticated scheduling and dispatching software integrated with mobile data terminals, radio frequency communications and automated identification cards. This system was described in the ***APTS: The State of the Art : Update '94*** report.

Considerable implementation progress has been made since the last report. Implementation of the automated scheduling and dispatching software was expected to be completed by November 1995. Modifications have been made to the software (Rides Unlimited from Paratransit Systems International, Inc.) to customize it for Community Transit and to more fully utilize its capabilities. "This software will interact with the MDTs through the use of radio frequency communication to provide drivers with their scheduled pick-ups and drop-offs. Also, in the event of a cancellation or no-show, the scheduling and dispatching software will modify the schedule (e.g., fill the space created by the cancellation/no-show), while keeping the scheduled customers on-time, and mitigating the effects of no-shows and cancellations on productivity (persons per vehicle-hour)."[36]

Specifications on the MDTs and the RF communications system are under development, with implementation expected in February-March 1996. Cellular digital packet data is being considered for the communication system. CDPD technology uses existing cellular telephone infrastructure. It detects idle air time and sends small data "packets" during this idle time. CDPD users are charged on a per-packet basis, so they are not paying for time that is not used.

Automated identification cards are expected to be implemented by April 1996. "The introduction of electronic identification technology will certify that the card holder has access to the Community Transit service and will ensure that the patron's sponsoring agency or agencies are charged appropriately for the trip. The identification card will interact with an MDT to identify the customer to the driver and will verify trip eligibility. The identification card used with the MDT will also create a 'trip record' for Community Transit. This record will contain data about the trip, such

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[36] **Schweiger, Carol L. and Judith McGrane, "The Challenge for Developing and Implementing Advanced Public Transportation Systems for Elderly and Disabled Customers,"** ***Proceedings of the First World Congress on Applications of Transport Telematics and Intelligent Vehicle-Highway Systems*****, Palais de Congrès de Paris, France, November 30 - December 3, 1994, Volume 4, p. 1795, ©1995.**

as trip length and duration, and will be used in the billing process to reconcile scheduled trips vs. actual trips."[37]

Santa Clara County, California

OUTREACH is a paratransit provider and broker in Santa Clara County, California. "OUTREACH serves nearly 7,500 registered clients annually, and in 1993-4 it provided more than 227,000 rides."[38] In 1994, OUTREACH began an advanced technology project that consisted of three phases. Phase 1, which has been completed, was the development of a digital geographic database (provided by Navigation Technologies) that is used by the two other technologies developed as part of this project: automated scheduling and dispatching, and AVL. Phase 2 consisted of implementing the scheduling and dispatch software (TRAPEZE™-QV from Trapeze Software Inc.), which was completed and became operational in February 1995. Phase 3 is the AVL system (provided by Trimble, with Motorola radios), which is in the process of being implemented and will be ready for testing in early 1996.

A critical issue in the implementation of the AVL system was the selection of the communications technology. CDPD technology, which sends data over existing cellular telephone channels, was being considered as a potential communications technology. Unfortunately, there is little experience in using CDPD for this particular application. Further, the cost of modifying the AVL to accommodate CDPD and the on-going cost of CDPD on a per vehicle basis was higher than expected. Therefore, OUTREACH chose to use a conventional radio system. With the Federal Communications Commission's backlog of applications for frequencies, particularly in the Los Angeles area, final approval of a frequency has not yet been granted. However, in September 1995, OUTREACH was granted a temporary license for a frequency so implementation of the AVL portion of the project is proceeding.[39]

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[37] Ibid, p. 1792.

[38] McQuarrie, Diane and Roberta Gardella, "Applied Intermodality in a Paratransit Environment," *Proceedings of the 1995 Annual Meeting of ITS America*, Washington, DC, March 15-17, 1995, Volume 2, ©1995, p. 736.

[39] Roberta Gardella, Chief Executive Officer, OUTREACH, San Jose, California.

Ontario, California

The ATHENA project is an operational test being conducted by the City of Ontario, California "to determine whether the application of off-the-shelf technologies can result in an increase in average vehicle ridership or average vehicle occupancy by providing people with the information needed to participate in personalized public transportation. Users will be provided with nearly instantaneous ride confirmation, and navigational assistance will be provided to drivers to make the system user friendly and convenient. Market acceptance of advanced communications technologies for personal transportation planning purposes will also be tested."[40] Technologies that will be used in ATHENA include PCDs, a telephone voice processing system, GIS, AVL and dynamic ride-matching software. The integration of these technologies will ensure ATHENA's seven-minute guaranteed pick-up.

Three systems will make up ATHENA: vehicle systems, an operations center and a communications system. Each equipped vehicle will be capable of knowing its location and reporting that to the operations center, receiving ride assignments from the operations center, and performing other functions. The operations center is responsible for monitoring all in-service vehicles, assigning riders to vehicles, providing navigation guidance, and maintaining all appropriate databases. The communications system will ensure all communications between vehicles and the operations center, and between users and the operations center.

Phase 2 of the ATHENA project began in August 1995. One of the first tasks is for the project team to conduct a preliminary design review in conjunction with stakeholders, and to begin working with the employers within the test area.[41] The test area has been identified as the Ontario International Airport area, in which employers will be recruited. It is expected that 100 drivers and 300 riders will be recruited to conduct the ATHENA operational test.

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[40] L.D. King, Inc., TRW Transportation Systems and Aegis Transportation Information Systems, **ATHENA: Stage 1 Report - Revised**, prepared for The City of Ontario, April 1995, p. 17.

[41] Kim Shultz, Transportation Projects Manager, City of Ontario, California.

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

"Many providers believe that a number of computer systems currently on the market do not meet their present requirements and are even less likely to be suited to future tasks, particularly the determination of trip-by-trip eligibility for complementary paratransit service. Given that these transportation systems have a number of requirements in common, the development of industry-wide functional specifications for software would benefit transportation providers. The objectives of this project are to specify the requirements for future computer software to manage and operate demand-responsive systems and to develop an implementation handbook to assist transportation providers in the procurement of such systems."[42]

In February 1994, this $200,000 project was awarded to Systan, Inc. This project, which is pointed toward the developers and vendors of paratransit software, will provide general specifications of capabilities that have been identified through a survey of paratransit providers. This survey listed 60 capability factors, and respondents were asked to rank the factors. An interim report describing the specifications was submitted in February 1995 and has been approved by the project panel.[43]

Currently, a handbook is being prepared to assist transportation providers understand the software aspect of computerized dispatching, and to provide guidance in selecting and implementing the "right" software. The handbook was scheduled to be completed in November 1995.

Houston, Texas

In 1993, AVL was demonstrated on Houston Metro's specialized paratransit service, METROLift. The AirTouch Teletrac AVL system was installed on all 153 vehicles. "The AirTouch Teletrac AVL system uses a subscriber-based radiolocation technology. The system uses a network of 25 radio towers in the Houston area, a location unit on the individual vehicle, and central computer tracking and mapping functions. The digital transceiver, called a vehicle location unit (VLU), is attached to an automobile, bus, or minivan. The location of the vehicle is tracked using a software program on a personal computer that is connected to a central computer by a modem. When the

[42] Transportation Research Board, **Transit Cooperative Research Program: Annual Report of Progress 1994**, pp. 30-31.

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

location of a vehicle is requested, the VLU receives a page and transmits a digital code, which is received by radio towers in the vicinity. A signal must be received by at least four towers to trilaterate on the vehicle's position, but more towers are usually used to provide increased accuracy. The system can page and locate a single vehicle, a group of vehicles, or all vehicles within a service area. The system also provides an emergency call button that a vehicle operator can push to receive immediate attention from the control center."[44]

The AVL system was not used for real-time scheduling during the demonstration. However, it was used to give directions to an operator to assist in locating a particular address, to provide customers with vehicle status and to initiate an emergency alarm condition.

An evaluation of the demonstration was conducted by the Texas Transportation Institute and Houston Metro in order to determine the success of the AVL implementation. First, the location accuracy was measured and compared with a differential GPS system. The AirTouch system was accurate within 150 feet at 2 sigma, except for the downtown area. In the downtown area, sometimes it was within 150 feet of the DGPS readings.

Second, changes in service efficiency were analyzed. The ratio of passenger miles to vehicle miles increased from before the demonstration to after AVL implementation. In the two years prior to implementation, this ratio was 1.11 and 1.04. After implementation, the ratio was 1.21. Another measure, on-time performance also improved. Before AVL implementation, in October 1993, the percent of late trips was 4.5 percent. After AVL implementation, in September 1995, it was 3.4 percent.

Third, METROLift dispatcher and operators were interviewed to evaluate their reaction to the new system. Overall, their reaction was positive. Dispatchers and operators indicated that the system was easy to use and made their jobs easier. They noted a few problems as well and suggested some improvements.

Fourth, customers were surveyed to determine their reaction to the system. Since customers were not informed specifically about the implementation of the AVL system, questions were not

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[44] Turnbull, Katherine F., Laura Higgins and Nitin Vaidya, "An Assessment of the METROLift Automatic Vehicle Location System," *Proceedings of The Second World Congress on Intelligent Transport Systems*, Pacifico Yokohama, Yokohama, Japan, November 9 - 11, 1995, Volume II, pp. 954.

specifically related to the AVL system, but were related to customer satisfaction. An increase in customer satisfaction, partially attributable to the AVL system, was noted. "A five percent increase was recorded in the number of respondents indicating that the service was much better than the previous year. Three percent more stated it was somewhat better. In addition, a three percent improvement was recorded in those reporting an excellent rating for METROLift on-time performance."[45]

[45] Ibid, p. 958.

3. TRAVELER INFORMATION

Traveler Information Systems provide travelers with information on one or more modes of transportation to facilitate decision making before their trip and during the trip (en-route). Information can be provided to trip makers at home, work, transportation centers, wayside stops, and 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, including telephones, monitors, cable television, variable message signs, kiosks, and personal computers. 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 INFORMATION

Traffic volumes in cities across the country are consistently rising with each passing year while transit ridership remains relatively static or is decreasing. Getting travelers to give up the convenience of driving their own cars is a difficult task. In doing so, it is essential to focus on a change in travel behavior, which entails providing accurate and timely information to travelers before their trip. This information will enable the traveler to make an informed decision about mode(s), as well as route(s) and departure times.

Pre-trip Information can include transit routes, schedules, fares, and other pertinent information (e.g., location of park-and-ride lots). 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.

Convenience of obtaining pre-trip information can be increased by using touch-tone telephones, personal computers, pagers, personal communications devices (PCDs), kiosks and/or voice synthesizers. Automated data retrieval systems to augment existing human-operator interfaces can provide information to the caller in a timely manner.

State-of-the-Art Summary

Pre-trip information systems in the past were primarily directed towards riders who knew the transit system already, and only wanted updates on schedules and transfers. New systems provide relatively easy-to-obtain information to the novice as well as the experienced transit passenger. Typically, these systems can be accessed by a touch-tone telephone. Newer systems include map displays of the service area based on geographic information systems (mostly for the operator providing information to the customer who has requested information) and schedule information that is provided on the Internet through the World Wide Web. These newer systems, whether accessed directly or through a customer service operator can locate the closest transit stop to the caller's origin, can provide directions to this stop, can identify the closest stop to the caller's destination, can provide detailed directions on transit between the origin and destination stops, and can provide directions to the final destination from the last stop.

Transit agencies have made great strides in reducing the amount of time a customer has to wait to obtain information. It was typical in years past to wait over five minutes for an operator to obtain and communicate information, provided the customer could get through in the first place. Automation has led to a greater amount of information being provided in generally less than a minute, and in most cases at an overall reduced operating cost. This has made it possible to handle a higher volume of calls than before.

With the expanding implementation of AVL systems, the potential for providing real-time information on bus arrival and departure times is slowly becoming reality. Real-time schedule information is beginning to be provided by several transit agencies through a variety of media, including electronic signs and kiosks.

Applications

Automated Trip Planning Systems

Automated Trip Planning Systems have been installed at many transit agencies by a variety of vendors, including Tidewater Consultants Inc., Megadyne Information Systems, Commuter Transportation Services, Inc., and TeleRide Sage. Transit agencies with these systems include:

- Seven transit agencies in San Diego County, California;
- Tri-County Metropolitan Transit District, Portland, Oregon;
- Washington Metropolitan Area Transportation Authority, Washington, DC area;
- New York City Transit, New York, New York;
- Peninsula Transportation District Commission, Hampton and Newport News, Virginia;
- Metro Dade County Transit Agency, Miami, Florida;
- Regional Transportation District, Denver, Colorado;
- Central Ohio Transit Authority, Columbus, Ohio; and
- Westchester County Department of Transportation, Westchester County, New York.

For example, the system developed by Tidewater Consultants Inc. is designed to run in a Windows-based environment on a standard PC. The system relates stops, routes, and schedules to a GIS based on a Rapid Routing Module, an algorithm that computes a trip plan for a customer who has called. Travelers call the transit agency's telephone information center, give their origin and destination, and the system computes a trip plan, generally in under 10 seconds. Looking at a pull-down menu, the telephone center agent then can describe to the caller the proposed itinerary, or can fax it or send it in the mail. These print-outs can be multi-lingual, in Braille and/or in large type.

In San Diego County, the system includes "InfoExpress," an interactive voice response system available 24 hours a day, seven days a week. Callers can get basic route, schedule, and general information in Spanish or English for seven transit agencies in greater San Diego. This enables information agents to help with more complicated questions like trip planning. The system has resulted in a marked increase in productivity - operators are now averaging 34 calls per hour, versus 28 calls per hour, and total information requests are over 100,000 calls per month versus 75,000 calls per month before introduction of the system.

Winston-Salem, North Carolina

The Winston-Salem Transit Authority (WSTA), through the Mobility Manager model project being developed under the FTA's APTS program (see Section 5.2), is bringing "one-stop shopping" to its customers. Mobility Manager will provide users with a menu of transportation services by telephone. By calling a single number, a prospective passenger will immediately be able to schedule a trip, ask about the status of a trip, make arrangements to transfer more readily from one mode of travel to another, or receive a schedule of transportation service available in the regional area. Participating transit services includes both private and not-for-profit providers.

In the future, the Mobility Manager project will be expanded to include electronic variable message signs to provide passengers with real-time information about a vehicle en route, such as updates on delays or revised schedules. This project will establish WSTA as a "test bed" site for new research in advanced public transportation technologies and methods of operations. At present, the core project team includes representatives from North Carolina State University and the Institute for Transportation Research and Education, University of North Carolina.

Los Angeles, California

Caltrans is directing the SMART TRAVELER program,[46] which is a free automated information service to provide commuters with:

- Up-to-the-minute freeway conditions and traffic speeds;
- Customized transit route planning; and
- Real-time carpool matching.

SMART TRAVELER provides a telephone information service operating 24 hours per day (1-800-COMMUTE), which provides Los Angeles County Metropolitan Transportation Authority (LACMTA) information. The telephone information service also provides an Automated Telephone Rideshare Matching system (called Ridestar from Commuter Transportation Services, Inc.), through which registered carpoolers can obtain a list of interested carpoolers, query the system based on specific needs on a specific day, and instantly send a personal voice message.

[46] SMART TRAVELER is a public/private partnership directed by Caltrans in conjunction with the LACMTA, Commuter Transportation Services, Inc., Federal Highway Administration, FTA, Health and Welfare Data Center, IBM, North Communications, Pacific Bell, and Pacific Bell Information Services.

See Section 3.2 for a description of the SMART TRAVELER kiosks, and Section 3.4 for a description of highway information available through SMART TRAVELER.

Seattle, Washington

The King County Department of Metropolitan Services is employing several forms of electronic communication technology to access vital transportation information relating to the greater Seattle/Puget Sound region. Riderlink is an on-line information resource available on the Internet via the WWW. It gives instant access to Seattle Metro bus routes, timetables, and maps, as well as information about vanpool and ridematch services, bicycle transportation, freeway congestion, the state's commute trip reduction law, and a variety of other transportation topics. Riderlink is described further in Section 3.4.

Seattle Metro's automated Bus-Time system makes schedule information available to anyone with a touch tone phone. People can access information about their route and bus stop. Telephone trunk lines are connected with two duplexed front-end computers. As callers respond to a series of questions to identify their route and bus stop, a digitized script is packaged and passed to a VAX 3800, where Seattle Metro schedule information, route information, bus stop information, and a digitized vocabulary are stored.

Riverside County, California

Touch screen kiosks, featuring full-motion color video, stereo sound, on-screen maps, personalized public transit itineraries, and carpool matches for commuters, have been installed in the Coachella Valley area of Riverside County, California. The $373,212 pilot project, called TransAction Network, has four kiosks at shopping centers with high pedestrian traffic. The TransAction Network is being introduced by Commuter Transportation Services Inc. and SunLine Transit Agency, and was developed by IBM and North Communications. The kiosks provide the public with a one-stop source of a variety of information in English or Spanish. Users are offered five touch screen options: Carpool Service; Route Service; SunBus Maps and Videos; Rideshare Videos; and Kiosk Help. By entering a destination, arrival, or departure time and a transportation option, a user can receive a free printout of a complete SunBus itinerary including route, bus stop, fare, and schedule, as well as a carpool match list (a list of people who live and work nearby and are available to carpool). Also included with the printout is a free SunBus ticket good for one ride.

Baltimore, Maryland

The Mass Transit Administration of Maryland's transit information center has been revamped. The computer system has been upgraded to contain all of the latest schedule information. When a customer calls the information center, the operator will call up the schedule on a computer screen, instead of looking through books. Moreover, the system will keep a running memory of the customer's call based on the number where the call came from. The caller's last question asked, home address, etc. can be brought up on screen by the operator, which will save time in processing the information request. There will also be five kiosks installed in greater Baltimore to provide the same information as the operators. The future intent is to have all information be real-time, after the AVL system is fully installed and refined.

Columbus, Ohio

For the past 10 years, DAVE Transportation Services, Inc. has provided door-to-door paratransit services for the disabled citizens of Franklin County, Ohio under contract to the Central Ohio Transit Authority. Beginning in March 1995, COTA implemented the Trip Information System. It allows those riders using a touch-tone phone to call 24 hours a day, seven days a week, to enter a personal identification number and quickly confirm their scheduled trips. Beginning in early 1996, COTA will implement the next phase which will allow passengers to schedule their trips using touch-tone phone and numeric codes to enter dates, times, origins, and destinations. According to the manager of special services, "This system is like a personal tape recording device for disabled passengers. The second phase will especially benefit speech-impaired people because it will be much faster for them to push telephone buttons than verbally communicate. The bottom line as to why we undertook this project was to cut costs associated with a manual call-back system, which is very labor intensive, especially as the demand for paratransit services keeps growing."[47]

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[47] "1995 Public Transportation Innovation Award Winners," *PTI Journal*, May 1995, p. 5.

Rochester, New York

The Rochester-Genesee Regional Transportation Authority (R-GRTA) has implemented an automated telephone system. Voice Integrators of Mahwah, New Jersey. designed the system using Direct Talk software installed on an IBM PS/2 computer, which is linked to the R-GRTA mainframe computer. When a call comes into the system, Direct Talk sends the request for route, time of day, direction, and location to the mainframe, and then translates the data into a verbal response to the caller. The typical time to complete this transaction is two minutes. The request for information begins with the caller giving the route number. If the route number is not known, a listing is provided, and the caller can choose from the list to complete the request. If further information is needed, the caller can cut back into the system to speak with a customer service representative without having to hang up and redial to obtain the necessary information. Information can be obtained anytime a customer calls, including weekends and holidays on 16 lines simultaneously. Incoming calls have increased from 2,000 calls daily to 3,600 calls daily, of which 70 percent are answered by the system.

Prior to the new system, the Customer Information Center received nearly one million calls annually, with four customer service representatives answering an average of 85 percent of all peak weekday calls over seven lines. Evaluation and analysis of the computer-generated reports showed that 15 percent of R-GRTA's customers were unable to obtain information and hung up. A week-long analysis by the Rochester Telephone Corporation showed that hundreds of other callers were getting busy signals during weekday peaks - weekends and holidays were even worse.

With support from transit systems in Columbus, Ohio, Baltimore, Maryland, and Buffalo, New York, who already have automated voice response systems, Regional Transit Service (R-GRTA's fixed-route service) customer service representatives and employees from the scheduling, planning, and management information systems departments formed an internal team to monitor and develop the system from concept to full implementation. The team evaluated issues that concern many transit operators when implementing this type of a system. They evaluated how to deal with timepoints, routes which loop together and do not follow the same route every time, route numbering, what information to provide, and how much information should be updated. R-GRTA decided, after evaluating and testing other transit information systems and surveying a sample of regular callers, that the voice response unit needed to be simple and target information calls from regular riders, which make up 85 percent of the callers. Also, the data system had to interface with the current schedule so that changes in schedules occur automatically in the voice response system.

The $150,000 capital cost is expected to be recovered by eliminating four part-time representative positions.

Newark, New Jersey

The New Jersey Transit's automated telephone information system that went into service in November 1993 has dramatically reduced the waiting time for customers calling NJT for bus and train schedules and has allowed the agency to answer more calls than ever before. The system provides callers with train schedule and fare information and supplements live operators, who continue to provide bus and rail schedule information for those customers who choose to speak to an operator or who need special assistance. Although the automated system provides only rail schedule information, it has benefited those calling for bus schedule information by allowing more callers to reach the agency. (Bus schedule information is not automated due to the number and complexity of NJT's bus routes.) The total number of calls handled by NJT in November 1993 compared to November 1992 increased by more than 40,000. In its first full month of operation, the new Interactive Voice Response System cut waiting times for those who called the agency's Transit Information Center from 85 to 27 seconds. "The initial response from our customers to this new technology has been excellent," said NJT Executive Director Shirley A. DeLibero. "The system already has processed about 100,000 calls (in the first month of operation), and our lost call rate, which measures the number of people who hang up prior to reaching an operator, has fallen from 10 percent to a low of 3 percent."[48]

Jamaica, New York

The Long Island Rail Road's Traveler Information Center provides callers with information, 24 hours a day, that ranges from fares and schedules, to up-to-the-minute status of train services, to

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[48] "NJ Transit's Customer Information Speeded Up by New System," *Passenger Transport*, January 24, 1994, p. 4.

special excursion packages and tours. In 1994, over 4.4 million calls for information were answered by the Center, setting a new record. This represents a 7.6 percent increase over the volume of calls fielded in 1993, and a 28.2 percent increase over 1992. The Center was originally automated in 1990 using "Teletrip," a highly sophisticated telephone travel information system featuring a computer-generated voice, and was designed to handle 72 incoming calls simultaneously. With a system upgrade in late 1993, the Center can now accommodate up to 100 calls at a time.

Honolulu, Hawaii

Pre-recorded phone messages that provide transit route information to more than 10,000 visitors to the island who call each week was initiated in Honolulu for their transit service called TheBUS. The message is recorded in both English and Japanese. The objective is to provide more efficient "places of interest" route information 24 hours daily without the necessity of speaking with TheBUS information agents. The service was developed by Harris Johnson, GTE Directories Services Corporation/On Call in Irving Texas, together with William L. Haig of Oahu Transit Services (TheBUS). All the computer equipment is housed at GTE Directories Services Corporation in Texas, eliminating the need for investment in costly equipment in Honolulu.

Starting with about 40 calls daily in November 1993, the rate of visitor calls is now about 100 daily. "Implementation time was meteoric. All we had to do is provide the route information script to and from 52 places of interest. They did the rest. Now we just promote it locally on a continuing basis."[49] TheBUS is expecting about 700 calls daily in summer 1996 as awareness of the service increases.

Detroit, Michigan

The Suburban Mobility Authority for Regional Transportation is in the process of designing a new regional customer telephone information system (RCTIS) in an effort to improve coordination of both paratransit and fixed-route service in the Southeastern Michigan area served by SMART. The RCTIS is envisioned to operate as follows. A customer calls a local or 800 telephone number (e.g.,

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[49] "Honolulu Introduces Visitor Information Phone Service," *Passenger Transport*, April 18, 1994, p. 16.

1-800-GO-SMART) to obtain information on linehaul and/or paratransit services. After making an initial menu selection or speaking directly with a customer service operator, either the requested information is provided, the call is automatically forwarded or transferred to the appropriate operator, or the call is transferred to a local service provider.

Any operator will be able to handle either linehaul or paratransit requests for information because the new RCTIS will provide them with an automated system that will assist them in giving specific trip planning information, reserving a ride on paratransit services, transferring their call directly to a local paratransit provider, providing general information, providing route-specific delay information, and logging complaints.

Options that are being considered for the RCTIS include:

- 800 number for all linehaul and paratransit information and reservations;
- Automated Trip Planning and Service Bulletins for linehaul service;
- Linehaul customer information database;
- Front-end menu options for both linehaul and paratransit;
- Limited off-hours information for both linehaul and paratransit;
- Automated Voice Response for both linehaul and paratransit;
- Caller Identification for both linehaul and paratransit; and
- Recording of linehaul telephone calls.

Atlanta, Georgia

The Metropolitan Atlanta Rapid Transit Authority is implementing a trip planning system that will support MARTA's customer information center and kiosks that will be available for the Olympics. The Passenger Routing and Information System (PARIS) (provided by Megadyne) requires an origin and destination to produce a nearest bus stop-to-nearest bus stop itinerary. Origin and destination can be input in the form of a street address, an intersection or a landmark. Although the itinerary does not provide instructions to reach a bus stop, it does take into account walking time and impossible walks (e.g., crossing a river without a bridge). All the options for a trip are ranked by PARIS, and the highest ranked option will be provided. MARTA will decide how to rank the options and whether or not to provide multiple options prior to full implementation. In addition, a limited amount of highway-related information can be obtained from PARIS.

The AVL system, which is being implemented by Transportation Management Solutions for the Olympics, will provide real-time vehicle status information to the itinerary planning system. This capability will enable the trip planning system to provide itineraries based on actual vehicle arrivals and departures as well as providing information on service disruptions. More information regarding the overall Traveler Information Showcase for the Olympics, which includes this itinerary planning system, is discussed in Section 3.4.

Houston, Texas

Houston Smart Commuter, an operational test sponsored by FTA, FHWA, Texas DOT and Metro, is assessing "the potential for encouraging greater utilization of high-occupancy commute modes (e.g., buses, carpools, and vanpools) by applying innovative approaches using advanced technologies to provide information."[50]

There are two components of the Houston Smart Commuter project: the bus component and the carpool component. "The bus component focuses on commuters living in the Kuykendahl [and Spring] park-and-ride lot market area[s] along I-45 North, and working in downtown Houston. The goal of this component is three-fold:

- Encourage a mode shift from single occupancy vehicles to buses,
- Change the times people choose to make their trips, and
- Shift travel routes.

"These changes in travel decisions will result from the provision of real-time information on traffic conditions, bus schedules, and directions on how to use the bus. The technologies to provide the real-time traffic and transit information [that are] under consideration include:

- Touch-tone and cellular telephones,
- Cable television,
- Videotex (both 'smart' and 'dumb' terminals), and
- Pocket systems."[51]

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[50] FTA Office of Technical Assistance and Safety, "Houston Smart Commuter", *APTS Brief 6*, June 1994, p. 1.

[51] Ibid, p. 2.

Minneapolis/St. Paul, Minnesota

In the Minneapolis/St. Paul, Minnesota area, transportation officials are looking to advanced technology to make transit operations more efficient and attractive to commuters. Called Travlink, this $6.5 million demonstration project is part of Minnesota Guidestar, Minnesota DOT's program for ITS, which is actively testing and deploying new technologies that improve the movement of people, goods and services. Travlink represents the integration of a computer-aided dispatch and AVL system based on the global positioning system, an advanced traveler information system (ATIS) and an automatic vehicle identification system in the I-394 corridor in the Minneapolis/St. Paul metropolitan area. Travlink is using "a variety of devices and systems to distribute both real-time and static transit and traffic information to travelers. A primary objective is to determine the extent to which improved information can assist travelers with trip-making decisions and influence travel behavior. Travlink is designed to encourage commuters to consider alternatives to single-occupant travel, especially public transit."[52]

Metropolitan Council Transit Operations is the transit operator in the Minneapolis/St. Paul metropolitan area, and currently has a fleet of approximately 800 buses. They operate on 120 routes with over 1,000 branching combinations. The Travlink project selected 80 buses on nine routes to be equipped with GPS CAD/AVL. Real-time information from these buses is used together with traffic information collected from the Traffic Management Center[53] to provide Travlink users with real-time, route-specific information on the operating conditions of the highway and transit systems, and with other personal-use types of information.

Pre-trip information provided through Travlink includes trip planning information in the I-394 corridor. "How Do I Get There" includes planning from Downtown Minneapolis to the Western Suburbs, from the Western Suburbs to Downtown, Downtown Minneapolis to/from Points of

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[52] Westinghouse Electric Corporation, Strgar-Roscoe-Fausch, Inc., 3M and Rennix, U.S. West Communications Services, Inc., and Motorola, **Travlink Project: Concept Definition and Preliminary System Design,** prepared for Minnesota DOT, Federal Highway Administration, Federal Transit Administration, Regional Transit Board and Metropolitan Transit Commission, April 1994, p. 1-1.

[53] This traffic information is provided through Genesis, which is an operational test of personal communication devices. The PCDs identified for Genesis include alphanumeric pagers, personal digital assistants (a small hand-held unit with 2-way radio frequency communications), and notebook computers. Currently, Genesis is in a six-month pilot phase which provides traffic information to commuters via 350 pagers and 50 Apple Newtons with pager cards.

Interest, and Downtown Minneapolis to/from the University of Minnesota/Minneapolis Campus. Many other types of information are available through Travlink - these are described in Section 3.2.

Videotext terminals that operate the Travlink software have been distributed to a group of people who have been recruited by the project. This group is made up of ⅓ carpoolers, ⅓ transit users and ⅓ people who drive alone. As of November 1995, there are 315 videotext terminal users and 10 businesses who are using the terminals.[54]

Terminal usage shows that:

- Users are accessing real-time bus stop information, but they want more;
- There is a high usage of traffic and construction information;
- The static text menus are not used very much; and
- There were 1,389 logons in the first month by the 150 recruited for the program.

In August 1995, over 90 participants logged onto the system one to five times; 17 logged on six to ten times; and nine logged on 11 to 15 times. Those participants that logged on one to five times could be categorized as: just under 70 percent of the bus riders, just under 80 percent of the people who drive alone, and 80 percent of the carpoolers. The majority of menu selections were for bus arrival times at stops, the next most frequent selection was for transit schedules and maps, and the next for traffic construction and maintenance. On-line activity is highest on weekdays from 3 pm to midnight. The next highest is from 6 to 9 am.

3.2 IN-TERMINAL AND WAYSIDE INFORMATION SYSTEMS

In-Terminal and Wayside Information Systems provide schedule updates and transfer information for passengers already en route. "This information includes arrival and departure times, information on transfers and connections, information on other regional transportation services and information on related services, such as park-and-ride lot availability."[55] This information can be provided via electronic signs, kiosks or television monitors. The information available through use of technologies such as AVL will help transit agencies now and in the future provide information in

[54] Marilyn Remer, Travlink Project Director, Minnesota DOT, St. Paul, Minnesota.

[55] Schweiger, Carol L., **Review and Assessment of En-Route Transit Information Systems**, prepared for FTA Office of Research, Demonstration and Innovation, July 1995, Report Numbers FTA-MA-26-7007-95-1 and DOT-VNTSC-FTA-95-7, p. 5.

real time. The key benefit for the traveler will be a more accurate sense of departure and arrival times for a trip.

State-of-the-Art Summary

Traditionally, in-terminal and wayside information has been disseminated manually in the form of paper schedules or static signs. Further, real-time information, such as actual bus arrival or departure time, has not been traditionally available to give to the customer. With the advent of advanced public transportation systems such as AVL, real-time, en-route transit information can be made available to the customer in a variety of forms.

However, automated in-terminal and wayside information systems are in their infancy in North America, primarily because APTS technologies needed to support these systems are just beginning to be fully implemented. Currently, there are only a few of these systems in operation, but many are being planned. A few transit agencies are providing smart kiosks which convey schedule information, trip planning information, and static files such as the location of popular restaurants. Visually and hearing disabled travelers are enjoying the benefits of kiosks that convey transit information in a form that they can acquire with a minimum of effort.

Applications

Halifax, Nova Scotia

Metro Transit has 14 video display kiosks, 14 speaker phones and four auto-dial phones (with direct connections to their information center) located throughout greater Halifax, all providing bus location information in real time. To access information from the phones, the traveler enters a four-digit code signifying his or her nearest bus stop. The system responds with information on the next two buses that will arrive at that location. Additional information regarding Metro Transit can be found in Section 2.3.

London, Ontario

The province of Ontario is partially sponsoring a demonstration project using generic specifications it developed for an AVL system implementation in London, Ontario. The project, scheduled for completion in the spring of 1997, will feature real-time information and scheduling. A key component is that, as a bus is on route, an algorithm within the central processing unit will predict the time at which the bus will be at all of its following stops. Based on battery-powered signposts, signals every 30 seconds from the bus will tell the dispatcher in real time what time the bus will be at all of the next stops. During times of inclement weather (e.g., snowstorm), information exchange between the dispatcher and operator can be very useful to the traveler in that corrective action can be taken at any time during the course of the route, if needed. Previously, the transit agency spent over $40,000 doing a one day survey on schedule adherence. With this system, data on schedule adherence will be gathered on an on-going basis, both saving money and providing management with valuable information to make the service more user-friendly.

The public information center will have the same information as the dispatchers and also provide information in real time. It is anticipated that the real-time bus stop arrival information will be available from the information center through automated messages, while the human operators will handle trip planning requests. One of the biggest complaints of customers in London is that transfers are not well coordinated. This system will guarantee transfers at transfer points, even if it means holding the bus for a period of time. This is due to the ability of the dispatcher to give instructions to the operator based on the dispatcher's knowledge of where all buses are located at any time. This is especially useful during off-peak times when headways are long.

Tucson, Arizona

The City of Tucson's transit agency, Sun Tran, is currently reviewing bids for an AVL system. As part of the overall package, there is a component for installing four touchscreen kiosks at their three transit transfer centers, including two kiosks at the downtown center and one in a transfer center that is about to be constructed. The initial plan is for the kiosks to provide basic schedule, route, and time information. As the AVL system is completed and implemented, the kiosks are anticipated to provide real-time information. Eventually three to six more kiosks will be installed in other locations in the city, with the University of Arizona campus most likely to receive at least one kiosk. Also included in the AVL system will be the automation of the telephone information center for some routes to provide real-time bus arrival information, and the implementation of annunciators on buses to comply with the Americans with Disabilities Act.

Minneapolis/St. Paul, Minnesota

As described in Section 3.1, Travlink is part of Minnesota Guidestar, and represents the integration of a computer-aided dispatch and AVL system based on the global positioning system, an advanced traveler information system and an automatic vehicle identification system in the I-394 corridor of the Minneapolis/St. Paul metropolitan area.

There are currently three interactive Travlink kiosks in downtown Minneapolis locations: two are located at business centers (Hennepin County Government Center and Commuter Connection in the Pillsbury Building) and one is located at a transit store. The kiosks provide information on the following topics:

- Transit Information:
  - How Do I Get There?
    - -- Downtown Minneapolis to Western Suburbs;
    - -- Western Suburbs to Downtown;
    - -- Downtown Minneapolis to/from Points of Interest; and
    - -- Downtown Minneapolis to/from the University of Minnesota/Minneapolis Campus;
  - Schedules and Maps;
  - Is My Bus Late?
  - Bus Fares;
  - Park-and-Ride Locations;
  - I-394 Commuter Services;
  - Special Events;
  - Elderly and Disabled Services;
  - Bus Service Changes;
  - Customer Service;
- Traffic Information:
  - Incidents and Delays; and
  - Construction and Maintenance.

Kiosk usage shows that:[56]

- Transit locations get more usage for transit information;
- Real-time bus stop information is not being utilized;
- There is a significant use of the traffic information;
- The static text menus are not used very much; and
- There is varying usage between locations - it is averaging between 250 to 500 logons per month.

In August 1995, the number of kiosk logons were:

- Approximately 200 at the Commuter Connection kiosk;
- Approximately 700 at the Government Center kiosk; and
- Approximately 1,200 at the Transit Store kiosk.

Kiosk activity was highest on weekdays from 1 to 3 pm. Next highest was weekdays from 3 to 6 pm, and next was weekdays from 11 am to 1 pm.

The most kiosk inquiries in August 1995 were made to the "How Do I Get There" menu item. The next highest number of inquiries were made to the schedules and maps menu item, and the next highest was traffic incidents and delays.

There are monitors at two major transit transfer centers that display real-time status information on arriving buses equipped with AVL, and schedule information on arriving buses not equipped with AVL. Also, there are electronic signs displaying the same information at four park-and-ride locations. The information displayed on the monitors and electronic signs is:

- Route number;
- Scheduled arrival time;
- Destination;
- Status (e.g., 15+ minutes late); and
- The current time.

By early 1996, enough information will be available to determine whether real-time traveler information encourages commuters to consider alternatives to single-occupant car travel, and whether on-time performance of buses has increased.

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[56] Marilyn Remer, Travlink Project Director, Minnesota DOT.

Cincinnati, Ohio

Metro bus operations of the Southwest Ohio Regional Transit Authority recently released an RFP for a Bus Service Management System. The RFP calls for a new state-of-the-art communications system, computer-aided dispatch/AVL, schedule adherence, next-stop annunciation, vehicle condition monitoring, and bus stop information kiosks. These advanced technologies will be deployed initially on a number of selected routes and analyzed for full fleet deployment.

A goal of this system is to provide real-time information to the public. The use of the vehicle logic unit in conjunction with the AVL will allow the bus to automatically initiate the next-stop audio and visual annunciators. It is also planned that these annunciators can be used to provide up-to-the-minute information about route conditions, detours, etc. on the vehicle. The real-time data about route/schedule adherence will be transferred to kiosks for the general public at major boarding areas, as well as at the fixed-route customer information service. "We consider this option one of the major benefits of our BSMS by providing the availability of timely, accurate information to the public. By providing real-time information on actual, as opposed to scheduled arrival of buses, and by providing the capability to positively inform passengers of temporary service changes at stops, the level of passenger information will be significantly improved."[57] Currently, passenger information at stops is provided on painted signs and is limited to route numbers servicing that particular stop.

The paratransit service called ACCESS, which is presently operated under contract with Mayflower, will also utilize the AVL on a few paratransit vehicles. Included will be schedule adherence, mobile data terminals, and vehicle condition monitoring. The paratransit operations will be issuing a separate RFP in the near future for additional software. This software will be for reservations, scheduling, and automated customer service/passenger information.

New York City, New York

The Baruch College Computer Center for Visually Impaired People, together with the New York City Metropolitan Transportation Authority (MTA), "is in the first phase of an 18-month project to develop a pilot Talking Directory Display System [TDDS] to be used in complex,

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[57] Gregory Lind, Project Manager - Radio/ITS, Metro/SORTA, Cincinnati, Ohio.

intermodal stations."[58] The New York City Transit subway system and the LIRR in "New York's Penn Station were chosen for the TDDS, which will provide three forms of accessible information:

- A schematic overview of the station displayed on a tactile/large print map;
- Spoken or displayed information in large print on a computer-assisted system connected to the map, which is activated by touching points on the map; and
- Information coordinated with large print and Braille signs installed on platform levels of the station at the demonstration site.

The information system is being designed to provide route information to let users easily, efficiently, and safely access major parts of the station. It will be like a three-sided telephone booth containing a podium-like structure that will house the computer,"[59] and will be activated when a person steps on a mat. It is expected to be operational in early 1996.

Ann Arbor, Michigan

The Ann Arbor Transportation Authority (AATA) recently initiated an 18-month, $1.9 million program designed to provide an Intelligent Transportation System. In September 1995, AATA issued a new request for proposals, which will contain several technologies including:

- Automatic annunciation and displays in the vehicle;
- A limited demonstration of wayside signs that indicate the status of the next bus (e.g., amount of time remaining before the arrival of the next vehicle);[60]
- Optional messages to cable television regarding real-time system and vehicle status; and
- On-board processor that interfaces with all on-board components, including passenger counters, annunciation systems, interior and exterior destination signs, public address systems and radios.

The Intelligent Transportation System will be implemented incrementally in phases. Phase I involves the implementation of a GPS-based AVL system, automatic annunciators, and interior signs. Phase II involves the implementation of a cashless payment system and a cash collection system.

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[58] Jim Fleming, "Projects Aid Transit Users with Sight, Hearing Impairments," *Passenger Transport*, July 17, 1995, Volume 53, Number 29, p. 12.

[59] Ibid, p. 12.

[60] Ann Arbor Transportation Authority, **Request for Proposal #328 - Intelligent Transportation System, Project Summary & Specifications**, August 30, 1995, p. 6-15.

Corpus Christi, Texas

The Corpus Christi Regional Transportation Authority (CCRTA) is considering the development of a demonstration program at their Staples Street Station to provide real-time next bus passenger information. The initial demonstration consists of installing a display kiosk, or "Intelligent Public Information Display," at their Staples Street Station. Customers will be able to find out the real-time status of their route and expected arrival time. If the initial demonstration is successful, CCRTA will test additional units at several stops. Also, CCRTA intends to install display units at other locations which would display the arrival time of the next bus. This demonstration program is part of a larger Request for Proposals utilizing Automated Vehicle Location equipment which was to be issued in Fall 1995.

Spokane, Washington

The Spokane Transit Authority is installing a new Electronic Passenger Information System designed to improve transit service and customer information at Spokane's new downtown transit facility called the Plaza. This $567,000 automated computer system will be used to control and monitor bus traffic and to provide passengers with scheduled arrival and departure times for buses using any one of the 10 bus bays located around the Plaza.

Bus Bay Availability Indicators, similar to traffic lights, will be located near the bus holding areas on Sprague and Riverside streets and will show the bus operators when their assigned bay is vacant. Banks of video monitors, similar to those in airport terminals, will be located inside the Plaza and will display current bus schedule information. In addition, each bus bay will have a large display sign which will indicate route name, number, and scheduled departure time for the bus currently parked in the bay.

New York City, New York

New York City Transit awarded a $3 million (Canadian $) contract in November 1994 to Telecite, a Montreal-based electronic services company, to supply electronic display boards for installation on subway platforms. Telecite will supply 409 multi-colored, animated display boards that will be installed in selected NYCT subway stations. Delivery and installation of the display boards was to begin in the fall of 1995 and continue through the summer of 1996.

The displays will provide timely messages, such as train service interruptions, next-train arrival time, or temporary service halts due to construction, as well as promotional messages. The displays will also include audio for the benefit of the visually impaired. The project was developed in collaboration with Transport Canada, Industry Canada, and the National Research Council of Canada.

San Francisco/Oakland, California

A joint effort by the San Francisco Municipal Railway and the Bay Area Rapid Transit agency is evaluating new "Talking Signs" for the visually impaired at San Francisco's Powell Street Station. This is the first use ever of remote audible signs in a transit facility. "Talking Signs" provide to blind and low-vision persons the same directional and usage clues that traditional visual signs provide to sighted persons. They work by sending information from installed infrared transmitters to a hand-held receiver. 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. "Talking Signs" were developed by Smith-Kettlewell of the California-Pacific Medical Center, Love Electronics and Talking Signs of Baton Rouge, Louisiana as part of a demonstration project being managed by Project ACTION under a contract with the FTA.

Houston, Texas

Metro will be involved in a public security project, in which closed-circuit television (CCTV) cameras and call boxes with two-way communication will be installed at park-and-ride lots and transit centers. These cameras and call boxes would be monitored from TranStar, Houston's transportation management center. Each bus stop on one major route downtown (that runs along Main Street) will also have a CCTV camera and a call box for security. These call boxes eventually will allow travelers to obtain bus schedule information initially and dynamic information at a later time.

Los Angeles, California

Caltrans is directing the SMART TRAVELER program, which is an automated information service to provide commuters with:

- Up-to-the-minute freeway conditions and traffic speeds;
- Customized transit route planning; and
- Real-time carpool matching.

SMART TRAVELER provided interactive (touch-screen) kiosks, which allowed the traveler to access the Los Angeles County Metropolitan Transportation Authority bus, train, and shuttle schedules, routes, and fares (information used for this activity came directly from LACMTA's mainframe computer, which contains complete information on over 1,000 bus and train routes). The kiosks also provided the traveler with the capability to build transit itineraries, which could be printed at the kiosk, and to access the current list of carpoolers registered in the area.

As discussed in Section 3.1, the 1-800-COMMUTE telephone information service (operating 24 hours per day) provides an Automated Telephone Rideshare Matching system and LACMTA information.

Seventy-eight kiosks were fully installed and operational, but removed in June 1995, due to funding problems. Also, the freeway conditions map that was displayed from kiosks is available through the Internet (see Section 3.4). In the future, SMART TRAVELER services may be available through cable television. Currently, a few kiosks are located at Caltrans as demonstration units, and several are in Santa Barbara to be used for future prototype development. The rest of the removed kiosks are being warehoused at LACMTA.

An evaluation of the usage of 41 of the kiosks resulted in the following:[61]

- 79% of survey respondents said that the Smart Traveler Kiosk was easy to use;
- 85% said they would use the kiosk again;
- 88% said they would encourage other people to use the kiosk services; and
- 56% requested information on MTA bus and train routes.

A more complete evaluation of the kiosks and their usage is available from Genevieve Giuliano, School of Urban and Regional Planning, University of Southern California.

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[61] Giuliano, Genevieve and Jacqueline M. Golob, **Los Angeles Smart Traveler Information Kiosks: A Preliminary Report**, Working Paper LCRI-95-02, Lusk Center Research Institute, University of Southern California, Revised, March 29, 1995.

3.3 IN-VEHICLE INFORMATION SYSTEMS

In-vehicle information systems include technical innovations which support the transit user enroute. Travelers are aided by on-board displays and communication devices which provide information on routes, schedules, and connecting services. Transit agencies are including these devices in their vehicles for two key reasons: 1) to facilitate the transit trip and make necessary information more user friendly, and 2) to comply with the requirements of the ADA. The ADA requires that all fixed-route transit vehicles provide both visual and audible information "at transfer points with other fixed routes, other major intersections, and destination points, and intervals along a route sufficient to permit individuals with visual impairments or other disabilities to be oriented to their location."[62] Further, any stop must be announced/displayed on request of an individual with disabilities. Automated annunciation devices also remove the responsibility for announcing stops from the drivers, leaving them free to concentrate on driving which should result in greater safety for passengers.

Although not strictly an in-vehicle information system for passengers, several transit agencies are experimenting with surveillance cameras on selected routes and equipment. It is intended to be a deterrent to crime and to curtail false injury claims made when vehicles are involved in accidents.

State-of-the-Art Summary

Rail systems typically have provided audio announcements for stops because they operate on exclusive rights-of-way. Bus systems are in the process of providing information through automated annunciator technology. This technology, based on GPS location or on odometer readings, automatically announces/displays stops, major intersections, and major transfer points. As transit agencies implement AVL systems, more accurate and real-time information will become available. Both rail and bus are beginning to implement in-vehicle information systems that provide not only transit-related information, but also news, weather, and advertising information.

[62] "Transportation for Individuals With Disabilities; Final Rule," *56 FR 45640*, September 6, 1991.

Applications

New York City, New York

The New York City Metropolitan Transportation Authority is implementing several pilot programs to test in-vehicle message systems. There are two "new technology" subway cars which are being tested which include real-time in-vehicle announcements. An RFP has just been released for the bus program AVL, which will include in-vehicle announcements. As part of this RFP, there will be a one-year pilot program based on the 126th Street Bus Depot and Bus Command Center locations. As part of the goal for service improvements, it is anticipated that accurate customer information will be transmitted in-vehicle and at kiosks at remote bus stops to provide real-time schedule information.

Corpus Christi, Texas

The Corpus Christi Regional Transportation Authority is considering upgrading their paratransit and fixed-route passenger information systems. Specifically, CCRTA is looking to upgrade their communications equipment in the fixed-route buses to provide next-stop audible annunciator, visual display, and on-board loudspeaker equipment. For the paratransit operation called Care-B, radio equipment on Care-B buses will be upgraded. Current scheduling software will be integrated with the radio enhancements to provide the ability for dynamic, real-time rescheduling of the fleet during the day, as no-shows provide gaps which can be filled with additional passenger pickups. This enhanced communication between operator, passenger, and dispatcher will help provide for accurate address and time information, avoiding wasted time and travel to incorrectly communicated addresses. The Request for Proposals was to be issued in October 1995.

Scranton, Pennsylvania

The County of Lackawanna Transit System in Scranton, Pennsylvania recently implemented one of the first AVL systems for public transit in which the Vehicle Tracking Unit can initiate the "next stop" announcement system. Designed by Auto-Trac, Inc., the Fleetservice system includes the following: differential GPS; GPS-triggered next-stop announcement system; on-time schedule monitoring; multiple mapping stations controlled by an area network; and a replay feature to play back the movement of any bus for any given time and date. See Section 2.3 for a further discussion of the COLTS AVL system.

Newark, New Jersey

New Jersey Transit is testing two Automated Voice Annunciator Systems (AVAS) to enhance bus service and comply with the ADA. One of the systems, called Automatic Passenger Information System, is developed and marketed by Clever Devices Ltd. and Siemens Transportation Systems, Inc. The other, called the Talking Bus System, was developed and marketing by Digital Recorders Inc. "Both systems are being evaluated on a trial basis along diverse and heavily patronized bus routes in northern New Jersey."[63]

"The [Automatic Passenger Information System] device [was] installed on NJ Transit bus No. 6335, which operates on a route between Dunellen and New York. The route was chosen because of its unique qualities, providing both long-distance runs and frequent stops along different legs of its intercity and interstate service."[64] This device uses the bus odometer to automatically read a pre-programmed announcement to customers on the bus at major stops being approached by the bus. Beside this audio announcement, the locations are displayed inside the bus just above the operator, for passengers with hearing disabilities. After the operator has stopped the bus and opened the door, visually impaired passengers outside the bus hear another automated announcement that identifies the bus route number and its destination. Hearing impaired customers can identify the bus route by the destination sign on the front of the bus.

The Talking Bus System uses GPS to determine vehicle location, which is then compared to stored route data. Once the vehicle location matches the route data, the message associated with that location is triggered. This system is being tested on different routes than the Automatic Passenger Information System.

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[63] "Voice Annunciator Tested on NJ Transit Buses," *Passenger Transport*, September 4, 1995, Volume 53, Number 35, p. 15.

[64] "Voice Annunciator System Is Tested on NJ Transit Buses," *Passenger Transport*, May 8, 1995, Volume 53, No. 19, p. 17.

As both systems are tested, NJT will be conducting two surveys: an initial survey to obtain public opinion on each system, and a second survey after several months to identify any changes in public opinion. In addition to the bus system, NJT is evaluating the potential for installing an AVAS in the Newark City Subway and/or on NJT rail service.

A final decision on which technology will be selected is expected in early 1996.

Transit Cooperative Research Program - Electronic On-Vehicle Passenger Information Displays

> "The state of the art of electronic communications is highly developed. However, information regarding these technologies and their applications is not widely disseminated. The purpose of this study is to identify and summarize (1) those electronic communication technologies presently in transit use and (2) non-transit applications of such technologies that have potential for transfer to transit. This study will summarize passenger information needs, operator concerns, and the ability of current and emerging technologies to meet those needs. It will identify (1) any disparities between the needs of passengers and operators and (2) the capabilities of electronic display systems."[65]

An interim report is currently being reviewed. This report contains study findings, including:

- Passenger and operator needs;
- Technology overview, including current practices and applications;
- Advertising revenue potential; and
- Cost and revenue information.

It also identified disparities between technology and needs, and provides guidelines to assist in deciding whether or not to purchase an on-vehicle electronic passenger information display system.

3.4 MULTIMODAL TRAVELER INFORMATION SYSTEMS

Multimodal Traveler Information Systems (MTISs) provide information on both highway and transit travel. The highway aspect of these systems can convey real-time information about traffic conditions, incidents, construction, weather conditions, and park-and-ride lot space availability, as well as static information regarding routes, directions, and travel services. The transit aspect can convey real-time transit vehicle arrival and departure information, system disruptions, and carpooling

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[65] Transportation Research Board, **Transit Cooperative Research Program: Annual Report of Progress 1994.**

opportunities, as well as static information on transit services, schedules, fares, routes, stop locations, and ridematching registration.

MTISs can be provided through the integration of transit and highway information on a variety of media, such as kiosks, electronic signage and personal computers. Often, the information is provided through a transportation management center, which has been defined as follows: "A transportation management center employs advanced technologies to provide transportation information and/or to manage and control transportation networks."[66] TMCs are discussed in Section 5.3.

State-of-the-Art Summary

Several MTIS are either under development or in various stages of implementation. FTA's **Review of and Preliminary Guidelines for Integrating Transit into Transportation Management Centers** discusses MTISs in Anaheim, Denver, Houston, and Minneapolis/St. Paul. Other MTISs of note, discussed in this section, include the Atlanta Traveler Information Showcase, the Bay Area's TravInfo, the Seattle Wide-area Information for Travelers (SWIFT), and Boston's SmarTraveler.

Further, an increasing number of MTIS implementations are available through the Internet's World Wide Web, which currently has many sites specifically for real-time traffic and static transit information. Because of the large number of WWW sites containing MTISs, only a few selected sites will be covered in this section.

Applications

Atlanta, Georgia

The Metropolitan Atlanta Rapid Transit Authority is implementing a number of Intelligent Transportation System projects that will connect their multimodal transit system with an advanced

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[66] Schweiger, Carol L., **Review of and Preliminary Guidelines for Integrating Transit into Transportation Management Centers**, prepared for the Volpe National Transportation Systems Center, funded by FTA's Office of Technical Assistance, Final Report, July 1994, Report No. DOT-T-94-25.

transportation management system (ATMS) and an advanced traveler information system. The Traveler Information Showcase is part of the advanced traveler information system, and has links to the ATMS. "The purpose of the Showcase - which is supported by the Federal Highway Administration (FHWA) and the Federal Transit Administration of the U.S. DOT in partnership with the Georgia Department of Transportation (GDOT), the Metropolitan Atlanta [Rapid] Transit Authority and others - is to provide the public with an impression of the value of real-time traveler information that is now only known to transportation planners and engineers. The Showcase demonstration is unique for three reasons: (1) the variety of data sources, (2) the numerous means for providing information directly to the public, and (3) the vast amount of real-time information available."[67]

During the Summer Olympics in 1996, traveler information for the Atlanta area will be available to travelers on a variety of devices. Traveler information will include:

- Traffic congestion and incidents on major highways;
- Updates on construction and road-closings;
- Bus and rail schedules;
- Directions to transit stops;
- Fare information; and
- Information on restaurants, hotels and points of interest.

This traveler information will be available through six technologies:

- 200 information kiosks (with touch-screens) located throughout Georgia;
- Wireless, hand-held computers (personal communications devices);
- Interactive television in hotel rooms;
- Dedicated transportation information channel on cable television;
- In-vehicle navigation devices; and
- On-line computer services (Internet and bulletin boards).

Private partners in the Showcase include:

- Battelle - project management and integration;
- TRW - development of the traveler information system;
- JHK and Associates - coordination and planning of traffic surveillance activities;
- SRC - coordination of the communications infrastructure and development of systems test plans;
- Walcoff and Associates - public relations and marketing; and
- BRW - operations support.

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[67] "Atlanta To Showcase Traveler Information," *The Traveler*, Issue One, July 1995, pp. 1 and 3.

The current timetable for the Showcase is:

- 1995 - Showcase system development;
- January - May, 1996 - Showcase system integration and testing;
- June - September, 1996 - Showcase operation; and
- October - December 1996 - Transfer of the system to Georgia DOT.

Currently, location information on MARTA's service area and schedules is being developed with the use of a GPS system to identify specific position information, and a GIS to enter this location information and provide mapping capability. About 10,000 bus stops and 2,500 landmarks are being mapped and will be integrated with the schedule information to be used in the traveler information system. This same information will be available through the previously mentioned 200 kiosks being installed by Georgia DOT as part of the ATMS being designed and implemented by TRW, Inc. The kiosk interface will assist users with trip planning. The interface to the Atlanta ATMS will give MARTA dispatchers access to Atlanta-area traffic conditions to improve bus-schedule performance and customer service.

Separate from the Showcase, but related, is the AVL that will be installed in 250 MARTA buses. This AVL project includes "an in-vehicle stop announcement system in 100 buses; an automatic passenger counting system in 15 buses; and variable message signs used for real-time customer information at 15 locations around Atlanta."[68]

The Internet component of the Traveler Information Showcase is being developed by Maxwell Laboratories. They will be providing real-time traffic information, MARTA schedules and locations, route guidance and other on-line services (e.g., yellow pages, etc.) to the general public via the Internet. This information will also be provided to in-vehicle devices and personal communications devices that are supported by the Showcase.[69]

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[68] "TMS, Inc. to Supply Advanced Info System," *Passenger Transport*, Monday, July 17, 1995, Volume 53, Number 29, p. 8.

[69] Dr. Joseph Masso, Vice President and Manager, Systems Applications, Maxwell Laboratories, La Jolla, California.

San Francisco/Oakland, California

TravInfo is the San Francisco Bay Area's Advanced Traveler Information System which is currently under development as an ITS Field Operational Test. TravInfo will cover 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. TravInfo is being implemented through a public/private partnership. As of November 1995, 25 organizations had agreed to participate in TravInfo.

Currently, a Traveler Information Center (TIC), the site for the collection, integration, and dissemination of traveler data, is being designed, and is expected to be operational by early 1996. "Data will be collected and integrated through manual or semi-automated processes. A human operator will interpret and make judgements about traffic and other traveler conditions. These decisions will be assisted with automated data fusion tools. As the system evolves from a manual to an automated system, human factors, as well as technical and cost constraints, will be major considerations for the design. Once the data is collected and fused by TravInfo, it will be disseminated to travelers in a variety of ways. The TIC will disseminate the data through the land-line data service and (perhaps) wireless data broadcast. The private sector will further disseminate the information by repackaging it into useful formats for various consumer groups. The information will also be available to the public over a Traveler Advisory Telephone System."[70]

Seattle, Washington

Seattle Wide-area Information for Travelers is an ATIS containing real-time traffic and transit information. "The primary objectives of this project are:

- To demonstrate delivery of traffic and transit information by FM subcarrier,
- To develop systems to aggregate, fuse, and deliver the source data from existing systems,
- To integrate traffic data from private traffic information providers, and
- To provide the traveler information to test subjects through three delivery devices."[71]

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[70] TRW/ASG, **Executive Summary: TravInfo Draft Top Level System Design**, prepared for Metropolitan Transportation Commission, December 14, 1994, p. 1.

[71] SWIFT Fact Sheet, provided by Larry L. Senn, Washington State DOT, undated.

The University of Washington will be improving their current system which can extract and fuse data from Washington State DOT (WSDOT) Seattle Freeway Management System's loop sensors and from Seattle Metro's AVL system for SWIFT. This data, along with data from Metro Traffic Control (which provides traffic condition reports locally), will be integrated for broadcast over Seiko Communications Systems' High Speed Data System. Three devices will be capable of receiving these broadcasts and other Seiko information services: the Seiko Message Watch™, a Delco Electronics vehicle navigation unit, and an IBM portable computer.

The SWIFT project team includes Seiko Communications Systems, WSDOT, IBM Corporation, Delco Electronics, Etak Inc., Metro Traffic Control, King County Metro, University of Washington, and FHWA.

In July 1996, a one-year test of SWIFT will begin, with an evaluation being completed by the end of 1997.

Boston, Massachusetts and Cincinnati, Ohio

SmartRoute Systems and MobilMedia Communications are testing alpha-numeric paging to provide traffic information to its subscribers in the Boston metropolitan area. SmartRoute Systems, through SmarTraveler, currently provides real-time traffic and transit information to Boston and Cincinnati commuters over a computerized telephone information service every day except Saturday. In Boston, data on Massachusetts Bay Transportation Authority subway, light rail, commuter rail, and bus service (in terms of major delays and trains out of service) is collected and reported through SmarTraveler throughout the day.

During the testing phase, up-to-the-minute traffic information is transmitted via the paging network to alpha-numeric pagers approximately 30 times per day. Information on accident locations, alternative route information, congestion information, and route travel times is being provided. At present, the additional cost to subscribe to this service over the pager costs $9.95 per month. In the future, SmartRoute Systems will be experimenting with technology to provide traveler advisories on electronic signs that are located on highways or in public garages.

Los Angeles, California

Caltrans is directing the SMART TRAVELER program, which is a free automated information service to provide commuters with:

- Up-to-the-minute freeway conditions and traffic speeds;
- Customized transit route planning; and
- Real-time carpool matching.

When operational, SMART TRAVELER interactive (touch-screen) kiosks allowed the traveler to view up-to-the-minute freeway conditions throughout the Los Angeles area (data used to develop the conditions comes from roadway sensors which measure exact speed at various locations throughout the Los Angeles roadway system). The WWW version of SMART TRAVELER (located at http://www.smart-traveler.com/) provides access to highway conditions in the following regions:

- North Coast;
- Cascade Mountains and Northeast Plateau;
- San Francisco Bay Area and San Jose/Silicon Valley;
- Central Coast;
- Sacramento and San Joaquin Valleys;
- Sierra Nevada Mountains;
- Yosemite National Park;
- Mojave Desert and Eastern California;
- Los Angeles Area; and
- San Diego Area.

Beside highway conditions, the WWW version of SMART TRAVELER contains information on:

- Bus service;
- Light rail service;
- AMTRAK service;
- Ridesharing;
- Park-and-ride lots;
- City of Los Angeles;
- Shuttle services;
- Los Angeles International Airport;
- Bicycle transportation; and
- Taxi services.

Internet Information

There is a proliferation of Internet sites on the WWW that provide real-time traffic information in addition to transit schedules, routing, and other information. Because the number of sites is increasing so rapidly and because there are a multitude of WWW sites, this subsection covers only selected sites that provide links to all traffic- and transit-related sites. This list is not meant to be all-inclusive.

http://transit.metrokc.gov/

Riderlink is a World Wide Web page that provides transportation information on the Seattle and Puget Sound region. While there are many other WWW sites that represent other transit agencies, Riderlink was one of the first Internet sites to provide transit information. Riderlink is a joint project between King County Metro and the Overlake Transportation Management Association (TMA), an organization made up of eight employers (15,000 employees) in a suburban office environment. Riderlink provides electronic access to rideshare and transit information and is designed to increase awareness of transportation options and encourage employees to try other commuting options by providing easy to access information.

Riderlink was on-line in December 1994, with four kiosks installed in May 1995 at selected Overlake TMA employer sites. Over 6,000 individuals accessed the page at least once in the first three months.[72] Information available on the page include:

- Bus routes, schedules and fares for Metro services;
- How to form a vanpool, driver qualifications, vanpool fees;
- On-line ridematch application;
- On-line forms to submit customer feedback to Metro;
- Bicycling information (including Metro's Bike & Ride program);
- Information about the Commute Trip Reduction Law;
- Ferry routes and schedules (from Washington State DOT);
- Freeway congestion information from WSDOT;
- Road construction updates from WSDOT;
- Overlake TMA information;

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[72] Campbell, Darwin and Catherine Bradshaw, "Riderlink: Transportation Options on the Internet," prepared for the American Public Transit Association COMPUTRAN '95, May 8-10, 1995, Reno, NV, p. 2.

- Information about employer transportation programs (kiosk sites only);[73] and
- 1996 - 2001 - Six Year Plan for Public Transportation.

In early 1996, Riderlink will include information about Community Transit and Pierce Transit bus routes, ferry schedules, and road construction updates.

http://dragon.princeton.edu/~dhb/

This page, which is maintained by the Intelligent Transportation Systems Program at Princeton University, provides the following:

- Information on highway, transit, and rail systems throughout the world. This information includes timetables and schedules, fares, current traffic conditions, worldwide subway navigation, etc.;
- Information on airports and airlines around the world;
- List of government and quasi-public organizations with an interest in transportation;
- Items of general interest (e.g., surveys), journals and magazines, images and sounds, documents, bibliographies, and data;
- Directories of resources related to railroads, aviation/aerospace, and automotive engineering and on-line publications; and
- List of transportation-related conferences and seminars, and calls for papers/participation.

http://www.Transit-Center.com

This page covers public transit information and links to other transportation-related sites. The Horizon Internet Transit Center contains lists of equipment and service providers, product specifications, a library and a calendar of events of interest to the public transit community. The library contains a law library, requests for proposals (RFPs), information for bids (IFBs), requests for qualifications (RFQs), information on Section 15, sample specifications for vehicles and equipment, and a photo gallery.

[73] Catherine Bradshaw, Capital Projects Coordinator, Sales and Customer Services, King County Department of Metropolitan Services, Seattle, Washington.

http://smagris.eleinf.uv.es/JULIE/transportes.html

This page provides links to many international transportation information sites on the WWW. Rail, bus, ferry, taxi, bicycle, and airline resources are covered by this page in addition to traffic, weather, mapping, and tourism.

4. ELECTRONIC FARE PAYMENT

Over the last few years, transit operators have adopted many innovations incorporating advanced technology in their fare payment systems, in order to achieve a variety of objectives, including:

- More sophisticated fare pricing systems, based on distance traveled, time of day, and user profile (e.g., school children, elderly, frequent users);
- Elimination of cash and coin handling, to improve security and lower costs;
- Automation of the accounting and financial settlement process to lower costs;
- Elimination of moving parts in fare boxes to increase reliability and maintainability; and
- Creation of multimodal and multi-provider transportation networks that are seamless for the rider but operationally and organizationally sound for the multiple modes and providers.

4.1 AUTOMATED FARE PAYMENT SYSTEMS

The application of advanced telecommunications, computer, and electronics technology to transit fare payment systems is resulting in the same increases in performance versus cost that are being observed in other economic areas such as telecommunications, personal finance, and information storage.

Two types of technological advancements with application to fare payment systems are discussed below. The first type is related to new hardware devices such as stored-value fare payment cards and electronic fare boxes. The second type is related to novel fare payment systems applications made possible by the existence of new hardware devices, such as the use of bank-issued credit cards for payment of bus fares, and the accompanying accounting and billing system that makes such a system efficient and effective.

Preparation of the discussion given below has been greatly facilitated by publication of two recent reports surveying the technological, organizational, and operational aspects of transit fare payment systems.[74, 75]

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[74] Bushnell, William R., **Smart Cards for Transit: Multi-Use Remotely Interrogated Stored-Data Cards for Fare and Toll Payment**, DOT Report No. FTA-MA-26-0020-95-1, April 1995.

[75] Multisystems, Inc.; and J.W. Leas & Associates, Applied Systems Institute, Inc., and Oram Associates, **Fare Policies, Structures, and Technologies**, prepared for the Transit Cooperative Research Program, Transportation Research Board, National Research Council, April 1995.

State-of-the-Art Summary: Advanced Fare Payment Media

Electronic and automated fare payment systems employ electronic communication, data processing and data storage techniques in the process of fare collection, and in subsequent record keeping and funds transfer. Electronic fare media are capable of storing information in readable, writable form. Examples of electronic fare media include smart cards containing microchips, and magnetic stripe cards or tickets.

A variety of technological advances in devices usable as electronic fare media have been made in recent years.[76, 77] A number of these have been adopted by North American transit systems in their quest for greater efficiency and operational effectiveness in their fare payment systems. In general, each of these advances is only one part of a transit operator's overall fare payment system, and each one can be employed as part of more than one overall systems approach.

Magnetic Stripe Cards

Magnetic stripes can be imprinted on cards made of heavy paper, thin plastic, or heavier plastic such as that used for standard credit and ATM cards. The magnetic material can have more easily written low coercivity, or more secure high coercivity. (Coercivity is a measure of how great an external magnetic field must be applied to alter the state of magnetization and thereby "rewrite" a magnetic storage medium.) Magnetic material can also be buried under a thin layer of plastic for very long life.

A number of transit authorities use read-only magnetic stripe passes for buses and subways. High coercivity magnetic media have been adopted by a number of transit systems to hinder the efforts of counterfeiters.

Contact-Type Integrated Circuit Smart Cards

Integrated Circuit (IC) smart cards each contain a microcomputer in addition to electronically erasable programmable memory (EEPROM) and read-only memory (ROM). The EEPROM can be used for storing information on the cash content of the card, use history, and other data subject to

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[76] Op. cit., Bushnell, William R., Appendix A: Automated Card Technology Profiles.

[77] Op. cit., Multisystems, Inc., et al., Chapter 6: Electronic Fare Payment Options.

change. ROM is used for storing the microprocessor's operating program, as well as card identification data. The microcomputer makes possible the performance of computational routines involved in verifying a user's positive identification number as must be done for some transactions; guarding against tampering; and providing for data encryption, if necessary, for security or privacy. The high immunity to tampering made possible by encryption can help guard against a card's cash content being tampered with, while allowing its cash content to be increased by valid transactions.

Contact-type IC smart cards employ an array of metal contacts in a small patch on one side of the card for carrying electrical power and signals between the card and the read-write unit into which it is inserted. Because generally there is no on-card battery, nonvolatile memory such as EEPROM must be used on the card. Recent advances in "flash memory," a type of EEPROM suited to multiple and rapid read-write operations, have increased the performance and lowered the price of IC smart cards.

Contact-type IC smart card technology represents a further development of the IC contact-type EEPROM cards that have been used in Europe for a number of years for pay telephones. These pay telephone cards are sold in fixed denominations, are used until their initial value is exhausted, and then are discarded or saved as collectibles. They employ IC semiconductor read-write memories with a particular hard-wired logical structure that allows their stored value to be decreased but not increased. A number of non-alterable bits of information contained in read only memory are used for identification (ID) of each card. They contain no microcomputer chip, but none is required given the relatively unsophisticated application. They do contain hardwired logic routines that allow their stored value to be decreased but not increased.

Proximity Cards

There are two techniques that eliminate the requirement for physical contact between card and reader. The most prevalent of these techniques uses radio frequency inductive coupling. Since RF inductive coupling does not require physical contact between circuits being coupled, but only requires that the circuits be in proximity, cards using this type of coupling are called "proximity" cards.

This technique employs an induction coil in the card read-write unit to generate an RF magnetic field that couples to another induction coil embedded in the card. The RF magnetic field provides power to the card's circuitry, and is modulated to carry signals to the card as well. The card must be equipped with a small power conditioning system to extract needed power from the magnetic field, regulate it, and provide it to the card's circuitry as long as the card is in the vicinity of the read-write unit. The card transmits signals back to the read-write unit by means of the same coil used to receive signals, or by means of a separate coil or antenna.

The distance between card and read-write unit over which proximity card systems can be made to work is primarily limited by the amount of energy in the RF induction field created by the read-write unit. In practical systems the distance is kept short - from approximately a foot (30 cm) down to an inch (2.5 cm). Some systems require distances of essentially zero, relying only on this scheme's contactless attribute and its capability to work with a rather random positioning of card with respect to read-write unit.

Proximity cards can be used for identification purposes. In this application, proximity ID cards simply identify their presence in the vicinity of a card reading unit. These cards need only contain circuitry capable of generating a single message when interrogated. That message can be stored in ROM at time of manufacture. Proximity ID cards share similarities with non-rewritable magnetic stripe cards such as Automated Teller Machine (ATM) or credit cards.

Proximity ID cards could be used as bus and subway passes; however, they are not being used for that application anywhere in North America. They are being used for keyless entry systems, personnel identification, and inventory security in stores. Texas Instruments has packaged proximity ID circuitry into small capsules that can be attached to or embedded in a variety of objects for ID purposes.

Proximity smart cards combine the non-contact capabilities of proximity cards with the operational capabilities of contact-type IC smart cards. In transit fare applications, they provide the operational capabilities for time-based and distance-based fare structures, intermodal and inter-operator transfers, and ancillary use as an "electronic coin purse" for small non-transit purchases, with sophisticated security capabilities. The capability of short-distance contactless interaction with a read-write unit offers the potential for greater passenger speed when boarding buses or going through subway turnstiles than is possible with coins, tokens, magnetic stripe cards, or IC contact-type fare cards.

Proximity smart cards have been used in operational tests by a number of U.S. transit systems, and more tests will be forthcoming.

Capacitively Coupled Cards

Capacitive coupling between card and read-write unit is the second technique used to eliminate the requirement for physical contacts. Capacitive coupling requires cards to each have two or more areas of metal foil covered by very thin layers of plastic insulator that are intimately positioned adjacent to similar areas in the read-write unit, thus creating capacitors that couple the circuits in the read-write unit and card. Both power and signals can be sent via this coupling. Capacitive coupling eliminates direct physical metal-to-metal contacts that can wear and corrode, thus increasing lifetime and reliability. Calling this technique "contactless" is somewhat of a misnomer, since plastic-to-plastic contact results when the card is inserted into the read-write unit required for guaranteeing the required precise alignment.

Although competing with proximity cards and contact cards in other markets, capacitively coupled cards have not entered the transit market yet.

State-of-the-Art Summary: Integrated Fare Payment Systems

Three types of integration of fare payment systems are being pursued by transit operators across the country. One type is the integration of fare payment systems for different modes of transportation, such as distance-based fare systems for trips involving rapid transit and bus operated by a single transit provider.

A second type involves integration of the financial systems and instruments involved in fare payment, with the rest of the nation's consumer financial system. This type includes creating commonalties and interfaces between transit systems, transit rider accounts and fare cards on the one hand; and banks, customer accounts, and credit, debit, and ATM cards on the other hand.

A third type of integration involves fare payment systems operated jointly by a number of transportation operators, allowing riders to pay a single fare for a journey involving more than one transit provider. This third type is the subject of Section 4.2, below.

Integrated fare payment systems use fare media that can be used for more than one transit mode (i.e., magnetic stripe cards usable for subway, bus, and passenger ferry tolls). The development of integrated fare payment systems has been made possible by advancements in recent decades in electronic data processing and storage, including magnetic recording technology and microcomputers, and in data communication.

Transit systems across the country are exploring and adopting integrated fare payment systems concepts that promise greater flexibility in fare structures, less expense in money handling, greater convenience for riders, and more efficient cooperation between fellow transit providers. Most of these advanced fare payment systems concepts rely on the use of electronic fare media.

Transit Passes

Transit passes are used by a number of transit systems, primarily as a marketing tool. Some carry pictures of the user and must be shown to a bus driver or subway attendant. Some are read-only magnetic stripe cards that must be swiped through a reader on subway turnstiles or bus fare boxes. A typical period of validity is one month; however, longer or shorter periods are used.

Transit pass systems reduce the number of monetary transactions to one per issuing period or less. Some transit passes are distributed and paid for by employers, or paid for by deductions from wages, reducing the number of financial transactions undertaken by the individual rider to zero.

Stored Value Fare Cards

Stored value fare cards hold value worth more than one transit fare. A single financial transaction serves for multiple rides. In addition, since fares are deducted in an automated fashion, time-based and distance-based fare structures are made possible with no manual computation. Stored value cards also store information that can be used in operating multi-operator transit networks. The origins and destinations of trips can be recorded on cards and subsequently read and used to split revenues between different transit operators. Fare media usable as stored value cards include read-write magnetic stripe cards, and contact-type and proximity smart cards.

Fare Systems Based on Passenger Accounts

It would be possible to operate a fare payment system based on the establishment of passenger accounts and the issuance of ID passes to riders. The entrance of passengers would be signaled by use of their pass, which could be a read-only magnetic stripe card, an RFID device, or even a bar code ID card. Passenger use information would be collected every time a passenger entered or exited a transit vehicle or station. The usage information would be processed and passengers would be billed periodically. Distance-based fares could be charged if passengers used their ID passes to indicate end points of trips as well as beginning points.

No present or contemplated system employs such a scheme. However, the fare payment system used on Phoenix Transit buses comes close.[78] Phoenix bus users can use their bank-issued credit cards to pay bus fares. In this case, Phoenix Transit relies on the banks to issue cards, keep track of accounts, and bill customers, all for the usual fees charged merchants by credit card companies.

Multi-Use Electronic Coin Purses

Multi-use electronic coin purses contain stored value that can be used for multiple bus rides, and for small purchases from cooperating merchants as well. While in principle multi-use electronic coin purse systems could be based on either read-write magnetic stripe card technology or read-write IC card technology, the IC card based systems are presently being most rapidly developed.

Cashless Purchase of Fare Media

To achieve greater economy, efficiency, and convenience, a number of transit systems are introducing fare media dispensing machines that take credit/debit cards for payment.[79] BART and Chicago Transit Authority are in the process of implementing cashless purchase of fare media. The Massachusetts Bay Transportation Authority, Portland's Tri-Met, and the Ann Arbor Transit Authority also are planning the introductions of such machines. King County Metro, WMATA, and

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[78] Schwenk, Judith C., **Bus Fare Payment with Credit Cards in Phoenix**, draft case study report, Volpe National Transportation Systems Center, Cambridge, Massachusetts, October 1995.

[79] Multisystems, Inc., et al., *op. cit.*, Chapter 7: Emerging Fare Payment/Media Purchase Developments.

Tri-Met use specialized ATMs that take bank cards for issuing fare media. Systems that use ATMs instead of credit card readers save the transit systems the fees charged by the credit card companies.

Applications

New York City Metropolitan Area

The first use of magnetic stripe fare cards in North America was on the Long Island Railroad in 1964, but New York City Transit (formerly New York City Transit Authority) stayed with coins and tokens for the next three decades. Now, however, long-lived thin plastic read-write magnetic stripe fare cards have been adopted by New York City Transit for their stored-value MetroCard system, both for subway fares and for bus fares. NYCT uses swipe-type readers on the buses; these are faster in use and more reliable than the ticket readers using mechanical card transport systems.

The New York Metropolitan Transit Authority, NYCT's parent organization, formed a subsidiary organization named the MTA Card Company (MTACC), that has developed the MetroCard. Eventually all NYCT rapid transit stations and buses will be equipped to take the card. Cards can be purchased at subway stations and nearby retail outlets in fixed denominations. They are rechargeable. MTACC is interested in developing multiple-use plans so that the card would be usable on other transit systems and for small purchases and telephones, in a manner similar to the Wilmington DART project (see below).[80]

Washington, DC

The Washington Metropolitan Area Transit Authority has equipped 19 rapid transit stations, 21 buses, and a number of its parking lots with proximity smart card read-write turnstiles and fare boxes. The prototype system, provided by Cubic, uses battery powered smart cards, thus eliminating the requirement of power conditioning circuitry on these prototype cards. System level in-service testing will last for a year.[81]

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[80] Ibid.

[81] Ibid.

Torrance, California

The City of Torrance tested proximity smart cards for bus fare payment over the course of a year in a program conducted by Echelon Industries, Inc., under the auspices of FTA and the State of California.[82] The cards used in the Torrance tests were batteryless.

Phoenix, Arizona

In 1991, the Phoenix Transit System was the first in the nation to install magnetic card readers on the electronic fare boxes on their buses. In May 1995, Phoenix Transit was again the first to introduce a commercial credit card bus fare payment program. This program also makes use of the magnetic card readers. Passengers with standard bank-issued credit cards already in their possession swipe their cards through the card readers on the fare boxes when boarding the buses. Accounts for individual cards are totaled and billed monthly. In this case, the credit card companies and banks pay for the media. The transit system pays the credit card companies for one transaction per card paying passenger per month.

Since the electronic farebox is not connected to an interactive network, it is not possible to check the validity of the credit cards in real time. An updated list of invalid card numbers is loaded into the fareboxes daily, thus limiting the amount of fare evasion possible. Phoenix Transit estimates the rate of invalid credit card use at around two percent.

From May to September, over $6,600 in fares were paid with credit cards. By batching uses by each credit card holder before billing the credit card companies (VISA, MasterCard, Discover, and American Express), Phoenix Transit claims to have reduced the fees paid to the credit card companies to five cents per fare from what otherwise would be 19 cents per fare transaction.[83]

Wilmington, Delaware

The Delaware Authority for Regional Transportation (DART) smart card system is one example of a multi-use electronic coin purse.[84] This project will involve DART, the Wilmington Trust

[82] Ray Rebeiro, Echelon Industries, Inc., Diamond Bar, California.

[83] Op. cit., Schwenk, Judith C.

[84] Op. cit., Multisystems, Inc., et. al., Chapter 7.

Bank, and a number of other retail outlets and service providers. The bank will issue to its customers ATM cards of the Money Access Center, a subsidiary of Electronic Payment Systems, Inc., of Wilmington. These will be contact-type stored value smart cards. The fare boxes of the 135 DART buses will be equipped with card read/write units. These cards will be usable at participating merchant locations for small purchases as well. Non-bank customers will be able to obtain similar cards also usable on buses and for other small purchases. Participating employers will be able to issue cards to their employees. These cards will be loaded with cash using ATM-like machines at work sites. Employers will be able to use this system to provide workers with monthly subsidies for transportation if they choose.

Atlanta, Georgia

As this report is being written, VISA International and the First Union Bank of Charlotte, North Carolina are planning the introduction of stored value contact-type IC cards in the Atlanta, Georgia area in time for the 1996 Olympics.[85] There actually will be two kinds of cards introduced by VISA. One will be of EEPROM type, sold in fixed denominations. When its value is exhausted, it can be discarded or kept as a collectible. The other will be a rechargeable smart card that also will be usable in conjunction with a wider range of financial services.

It is anticipated that all merchants and consumer services that presently take VISA cards will be equipped to take the new ones as well. In addition, since the stored value aspect of the card reduces the transaction expenses associated with presently used credit cards, adoption might be even wider.

One provider of services that will accept the new cards will be the Metropolitan Atlanta Rapid Transit Authority. MARTA will install card readers at turnstiles and on bus fare boxes. MARTA estimates that it may eventually decrease its rail system cash-handling costs by 80 percent if this system becomes generally used.

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[85] VISA International, publicity release.

Chicago, Illinois

The Chicago Transit Authority is in the process of introducing a new automated fare collection system, using read-write magnetic stripe stored value cards.[86] The CTA is equipping all its rapid transit stations with turnstiles that will take these cards, and its bus fare boxes with read-write units. These cards will also be usable for fare payment on PACE buses and Metra commuter trains and for small purchases from cooperating Chicago merchants. Stored value cards will be dispensed by special ATMs in stations and at other sites in the Chicago area, and distributed to employees by employers cooperating with CTA's commuter subsidy plan. Various Chicago-area merchants will have CTA ticket processing units capable of adding value to fare cards. All transactions involving fare cards will be recorded by the agencies involved, and records will be relayed via computer network to CTA's Network Manager. Settlements will be performed periodically.

CTA fare boxes and turnstiles will continue to take coins and tokens from people not having the new fare cards. In addition, rapid transit stations will each be equipped with some turnstiles that take proximity-type fare cards held by handicapped riders. Turnstiles will all be equipped with proximity card readers to read ID cards in the possession of maintenance personnel. Eventually, CTA might adopt proximity cards for all riders as well.

Standards Development and Adoption

The development, promulgation, and adoption of standards is an issue of utmost importance in the spread of use of a new technology. Adoption of standards can have a number of different effects. On the one hand, it can greatly stimulate adoption of a technology in the marketplace. On the other hand, it can tend to freeze the further development of a technology. Commercial broadcast television in the U.S. serves as an example of both of these effects. Early adoption of standards for commercial TV in the U.S. allowed for explosive growth of industry here in the immediate post-World War II years. However, U.S. technology was frozen at a level that subsequently proved to be inferior to that achieved soon after in Europe.

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[86] Chicago Transit Authority, Revenue Equipment Technology and Maintenance Dept., promotional poster: "Could this be a typical day in John's life in 1996?"

The technology of communicating data over telephone lines provides a counter example. New standards for increasingly fast data transmission over telephone lines periodically emerge, but the new modems that capitalize on these standards also generally operate according to the old ones if such operation is needed. This capability for backward compatibility increases the flexibility for all users of the technology, thus spurring both greater adoption in the marketplace and further technological advancement. Since smart cards probably share more in common with data transmission devices than they do with TV sets, adoption of standards for their design and use probably will greatly enhance their use, as the related technology continues to develop.

The International Standards Organization (ISO) standards for plastic magnetic stripe cards have existed for many years and are adhered to by issuers of most credit cards and bank cards used in ATMs. These standards have allowed adoption and use of bank and credit cards in a network that spans the globe. An international traveler today might use an ATM card issued by a bank in any small U.S. town to obtain local currency from a street corner ATM in virtually any city in the world, and have it charged to their account back home.

ISO standards also exist for the contact-type read-write memory cards used in European pay telephones. These standards are followed by many, but not all, issuers of contact-type read-write memory cards and smart cards.

Standards are also under development for proximity and capacitively coupled cards.[87] The ISO Committee for Contactless Cards, known as Working Group 8, has task forces developing two sets of standards. Task Force 1 is developing a set covering both capacitively and inductively coupled cards designed for insertion into a slot or placement on a surface. Task Force 2 is developing another set for inductively coupled cards designed for use at greater distance. Issues being addressed include carrier frequencies, baud rate, data transfer protocols, and encryption. Task Force 1 is also addressing physical dimensions. Application areas being specifically targeted include identification, and revenue collection.

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[87] "Contactless Standards Enter Final Leg," *Standards Update*, Volume 2.1, July 1995, published by the Smart Card Forum.

4.2 MULTI-CARRIER FARE INTEGRATION SYSTEMS

Spurred by the availability of new technology, the search for ways to decrease operating costs, and the desire to attract more riders by offering enhanced transportation services, efforts continue around the country to forge regional links between transit providers.

San Francisco Bay Area

The TransLink system is being developed and implemented by Bay Area Rapid Transit, the Oakland Metropolitan Transit Commission, and the Central Contra Costa County Transit Authority (CCCTA). This system uses magnetic stripe stored value tickets good at all of the 34 BART stations and 45 BART Express buses, as well as the 112 CCCTA buses. Each ticket has its own serial number that eventually will allow individual rides to be tracked. All the buses used in the system are equipped with bus ticket validators supplied by CGA of France. In the future, the system might expand to include the light rail vehicles and buses of San Francisco Muni, and the buses operated by Golden Gate Transit.

Possibilities exist for both organizational and technological changes in TransLink in the future. The participants continue to evaluate their individual needs, and to assess further possible choices of advanced fare media.[88]

Los Angeles Metropolitan Area

The Los Angeles Metrocard project involves the Los Angeles County Metropolitan Transit Authority in a leadership role, Culver City Municipal Bus Lines (28 buses), Foothill Transit (198 buses), and Montebello Bus Lines (54 buses). The buses have been equipped with ticket processing units supplied by GFIGenfare, that are used with the stored-value magnetic stripe Metrocards. The initial phase of this project was a test period that lasted until July 1995. During the test period Metrocards were sold in denominations of $10, $20, and $30. Now that testing is over and has been deemed a success, more widespread marketing of Metrocards will ensue, and LACMTA may join in use of Metrocards on its own buses.[89]

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[88] Op. cit., Multisystems, Inc., et. al., Chapter 7.

[89] Ibid.

San Diego Metropolitan Area

The Metropolitan Transit Development Board (MTDB) was created to bind together most of the greater San Diego area's transit operators to form the Metropolitan Transit System (MTS). MTDB served as the leader in the effort to develop the Uniform Fare Structure Agreement. MTS has implemented a common transit pass valid for travel on all fixed-route buses in the region and the San Diego Trolley as well, and has also implemented a formula for distributing pass revenue. A common transfer policy between carriers has also been implemented.[90]

Ventura County, California

In an effort sponsored by Caltrans in coordination with FTA and the Volpe Center, the Ventura County Transit Commission (VCTC) and Echelon Industries, Inc. are undertaking a project to link the operations of eight transit agencies in the county to provide transit users with more seamless transit service throughout the county.[91] This project represents the greater part of Phase III of the Small Business Innovative Research (SBIR) program undertaken by Echelon. The Echelon Phase II SBIR work involved the transit systems in Torrance and Gardena, California. Phase III work started in mid-1995 and is scheduled to proceed for 18 months.

The largest of the transit agencies in Ventura County is South Coast Area Transit, serving the cities of Oxnard, Ventura, and Port Hueneme with buses running on fixed routes. Moorpark operates its own buses over fixed routes. Camarillo, Simi Valley, and Thousand Oaks each operate fixed-route and dial-a-ride service. Fillmore and Santa Paula offer dial-a-ride service only, and Ojai operates a trolley that services Ojai and Meiners Oaks.

Transit users will experience a countywide distance based fare structure, implemented using proximity smart fare payment cards. The buses will be linked by radio to a central facility. Riders will be able to request upgrades in fare card stored values by phone, chargeable to their credit cards. Upgrade information will be communicated to all buses, and the augmentation will take place automatically when riders use their fare cards.

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[90] Ibid.

[91] Ray Rebeiro, Echelon Industries, Diamond Bar, California.

The smart fare payment cards will identify riders according to the categories that must be recorded under Section 15 of the Federal transit regulations, thereby decreasing the expenses associated with meeting Federal requirements for collection of ridership data. Information collected will also be used for the planning of transit operations throughout Ventura County.

Greater Seattle-Puget Sound Region

The Central Puget Sound Fare Integration Project is being undertaken in a region in western Washington State wrapping around Puget Sound and covering King, Snohomish, Pierce, and Kitsap Counties. Seattle lies in King County; Everett in Snohomish; Tacoma in Pierce; and Bremerton (across Puget Sound from Seattle) in Kitsap County. Participating organizations include the King County Department of Metropolitan Services (King County Metro), Kitsap Transit, Pierce Transit, Everett Transit, Community Transit (operating throughout Snohomish County), the Puget Sound Regional Council, the Washington State Ferry System, the Regional Transportation Authority, and the Cascadia Project.

As stated in the project's "Feasibility Study Draft Report:"[92]

> The purpose of the Central Puget Sound Fair Integration Project is to create a "seamless" fare system for customers to transfer easily between systems and modes for bus, ferry, rail, and vanpool trips. The introduction of new fare collection technologies can achieve this goal and, at the same time, dramatically improve each agency's fare collection equipment and capabilities. This current planning effort has a near term mission to address existing needs and support the longer term regional vision . . .

This project is an outgrowth of an earlier regional pass program conducted from 1985 through 1990. That program, involving King County Metro, Community, Pierce, Kitsap and Everett transit agencies, Washington State Ferries, and the Seattle Monorail, reached a high of 2,400 passes issued per month, but eventually was terminated because of difficulties in establishing bilateral sales agreements and running the accounting and revenue control systems, and the increased county-to-county service introduced by one participating transit operator.

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[92] Carlson, Candace, King County Dept. of Metropolitan Services, Seattle, Washington, and Paul Lavallee, IBI Group, **Regional Fare & Technology Integration - Feasibility Study Draft Report**, Bellevue, Washington, July 19, 1995.

At present, alternative plans for fare integration systems, including the introduction of advanced technology, are being assessed. An operational test of smart fare cards has been proposed. Funding and implementation scenarios and other relevant issues are being intensively studied. The system definition phase of the project was scheduled for completion in the Fall of 1995, to be followed by development of detailed specifications and the procurement cycle, with implementation slated for Summer 1998.

5. TRANSPORTATION DEMAND MANAGEMENT TECHNOLOGIES

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 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. Four TDM technologies are discussed in this chapter:

- Real-Time Ridesharing;
- Mobility Manager;
- Transportation Management Centers; and
- High Occupancy Vehicle Facility Monitoring.

5.1 REAL-TIME RIDESHARING

Real-time ridesharing has also been called dynamic ridesharing and single-trip ridesharing. It differs from regular carpooling and vanpooling in that ridesharing is arranged for individual trips rather than for trips made on a regular basis and requests for ridesharing can be made close to the time when the travel is desired. A trip request may be made for any time of day or direction of travel, but a match is more likely to be found for travel in peak periods in principal commutation directions.

In the normal real-time ridesharing operational mode, a person wishing to obtain a ride initiates a request to a ridesharing operations center or central database. The database is searched for a match with trips offered by drivers who have registered for this program. In most instances, the names and means of contacting possible drivers are provided to the requesting party. Arrangements are then made by direct contact between both parties. In some instances, the ridesharing operations staff may make the contacts with potential drivers and put the parties in touch only if a reasonable match is found.

State-of-the-Art Summary

The concept of real-time ridesharing is still in the experimental stage. Results of two early tests of organized real-time ridesharing have shown significant numbers of drivers registering but few requests for rides. However, it would be premature to reject the concept based on the results of these two limited tests. Three other upcoming projects should provide more definitive evidence as to whether this concept has merit. Nevertheless, even if dynamic ridesharing does not prove to be viable on its own, it may still be a worthwhile adjunct to other ridesharing programs if the added cost is small.

Even though results from the two early tests show limited utilization, evidence of the potential for real-time ridesharing does exist. In Oakland, California, Northern Virginia, and to a lesser extent in Houston, Texas, passengers waiting by the roadside are picked up by drivers wishing to form carpools in order to take advantage of the time savings offered by use of HOV lanes. This form of ridesharing has been termed casual carpooling or instant ridesharing. One likely reason for the continued operation and success of casual carpooling is the ease and speed with which a ride may be obtained. With casual carpooling, obtaining a ride may be immediate or require only a short wait. For most organized real-time ridesharing programs, persons wishing to obtain a ride must first obtain a list of possible matches and then call persons on the list to try to arrange for the trip. This can be a somewhat time consuming and onerous process which would tend to inhibit participation. The Ontario project, which will attempt to remove much of this burden and will guarantee a ride, will provide valuable information on this aspect.

Since organized real-time ridesharing is still a relatively new concept, there are a number of organizational, logistical, and safety issues associated with it that are worthy of further research or testing.

Applications

Bellevue, Washington

The Bellevue Smart Traveler (BST) project was developed by the Bellevue Transportation Management Association and the University of Washington. BST developed a Traveler Information

Center which provided dynamic ride matching information, real-time traffic congestion information emphasizing the advantages of HOV travel over SOV travel, and access to bus information. Employees at downtown Bellevue companies were eligible for registration for the program. Registered individuals could access the TIC information via telephone and alphanumeric pagers. For ridesharing purposes, registered users were divided into ride groups based upon where they lived or their preferred pick-up/drop-off points and the routes they traveled. When they offered or sought rides, their messages were sent only to members of their ride group.

One hundred and thirty-four persons applied for membership but only 53 were accommodated. The rest did not fit into a viable ride group. During the period of November 1993 to March 1994, members of these groups offered 496 rides. They sought rides 145 times but received information on specific rides only 40 times. Six ride matches were logged. Logging a ride was encouraged but not required; consequently, the total number of rides taken is not known. Only 30 requests for traffic information and six requests for transit information were received at the TIC from registered users. Non-registrants could access the TIC's traffic and transit information by telephone and did so a total of 112 times.

Conclusions from the project were that participants liked the idea of dynamic ridesharing, liked the presentation of the information, were comfortable with the technology, were willing to offer rides, and used the BST to receive other forms of information. However, for various reasons they were either unable or unwilling to rideshare. Reasons for the limited number of ride requests may include: few ride choices due to the modest size of the ride groups, the uncertainty of obtaining a return trip, insufficient time to achieve the behavioral changes necessary to make dynamic ridesharing a viable alternative, and the inconvenience of ridesharing.[93, 94]

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[93] Haselkorn, Mark, Jan Spyridakis, Brian Goble, and Susan Michalak, "Bellevue Smart Traveler: An Integrated Phone and Pager System for Downtown Dynamic Ride Sharing," *Proceedings of the IVHS America 1994 Annual Meeting*, pp. 126-131.

[94] Haselkorn, Mark, and Jan Spyridakis, **Bellevue Smart Traveler: Design, Demonstration, and Assessment**, Abstract, final project report, Seattle, Washington, August 1995.

Sacramento, California

Rideshare Express was the name ultimately selected for the dynamic ridesharing element of the California Department of Transportation's Sacramento Rideshare program. This test began in late 1994. The area covered by the test project encompassed the City of Sacramento plus six other Transportation Management Areas, some nearly 100 miles away. A total of 360 persons registered as drivers. There was informal screening of trip requestors through questions asked concerning home and work locations, trip purpose, etc. Trip matching was by identical origin and destination zip codes, ranked according to the closest time period to the request.

Only about 10 legitimate dynamic rideshare requests were recorded as of October 1995. Of these requests, only one resulted in a matchlist being given. It is not known whether this resulted in a ride actually being taken. There were some major reasons for the poor initial results:

- The coverage area was so large that the likelihood of a trip request matching a driver origin and destination zip code was small.
- The system marketing and promotion was limited and often bundled with regular rideshare material; consequently, many people were unaware of the dynamic ridesharing program.
- Other options, including family, friends, and co-workers, are easier to secure.
- There is a considerable reluctance to ride with strangers due to concern for personal security.

SACOG, the Metropolitan Planning Organization for the Sacramento area, is in the design phase of a new trip planning system. When information regarding a specific trip is requested, the system will choose the best mode (or combination of modes) and itinerary plus other viable options. Dynamic ridesharing is one of the possible modes. The trip planning software is an enhanced version of that used in the Los Angeles SMART TRAVELER project. The new software will incorporate a GIS-based, rather than a zip code-based, origin and destination location system. For dynamic ridesharing, this would allow drivers and riders in different zip codes to be matched and passengers with intermediate origins and/or destinations to be matched with drivers having different origins and destinations as long as they would be on the same route of travel. Dynamic ridesharing also could be one mode of a multimodal trip.[95, 96]

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[95] Raghu Kowshik, Institute of Transportation Studies, University of California, Davis, California.

[96] Velma Lucero, Sacramento Council of Governments, Sacramento, California.

Los Angeles, California

The Los Angeles SMART TRAVELER project was initiated to alleviate travel difficulties following the 1994 Northridge earthquake. As part of an overall ridesharing program, Commuter Transportation Services, Inc. operated a dynamic ridesharing element for an area encompassing about 60,000 people who were most affected by the earthquake. Persons calling 1-800-COMMUTE could select dynamic ridesharing from the options menu. Rides were offered and requested via telephone. Ride matchlists were provided to the requester who had the option of calling the potential matches or having a message automatically sent to persons on the list. The system recorded an average of 20 to 40 calls per week. It is not known how many rides were actually arranged. The dynamic ridesharing service operated only from July 1994 to September 1994.[97]

Seattle, Washington

The Seattle Smart Traveler (SST) is one element of the Seattle Wide Area Information for Travelers project. It will be a test of dynamic ridesharing at the University of Washington (UW). All UW faculty, students, and staff who register will be eligible to participate in the program. Participants will register for the dynamic ridesharing program using the World Wide Web. The regular trips they take will also be entered at that time. Trips can be added or deleted at any time, even on a daily basis. Most persons requesting a ride will obtain a matchlist and a contact number through the WWW. Persons having one of the watch pagers will get the matchlist and contact number via the pager screen. Most arrangements will be made via WWW e-mail. Telephone contact will be necessary for pager users if access to a computer is not convenient.

A geographic information system will be used to geocode intersections and major landmarks for origin/destination matching. A matchlist for each trip request will be created using a radius around the origin and destination of 15 percent of the trip distance. An option to expand this radius to 25 percent will be available.

This project appears to be as close to the ideal situation as one could expect to find for a real-time ridesharing test. The UW is a concentrated destination with a daytime population of about

[97] Donald Loseff, University of Washington, Seattle, Washington.

35,000, although an estimated 70 percent either live on the campus or within walking distance of it. Parking on the campus is limited, and, consequently, there is a heavy commute by public transportation. There is also a substantial regular ridesharing program at the University. Most of the potential participants are computer literate and would not likely be inhibited by electronic mail and pager technology. Start-up of the SST is anticipated in January 1996.[98]

Houston, Texas

The Metropolitan Transit Authority is implementing a major new ridesharing effort. The real-time ridesharing component of this program is one of the two elements of the Houston Smart Commuter project. In the I-10 West Corridor, real-time rideshare-matching will be made available to the employees of several companies in the Post-Oak/Galleria area, a non-downtown employment center. Employees, both drivers and passengers, must register for the service. Persons wishing to obtain a ride will call the real-time rideshare operations center. They will be given a match list of persons to call to arrange for their trip. This list can be provided verbally or by fax. Criteria for matching will be first by zip codes and then by personal preferences of both the driver and potential passenger (gender, non-smoker, etc.). Initially, requests will be received by an operator who will be able to provide a match list within seconds. Soon thereafter, the process will be completely automated and persons will also be able to access ridematching information by personal communications devices and, later, by personal computer.

The I-10 corridor, the most congested corridor in the region, is not well served by transit but contains an HOV lane. The incentive to rideshare is the time savings provided by the ability to use the HOV lane. Real-time ridesharing is one way to obtain the three or more passengers required to use the lane during the height of the peak periods. Because of the careful selection of company participants, it should provide a somewhat more comfortable feeling regarding personal security than picking up strangers at park-and-ride lots and bus stops. This casual carpooling or instant ridesharing occurs in Houston, but to a much lesser extent than in Northern Virginia and Oakland, California.

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[98] Ibid.

The real-time ridesharing system hardware and software development and installation costs are estimated to be in the $650,000 range. The ridesharing element is expected to be operational in the first half of 1996.[99]

Ontario, California

Ontario's ATHENA project will involve single-trip ridesharing. However, it will differ from other formalized real-time ridesharing projects in that no match list will be given to ride requestors and they will not have to contact potential trip providers to arrange for the trip. The ATHENA computer will find the best match and advise the driver and rider of the pick-up point, the scheduled pick-up time, and fares to be charged. ATHENA will incorporate a central computing and dispatch center that interfaces with vehicles containing personal digital assistants (PDAs) which have messaging and GPS vehicle location capability. Initially, travelers will request rides via telephones. Pagers may be a later option. The ride may be provided in a single occupant vehicle, a carpool, or a vanpool. A taxi firm will provide the trip if no other vehicle is available. Hotel and rental car shuttles may be incorporated in the future.

The project's final design stage is to begin in February 1996. Registration of the 100 driver participants is anticipated in July 1996. Employees with residences in eight corridors within the city limits and working in clusters of companies near the Ontario airport will be targeted. The 12-month test is scheduled to be operational in January 1997.[100, 101, 102]

Anaheim, California

A demonstration project in Anaheim will try to lure short distance commuters into available space on vanpools. The Anaheim Transportation Network (ATN), a transportation partnership, will

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[99] Sholeh Karimi, Metropolitan Transit Authority, Houston, Texas.

[100] L.D. King, ESL Transportation Systems, and AEGIS Transportation Information Systems, **Draft Statement of Work, ATHENA Stage 2, Detailed Design and Operational Test and Evaluation**, Ontario, California, October 29, 1994.

[101] AEGIS Transportation Information Systems, Inc., **ATHENA - A "Smart Community" System, Smart Traveler Projects Review**, Draft Copy, Ontario, California, undated.

[102] Jill Kollman, L.D. King, Inc., Ontario, California.

administer the project which will be operated by a local vanpool company. The ATN plans to operate five vans which will pick up most of the passengers in Riverside, California, about 40 or more miles from downtown Anaheim. The vans will make a second stop about 10 miles or so from downtown to pick up short distance commuters. The ATN will use AVL, cellular telephones, and traffic reports to provide the fastest travel routes from Riverside to the intermediate pick up points and thence to downtown. Commuters desiring to board the vans at the intermediate stops will call the vanpool dispatcher to reserve seats and to learn the expected times of arrival. They will be able to reserve seats on a real-time basis.

The ATN will try to strike a balance between the number of long distance riders needed to insure the financial viability of the program, and the availability of seats for short distance commuters. A major question to be answered in this test will be the demand for short commute trips by vanpools. This service will be competing with regular automobile commutation, which would likely be faster but more expensive, and bus service, which would be slower but cheaper. The test was expected to be operational in late 1995.[103]

Oakland, California

Each weekday morning, passengers wait on the Oakland side of the San Francisco-Oakland Bay Bridge to be picked up by drivers wishing to fill their vehicle with enough people to qualify for use of the HOV lane on the bridge. Pick-up points are usually near BART stations and Alameda-Contra Costa Transit (AC Transit) bus stops. Passengers are normally dropped off near the Transbay Bus Terminal in downtown San Francisco, although drivers may take passengers to other San Francisco destinations. Carpools gain the dual benefit of a 10 to 20 minute time savings and avoidance of the $1.00 toll by their use of the HOV toll bypass lanes. Drivers receive no money from passengers. Since there are no HOV lanes in the westbound direction, there is no evening casual carpooling activity. This may change as a 20-mile HOV segment is constructed on I-80.

These "casual carpools" have become popular in spite of the often-mentioned personal security threat from picking up strangers. It is estimated that about 8,000 people are commuting by

[103] *Inside ITS*, May 8, 1995, pp. 10-11.

this method. Casual carpooling has taken riders from BART and AC Transit, however. Responses to a 1992 mail-back survey indicated that 25 percent of drivers, 71 percent of riders, and 54 percent of those that were both formerly used transit. In actuality, Bay Bridge casual carpooling would not exist without the region's rail and bus services because participants need a way to get back to their original starting point in the evening. Enough casual carpool passengers were driving their cars to the free BART station parking lots and carpooling with someone else that BART instituted a validation procedure at some of their lots. Although difficult to prove, it is likely that casual carpooling has increased auto traffic somewhat.[104,105,106]

Northern Virginia

Although informal, casual or instant carpooling in the Shirley Freeway corridor, which began in the mid-1970s, has become quite well organized. Northern Virginia commuters wishing to obtain a ride to the Pentagon or into Washington, DC stand at several suburban locations, usually near parking lots or bus stops. They are picked-up by drivers wanting to have at least three people in their vehicle in order to legally use the HOV lanes on the freeway. At times, drivers have to wait at pick-up points in order to get the required number of passengers. Destinations are indicated verbally or with a windshield sign, except in a few locations where passengers stand in certain spots according to which Potomac River bridge they wish to cross. A similar arrangement occurs during the evening peak period exodus from the District, except that there are fewer pick-up points and fewer people participate. Rides home are somewhat more difficult to find.

Casual carpooling is more flexible than standard carpooling and generally faster, cheaper, and more comfortable than bus service. Carpools and vanpools on the HOV lanes benefit from a time advantage generally in the range of five to 15 minutes over travel in the non-HOV lanes. Counts of casual carpooling participants are infeasible due to the large number of pick-up points. However, based upon counts made at a few major pick-up points and the differential between morning and

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[104] Beroldo, Steve "Casual Carpooling in the San Francisco Bay Area," *Transportation Quarterly*, January 1990, pp. 133-150.

[105] Chow, Vernon, **Casual Carpooling**, Senior Thesis, Cambridge, Massachusetts, 1994, Chapter 3.

[106] Brock, Valerie, **Casual Carpooling: An Update**, report published by RIDES for Bay Area Commuters, February 1993.

evening transit ridership in the corridor, it appears that somewhere between 2,500 and 5,000 passengers and drivers are participating in casual carpools during the morning peak. Since casual carpooling in the evening peak is lower and evening transit ridership is larger than morning ridership, it would appear that casual carpooling is taking passengers away from transit. Although this might be perceived as undesirable, WMATA is able to reduce operating expenditures by providing less morning service on some routes in the corridor than in the evening.

The personal security issue does not seem to be a severe detriment to the popularity of this form of ridesharing, although it is probable that some are unwilling to participate for this reason. Most of the drivers and riders hold white collar jobs and are likely in a similar socio-economic class. This homogeneity undoubtedly removes much of the potential uneasiness of getting in a car with strangers. Reports of robberies or assaults from participants in this carpooling arrangement have been very rare.[107, 108]

5.2 MOBILITY MANAGER

The term "mobility manager" was coined in 1991 in an FTA report that identified the potential for market-oriented local transportation.[109] Mobility Manager was defined as "a mechanism for achieving the integration and coordination of transportation services offered by multiple providers--public, private for-profit, and private non-profit--involving a variety of travel modes and multiple sources of funding. This integration is accomplished through electronic technologies, allowing the programmatic integrity of all participants to be preserved, while at the same time automating most of the transactions - financial and otherwise - which occur in the system. Mobility Manager's function resembles that of a travel agency and a financial clearinghouse."[110] Recently, this term has been expanded to cover <u>all</u> services offered by public transportation agencies outside of the traditional services that have been offered throughout history.

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[107] Ronald Boenau, Federal Transit Administration, Washington, DC.

[108] Op. cit., Chow, Vernon.

[109] Jeffrey A. Parker and Associates and International Taxicab and Livery Association, **Mobility Management and Market-Oriented Local Transportation**, prepared for FTA Office of Technical Assistance and Safety, March 1991, Report Number DOT-T-92-07.

[110] Ibid, p. 4.

State-of-the-Art Summary

An increasing number of transportation agencies are embracing the concepts of mobility management, and are beginning to implement innovations that identify them as mobility managers. Also, critical research and practical applications of mobility management are being conducted in a Transportation Research Board Transit Cooperative Research Program (TCRP) project entitled Strategies to Assist Local Transportation Agencies in Becoming Mobility Managers (project B-7).

Applications

Beaver County, Pennsylvania

In 1994, the Beaver County Transit Authority (BCTA) began to plan and design a Mobility Manager system. BCTA's vision of a Mobility Manager is that it "will coordinate scheduling, routing, information systems and billing of a range of travel services, not just cars and buses. Delivery of these services will be facilitated through a specialized transportation database and advanced communications and vehicle location system. Mobility Manager service providers will be attached to a special data terminal and transmitter/receiver. Users of Mobility Manager can access services from a computer and modem at home or at the office by using a touch-tone telephone, either fixed or cellular."[111] A team consisting of the following members are conducting the planning and design phases (Phases 1 and 2) of the project:

- Michael Baker, Jr., Inc. (lead);
- TRW Transportation Systems;
- Castle Rock Consultants;
- DKS and Associates;
- Ellen Williams and Associates; and
- Morgan State University National Transportation Center.

As of September 1995, the following Phase 1 activities had been accomplished:

- Identification of User Services and Functional Needs;
- Evaluation of Available Technologies;
- Alternatives Evaluation;

[111] "'Mobility Manager' Creates New Beaver County Transit Model," *ITS America News*, August 1995, Vol. 5, No. 8, p. 14.

- Systems Definition;
- Plan for Deployment;
- Plan for Human Factors; and
- Draft Concept of Operations.

The following Phase 1 activities were to be completed by October 1995:

- Identification of Costs-Benefits;
- Identification of Public Education/Awareness;
- Identification of Legal/Institutional Issues;
- Schedule and Budget for Future Activities;
- Plan for Evaluation; and
- Phase 1 Final Report.

In 1996, Phase 2 will consist of producing performance specifications for the system, including system and component specifications, a management plan and a solicitation document. In addition, a refined budget for the future phases of the project will be produced.

Northern Virginia

The Potomac and Rappahannock Transportation Commission's (PRTC) Smart Flexroute Integrated Real-Time Enhancement System is a 30-month operational test of a transit operation (OmniRide) that includes flexible and fixed-route, and demand-responsive services. This operation is located in the Prince William area of Virginia, 25 miles southwest of Washington, DC. "Using ITS technologies including global positioning system-based automatic vehicle location, real-time scheduling software, geographic information system and digital communications through mobile data terminals, the test will integrate flexible routing, commuter bus and rail, feeder bus and human services transportation in a low density environment. Small, multi-purpose vehicles will switch between service types on an as-needed basis, allowing the most appropriate vehicle to respond to each request in real-time using the integrated computerized dispatching software developed for the operations test."[112]

The project team consists of:

- FHWA/FTA - technical advisors and evaluation;

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[112] "Virginia Operational Test to Evaluate Flexible Routing Service," *ITS America News*, August 1995, Vol. 5, No. 8, p. 1.

- Gandalf Mobile Systems Inc. - hardware and software for MDTs, GPS AVL and card readers;
- Northern Virginia Planning District Commission - GIS and local evaluation;
- SG Associates - operations manager;
- Tidewater Consultants Inc. - technical project management;
- Trapeze Software Inc. (formerly UMA Systems) - develop computerized scheduling/dispatching system and software coordinator; and
- Virginia Department of Rail and Public Transportation - project oversight.

New local transit service began in December 1994 with the introduction of three flag-stop routes feeding two Virginia Railway Express (VRE) commuter rail stations serving Washington, DC. A fourth route was added in March 1995, and another in July 1995 serving a third VRE station. In April 1995, flexible route operations began along three corridors. By September 1995, flexible route service in five corridors and feeder service on five routes were operational with a total of 20 vehicles.

"Riders can access the service like a fixed-route bus if their origin and destination are near OmniLink stops. If bus stops are not convenient, riders can call 24 to 48 hours in advance to arrange for the bus to pick them up in their neighborhood. Standing orders for repeat trips are also accepted.

"To increase operating efficiency, buses do not have to return to the route at point of departure. Drivers may select the route between stops when deviations are required. Bus stops were installed at locations where the street network requires the vehicle to pass the stop, regardless of the path traveled. As demand patterns emerge, additional stops will be added, provided they do not minimize the opportunity for route deviation."[113]

As of September 1995, all service was being operated without the benefit of advanced technology, which was in the process of being tested and implemented. Approximate weekly ridership as of the week of August 28, 1995 was 1,950 on the flexible service and 1,650 on the feeder service. (NOTE: Not all service was operational when these figures were compiled.)

Winston-Salem, North Carolina

In 1995, the Winston-Salem Transit Authority completed Phase 1 of their Mobility Management project. Phase 1 was the implementation of several APTS technologies in WSTA's demand-responsive service (called Trans-AID). Trans-AID operates 19 small buses. The

[113] Eric Marx, "PRTC's OmniLink Serves Suburban Neighborhoods," *Passenger Transport*, Monday, September 4, 1995, Volume 53, Number 35, p. 8.

technologies that are currently operational after the completion of Phase 1 are: computerized scheduling and dispatching, mobile data terminals, automatic vehicle location and electronic fare collection. AVL and MDT equipment was placed on three buses in this phase. The Phase 1 work was accomplished by a public/private team consisting of the following:

- WSTA;
- The City of Winston-Salem;
- North Carolina Department of Transportation;
- Federal Transit Administration;
- North Carolina State University - Civil Engineering Department and Institute for Transportation Research and Education;
- On-Line Data Products (scheduling/dispatch software and systems integrator);
- Gandalf Mobile Systems (MDTs, AVL and interface between MDTs and AVL); and
- Tidewater Consultants (implementation guidance).

Between September 1994 and February 1995, an evaluation of the computerized scheduling and dispatch system was performed. Overall evaluation results for this period include:

- Passenger trips increased 17.5 percent, vehicle miles increased 25.1 percent, vehicle hours increased 32.0 percent, and the client base increased 100 percent as a result of a larger service area and increased same-day calls;
- Operating expense per vehicle mile decreased 8.5 percent, operating expense per passenger trip decreased 2.4 percent and operating expense per hour decreased by 8.6 percent;
- Vehicle miles per passenger trip increased 5.4 percent and vehicle hours per passenger trip increased 9.5 percent; and
- Passenger wait time decreased over 50 percent.[114]

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

This study, being conducted by Crain and Associates, is examining transportation agencies that have undertaken programs to become mobility managers. In this study, the term mobility manager is defined <u>not</u> as a technological innovation that enables a transit agency to become a "travel agent" and clearinghouse, but rather as an "organization that has gone beyond traditional public transportation to expand the array of services offered to consumers. [TCRP B-7 is focusing on]

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[114] **The Winston-Salem Transit Authority Mobility Management Project, Phase I: Enhancing Services Delivery Through Advanced Technology Systems**, Final Report-Draft, September 12, 1995.

showcasing mobility managers in case studies so that their experiences can be shared with other transportation agencies."[115]

Phase I of the project is near completion. This phase consisted of three specific tasks:

- Compiling a compendium of mobility management examples from 60 agencies;
- Conducting seven case studies which cover mobility management projects over a wide range of agencies in terms of size, geographic location, environment and organizational structure; and
- Review institutional barriers, both internal and external.[116]

Phase II, which begins in December 1995, will consist of a pilot program conducted with two agencies that are already mobility managers. King County Metro and LYNX in Orlando, Florida have been selected as the two pilots. The project will assist Metro in developing institutional partnerships with other agencies and employers, and in developing performance standards for mobility management. The project will assist LYNX in developing a business plan to become a "one-stop" agency, including relationships with the private sector, and marketing itself as a one-stop agency.

5.3 TRANSPORTATION MANAGEMENT CENTERS

The term transportation management center (TMC) has been used to describe multimodal centers with some level of automation that provide multimodal transportation information, and/or manage both traffic and traffic operations. The use of this term has been somewhat limited in existing centers - most existing centers are still called traffic management centers, primarily because they do not include transit. A related term, advanced traffic management systems, uses the word *traffic* instead of *transportation*.

In 1994, FTA sponsored a study to review the state-of-the-art in integrating transit into transportation management centers.[117] In this study, the following definition for TMC was used: a transportation management center employs advanced technologies to provide transportation information and/or to manage and control transportation networks.

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[115] "'Mobility Managers' -- What Are the Secrets of Success?," TCRP flyer soliciting input for TCRP B-7, undated.

[116] Gail Murray, Crain and Associates, Menlo Park, California.

[117] Schweiger, Carol L., **Review of and Preliminary Guidelines for Integrating Transit into Transportation Management Centers**, prepared for FTA Office of Technical Assistance, Final Report, July 1994, Report Number DOT-T-94-25.

This section updates information presented in the FTA study, specifically where transit is an integral part of a TMC. Often, output from a TMC is input to a multimodal traveler information system. MTISs are described in Section 3.4.

State-of-the-Art Summary

There are a wide range of technologies that are used in a TMC, including:

- Adaptive signal control;
- AVL;
- Computerized signal system;
- GIS;
- Graphics-based display;
- Incident detection;
- Automated logging/recording;
- Video surveillance cameras;
- Closed-circuit television;
- Video imaging detection system;
- Inductive loops/loop detectors;
- Ramp meters;
- Vehicles as traffic probes;
- Surveillance aircraft;
- Roadside-mounted radar detectors; and
- Automatic vehicle identification.

Technologies that are used to distribute traffic and transit information from a TMC include:

- Cable television;
- Radio broadcast;
- Personal computer/modem;
- Personal communication devices;
- Pagers;
- Information kiosks;
- Telephone;
- Displays (non-interactive);
- Electronic signs on-board vehicles (automobile and/or transit);
- Variable message signs; and
- Highway advisory radio.

Applications

There are many technologies employed in TMCs, and several of them are directly related to transit, including adaptive signal control and AVL. Adaptive signal control is being tested in Anaheim, California, and will be tested in Houston, Texas; Bloomington, Minnesota; and Montgomery County, Maryland in the next year. AVL, which gives the TMC information regarding vehicle speeds and congestion levels (e.g., buses as probes), exists or is being implemented in many locations that have TMCs, including Anaheim, Denver, suburban Detroit, Minneapolis, Houston, San Antonio, Seattle, and Milwaukee.

Anaheim, California

The City of Anaheim's Traffic Management Center was originally designed in November 1986. When it started, the city funded the project and it was led by the city's Traffic Engineering staff. Since then, several other city departments, the California Department of Transportation (Caltrans), FHWA, Orange County Transportation Authority (OCTA) and other local agencies have become involved. Also, the Traffic Management Center has a two-way communication link with the Caltrans District 7 Traffic Operations Center in Los Angeles and the District 12 Office in Orange County. This link provides the city with information on freeway conditions and provides Caltrans with information on city streets. The city has an extensive traveler information system that is accessible through cable television, remote kiosks and advisory telephone.

In 1992, JHK and Associates performed a study to define a transit ITS project for short-term implementation in Anaheim. One of the objectives of this study was to "develop a detailed description of an operational test of an integrated transit/traffic traveler information system in Anaheim."[118] The objective of this study was to design a regional traveler information system, incorporating both transit and traffic information, and an AVL system. This effort is being led by OCTA, with Rockwell International as the systems manager, and with support from the City of Anaheim, the City of Santa Ana and Caltrans. The first phase of this work is an operational test in which 10-15 buses will be equipped with GPS devices. These vehicles will act as probes

[118] **JHK & Associates, City of Anaheim/Orange County Transportation Authority Transit IVHS Pre-Project Design Review of Current Situation**, Discussion Paper, June 1992, p. 1-1.

on selected routes between Anaheim and Santa Ana. Information derived en-route will be forwarded to the Anaheim TMC to determine congestion levels, and to OCTA's TMC, which will forward the real-time information to kiosks at several transit centers. Also, information will be used for future planning and scheduling. Technical design was expected to be completed in late 1995, with the actual field operational test and integration into the existing traveler information system expected to commence in late 1996.

Houston, Texas

The Houston TranStar (formerly the Greater Houston Transportation and Emergency Management Center) is a center that will function as a control facility for the coordination of the computerized transportation management system currently being installed in the Houston region, and for emergency management programs in the greater Houston area. TranStar is cooperatively managed by Texas DOT, Harris County, Metropolitan Transit Authority, and the City of Houston. Currently, TranStar is located at an interim facility while the final site is under construction. "Scheduled for completion in late 1995, this center is an $11.5 million, 52,000-square-foot facility from which every aspect of traffic and emergency management within metropolitan Houston will be controlled."[119] Metro is unique among transit agencies since it is not only responsible for operating the bus system, but also for operating and maintaining the HOV lanes. For traffic incidents, alternate routing and/or scheduling strategies will be developed at TranStar with transit personnel, and TranStar will advise Metro dispatching of the alternatives. Further, when AVL is installed in the Metro bus system, the data from the AVL system will be available at TranStar, particularly for incidents and special events.

The City of Houston is installing an Emergency Priority System which uses infrared equipment to change traffic signals for fire trucks and ambulances. This system will be available on 2,800 signals in Metro's service area. The City is providing this infrared equipment to Metro for its buses. The system for buses will not pre-empt traffic signals, but will extend the green

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[119] MacLennan, Robert, "Houston Metro Is Moving Into the Fast Lane with ITS," *Passenger Transport*, September 4, 1995, Volume 53, Number 35, p. 16.

phase. The infrared system is in compliance with the SAE J1708 standard, and will not require any intervention by the bus driver. As each bus triggers a priority, the infrared system will record the vehicle's number, vehicle type, the time that the priority was given and the direction of the vehicle. Also, automatic vehicle identification (AVI) readers will be installed within park-and-ride facilities to monitor the arrival and departure of the transit vehicles. Further, AVI readers will be temporarily installed at park-and-ride facilities and bus loading facilities to monitor special event shuttle bus operations.

Further, Houston is developing an information delivery system, which "will be capable of providing high quality graphical and text presentations, will be interactive, allowing users to query for additional information in response to specific traffic and transit needs, and will be user-friendly and capable of providing updated travel time and transit schedule information every three minutes. The real-time traffic and transit information utilized in the I-45 North component [of Houston's Smart Commuter] will be provided through the Traffic Management Center and Metro's Transit Information System."[120]

Houston Metro's integrated intelligent transportation system (I^2TS), which will reside in TranStar, consists of the following elements:

- Regional Computerized Traffic Signal System;
- Transit Operational Control and Management System; and
- Texas DOT Regional Freeway Management Center.

These elements will be integrated by a metropolitan area network using Synchronous Optical Network (SONET) technology.

An ATIS is a key component of the I^2TS, and it will include en-route transit information. All 1,500 transit vehicles, transfer centers and 29 park-and-ride lots will be supported by the I^2TS. "ATIS request and response are supported by the SONET network's interconnect with the public telephone network (including cellular), as well as direct field interconnects with kiosk terminals."[121]

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[120] Metropolitan Transit Authority of Harris County, **Request for Technical Proposals for Commuter Information Delivery System for the North Freeway Corridor**, Metro Request for Technical Proposal (RFTP) No. 94X233P, March 13, 1995, p. 7.

[121] Abernethy, Bruce, "An ITS for Houston Metro," *Traffic Technology International '95*, UK & International Press, Surrey, United Kingdom, p. 94.

In addition to the implementation of AVL, VMS at park-and-ride lots, transfer centers and along the roadways, and kiosks at park-and-tide lots and transfer centers, on-board traveler information will also be available.

Minneapolis/St. Paul, Minnesota

The Mn/DOT Traffic Management Center manages traffic on Twin Cities metropolitan area freeways. The local transit agency, the Metropolitan Council of Transit Operations (MTC), will be a part of the Traffic Management Center through a project called "Speedlight." This project will allow buses on the I-394 corridor to preempt ramp meters, which allows them to enter the highway without the waiting that cars experience. The MTC is also an integral part of the Travlink project (described in Section 3.2).

One of Travlink's objectives is to "provide real-time transit schedule and traffic information for use at homes, workplaces, transit stations and other activity centers."[122] This traffic information will be collected from the Traffic Management Center through Genesis, which is an operational test of a personal communication device[123] that will provide the user with real-time, route-specific information on the operating conditions of highway and mass transit systems and other personal-use types of information. Depending on market research, real-time information will become available at kiosks at transit centers and business/shopping complexes, as well as by telephone.

Montgomery County, Maryland

Montgomery County is in the process of developing and implementing an advanced transportation management system. One of the goals of this system is to regulate bus and other transit flows by using the traffic signal system, without fundamentally causing gridlock for other vehicle traffic. In the spring of 1996, buses will be outfitted with GPS AVL. The AVL system will provide real-time transit information to the transportation management control center. Start-up

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[122] Westinghouse Electric Corporation, **Travlink Operational Test System Definition Document**, Revision C, September 29, 1993, p. 1.

[123] PCDs identified for Genesis include alphanumeric pagers, personal digital assistants (a small hand-held unit with 2-way radio frequency communications), and notebook computers.

funding of $1 million for the whole system was provided by FHWA. The State of Maryland has allocated an additional $2.5 million, of which $1.5 million is for full deployment of the transit related activities and $1 million for the public information component. When fully implemented by mid-1996, the advanced transportation management system will include the following capabilities and functions:

- Advanced traffic responsive traffic signal control;
- Automated sign control system;
- 200-camera video surveillance system;
- Sophisticated electronic transportation monitoring systems;
- Silent alarm for transit operators en-route which will activate a one-way microphone so that the control center can hear an incident in progress and can contact the appropriate entity to respond;
- Incident response and logging;
- Time-critical GIS;
- Automated transportation information system;
- Integrated transit and traffic operations;
- Vehicle tracking systems (GPS and others);
- Automated incident management system;
- Aerial surveillance operations;
- Automated integration with police/fire computer-aided dispatch systems;
- Automated transportation planning support;
- Sophisticated fiber optic-based communication system;
- Integration with future automated highway systems; and
- Text messages sent to buses for broadcast to passengers and the operator.[124]

Also, the County's transit system (Ride On) dispatching operation and their information center is co-located with the traffic management and control facility. This was done to improve coordination between traffic engineering and transit services, and ultimately, to ensure the efficient utilization of transportation capacity in the County.

Metropolitan New York/New Jersey/Connecticut

TRANSCOM is a consortium of highway, transit and public safety agencies in the New York City metropolitan area including New York, New Jersey and Connecticut. TRANSCOM began operation in 1985 and in its role of coordinating these agencies to improve mobility, it has become "an almost indispensable element of the region's complex transportation network. [TRANSCOM]

[124] "Advanced Transportation Management System," handout available at Montgomery County DOT TMC.

continuously monitors traffic conditions, construction schedules, road closings, accidents, weather-related incidents and any other event that might disrupt traffic on the estimated 6,000 miles of highway and 2,000 miles of track within the 500 square mile metropolitan area."[125]

One of TRANSCOM's on-going objectives is to increase transit agency participation. This objective led to FTA granting Section 8 funds for TRANSCOM, in cooperation with local metropolitan planning organizations, "to develop incident management plans for transit corridors."[126] For the Port Authority Trans-Hudson (PATH), TRANSCOM developed an interagency communication and operation plan for PATH Hoboken service disruptions. TRANSCOM also developed a "Framework for an Incident Management Plan and Opportunities for Interagency Communications Linkages for Long Island Rail Road Service Disruptions," in conjunction with the New York Metropolitan Transportation Council. These two plans:

- Identified linkages to external agencies that might be affected by service disruptions;
- Outlined a sequence of notification procedures;
- Assigned responsibilities when service is suspended temporarily; and
- Complemented internal operational efforts for train operations, service recovery, police/fire notifications and provision of alternate service.[127]

Through these incident management plans, TRANSCOM is reinforcing the idea that transit agencies are an integral part of the region's total transportation picture - when there is an incident on a specific transit agency's route, it does affect traffic as well as transit, and it should be accurately reported to the traveling public along with possible alternatives.

Other projects for which TRANSCOM has received Federal funding include:

- Alternate Bus Routing System, which uses a video imaging detection system and vehicle to roadside communication system, will calculate the travel times of parallel routes from Interchange 127 of the Garden State Parkway to Interchange 11 of the New Jersey Turnpike, and transmit this information to 400+ buses using this Raritan corridor;
- Regional variable message sign (VMS) program, with VMS at 20 locations throughout the NY/NJ/CT region; and

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[125] "The Finger on the Pulse of the Roadways," *The New York Times*, December 31, 1992.

[126] TRANSCOM, **An Interagency Communication and Operation Plan for PATH-Hoboken Service Disruptions**, in conjunction with the North Jersey Transportation Coordinating Council, June 15, 1992, p. I.

[127] Ibid, p. 13-14.

- Regional Video Linkage to connect TRANSCOM's member agencies' video feeds into TRANSCOM's Operation Information Center.[128]

San Antonio, Texas

The San Antonio TransGuide, an ITS Operations Control Center, is a 51,000 square-foot facility overseen by Texas DOT, housing Texas DOT, local law enforcement, fire, 911 and emergency back-up, and VIA Metropolitan Transit. It manages all urban areas and road corridors in 39 counties covering 45,000 square miles, roughly the size of New York State. Included are all bridge crossings to Mexico from Del Rio to Matamoros. Along I-35, cameras are being installed every five miles so that if there are accidents, stalled vehicles or other incidents, TransGuide will have instant information to inform travelers in real-time to make alternate plans.

VIA has a dispatching operation in TransGuide, in addition to their other control rooms downtown and in the new Alamo Dome. At TransGuide, advanced technologies include a graphics-based display, incident detection and automated logging/recording, and staff is currently mapping information for a computerized signal system. Using an FTA grant, VIA has tied into the fiber optic network installed from TransGuide to their two existing control rooms. This grant will also add cameras to the surveillance network. These cameras will be installed in the park-and-ride lots for security and for determining the occupancy level at the lots.

Currently, VIA collects data on ridership manually, and on vehicle location through their existing automatic vehicle monitoring (AVM) system. The AVM system, which is a signpost system, will be replaced in the near future by a GPS AVL system. VIA has a computerized customer service line for those customers who know their bus stop number. This system tells customers when the next three buses will arrive at that specific bus stop based on schedules (not actual arrival times). If a customer does not know their bus stop number, there are 11 operators on duty at peak times to answer route and schedule questions.

In the future, VIA will distribute information on timetables (tentatively November 1995), real-time arrivals/departures, routes, route details, fares, bus location and next-stop announcements from the OCC. In addition, real-time information is provided on selected radio stations and Channel 54,

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[128] **TRANSCOM 1994 Business Plan and Budget**, December 1993, pp. 15-16.

TransGuide's over-the-air low-power television station. This station provides continuous information on traffic and construction activities. Commencing in October 1995, information was to be provided in real time over the Internet. Also, kiosks at park-and-ride lots and major transfer points will display when the next bus will arrive. Next-stop announcements on-board the buses will be implemented in the near future.

Seattle, Washington

Currently, Washington State DOT is working with three Seattle-area transit agencies and several local agency traffic systems to integrate several transportation functions in a networked system, the North Seattle ATMS. WSDOT is including transit priority treatments and information exchange. Transit operators will receive real-time traffic information (on freeways and arterials) and freeway closed-circuit television camera images. Traffic managers will receive bus location information.[129]

Atlanta, Georgia

Atlanta's new TMC will be a real-time integrated system covering all surface transportation in the five-county greater Atlanta region. (Fifty percent of the total vehicular traffic and 44 percent of the state's population is in the five-county area.) The Georgia Department of Transportation will oversee the TMC's operations. The TMC is one part of an advanced transportation management system, which also contains:

- Transportation control centers (TCCs);
- A communication network between the TMC and the TCCs;
- Integrated and interactive computerized data processing;
- Control and management software for the integration of field-deployed equipment;
- A field communications network; and
- Field equipment upgrades.

The functions of the TMC include:

- 24-hour operations;
- Data backup;

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[129] Les Jacobson, Traffic Systems Manager, Northwest Region Traffic Office, Washington State DOT, Seattle, Washington.

- System-wide planning coordination;
- Incident management coordination;
- Cross-jurisdictional special event coordination;
- Media coordination and cooperation; and
- System software support and maintenance.

The heart of the TMC is a geographic information system.

Metropolitan Atlanta Rapid Transit Authority dispatching will not be included in the TMC, but MARTA will have an informational presence. A MARTA representative will, however, be located at the TMC during special events. All the technology that will be utilized at the TMC is being designed with transit in mind, particularly since transit information will be available through the TMC by the 1996 Olympics.

A communications network will enable MARTA to provide real-time routes, schedules and ridership to the TMC. Also, as MARTA installs their new GPS-based AVL system (from Transportation Management Solutions, Inc.), the information from the AVL system will be provided to the TMC.

Two field operational tests (FOTs) are being conducted in conjunction with both the Olympics activities and the TMC development. One FOT is an advanced traveler information system in which traveler information will be distributed at kiosks located at welcome centers all over the state of Georgia. The other FOT involves an en-route traveler information system, which will include a radio link with MARTA and Cobb Community Transit.

Additional information regarding Atlanta is discussed in Sections 3.1 and 3.4.

5.4 HIGH OCCUPANCY VEHICLE FACILITY MONITORING

High occupancy vehicle (HOV) lanes on access controlled roadways have proven to be popular because of their potential to provide faster travel times to and from the central areas of cities. Due to the travel time advantage that HOV lanes offer, some drivers will use these lanes with less than the minimum number of passengers allowed. In order for these lanes to serve the intended purpose of increasing carpooling, vanpooling, and bus transit usage, violators of the minimum passenger requirement must be deterred. A number of enforcement approaches have been tried. These have included motorists reporting of violators, remote apprehension, use of trained individuals rather than enforcement officers for violation detection, and stationing enforcement officers at the entrance to or somewhere along the lane. The last approach is the most effective method but it is costly as well as a potential safety hazard. This has led some agencies to look for a technological solution to the problem.

State-of-the-Art Summary

A number of automated methods of vehicle occupancy detection have been considered, and a few have been the subject of limited testing. Potential technologies include video camera, transponder, near infrared, millimeter wave, and thermal infrared. Except for transponders, all would have to be complemented with image processing and pattern recognition in order to have a completely functional and automated process. They also have definite technological limitations, including difficulty in detecting small children or passengers lying down.

Only transponder technology appears readily implementable now. However, the potential for fraudulent use of HOV lanes with transponders makes this approach suspect. Other technologies, if adequately funded for research and development, seem at least a year away from a deployment stage. The accuracy of passenger identification is the critical element. It must be very high in order for any of these approaches to be selected for implementation.

The potential technological approaches are described below.

Video

The latest video cameras are capable of capturing images of vehicles traveling at high speeds. In order to determine vehicle occupancy, video cameras would be aimed to "look" inside vehicles using the HOV lanes. The video images would be observed at a remote location for identification of HOV lane minimum passenger requirement violations.

In order to minimize enforcement costs, it would be necessary to be able to issue citations by mail rather than by enforcement personnel located downstream beside the lane. (Mailed citations are not legal in all jurisdictions, however; some require personal issuance at the scene of the violation.) This would require a more accurate method of determining occupancy than is presently possible with video cameras. Tinted windows and various light conditions make passenger identification a difficult task.

Video cameras have been tested but are not currently being used to determine the occupancy of vehicles, although they are being used in many locations to monitor traffic flows and incidents.[130]

Transponders

A passenger transponder system would operate in a manner similar to an automated vehicle identification system. An AVI system consists of a vehicle-mounted transponder which communicates with a wayside sensor or reader. The reader-transponder interaction can function in several different ways, depending upon the power source.

For verification of vehicle occupancy, each passenger of a carpool or vanpool using the HOV lane would have to be issued a transponder. The wayside reader would record the number of transponders inside a vehicle as it passes the reader. A major drawback to this method is that there is no assurance that the number of persons in a vehicle matches the number of transponders identified, since a transponder can be placed in a vehicle without its owner present. Another disadvantage is that persons would have to apply for and obtain a transponder. This would tend to discourage use of HOV lanes by infrequent carpoolers who might not want to go through the inconvenience of the application process.

Although this technology has not been used in HOV lane operations, transponders are used in applications worldwide, many of which are automated toll collection systems.[131]

Near Infrared

This concept uses near infrared strobe light illumination to permit infrared pictures to be taken of passing vehicles. In this instance, an image analysis algorithm would process the digitized images of the interior contents of a vehicle. Vehicle occupants would be identified by their shapes. This approach eliminates the problem of being able to see into a vehicle with tinted windows or under poor

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[130] Texas Transportation Institute, Interim Report, **Use of Advanced Technology in HOV Lane Enforcement**. College Station, Texas, February 1994.

[131] Ibid.

lighting conditions. Development of the algorithm is the most difficult aspect of the approach. It must be capable of identifying occupants in vehicles traveling at freeway speeds at very close spacing. This approach is limited by what can be seen through the windows and is not able to distinguish between a live person and a mannequin. Multiple cameras could alleviate much of the vision limitation.[132]

Millimeter Wave

The millimeter wave approach would use a scanner to receive reflected radio waves from a vehicle and its contents. A processing algorithm would identify vehicle occupants by their reflected wave patterns. This differs from the near infrared in that a near infrared approach produces a still picture which is processed by the algorithm. Millimeter wave technology shares many of the same difficulties and limitations as near infrared.[133]

Thermal Infrared

Theoretically, thermal infrared technology could be used to distinguish a live person from a dummy or a warm vehicle component. The weakness in this approach is that thermal infrared wavelengths will not penetrate window glass.[134]

Applications

Caltrans

The California Department of Transportation conducted a test in 1990 to assess the utility of video cameras for vehicle occupancy identification purposes. Four high-speed color video cameras

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[132] Gary Gimmestead, Georgia Tech Research Institute, Atlanta, Georgia.

[133] Eugene Greneker, Radar and Instrumentation Development Laboratory, Georgia Tech Research Institute, Atlanta, Georgia.

[134] Gary Gimmestead, Georgia Tech Research Institute, Atlanta, Georgia.

with zoom lenses were aimed at passing vehicles from different angles. The test produced a 21 percent false indication rate.[135]

Atlanta, Georgia

Researchers at Georgia Tech Research Institute have experimented with near infrared and millimeter wave technologies. The Georgia Department of Transportation's Office of Materials and Research is funding work on the near infrared approach. The Georgia DOT has several uses for images produced by this technique, one of which is to determine the occupancy of vehicles. A prototype system is to be delivered in a year.[136]

A crude test of the millimeter wave approach reportedly was successful, but considerable further work would be necessary before this technology would be ready for implementation. It was evident that a higher resolution scanner and faster signal processing would be needed. Funding is not presently available for additional research on this approach.[137]

College Station, Texas

The Texas Transportation Institute (TTI) is studying the applicability of various automated techniques for enforcing the occupancy restrictions on an HOV lane in the Dallas area. An interim report identified video, automated vehicle identification, and machine vision as potentially applicable advanced technologies. TTI defined machine vision as encompassing "those technologies that utilize electro-optical infrared sensors and/or image processors with pattern recognition." The researchers concluded that there is no currently available technology that offers significant advantages over the current manual enforcement process, but that machine vision technologies appear to offer promise and are worthy of further research and testing.[138]

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[135] Op. cit., Texas Transportation Institute.

[136] Gary Gimmestead, Georgia Tech Research Institute, Atlanta, Georgia.

[137] Eugene Greneker, Radar and Instrumentation Development Laboratory, Georgia Tech Research Institute, Atlanta, Georgia.

[138] Op. cit., Texas Transportation Institute.

As part of their current effort, TTI will advertise for bids on a video system that will record and match license plate numbers with the number of occupants in the vehicle as seen through the cameras. Repeat HOV lane users with a good history of legal usage will be filtered out of the screening process, leaving only new users or those with less than the HOV lane occupancy requirement (two or more in this instance) to be shown to the person viewing the video images. It is hoped that this screening process will dramatically reduce the number of vehicle images that must be viewed. When active lane enforcement is in effect, information on the vehicles that need to be checked is relayed to enforcement personnel. Vehicles for which occupancy cannot be determined through the cameras will not be stopped for occupancy verification. It is hoped that the utilization of this process, or the perception of its use, will reduce the number of enforcement personnel required, as well as the lane violation rate.

The accuracy of occupancy verification using video technology is a major issue. A previous TTI test of video cameras indicated that front seat occupants could be clearly identified in about 75 percent of the passing vehicles when viewing a copy of a video tape played on a standard video cassette recorder. Back seat passengers were harder to see. However, this percentage was substantially increased by using the original tape with stop frame and video enhancement. Nevertheless, current video systems do not appear to be sufficiently accurate for completely remote verification and citation.[139]

Tampa, Florida

In February 1995, the Center for Urban Transportation Research at the University of South Florida conducted a field demonstration for the Hillsborough County Metropolitan Planning Organization to evaluate the feasibility of using video cameras as an automated method of gathering traffic performance data. Two of the six video cameras used in the demonstration were set up at an exit ramp from Interstate 4 to downtown Tampa; one positioned to record license plates, and one positioned to record vehicle occupancy. Vehicle occupancy was automatically captured on video tape for manual analysis. The accuracy of the vehicle occupancy counts resulting from this test was

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[139] Shawn Turner, Texas Transportation Institute, College Station, Texas.

deemed adequate for average vehicle occupancy estimation but would not be adequate for automated enforcement of HOV lane occupancy requirements.[140]

[140] Pietrzyk, Michael C., "An application of ITS Technology for Congestion Management Systems," *Compendium of Technical Papers, Institute of Transportation Engineers Annual Meeting*, 1995.

6. FTA-SPONSORED FIELD OPERATIONAL TESTS AND RESEARCH

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. 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
U.S. Department of Transportation
Federal Transit Administration (TRI-10)
Office of Mobility Innovation
400 Seventh Street, SW
Washington, DC 20590
(202) 366-4991

Table 6.1 Current FTA-Sponsored APTS Field Operational Tests and Research[141]

Title	FTA Contact	Local Agency	Local Contact
FLEET MANAGEMENT			
Orange County Smart Vehicle (See also Traveler Information)	Ronald Boenau (202) 366-0195	California DOT Orange County, California	Dean Delgado (714) 560-5744
Santa Clara County Smart Vehicle	Ronald Boenau (202) 366-0195	California DOT - Div. of New Technology and Research Sacramento, California	Cliff Loveland (916) 654-9970
Denver Smart Vehicle	Denis Symes (202) 366-0232	Regional Transportation District Denver, Colorado	Lou Ha (303) 299-6265
Atlanta ITS Project (See also Trvl'r Info and TDM Tech)	Denis Symes (202) 366-0232	Metropolitan Atlanta Rapid Transit Authority Atlanta, Georgia	Gerald Pachucki (404) 848-5320
Chicago Smart Intermodal (See also Traveler Information)	Sean Ricketson (202) 366-6678	Chicago Transit Authority Chicago, Illinois	Ron Baker (312) 664-7200 x4105
Baltimore Smart Vehicle	Denis Symes (202) 366-0232	Mass Transit Administration Baltimore, Maryland	Ray Carroll (410) 767-3327
Ann Arbor Smart Intermodal (See also Electronic Fare Payment)	Sean Ricketson (202) 366-6678	Ann Arbor Transportation Authority Ann Arbor, Michigan	Bill Hiller (313) 973-6500
Winston-Salem Mobility Manager	Ronald Boenau (202) 366-0195	Winston-Salem Transit Authority Winston-Salem, North Carolina	John Stone (NC State U) (919) 515-7732
Dallas Smart Vehicle Evaluation	W. Raymond King (202) 366-6667	Dallas Area Rapid Transit Dallas, Texas	John Hengs (214) 749-2961
Northern Virginia Smart Route Sys.	Ronald Boenau (202) 366-0195	Potomac-Rappahannock Transportation Commission Woodbridge, Virginia	Eric Marx (703) 490-4811
Milwaukee Smart Vehicle	Sean Ricketson (202) 366-6678	Milwaukee County Milwaukee, Wisconsin	Ron Rutkowski (414) 278-4888

[141] Based on information provided by FTA, Office of Mobility Innovation.

Table 6.1. Current FTA-Sponsored Field Operational Tests and Research (continued)

Title	FTA Contact	Local Agency	Local Contact
TRAVELER INFORMATION			
Los Angeles Smart Traveler	Ronald Boenau (202) 366-0195	California DOT - Div. of New Technology and Research Sacramento, California	Cliff Loveland (916) 654-9970
Orange County Smart Vehicle (See also Fleet Management)	Ronald Boenau (202) 366-0195	California DOT Orange County, California	Dean Delgado (714) 560-5744
Atlanta ITS Project (See also Fleet Mgmt and TDM Tech)	Denis Symes (202) 366-0232	Metropolitan Atlanta Rapid Transit Authority Atlanta, Georgia	Gerald Pachucki (404) 848-5320
Chicago Smart Intermodal (See also Fleet Management)	Sean Ricketson (202) 366-6678	Chicago Transit Authority Chicago, Illinois	Ron Baker (312) 664-7200 x4105
Twin Cities' Travlink and Genesis Evaluation	Sean Ricketson (202) 366-6678	Regional Transit Board St. Paul, Minnesota	Marilyn Remer (612) 282-2469
Houston Smart Commuter (See also TDM Technologies)	W. Raymond King (202) 366-6667	Metropolitan Transit Authority of Harris County Houston, Texas	Sholeh Karimi (713) 613-0315
ELECTRONIC FARE PAYMENT			
California Smart Traveler	Ronald Boenau (202) 366-0195	California DOT - Div. of New Technology and Research Sacramento, California	Cliff Loveland (916) 654-9970
Delaware Smart DART	Sean Ricketson (202) 366-6678	Delaware DOT Wilmington, Delaware	
Washington DC Advanced Fare Media	Irv Chambers (202) 366-0238	Washington Metropolitan Area Transportation Authority Washington, DC	Ramon Abromovich (202) 962-5274
Ann Arbor Smart Intermodal (See also Fleet Management)	Sean Ricketson (202) 366-6678	Ann Arbor Transportation Authority Ann Arbor, Michigan	Bill Hiller (313) 973-6500
Delaware County Ridetracking	Sean Ricketson (202) 366-6678	Delaware County Transit Delaware County, Pennsylvania	Judy McGrane (610) 532-2900
Chattanooga Smart Card	Sean Ricketson (202) 366-6678	Chattanooga Area Regional Transportation Authority Chattanooga, Tennessee	Art Barnes (615) 629-1411

Table 6.1. Current FTA-Sponsored Field Operational Tests and Research (continued)

Title	FTA Contact	Local Agency	Local Contact
TDM TECHNOLOGIES			
Sacramento Rideshare	Ron Boenau (202) 366-0195	California DOT - Div. Of New Technology and Research Sacramento, California	Cliff Loveland (916) 654-9970
Atlanta ITS Project (See also Trvl'r Info and Fleet Mgmt)	Denis Symes (202) 366-0232	Metropolitan Atlanta Rapid Transit Authority Atlanta, Georgia	Gerald Pachucki (404) 848-5320
Houston Smart Commuter (See also Traveler Information)	W. Raymond King (202) 366-6667	Metropolitan Transit Authority of Harris County Houston, Texas	Sholeh Karimi (713) 613-0315
Seattle Smart Traveler	Ron Boenau (202) 366-0195	Municipality of Metropolitan Seattle Seattle, Washington	Mark Haselkorn (U Wash) (206) 543-2577
OTHER			
Operational Test Evaluation	Ronald Boenau (202) 366-0195	Volpe National Transportation Systems Center Cambridge, Massachusetts	Robert Casey (617) 494-2213
Technology Research	Denis Symes (202) 366-0232	Volpe National Transportation Systems Center Cambridge, Massachusetts	Robert S. Ow (617) 494-2411

APPENDIX A

CONTACTS

Table A.1 List of Contacts[A-1]

City, State Name	Address	Contact(s)	Phone #	FAX # E-Mail
Phoenix, AZ PTD	City of Phoenix Public Transit Department 302 North First Avenue, Suite 700 Phoenix, AZ 85003	Jeff Dolphini	(602) 262-7242	(602) 495-2002
Scottsdale, AZ On-Line	On-Line Data Products, Inc. 14255 North 79th Street, Suite 2 Scottsdale, AZ 85260	Robert Dukes	(602) 483-3822	(602) 483-2339
Tuscon, AZ SunTran	City Department of Transportation 201 North Stone Avenue Tuscon, AZ 85726-7210	Jill Merrick	(520) 791-4371	(520) 791-4608 USCOFTBQ@ibmmail.com
Alameda, CA Ferry Services	City of Alameda - Ferry Services 2263 Santa Clara Avenue Alameda, CA 94501-4456	Cheri Sheets	(510) 748-4515	(510) 748-4697
Anaheim, CA ATMC	Anaheim Traffic Management Center 201 South Annaheim Blvd., 5th Floor Anaheim, CA 92805	James Paral Principal Traffic Engineer	(714) 254-5183	(714) 254-5225
Davis, CA ITS	Institute of Transportation Studies University of California Davis, CA	Raghu Kowshik	(916) 752-2029	(916) 752-6572 rrkowshik @poppy.engr.ucdavis.edu
Menlo Park, CA Crain and Associates	Crain and Associates 120 Santa Margarita Menlo Park, CA 94025	Gail Murray	(415) 323-3444	
La Jolla, CA Maxwell Labs.	Maxwell Laboratories, S-CUBED Dvivision PO Box 1620 La Jolla, CA 92038-1620	Dr. Joseph Masso	(619) 587-7226	(619) 755-0474 masso@scubed.com

[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, then followed by all others. An additional list, which is ordered alphabetically by the contacts' last names is included as Table A.2.

Table A.1 List of Contacts (continued)

City, State Name	Address	Contact(s)	Phone #	FAX # E-Mail
Los Altos, CA SYSTAN, Inc.	SYSTAN, Inc. PO Box U (343 2nd Street, Suite B) Los Altos, CA 94023	Roy Lave	(415) 941-3311	
Los Angeles, CA LACMTA	Los Angeles County Metropolitan Transit Auth. 425 South Main Street Los Angeles, CA 90013	Ron Ledford	(213) 972-4645	(213) 972-4762
Los Angeles, CA USC	School of Urban and Regional Planning University of Southern California Los Angeles, CA	Genevieve Guiliano	(213) 740-3956	
Napa, CA The Vine	The Vine-City of Napa 1600 First Street Napa, CA 94559-0660	Celinda Romaine-Dahlgren	(707) 257-9520	(707) 257-9522
Oakland, CA AC Transit	Alameda-Contra Costa Transit 1600 Franklin Street Oakland, CA 94612	Bob Garside	(510) 891-4854	(510) 891-7157
Oakland, CA BART	Bay Area Rapid Transit District 800 Madison Street Oakland, CA 94607-2688	James Gallagher Director of Operations	(510) 464-6000	
Oakland, CA MTC	Metropolitan Transportation Commission Joseph P. Bort Metrocenter - 101 8th St. Oakland, CA 94607-4700	Joel Markowitz Manager, Advanced Systems Applications	(510) 464-7760	(510) 464-7848
Ontario, CA City of Ontario	City of Ontario Civic Center 303 East B Street Ontario, CA 91764	Kim Shultz Transportation Projects Manager	(909) 391-2510	(909) 391-0692
Ontario, CA L.D. King, Inc.	L.D. King, Inc. 2151 East D Street, Suite 100B Ontario, CA 91764	Jill Kollmann	(909) 988-5492	

Table A.1 List of Contacts (continued)

City, State Name	Address	Contact(s)	Phone #	FAX # E-Mail
Orange, CA OCTA	Orange County Transportation Authority 550 South Main Street PO Box 14184 Orange, CA 92613-1584	Dean Delgado Senior Transportation Analyst	(714) 560-5744	(714) 560-5794
Palo Alto, CA Metro Dynamics	Metro Dynamics 299 California Avenue, Suite 305 Palo Alto, CA 94306	Ivan Deirossi Project Manager	(415) 325-4949	
Richmond, CA ITS	California Path - UCB Building 452, 1357 South 46th Street Richmond, CA 94804-4698	Mark Hickman	(510) 231-5644	mhickman @path2.its.berkeley.edu
Riverside, CA SunLine	Riverside Transit Agency 1825 Third Street Riverside, CA 92507-3484	Anne Burnburg Customer Service Manager	(619) 343-3456 x162	
Sacramento, CA CAATS	CA Alliance for Advanced Transportation Systems PO Box 942873 MS-83 Sacramento, CA 94273-0001	Robert Ratcliff Alliance Manager	(916) 654-8367	(916) 657-4677 rratclif@ix.netcom.com
Sacramento, CA SaCOG	Sacramento Council of Governments Sacramento, CA	Velma Lucero	(916) 323-8304	
San Diego, CA SDTC	San Diego Transit Corporation PO Box 2511 San Diego, CA 92112-2511	Betty Knutson Senior Information Specialist	(619) 238-0100 x469	
San Fancisco, CA Muni	San Francisco Municipal Railway 131 Lenox Way San Francisco, CA 94127-1100	Len Olson	(415) 759-4360	(415) 759-4363
San Francisco, CA Muni	San Francisco Municipal Railway 949 Presidio Avenue San Francisco, CA 94115	Annette Williams Accessible Services Program Manager	(415) 923-6142	

Table A.1 List of Contacts (continued)

City, State Name	Address	Contact(s)	Phone #	FAX # E-Mail
San Jose, CA OUTREACH	OUTREACH 97 East Brokaw Road, Suite 140 San Jose, CA 95112	Roberta Gardella Chief Executive Officer	(408) 436-2865	(408) 437-9499
Santa Barbara, CA Easy Lift	Easy Lift Solutions 423 West Victoria Street Santa Barbara, CA 93101	Tom Roberts	(805) 568-5179	(805) 568-5120
Santa Monica, CA Muni Bus Lines	Santa Monica Municipal Bus Lines 1660 7th Street Santa Monica, CA 90401	Janet Shelton	(310) 451-5444	(310) 451-3163
Stockton, CA San Jaoquin RTD	San Jaoquin Regional Tranait District 1533 East Lindsay Street Stockton, CA 95205	Kal Raouda	(209) 948-5566	(209) 948-8516 kraouda@aol.com
Denver, CO RTD	Regional Transportation District 1900 31st Street Denver, CO 80216	Lou Ha	(303) 299-6265	(303) 299-6060
Washington, DC TRB	Transportation Research Board 2101 Constitution Avenue, NW Washington, DC 20418	Stephanie Nellons-Robinson Sen. Program Officer	(202) 334-3502	(202) 334-2003
Cocoa, FL SCAT	Space Coast Area Transit 401 South Vann Avenue Cocoa, FL 32922	Jim Liesenfelt	(407) 635-7815	(407) 633-1905
Ft. Lauderdale, FL BCMTD	Broward County Mass Transit District 3201 West Copans Road Pompano Beach, FL 33069	Bruce Coleman	(305) 357-8379	(305) 357-8378
Miami, FL MDTA	Metro-Dade Transit Authority 3300 Northwest 32nd Avenue Miami, FL 33142	Hugh Chen	(305) 637-3727	(305) 637-3719

Table A.1 List of Contacts (continued)

City, State Name	Address	Contact(s)	Phone #	FAX # E-Mail
Palatka, FL Arc Transit	Arc Transit 1209 Westover Drive Palatka, FL 32177	Boyd Thompson	(904) 325-9999	(904) 328-9410
Tampa, FL Hartline	Hillsboro Area Regional Transit Authority 43 East 21st Avenue Tampa, FL 33605	Steve Roberts	(813) 623-5835	(813) 664-1119
Tampa, FL ISD	Innovative Software Designers 2001 Pan Am Circle Tampa, FL 33607	Scott Vanover	(800) 881-0088	
Atlanta, GA GA Tech RI	Georgia Tech Research Institute Atlanta, GA	Gary Gimmestead	(404) 894-3419	
Atlanta, GA GA Tech RI	Radar & Instrumentation Development Laboratory Georgia Tech Research Institute Atlanta, GA	Eugene Greneker	(404) 528-7744	(404) 528-7749
Atlanta, GA GDOT	Georgia DOT 2 Capitol Square Atlanta, GA 30334	Lawson Stapleton Assistant State Traffic Operations Engineer	(404) 656-5423	(404) 656-3607
Atlanta, GA MARTA	Metropolitan Atlanta Rapid Transit Authority 2424 Piedmont Road Atlanta, GA 30324-3330	Harriet Robbins-Smith	(404) 848-4224	(404) 848-5321
Honolulu, HI TheBUS	TheBUS 811 Middle Street Honolulu, HI 96819-2388	William Haig Customer Service Manager	(808) 848-4440	
Sioux City, IA Sioux City TS	Sioux City Transit System 2505 Fourth Street Sioux City, IA 51101	Dan Jensen	(712) 279-6405	

Table A.1 List of Contacts (continued)

City, State Name	Address	Contact(s)	Phone #	FAX # E-Mail
Chicago, IL CTA	Chicago Transit Authority Box 3555 Chicago, IL 60654	Ron Baker David Phillips	(312) 664-7200 x4105 (312) 664-7200 x307	(312) 664-2748
Chicago, IL Pace	Pace Suburban Bus 550 West Algonquin Arlington Heights, IL 60005	Mike Bohm John Pikhay	(708) 364-7223 (708) 228-2401	(708) 439-8116
Oak Park, IL IDOT	Illinois DOT - Traffic Systems Center 445 Harrison Street Oak Park, IL 60304-1499	Tony Cioffi Operations Chief	(708) 524-2145	(708) 524-1455
Rock Island, IL RICMT	Rock Island County Metropolitan Transit 2000 Third Avenue Rock Island, IL 61201	Jeff Nelson	(309) 788-3360	
Gary, IN Tradewinds RCI	Tradewinds Rehabilitation Center, Inc. PO Box 6308 (5901 West 7th Avenue) Gary, IN 46404-6308	Lisa Premil	(219) 949-4000	(219) 949-8134
Louisville, KY TARC	Transit Authority of River City 1000 West Broadway Louisville, KY 40203	John Woodford	(502) 561-5104	(502) 561-5244
New Orleans, LA RTA	Regional Transit Authority 6700 Plaza Drive New Orleans, LA 70127	Valarie Moton	(504) 243-3723	(504) 243-3872
Boston, MA MBTA	Massachusetts Bay Transportation Authority 10 Park Plaza Boston, MA 02116	Robert Clark Program Manager	(617) 722-3493	
Cambridge, MA Multisystems, Inc.	Multisystems, Inc. 10 Fawcett Street Cambridge, MA 02138	Kurt Dossin	(617) 864-5810	(617) 864-3521

Table A.1 List of Contacts (continued)

City, State Name	Address	Contact(s)	Phone #	FAX # E-Mail
Cambridge, MA SmartRoute	SmartRoute Systems 141 Portland Street, Suite 8100 Cambridge, MA 02139	Katy Miller Marketing Manager	(617) 494-8100	
Cambridge, MA Volpe Center	Volpe National Transportation Systems Center Kendall Square Cambridge, MA 02142	Robert S. Ow Elisabeth Carpenter	(617) 494-2411 (617) 494-2126	
Baltimore, MD MTA	Mass Transit Administration 6 Saint Paul Street Baltimore, MD 21202	Ray Carroll David Hill Robert Spivery	(410) 767-3327	(410) 333-4810
Germantown, MD PS	Paratransit Software 21713 Brink Meadow Lane Germantown, MD 20874	Edward Neigut Owner	(301) 540-8878	
Rockville, MD County Exec Offc	Montgomery County County Executive Office Rockville, MD 20850	Gordon Aoyagi Sr Assistant Chief Admin. Officer	(301) 217-2533	
Rockville, MD MCDOT	Montgomery County DOT - Div of Transit Svcs 110 North Washington Street, #200 Rockville, MD 20850	Marc Atz Section Chief	(301) 217-2097	
Rockville, MD MCDOT	Montgomery County DOT - Div of Traffic Eng 101 Monroe Street, 11th Floor Rockville, MD 20850	Gene Donaldson Engineer & ITS Project Dev. Coord.	(301) 217-2190	(301) 217-2637
Ann Arbor, MI AATA	Ann Arbor Transportation Authority 2700 South Industrial Ann Arbor, MI 48104	William Hiller	(313) 973-6500	(313) 973-6338 Bill.Hiller@um.cc.umich.edu
Detroit, MI SMART	Suburban Mobility Auth. for Reg. Transport. 660 Woodward Avenue, Suite 950 Detroit, MI 48226-3515	Mac Lister Manager, Information Systems	(313) 223-2127	(313) 223-2390

Table A.1 List of Contacts (continued)

City, State Name	Address	Contact(s)	Phone #	FAX # E-Mail
Minneapolis, MN MnDOT	Minnesota DOT Traffic Management Center 110 4th Avenue, South Minneapolis, MN 55404	Glen Carlson Manager, Traffic Management Center	(612) 341-7500	(612) 341-7239
Minneapolis, MN MTC	Metropolitan Council Transit Operations 560 Sixth Avenue, North Minneapolis, MN 55411	Sam Jacobs Jerrold Olson Dennis Tollefsbol	(612) 349-7571 (612) 349-7400 (612) 349-7770	(612) 349-7675
St. Paul, MN Minnesota DOT	Mn DOT - Transport. Res. and Invest. Mgmt. Div. Ford Building, 2nd Floor - 117 University Avenue St. Paul, MN 55155	Marilyn Remer Director, Travlink	(612) 282-2469	(612) 296-6599
Kansas City, MO KCATA	Kansas City Area Transportation Authority 12 East 18th Street Kansas City, MO 64108	Dave Olsen Delores Brehm	(816) 346-0233 (816) 346-0238	(816) 346-0305
Raleigh, NC DOT	City of Raleigh Department of Transportation PO Box 590 Raleigh, NC 27602	Bob Olason	(919) 831-6785	(919) 831-6821 corcat@nando.net
Raleigh, NC ITRE	Institute for Transport. Research and Ed., UNC 1100 Navaho Drive Raleigh, NC 27609	Anna Nalevanko Program Director, Public Transportation	(919) 878-8080	(919) 878-8129
Raleigh, NC NC State U	Department of Civil Engineering NCSU Box 7908 Raleigh, NC 27695	John Stone	(919) 515-7732	stone@eos.ncsu.edu
Winston-Salem, NC WSTA	Winston-Salem Transit Authority PO Box 2511 Winston-Salem, NC 27102	Nedra Woodyatt	(910) 727-8131	
Jersey City, NJ TRANSCOM	TRANSCOM Newport Fin. Ctr., 111 Pavonia Ave., 6th Floor Jersey City, NJ 07310-1755	David Judd Bill Burke	(201) 963-4033	(201) 963-7488

Table A.1 List of Contacts (continued)

City, State Name	Address	Contact(s)	Phone #	FAX # E-Mail
Newark, NJ NJTA	New Jersey Transit Headquarters 1 Penn Plaza East Newark, NJ 07105-2246	Jim Kemp John Wilkins Armando Arrastia	(201) 491-7861 (201) 491-7797 (201) 491-7078	(201) 491-7837
Albuquerque, NM SunVan	City of Albuquerque - Transit & Parking Dep't 601 Yale, Southeast Albuquerque, NM 87106	Linda Dowling	(505) 764-6154	(505) 764-6146 ldowling@cabq.gov
Albuquerque, NM Sandia Nat'l Labs.	Sandia National Laboratories Department 9600 Albuquerque, NM 87185	David L. Caskey Philip D. Heermann	(505) 845-8425 (505) 844-1527	(505) 844-3322 (505) 844-5946
Albany, NY CDTA	Capital District Transportation Authority 110 Watervliet Avenue Albany, NY 12206	Carey Roessel	(518) 482-4199	(518) 482-9039
Buffalo, NY Metro	Niagra Frontier Transportation Authority 181 Ellicott Buffalo, NY 14205	Jim Nagle	(716) 842-3501	(716) 842-3540
Jamaica, NY LIRR	Long Island Rail Road Jamaica Station Jamaica, NY 11435	Ken Lettow Deputy Project Manager	(718) 558-7400	
Long Island, NY MTA LI Bus	MTA Long Island Bus 700 Commercial Avenue Garden City, NY 11530	Victor Simuoli Donald Cameron	(516) 542-0100	(516) 542-1428
New York, NY Baruch College	Baruch College New York, NY	Karen Luxton Gourgey Project Manager	(212) 802-2140	
New York, NY NYCT	New York City Transit 370 Jay Street Brooklyn, NY 11201-3878	Dave Weiss	(718) 243-7542	

Table A.1 List of Contacts (continued)

City, State Name	Address	Contact(s)	Phone #	FAX # E-Mail
New York, NY NYCT	New York City Transit 130 Livingston Street Brooklyn, NY 11201	Isaac Takyi Angeltia Hutchinson	(718) 694-3652 (718) 694-3652	(718) 488-6468
Rochester, NY R-GRTA	Rochester-Genesee Regional Transportation Auth. PO Box 90629 (1372 East Main Street) Rochester, NY 14609	Chip Walker Howard Gates	(716) 654-0247 (716) 654-0200	(716) 654-0293
Syracuse, NY CENTRO	Central NY Regional Transportation Authority 1 Centro Ctr.; 200 Cortland Avenue, PO Box 820 Syracuse, NY 13205	John Clare	(315) 442-3300	(315) 442-3337
White Plains, NY WCDOT	Westchester County Department of Transportation 112 East Post Road White Plains, NY 10601	Richard Stiller	(914) 285-5118	(914) 682-2987
Cincinnati, OH SORTA	Southwest Ohio Regional Transit Authority 4700 Paddock Road Cincinnati, OH 45229	Greg Lind	(513) 632-7571	(513) 242-3576
Columnbus, OH COTA	Central Ohio Transit Authority 1600 McKinley Avenue Columbus, OH 43222	Mike McCann Lynn Rathke	(614) 275-5838 (614) 275-5850	(614) 275-5933
Columbus, OH DAVE	DAVE Transportation Columbus, OH	Jeff Smith Project Manager	(614) 275-5850	
Grand River, OH Laketran	Laketran PO Box 158 Grand River, OH 44085-0158	Bill Hamilton	(216) 350-1000	(216) 354-4202
Corvallis, OR OSU	Transportation Research Institute-OSU 100 Merryfield Hall Corvallis, OR 97331-4304	Katharine Hunter- Zaworski	(503) 737-4982	(503) 737-3462 hunterk@ccmail.orst.edu

Table A.1 List of Contacts (continued)

City, State Name	Address	Contact(s)	Phone #	FAX # E-Mail
Eugene, OR Lane Co MTD	Lane County Mass Transit District PO Box 7070 Eugene, OR 97402	Mike Northup	(503) 741-6137	(503) 741-6111 mnorthup@ltd.lane.or.us
Portland, OR Tri-Met	Tri-County Metro. Transportation Dist. of Oregon 4012 Southeast 17th Avenue Portland, OR 97202	John Lutterman Ken Turner Martha Woodsworth	(503) 238-4922 (503) 238-4918 (503) 238-4961	(503) 239-3088 kturne01@reach.com
Folsom, PA CTDC	Community Transit of Delaware County PO Box 404 (901 Morton Avenue) Folsom, PA 19033-0404	Judy McGrane General Manager	(610) 532-2900	(610) 532-8638
Media, PA ABSI	Automated Business Solutions, Inc. 55 State Road Media, PA 19063	Stephen Pellegrini President	(610) 565-2800	(610) 565-5307
Philadelphia, PA SEPTA	Southeastern Pennsylvania Transport. Authority The Sovereign Building, 714 Market Street Philadelphia, PA 19106	Mike Marionosky MIS Specialist	(215) 580-7552	
Pittsburgh, PA PAT	Port Authority of Allegheny County 2235 Beaver Avenue Pittsburgh, PA 15233	Scott Baker Director, Transit Operations (acting)	(412) 237-7000	
Rochester, PA Beaver C'nty TA	Beaver County Transit Authority 200 West Washington Street Rochester, PA 15074-2235	Bruce Ahern General Manager	(412) 728-4255	(412) 728-8333
Scranton, PA COLTS	County of Lackawanna Transit System North South Road Scranton, PA 18504	Kurt Kempter	(717) 346-2061	(717) 343-3819
College Station, TX TTI	Texas Transportation Institute Texas A&M University College Station, TX	Shawn Turner	(409) 845-8829	(409) 845-6008 shawn-turner@tamu.edu

Table A.1 List of Contacts (continued)

City, State Name	Address	Contact(s)	Phone #	FAX # E-Mail
Corpus Christi, TX CCTS	Corpus Christi Transit System 1812 S Alameda Corpus Christi, TX 78404-2933	Len Brandrup	(512) 289-2712	(512) 289-0605
Dallas, TX DART	Dallas Area Rapid Transit 3021 Oak Lane/PO Box 660163 Dallas, TX 75266	Chris Patrick	(214) 928-6022	(214) 928-6353
El Paso, TX SunMetro	SunMetro 700A San Francisco El Paso, TX 79901	Terry Murphy	(915) 533-1220	(915) 534-5816
Houston, TX Metro	Metropolitan Transit Authority PO Box 61429 Houston, TX 77208-2429	Bill Kronenberger Sholeh Karimi	(713) 739-6013 (713) 613-0315	(713) 739-6824
Houston, TX TranStar	Houston TranStar 701 North Post Oak Houston, TX 77024	Doug Wiersig Executive Director	(713) 658-4314	(713) 658-4382
San Antonio, TX TransGuide	TransGuide 3500 NW Loop 410, PO Box 29928 San Antonio, TX 78284	Patrick McGowan Traffic Management Engineer	(210) 731-5247	
Norfolk, VA Tidewater RT	Tidewater Regional Transit PO Box 2096 Norfolk, VA 23501	Milt Woodhouse	(804) 640-6214	(804) 640-6304
Virginia Beach, VA TCI	Tidewater Consultants, Inc. 160 Newtown Road Virginia Beach, VA 23462	Jerome C. Barenti Senior Director	(804) 497-8951	
Woodbridge, VA PRTC	Potomac and Rappahannock Transport. Comm. 1549 Old Bridge Road, Suite 209 Woodbridge, VA 22192	Eric Marx	(703) 490-4811 x117	(703) 490-5254

Table A.1 List of Contacts (continued)

City, State Name	Address	Contact(s)	Phone #	FAX # E-Mail
Bremerton, WA Kitsap Transit	Kitsap Transit 234 South Wycoff Bremerton, WA 98312	Doug Johnson	(360) 478-6224	(360) 377-7086
Bremerton, WA PSI	Paratransit Systems International Inc. 4810 Auto Center Way Bremerton, WA 98312	Ginny Obert Marketing Manager	(800) 926-2345	
Seattle, WA Metro	King County Department of Metropolitan Services 821 Second Avenue (MS42) Seattle, WA 98104	Catherine Bradshaw	(206) 684-1770	(206) 684-2034 catherine.bradshaw@metrokc.gov
Seattle, WA Metro	King County Department of Metropolitan Services 821 Second Avenue (MS53) Seattle, WA 98104	Tom Friedman Dr. Peggy Willis	(206) 684-1513 (206) 684-1522	(206) 684-2059
Seattle, WA Metro	King County Department of Metropolitan Services 821 Second Avenue (MS55) Seattle, WA 98104	Paul Toliver General Manager	(206) 684-2100	
Seattle, WA Metro	King County Department of Metropolitan Services 821 Second Avenue (MS68) Seattle, WA 98104	Dan Overgaard	(206) 684-1415	(206) 684-1860 dan.overgaard@metrokc.gov
Seattle, WA Univ. Of WA	University of Washington Seattle, WA	Donald Loseff James Eastman	(206) 616-4078	 jeastman@u.washington.edu
Seattle, WA WSDOT	WA State DOT - WA State Transportation Center 1107 NE 45th Street, Suite 535 Seattle, WA 98105-4631	Larry Senn	(206) 543-6741	(206) 685-0767
Seattle, WA WSDOT	WA State DOT, Northwest Region Traffic Office PO Box 330310 Seattle, WA 98133-9710	Les Jacobson	(206) 440-4487	(206) 440-4804 ljacobso@wsdot.wa.gov

Table A.1 List of Contacts (continued)

City, State Name	Address	Contact(s)	Phone #	FAX # E-Mail
Spokane, WA Spokane TA	Spokane Transit Authority West 1230 Boone Avenue Spokane, WA 99201-2686	Teresa Stueckle Customer Relations Manager	(509) 325-6000	
Milwaukee, WI County DOPW	Milwaukee County Dep't of Public Works 907 North 10th Street Milwaukee, WI 53233	Ron Rutkowski	(414) 278-4888	(414) 223-1850
Milwaukee, WI County Transit Sys.	Milwaukee County Transit System 1942 North 17th Street Milwaukee, WI 53205	Tom Labs Greta Gneiser	(414) 937-3227 (414) 937-3284	(414) 344-0148
Sheboygen, WI Sheboygen Transit	Sheboygen Transit System 608 South Commerce Sheboygen, WI 53081	Ray Ann Brunette	(414) 459-3281	(414) 459-0231
Calgary, AB Calgary Transit	City of Calgary Transportation Department PO Box 2100, Station M Calgary, AB T2P 2M5 CANADA	Neil McKendrick	(403) 277-9727	(403) 230-1155 tpctnm@gov.calgary.ab.ca
Winnipeg, MB City Transit System	City of Winnipeg Transit System 421 Osborne Street Winnipeg, MB R3L 2A2 CANADA	Bill Menzies	(204) 986-5737	(204) 986-6863
Halifax, NS MTD	Metro. Transit Division of Metropolitan Authority 200 Ilsley Avenue Dartmouth, Nova Scotia B3B 1V1 CANADA	Moss Mombourquette	(902) 421-2647	(902) 421-8072
Hamilton, ON HSRC	Hamilton Street Railway Company 330 Wentworth Street, North Hamilton, Ontario L8L 5W2 CANADA	Gord Heidman Bob Krbavak	(905) 528-4200 (905) 528-4200 x418	(905) 528-5410
London, ON LTC	London Transit Commision 450 Highbury Road London, Ontario N5W 5L2	Bill Brock Dir., Transportation Operations Manager	(519) 451-1340 x316	(519) 451-4411

Table A.1 List of Contacts (continued)

City, State Name	Address	Contact(s)	Phone #	FAX # E-Mail
Mississauga, ON Trapeze	Trapeze Software Inc. 2800 Skymark Ave., Building 1, Unit 33 Mississauga, Ontario L4W 5A6 CANADA	Fran Fendelet Marketing Manager	(905) 629-8727	(905) 238-8408
Ottawa, ON OC Transpo	Ottawa-Carleton Transport 1500 Saint Laurent Boulevard Ottawa, Ontario K1G 0Z8 CANADA	Peter van der Kloot Helen Gault	(613) 741-6440	(613) 230-6543
Toronto, ON CUTA	Canadian Urban Transit Association 55 York Street, Suite 901 Toronto, Ontario M5J 1R7 CANADA	Brendon Hemily Mgr of Research and Technical Services	(416) 365-9800	(416) 365-1295
Toronto, ON Teleride Sage	Teleride Sage Ltd. 156 Front Street West, 5th Floor Toronto, Ontario M5J 2L6 CANADA	Andrew Hay Director of Sales and Marketing	(416) 596-1940	(416) 595-5653
Toronto, ON TTC	Toronto Transit Commission Operations Engineering Branch 1138 Bathurst St Toronto, Ontario M5R 3H2 CANADA	Chris Seewald	(416) 393-4404	(416) 535-4524
Toronto, ON TTC	Toronto Transit Commission Service Delivery Branch 1138 Bathurst Street Toronto, Ontario M5R 3H2 CANADA	Sharon Bone Adelgard von Zittwitz	(416) 393-2151	(416) 534-8957
Hull, QC STO	Societe de Transport L'Outaouais 111 Jean-Proulx Hull, Quebec J8Z 1T4	Sallah Barj	(819) 770-7900	(819) 770-5987
Montreal, QC GIRO	GIRO 75, rue de Port-Royal est, bureau 500 Montréal, Québec H3L 3T1 CANADA	Nigel Hamer	(514) 383-0404	(514) 383-4971
Montreal, QC MUCTC	Montreal Urban Community Transit Commission PO Box 2000, Bureau E3000 Montreal, Quebec H5A 1J6 CANADA	Serge Belanger	(514) 280-5829	(514) 280-5888

Table A.1 List of Contacts (continued)

City, State Name	Address	Contact(s)	Phone #	FAX # E-Mail
Montreal, QC MUCTC	Montreal Urban Community Transit Commission PO Box 2000, Bureau E1200 Montreal, Quebec H5A 1J6 CANADA	Martine Lavoir	(514) 280-5373	(514) 280-5333
Valencia, SPAIN LISITT	LISITT, Universidad de Valencia C/Hugo de Moncada 4-Entr. 46010 Valencia, SPAIN	Julie Dassiu	+34 6 360 4484	+34 6 361 6198 julie@glup.eleinf.uv.es

Table A.2 Contacts - Alphabetical Person Index

Organization	Contact(s)	Phone #
Beaver County Transit Authority Rochester, PA	Bruce Ahern General Manager	(412) 728-4255
Montgomery County Rockville, MD	Gordon Aoyagi Sr Assistant Chief Admin. Officer	(301) 217-2533
New Jersey Transit Headquarters Newark, NJ	Armando Arrastia	(201) 491-7078
Montgomery County DOT - Div of Transit Svcs Rockville, MD	Marc Atz Section Chief	(301) 217-2097
Chicago Transit Authority Chicago, IL	Ron Baker	(312) 664-7200 x4105
Port Authority of Allegheny County Pittsburgh, PA	Scott Baker Director, Transit Ops (acting)	(412) 237-7000
Tidewater Consultants, Inc. Virginia Beach, VA	Jerome C. Barenti Senior Director	(804) 497-8951
Societe de Transport L'Outaouais Hull, QC CANADA	Sallah Barj	(819) 770-7900
Montreal Urban Community Transit Commission Montreal, QC CANADA	Serge Belanger	(514) 280-5829
Pace Suburban Bus Arlington Heights, IL	Mike Bohm	(708) 364-7223
Toronto Transit Commission Toronto, ON CANADA	Sharon Bone	(416) 393-2151
King County Department of Metropolitan Services Seattle, WA	Catherine Bradshaw	(206) 684-1770
Corpus Christi Transit System Corpus Christi, TX	Len Brandrup	(512) 289-2712
Kansas City Area Transportation Authority Kansas City, MO	Delores Brehm	(816) 346-0238
London Transit Commision London, ON CANADA	Bill Brock Transportation Ops Manager	(519) 451-1340 x316
Sheboygen Transit System Sheboygen, WI	Ray Ann Brunette	(414) 459-3281
TRANSCOM Jersey City, NJ	Bill Burke	(201) 963-4033
Riverside Transit Agency Riverside, CA	Anne Burnburg Customer Service Manager	(619) 343-3456 x162
MTA Long Island Bus Garden City, NY	Donald Cameron	(516) 542-0100

Table A.2 Contacts - Alphabetical Person Index (continued)

Organization	Contact(s)	Phone #
Minnesota DOT Traffic Management Center Minneapolis, MN	Glen Carlson Manager, Traffic Management Ctr	(612) 341-7500
Volpe National Transportation Systems Center Cambridge, MA	Elisabeth Carpenter	(617) 494-2126
Mass Transit Administration Baltimore, MD	Ray Carroll	(410) 767-3327
Sandia National Laboratories Albuquerque, NM	David L. Caskey	(505) 845-8425
Metro-Dade Transit Authority Miami, FL	Hugh Chen	(305) 637-3727
Illinois DOT - Traffic Systems Center Oak Park, IL	Tony Cioffi Operations Chief	(708) 524-2145
Massachusetts Bay Transportation Authority Boston, MA	Robert Clark Program Manager	(617) 722-3493
Broward County Mass Transit Pompano Beach, FL	Bruce Coleman	(305) 357-8379
LISITT, Universidad de Valencia Valencia, SPAIN	Julie Dassiu	+34 6 360 4484
Metro Dynamics Palo Alto, CA	Ivan Deirossi Project Manager	(415) 325-4949
Orange County Transportation Authority Orange, CA	Dean Delgado Senior Transportation Analyst	(714) 560-5744
City of Phoenix Public Transit Department Phoenix, AZ	Jeff Dolphini	(602) 262-7242
Montgomery County DOT - Div of Traffic Eng Rockville, MD 20850	Gene Donaldson Eng & ITS Project Dev. Coord.	(301) 217-2190
Multisystems Cambridge, MA	Kurt Dossin	(617) 864-5810
City of Albuquerque - Transit & Parking Dep't Albuquerque, NM	Linda Dowling	(505) 764-6154
On-Line Data Products, Inc. Scottsdale, AZ	Robert Dukes	(602) 483-3822
University of Washington Seattle, WA	James Eastman	(206) 616-4078
Trapeze Software Inc. Mississauga, ON CANADA	Fran Fendelet Marketing Manager	(905) 629-8727
King County Department of Metropolitan Services Seattle, WA	Tom Friedman	(206) 684-1513

Table A.2 Contacts - Alphabetical Person Index (continued)

Organization	Contact(s)	Phone #
Bay Area Rapid Transit District Oakland, CA	James Gallagher Director of Operations	(510) 464-6000
OUTREACH San Jose, CA	Roberta Gardella Chief Executive Officer	(408) 436-2865
Alameda-Contra Costa Transit Oakland, CA	Bob Garside	(510) 891-4854
Rochester-Genesee Regional Transportation Auth. Rochester, NY	Howard Gates	(716) 654-0200
Georgia Tech Research Institute Atlanta, GA	Gary Gimmestead	(404) 894-3419
School of Urban & Regional Planning, USC Los Angeles, CA	Genevieve Giuliano	(213) 740-3956
Milwaukee County Transit System Milwaukee, WI	Greta Gneiser	(414) 937-3284
Radar & Instr. Dev. Lab. - Georgia Tech Atlanta, GA	Eugene Greneker	(404) 528-7744
Regional Transportation District Denver, CO	Lou Ha	(303) 299-6265
TheBUS Honolulu, HI	William Haig Customer Service Manager	(808) 848-4440
GIRO Montréal, QC CANADA	Nigel Hamer	(514) 383-0404
Laketran Grand River, OH	Bill Hamilton	(216) 350-1000
Teleride Sage Ltd. Toronto, ON CANADA	Andrew Hay Director of Sales and Marketing	(416) 596-1940
Sandia National Laboratories Albuquerque, NM	Philip D. Heermann	(505) 844-1527
Hamilton Street Railway Company Hamilton, ON CANADA	Gord Heidman	(905) 528-4200
Canadian Urban Transit Association Toronto, ON CANADA	Brendon Hemily Mgr of Research and Tech Svcs	(416) 365-9800
California Path - UC, Berkeley Richmond, CA	Mark Hickman	(510) 231-5644
Mass Transit Administration Baltimore, MD	David Hill	(410) 767-3327
Ann Arbor Transportation Authority Ann Arbor, MI	William Hiller	(313) 973-6500

Table A.2 Contacts - Alphabetical Person Index (continued)

Organization	Contact(s)	Phone #
Transportation Research Institute-OSU Corvallis, OR	Katharine Hunter-Zaworski	(503) 737-4982
New York City Transit Brooklyn, NY	Angeltia Hutchinson	(718) 694-3652
Metropolitan Council Transit Operations Minneapolis, MN	Sam Jacobs	(612) 349-7571
WA State DOT, Northwest Region Traffic Office Seattle, WA 98133-9710	Les Jacobson	(206) 440-4487
Sioux City Transit System Sioux City, IA	Dan Jensen	(712) 279-6405
Kitsap Transit Bremerton, WA	Doug Johnson	(360) 478-6224
TRANSCOM Jersey City, NJ	David Judd	(201) 963-4033
Metropolitan Transit Authority Houston, TX	Sholeh Karimi	(713) 613-0315
New Jersey Transit Headquarters Newark, NJ	Jim Kemp	(201) 491-7861
County of Lackawanna Transit System Scranton, PA	Kurt Kempter	(717) 346-2061
San Diego Transit Corporation San Diego, CA	Betty Knutson Senior Information Specialist	(619) 238-0100 x469
L.D. King, Inc. Ontario, CA	Jill Kollmann	(909) 988-5492
Institute of Transportation Studies - Univ. of CA Davis, CA	Raghu Kowshik	(916) 752-2029
Hamilton Street Railway Company Hamilton, ON CANADA	Bob Krbavak	(905) 528-4200 x418
Metropolitan Transit Authority Houston, TX	Bill Kronenberger	(713) 739-6013
Milwaukee County Transit System Milwaukee, WI	Tom Labs	(414) 937-3227
SYSTAN, Inc. Los Altos, CA	Roy Lave	(415) 941-3311
Montreal Urban Community Transit Commission Montreal, QC CANADA	Martine Lavoir	(514) 280-5373
Los Angeles County Metropolitan Transit Auth. Los Angeles, CA	Ron Ledford	(213) 972-4645

Table A.2 Contacts - Alphabetical Person Index (continued)

Organization	Contact(s)	Phone #
Long Island Rail Road Jamaica, NY	Ken Lettow Deputy Project Manager	(718) 558-7400
Southwest Ohio Regional Transit Authority Cincinnati, OH	Greg Lind	(513) 632-7571
Suburban Mobility Auth. for Reg. Transport. Detroit, MI	Mac Lister Manager, Information Systems	(313) 223-2127
University of Washington Seattle, WA	Donald Loseff	(206) 616-4078
Sacramento Council of Governments Sacramento, CA	Velma Lucero	(916) 323-8304
Tri-County Metro. Transportation Dist. of Oregon Portland, OR 97202	John Lutterman	(503) 238-4922
Southeastern Pennsylvania Transport. Authority Philadelphia, PA	Mike Marionosky MIS Specialist	(215) 580-7552
Metropolitan Transportation Commission Oakland, CA	Joel Markowitz Manager, Advanced Sys. Apps.	(510) 464-7760
Potomac and Rappahannock Transport. Comm. Woodbridge, VA	Eric Marx	(703) 490-4811 x117
Maxwell Laboratories, S-CUBED Dvivision La Jolla, CA	Dr. Joseph Masso	(619) 587-7226
Central Ohio Transit Authority Columbus, OH	Mike McCann	(614) 275-5838
TransGuide San Antonio, TX	Patrick McGowan Traffic Management Engineer	(210) 731-5247
Community Transit of Delaware County Folsom, PA	Judy McGrane General Manager	(610) 532-2900
City of Calgary Transportation Department Calgary, AB CANADA	Neil McKendrick	(403) 277-9727
City of Winnipeg Transit System Winnipeg, MB CANADA	Bill Menzies	(204) 986-5737
City Department of Transportation Tuscon, AZ	Jill Merrick	(520) 791-4371
SmartRoute Systems Cambridge, MA	Katy Miller Marketing Manager	(617) 494-8100
Metro. Transit Division of Metropolitan Authority Dartmouth, NS CANADA	Moss Mombourquette	(902) 421-2647
Regional Transit Authority New Orleans, LA	Valarie Moton	(504) 243-3723

Table A.2 Contacts - Alphabetical Person Index (continued)

Organization	Contact(s)	Phone #
SunMetro El Paso, TX	Terry Murphy	(915) 533-1220
Crain and Associates Menlo Park, CA	Gail Murray	(415) 323-3444
Niagra Frontier Transportation Authority Buffalo, NY	Jim Nagle	(716) 842-3501
Institute for Transport. Research and Ed., UNC Raleigh, NC	Anna Nalevanko Program Dir, Public Transport	(919) 878-8080
Paratransit Software Germantown, MD	Edward Neigut Owner	(301) 540-8878
Transportation Research Board Washington, DC	Stephanie Nellons-Robinson Sen. Program Officer	(202) 334-3502
Lane County Mass Transit District Eugene, OR	Mike Northup	(503) 741-6137
Paratransit Systems International Inc. Bremerton, WA	Ginny Obert Marketing Manager	(800) 926-2345
City of Raleigh Department of Transportation Raleigh, NC	Bob Olason	(919) 831-6785
Kansas City Area Transportation Authority Kansas City, MO	Dave Olsen	(816) 346-0233
Metropolitan Council Transit Operations Minneapolis, MN	Jerrold Olson	(612) 349-7400
San Francisco Municipal Railway San Francisco, CA	Len Olson	(415) 759-4360
King County Department of Metropolitan Services Seattle, WA	Dan Overgaard	(206) 684-1415
Volpe National Transportation Systems Center Cambridge, MA	Robert S. Ow	(617) 494-2411
Anaheim Traffic Management Center Anaheim, CA	James Paral Principal Traffic Engineer	(714) 254-5183
Dallas Area Rapid Transit Dallas, TX	Chris Patrick	(214) 928-6022
Automated Business Solutions, Inc. Media, PA	Stephen Pellegrini President	(610) 565-2800
Chicago Transit Authority Chicago, IL	David Phillips	(312) 664-7200 x307
Pace Suburban Bus Arlington Heights, IL	John Pikhay	(708) 228-2401

Table A.2 Contacts - Alphabetical Person Index (continued)

Organization	Contact(s)	Phone #
Tradewinds Rehabilitation Center, Inc. Gary, IN	Lisa Premil	(219) 949-4000
San Jaoquin Regional Tranait District Stockton, CA	Kal Raouda	(209) 948-5566
California Alliance for Advanced Transport. Sys. Sacramento, CA	Robert Ratcliff	(916) 654-8367
Central Ohio Transit Authority Columbus, OH	Lynn Rathke	(614) 275-5850
Mn DOT - Transport Res. and Invest. Mgmt. Div. St. Paul, MN	Marilyn Remer Director, Travlink Project	(612) 282-2469
Metropolitan Atlanta Rapid Transit Authority Atlanta, GA	Harriet Robbins-Smith	(404) 848-4224
Hillsboro Area Regional Transit Authority Tampa, FL	Steve Roberts	(813) 623-5835
Easy Lift Solutions Santa Barbara, CA	Tom Roberts	(805) 568-5179
Capital District Transportation Authority Albany, NY	Carey Roessel	(518) 482-4199
The Vine-City of Napa Napa, CA	Celinda Romaine-Dahlgren	(707) 257-9520
Milwaukee County Dep't of Public Works Milwaukee, WI 53233	Ron Rutkowski	(414) 278-4888
Toronto Transit Commission Toronto, ON CANADA	Chris Seewald	(416) 393-4404
WA State DOT - WA State Transportation Center Seattle, WA 98105-4631	Larry Senn	(206) 543-6741
Santa Monica Municipal Bus Lines Santa Monica, CA	Janet Shelton	(310) 451-5444
City of Ontario Ontario, CA	Kim Shultz Transportation Projects Manager	(909) 391-2510
MTA Long Island Bus Garden City, NY	Victor Simuoli	(516) 542-0100
DAVE Transportation Columbus, OH	Jeff Smith Project Manager	(614) 275-5850
Mass Transit Administration Baltimore, MD	Robert Spivery	(410) 767-3327
Georgia DOT Atlanta, GA	Lawson Stapleton Asst State Traffic Ops Engineer	(404) 656-5423

Table A.2 Contacts - Alphabetical Person Index (continued)

Organization	Contact(s)	Phone #
Westchester County Department of Transportation White Plains, NY	Richard Stiller	(914) 285-5118
Department of Civil Engineering - NCSU Raleigh, NC	John Stone	(919) 515-7732
Spokane Transit Authority Spokane, WA 99201-2686	Teresa Stueckle Customer Relations Manager	(509) 325-6000
New York City Transit Brooklyn, NY	Isaac Takyi	(718) 694-3652
Arc Transit Palatka, FL	Boyd Thompson	(904) 325-9999
King County Department of Metropolitan Services Seattle, WA	Paul Toliver General Manager	(206) 684-2100
Metropolitan Council Transit Operations Minneapolis, MN	Dennis Tollefsbol	(612) 349-7770
Tri-County Metro. Transportation Dist. of Oregon Portland, OR 97202	Ken Turner	(503) 238-4918
Texas Transportation Institute - Texas A&M U College Station, TX	Shawn Turner	(409) 845-8829
Ottawa-Carleton Transport Ottawa, ON CANADA	Peter van der Kloot Helen Gault	(613) 741-6440
Innovative Software Designers Tampa, FL	Scott Vanover	(800) 881-0088
Toronto Transit Commission Toronto, ON CANADA	Adelgard von Zittwitz	(416) 393-2151
Rochester-Genesee Regional Transportation Auth. Rochester, NY	Chip Walker	(716) 654-0247
New York City Transit Brooklyn, NY	Dave Weiss	(718) 243-7542
Houston TranStar Houston, TX	Doug Wiersig Executive Director	(713) 658-4314
New Jersey Transit Headquarters Newark, NJ	John Wilkins	(201) 491-7797
San Francisco Municipal Railway San Francisco, CA	Annette Williams Accessible Services Program Mgr	(415) 923-6142
King County Department of Metropolitan Services Seattle, WA	Dr. Peggy Willis	(206) 684-1522
Transit Authority of River City Louisville, KY	John Woodford	(502) 561-5104

Table A.2 Contacts - Alphabetical Person Index (continued)

Organization	Contact(s)	Phone #
Tidewater Regional Transit Norfolk, VA	Milt Woodhouse	(804) 640-6214
Tri-County Metro. Transportation Dist. of Oregon Portland, OR 97202	Martha Woodsworth	(503) 238-4961
Winston-Salem Transit Authority Winston-Salem, NC	Nedra Woodyatt	(910) 727-8131

TABLE A.3 Paratransit Contacts and Their Suppliers

User	Contact	Phone #	Automated System/Vendor
Municipality of Anchorage Anchorage, AK	Mike Guinn	907-343-4778	PASS™
Care A Van Juneau, AK	Eric Harrison	907-586-4482	Dispatch Manager
Metro Area Express Birmingham, AL	Shirley Glasscock	205-322-7701	DISPATCH-A-RIDE
Mobile Association for the Blind Mobile, AL	Jim Bullock	205-470-8645	Dispatch Manager
Hot Springs Intra-City Transit Hot Springs N. Park, AR	Monya Mettitt	501-321-2021	Dispatch Manager
Glendale Dial-a-Ride Glendale, AZ	Cathy White	602-930-3501	PASS™
E. Contra Costa Transit Auth. (Tri-Delta Transit) Antioch, CA	Anne Muzzini	510-754-6622	PASS™
Kern Regional Transit Bakersfield, CA	Dan Chianello	805-637-2390	DISPATCH-A-RIDE
Golden Empire Transit Bakersfield, CA	Chester Moland	805-324-9874	PASS™
Clovis Roundup Transit Clovis, CA	Lynn Bawdon	209-297-2483	Dispatch Manager
City of Fresno Fresno, CA	Mike Bonner	209-498-4023	PASS™
Sun-Dial Sunline Transit Agency Indio, CA	Terry Rogers	619-342-1882	PASS™
Livermore Amador Valley Transit Authority Livermore, CA	Mike Tanner	510-455-7563	PASS™
Los Angeles County - Access Los Angeles, CA	Shelly Lyons	213-623-8170	PASS™
Orange County Transportation Authority Orange, CA	Mark Maloney	714-560-6282	TRAPEZE™-QV

TABLE A.3 Paratransit Contacts and Their Suppliers (continued)

User	Contact	Phone #	Automated System/Vendor
Western Contra Costa Pinole, CA	Charley Anderson	510-724-3331	PASS™
Meditrans Riverside, CA	Judy Greis	909-682-1162	Dispatch Manager
Riverside Transit Agency Riverside, CA	Jay Peterson	909-684-0850	MIDAS
Paratransit, Inc. Sacramento, CA	Linda Campbell	916-454-4191	PASS™
San Mateo County Transit San Carlos, CA	Michael Kopaczewski	415-508-6340	PASS™
American Red Cross Coordinated Transportation Services San Diego, CA	John Pritting	619-291-2620	PASS™
Outreach San Jose, CA	Katie Heatley	408-436-2865	TRAPEZE™-QV
Easy Lift Transportation Santa Barbara, CA	Tom Roberts	805-568-5179	Easy Lift™ Scheduling Solution
City of Santa Maria Santa Maria, CA	Betty Fisher		Easy Lift™ Scheduling Solution
Sonoma County Transit Santa Rosa, CA	Bryan Albee	707-585-7516	PASS™
San Joaquin Regional Transit District Stockton, CA	Rex Clark	209-948-0624	PASS™
TMSI North Charleston, SC	Laurence Thomas	803-744-9732	DISPATCH-A-RIDE
DAVE Transportation Union City, CA	F. Scott Jewell	510-471-1415	DISPATCH-A-RIDE
County Connection Walnut Creek, CA	Rick Ramacier	510-676-1976	PASS™
Dave Transportation Services (RTD/Denver) Denver, CO	Robert Wilson	303-321-1844	TRAPEZE™-QV

TABLE A.3 Paratransit Contacts and Their Suppliers (continued)

User	Contact	Phone #	Automated System/Vendor
Community Wheels Wheat Ridge, CO	Hank Braaksma	303-235-6970	DISPATCH-A-RIDE
HART-Danbury Danbury, CT	Lou May	203-774-4070	TRAPEZE™-QV
Transportation Association of Greenwich Greenwich, CT	Pam Schaffner	203-869-8882	DISPATCH-A-RIDE
Greater New Haven Transit District Hamden, CT	Donna Carter	203-288-6282	TRAPEZE™-QV
U.C.P. Transportation Hartford, CT	Peter Siskin	203-236-6201	Dispatch Manager
Norwalk Transit District Norwalk, CT	Nancy Carroll	203-853-3338	DISPATCH-A-RIDE
Trans-Hernando Brooksville, FL	Richard Cook	904-799-1510	Dispatch Manager
Sumter County Transit Bushell, FL	Jim Sparks	904-568-6678	Dispatch Manager
Space Coast Area Transit Cocoa, FL	Don Lusk	407-635-7815	PASS™
Accent Mide-Van Gainsville, FL	Herry Hilson	904-335-4171	Dispatch Manager
Coordinated Transportation Gainsville, FL	Marion Mark	904-334-1604	Dispatch Manager
Monroe County Key West, FL	Dave Owens	305-294-4641	Dispatch Manager
AAA STS Miami, FL	Ron Thorp	305-633-6090	Dispatch Manager
Flager County Transit Palm Coast, FL	Bob Parson	904-437-7277	Dispatch Manager
Suncoast Center Independent Sarasota, FL	Bill Knight	813-351-9545	Dispatch Manager

TABLE A.3 Paratransit Contacts and Their Suppliers (continued)

User	Contact	Phone #	Automated System/Vendor
Yellow Cab of Tampa Tampa, FL	Louie Minardi	813-253-8871	Dispatch Manager
Ambulette West Palm, FL	Charlie Frederick	407-790-6301	Dispatch Manager
Palm Beach County West Palm Beach, FL	Angela Morlok	407-684-4170	PASS™
University of Georgia Athens, GA	Ron Hamlin	706-369-6220	Dispatch Manager
Metropolitan Atlanta Rapid Transit Authority Atlanta, GA	Darice Gamble	404-848-5392	TRAPEZE™-QV
Maui Economic Opportunity, Inc. Kahului, HI	Don Medeiros	808-877-7651	DISPATCH-A-RIDE
Municipal Transit Administration Clinton, IA	Cheryl Williams	319-263-8152	Dispatch Manager
Des Moines Metropolitan Transit Authority Des Moines, IA	Tom Blair	515-283-8111	CADMOS Pro+
Muscabus Muscatine, IA	Kathy Meier	319-263-8152	Dispatch Manager
Black Hawk County Transit Authority Waterloo, IA	Walt Stephenson	319-234-5714	PASS™
Ace Cab (Shared-ride and Dial-a-Ride) Indiana	Mike Personnette	219-295-6886	CADMOS Pro+
Idaho Transportation Various locations throughout ID	Burt Bates	208-334-8146	Dispatch Manager
Bloomington Public Transportation Corp. Bloomington, IN	Dave Gionet	812-332-5688	DISPATCH-A-RIDE
Madison County Transit Granite City, IL	Todd Plesko	618-797-0660	TRAPEZE™-QV
City of Henderson Henderson, KY	Pam Stone	502-831-1249	Dispatch Manager

TABLE A.3 Paratransit Contacts and Their Suppliers (continued)

User	Contact	Phone #	Automated System/Vendor
Jefferson Parish Metairie, LA	Karleen Smith	504-836-6166	PASS™
Dave Systems/MBTA Boston, MA			GIRO/ACCES
MVRTA Specialized Services Bradford, MA	Kathie Hanson	508-521-2688	DISPATCH-A-RIDE
Kiessling School Transportation, Inc. Braintree, MA	Paula Kiessling	617-471-7433	DISPATCH-A-RIDE
Brockton Area Transit Brockton, MA	Lisa Marognano	508-584-5530	TRAPEZE™-QV
DAVE Transportation Services Cambridge, MA	David Naiditch	617-491-0941	MIDAS
Thompson Transit Framingham, MA	Joanne Thompson	508-626-9405	DISPATCH-A-RIDE
GMTA Greenfield, MA	Thomas Chilik	413-774-5195	Dispatch Manager
Share-A-Ride Lexington, MA	Steve Skiffington	617-862-8313	PtMS
Lowell Regional Transit Authority Lowell, MA	Tim Goddard	508-454-8021	DISPATCH-A-RIDE
Greater Lynn Senior Services, Inc. Lynn, MA	Dennis Erickson	617-599-0110	DISPATCH-A-RIDE
Transit Service Inc. New Bedford, MA	Walter Callahan	508-992-3814	Dispatch Manager
Southeastern Regional Transit Authority New Bedford, MA	David Peixoto	508-997-5211	DISPATCH-A-RIDE
Pioneer Valley Transit Authority Springfield, MA	Pam Wells	413-732-6248	DISPATCH-A-RIDE
Veterans Transportation Services Waltham, MA	JoAnn Zebal	617-899-7433	DISPATCH-A-RIDE

TABLE A.3 Paratransit Contacts and Their Suppliers (continued)

User	Contact	Phone #	Automated System/Vendor
Mass Transit Administration Baltimore, MD	Bill Newby	410-333-3623	PASS™
URTA Columbia, MD	Janet McGlynn	410-997-7588	PtMS
Germantown Taxi Germantown, MD	Mike Salmany	301-990-7000	CADMOS Pro+
Ann Arbor Transportation Authority Ann Arbor, MI	Bill Hiller	313-677-3944	TRAPEZE™-QV
Suburban Mobility for Regional Transportation Detroit, MI	Mac Lister	313-223-2137	TRAPEZE™-QV
Mass Transportation Authority Flint, MI	Sylvia Machray	810-767-6950	TRAPEZE™-QV
Kids Kab Troy, MI	Gene O'Neill	810-362-8280	TRAPEZE™-QV
Ogenaw Public Transit West Branch, MI	Shirley Buck	513-345-5790	Dispatch Manager
Anoka County Transit Anoka, MN	Tim Kirchoff	612-422-7088	PASS™
Southwest Metro Eden Prairie, MN	Tom Juhnke	612-934-7928	PASS™
Rock County Heartland Luverne, MN	Debbie Fick	507-283-2343	Dispatch Manager
Metro Mobility Minneapolis/St. Paul, MN	Mark Fuhrmann	612-221-1932	PASS™
Minnesota DOT - DARTS West St. Paul, MN	Mark Hoisser	612-455-1560	TRAPEZE™-QV
Bi-State Development Agency St. Louis, MO	Janis Shetley	314-982-1400	PASS™
Alamance County Transportation System Burlington, NC	Charlie DeHart	919-222-0565	DISPATCH-A-RIDE

TABLE A.3 Paratransit Contacts and Their Suppliers (continued)

User	Contact	Phone #	Automated System/Vendor
City of Charlotte Charlotte, NC	Bobbi MacDonald	704-336-5099	PASS™
BARTS Elizabethtown, NC	Cindy Allen	910-862-6930	Dispatch Manager
Winston-Salem Transit Authority Winston-Salem, NC	Nedra Woodyatt	910-727-8131	PASS™
MOBY/Omaha Metro Area Transit Omaha, NE	Rick Van Doren	402-341-7560	DISPATCH-A-RIDE
SCUCS Mt. Ephraim, NJ	Dale Keith	609-456-1121	PtMS
Regional Transportation Commission Clark County, NV	Dean Greenwood	702-455-5774	PASS™
Citilift Reno, NV	Lee Rogers	702-348-0400	PASS™
Westchester County Department of Transportation White Plains, NY	Mary Helmsworth-Hamby	914-285-5149	MIDAS
United Disability Services Akron, OH	Howard Taylor	216-762-9755	DISPATCH-A-RIDE
Greater Cleveland Regional Transit Authority Cleveland, OH	John Boberek	216-566-5195	MIDAS
Laketran Grand River, OH	David Raymond	216-350-1024	PASS™
PARTA Kent, OH	Clark Hart	216-678-1287	PASS™
Sidney Dial-a-Ride Sidney, OH	Jerry Alexander	513-498-8117	Dispatch Manager
Toledo Area Transit Authority Toledo, OH	Sharon Dart-Roughton	419-245-5232	TRAPEZE™-QV
Western Reserve Transit Authority Youngstown, OH	Marianne Vaughn	216-744-8431	PASS™

TABLE A.3 Paratransit Contacts and Their Suppliers (continued)

User	Contact	Phone #	Automated System/Vendor
White-Line Tulsa, OK	Kenny White	918-582-4111	PASS™
Tri-County Metro. Transport. Dist. of Oregon Portland, OR	Dave Hefflin	503-233-5707	PASS™
Berks Area Reading Transportation Authority Reading, PA	Richard Roebuck	610-921-0601	MIDAS
Metropolitan Bus Authority Rio Piedras, PR	Edgar Figueroa	809-766-0867	DISPATCH-A-RIDE
Aiken Area Council Aikens, SC	George Alexander	803-648-5447	Dispatch Manager
TMSI Beaufort, SC	Audlyn Williams	803-525-6273	DISPATCH-A-RIDE
Senior Services Chester Co. Chester, SC	Belinda Jolley	803-385-3838	Dispatch Manager
DART Columbia, SC	Mitzi Teel	803-771-0315	PASS™
TMSI Orangeburg, SC	Delores McLeod	803-531-1859	DISPATCH-A-RIDE
TMSI Walterboro, SC	Melville Padgett	803-549-1863	DISPATCH-A-RIDE
Sioux Falls Paratransit Sioux Falls, SD	David Braun	605-339-7183	DISPATCH-A-RIDE
K-TRANS Knoxville, TN	Paulette Lay	615-546-3752	DISPATCH-A-RIDE
Hancock County Transportation Sneedville, TN	Betty Kay Fugate	615-733-4341	Dispatch Manager
Amarillo City Transit Amarillo, TX	Connie Swafford	806-378-3094	PASS™
Capital Metropolitan Transportation Authority Austin, TX	Jan Johnson	512-389-7400	PASS™

TABLE A.3 Paratransit Contacts and Their Suppliers (continued)

User	Contact	Phone #	Automated System/Vendor
CARTS Austin, TX		512-478-7433	PASS™
Dallas Area Rapid Transit Dallas, TX	Donnie Thompson	214-828-6628	MIDAS
Dallas Area Rapid Transit Dallas, TX			GIRO/ACCES
Sun Metro Lift El Paso, TX	James Peterson	915-533-1220	TRAPEZE™-QV
Gulf Coast Center Galveston, TX	James Shotwell	409-945-0820	PASS™
Metropolitan Transit Authority Houston, TX	Jim Laughlin	713-739-4986	PASS™
VIA Metropolitan Transit San Antonio, TX	Leonard Zych	210-227-5371	TRAPEZE™-QV
Utah Transit Authority Salt Lake City, UT	Claire Fiet	801-262-5626	PASS™
Mountain Empire Older Citizens Big Stone Gap, VA	Michael Henson	703-523-4208	PtMS
STAR Richmond, VA	Charles Long	804-353-7827	DISPATCH-A-RIDE
American Contracting Management Virginia	Jim McCleary	703-960-2264	CADMOS Pro+
Kitsap Transit Bremerton, WA	Ellen Gustafson	206-478-6223	PASS™
Island Transit Coupeville, WA	Martha Rose	206-678-3949	DISPATCH-A-RIDE
Community Transit - Snohomish Everett, WA	Bob Brown	206-348-2365	PASS™
Intercity Transit Olympia, WA	Glenn Chipman	206-786-8585	PASS™

TABLE A.3 Paratransit Contacts and Their Suppliers (continued)

User	Contact	Phone #	Automated System/Vendor
King County Department of Metropolitan Services Seattle, WA	Janie Elliott	206-689-3115	PASS™
3A/EDJ Transit Seattle, WA	John Eichelberger	206-723-9760	Dispatch Manager
Pierce Transit Tacoma, WA	Tom Young	206-581-8080	PASS™
Centra Clarksburg, WV	Robert Boylan	304-623-6002	Dispatch Manager
City of Cheyenne, Transit Department Cheyenne, WY	Michelle Johnson	307-637-6299	DISPATCH-A-RIDE
Calgary Handi-Bus Calgary, Alberta CANADA	Gary Clark	403-276-8028	TRAPEZE™-QV
Abbotsford HandyDart Abbotsford, British Columbia CANADA		604-855-0081	Rides Unlimited
Kamloops HandyDart Kamloops, British Columbia CANADA		604-376-7525	Rides Unlimited
Comox HandyDart Lazo, British Columbia CANADA		604-339-5453	Rides Unlimited
Port Alberni HandyDart Port Alberni, British Columbia CANADA		604-724-1311	Rides Unlimited
Farwest Transport Victoria, British Columbia CANADA		604-479-3111	Rides Unlimited
Carefree Society Prince George, British Columbia CANADA		604-562-1394	Rides Unlimited
Burlington Transit - Handitrans Burlington, Ontario CANADA	Vince Mauceri	905-335-7869	TRAPEZE™-QV
Transhelp - Peel Mississauga, Ontario CANADA	Norm McLeod	905-791-1015	TRAPEZE™-QV
North Bay Transit North Bay, Ontario CANADA	Terry Brent	705-474-4340	TRAPEZE™-QV

TABLE A.3 Paratransit Contacts and Their Suppliers (continued)

User	Contact	Phone #	Automated System/Vendor
Toronto Transit Commission Toronto, Ontario CANADA			GIRO/ACCES
Montreal Urban Community Transit Corporation Montreal, Quebec CANADA			GIRO/ACCES

APPENDIX B

ADVANCED PUBLIC TRANSPORTATION SYSTEMS

MENTIONED IN THIS

STATE OF THE ART, UPDATE '96 REPORT

ADVANCED PUBLIC TRANSPORTATION SYSTEMS MENTIONED IN THIS STATE-OF-THE-ART, UPDATE '96 REPORT*

Agency or Location	Advanced Communications	Automatic Vehicle Location	Automatic Passenger Counters	Operations Software	Automated Transit Information	Multimodal Traveler Information	Automated Fare Payment	Multi-Carrier Fare Integration	Real-Time Rideshare Matching	*Mobility Manager*	Transportation Management Centers	Traffic Signal Priority	HOV Facility Monitoring
UNITED STATES													
Phoenix Transit System, AZ		X		X			X						
SunTran (Tucson), AZ		X	X	X	X								
AC Transit (Oakland), CA		X	X	X	X								
Anaheim, CA						X			X		X	X	
ATHENA (Ontario), CA		X		X	X				X				
Bay Area Rapid Transit, CA				X									
Caltrans (Los Angeles), CA					X	X			X				
Los Angeles, CA								X					
Los Angeles MTA, CA		X		X								X	
Muni (San Francisco), CA		X			X								
Outreach (Santa Clara Co.), CA		X		X									
Riverside Co., CA					X								
Sacramento, CA									X				
SamTrans (San Mateo), CA		X											
San Diego Co. TAs, CA					X								
San Francisco/Oakland, CA						X		X	X				
Santa Monica Mun. BL, CA		X											
Stockton RTD, ,CA		X		X								X	
The Vine (Napa), CA		X		X	X							X	
Torrance Transit, CA							X						
Ventura Co. TC, CA								X					
RTD (Denver), CO	X	X		X	X								
WMATA, DC	X				X		X						
DART (Wilmington), DE							X						
Arc Transit (Palatka), FL		X		X			X						
Broward Co. Transit, FL		X		X	X								
Ctr. for Urban Transp. Res., FL													X
Hartline (Hillsborough Co.), FL		X											
Metro-Dade Trans. Agency, FL		X		X	X								

ADVANCED PUBLIC TRANSPORTATION SYSTEMS MENTIONED IN THIS STATE-OF-THE-ART, UPDATE '96 REPORT* (Continued)

Agency or Location	Advanced Communications	Automatic Vehicle Location	Automatic Passenger Counters	Operations Software	Automated Transit Information	Multimodal Traveler Information	Automated Fare Payment	Multi-Carrier Fare Integration	Real-Time Rideshare Matching	Mobility Manager	Transportation Management Centers	Traffic Signal Priority	HOV Facility Monitoring
Georgia DOT						X					X		
Georgia Tech (Atlanta), GA													X
MARTA (Atlanta), GA		X	X	X	X	X	X						
TheBUS (Honolulu), HI					X								
Chicago TA, IL	X	X	X	X	X		X					X	
PACE Suburban Bus, IL	X	X	X	X								X	
Gary Pub. Transp. Corp., IN		X		X									
Sioux City TS, IA		X		X									
TA of River City (Louisville), KY		X	X	X									
RTA (New Orleans), LA		X		X	X								
Montgomery Co. Ride-On, MD		X		X	X						X	X	
MTA (Baltimore), MD		X	X	X	X								
Mass. Bay TA, MA				X									
SmarTraveler (Boston), MA						X							
Ann Arbor TA, MI		X		X	X		X					X	
SMART (Detroit), MI		X		X	X								
MTC (Minneapolis), MN		X	X	X	X						X		
Bi-State Devel. Agency, MO	X												
Kansas City Area TA, MO		X											
New Jersey Transit, NJ	X	X		X	X								
Princeton Univ., NJ						X							
Sun Tran (Albuquerque), NM		X											
Bee-Line (Westchester Co.), NY		X			X								
Capital District TA, NY		X		X									
Long Island Railroad, NY				X	X								
Metro (Buffalo), NY		X		X	X								
MTA Long Island Bus, NY		X		X	X								
New York City Transit, NY		X		X	X		X						
Rochester-Genessee RTA, NY		X		X	X								
RTA (Syracuse), NY		X			X								

ADVANCED PUBLIC TRANSPORTATION SYSTEMS MENTIONED IN THIS STATE-OF-THE-ART, UPDATE '96 REPORT* (Continued)

Agency or Location	Advanced Communications	Automatic Vehicle Location	Automatic Passenger Counters	Operations Software	Automated Transit Information	Multimodal Traveler Information	Automated Fare Payment	Multi-Carrier Fare Integration	Real-Time Rideshare Matching	Mobility Manager	Transportation Management Centers	Traffic Signal Priority	HOV Facility Monitoring
TRANSCOM (NY, NJ, CT)											X		
Capital Area Trans. (Raleigh), NC		X		X	X								
Winston-Salem TA, NC		X		X	X		X			X			
COTA (Columbus), OH			X		X								
Laketran (Grand River), OH		X		X	X								
Smart Traveler (Cincinnati), OH						X							
SORTA (Cincinatti), OH		X		X	X								
Lane Trans. Dist. (Eugene), OR			X										
Tri-Met (Portland), OR		X	X	X	X								
Beaver Co. TA (Rochester), PA		X		X	X					X			
Comm. Trans. (Del. Co.), PA				X									
Co. of Lackawana TS, PA		X		X	X								
SEPTA (Philadelphia), PA	X			X									
Corpus Christi TS, TX		X	X	X	X							X	
Dallas Area RT, TX		X		X									
MTA of Harris Co., TX		X		X	X	X			X		X		
Sun Metro (El Paso), TX		X	X	X									
Texas Transp. Inst., TX													X
VIA (San Antonio), TX		X									X		
PRTC (Woodbridge), VA		X		X						X			
Northern Virginia									X				
Peninsula TDC (Hampton), VA					X								
Tidewater RT (Norfolk), VA		X											
Bellevue TMA, WA									X				
King Co. Metro (Seattle), WA		X	X	X	X							X	
Kitsap Transit (Bremerton), WA		X		X								X	
Pierce Transit (Tacoma), WA	X												
Seattle/Puget Sound, WA						X		X					
Spokane TA, WA					X								
SWIFT (Seattle), WA						X			X		X		

ADVANCED PUBLIC TRANSPORTATION SYSTEMS MENTIONED IN THIS STATE-OF-THE-ART, UPDATE '96 REPORT* (Continued)

Agency or Location	Advanced Communications	Automatic Vehicle Location	Automatic Passenger Counters	Operations Software	Automated Transit Information	Multimodal Traveler Information	Automated Fare Payment	Multi-Carrier Fare Integration	Real-Time Rideshare Matching	Mobility Manager	Transportation Management Centers	Traffic Signal Priority	HOV Facility Monitoring
Milwaukee Co. TS, WI	X	X	X	X									
Sheboygan TS, WI		X											
CANADA													
Calgary Transit, AB			X										
Winnipeg Transit, MB			X										
MTD (Dartmouth/Halifax), NS		X		X	X								
Hamilton St. Railway Co., ON		X	X	X									
London TC, ON		X		X	X								
OC Transpo (Ottawa), ON		X	X	X									
Toronto TC, ON		X		X	X							X	
STCUM (Montreal), QC			X										
STO (Hull) QC		X		X	X		X					X	

* Does *not* include all the systems listed in Table A.3.

APPENDIX C

ITS SYSTEM ARCHITECTURE AND STANDARDS

This appendix provides definition of a "system architecture," and presents an overview of the transit involvement in the ongoing national ITS system architecture program.

Objectives of a System Architecture

A system architecture is simply a description of how system components interact to achieve system goals. It accomplishes three main objectives:

- Defines complete system operation;
- Defines what each component does; and
- Defines what information is passed between 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 added twist 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 between components, which is necessary to allow independent development of the components. Overall, a system architecture organizes and guides system development in the same way that Gantt and PERT charts aid project management.

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 communications pathways. The resulting standards ensure equipment compatibility and interoperation, 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.

To better understand the system architecture concept and its usefulness, consider the example of a home stereo system. Consider if the radio, compact disk and cassette recorder were considered independently rather than as a system. To provide the full function of the system, without a system architecture, would require three amplifiers, three sets of speakers, and three volume controls. The speakers and amplifiers are especially troublesome because they are some of the most expensive components. In contrast, consider an integrated home stereo system architecture. The architecture reduces the system to a single amplifier and a single set of speakers, a tuner, a CD player, and a cassette tape deck, but adds the complication of "Sound Input & Output Controller." Note that this component was not initially envisioned, but an analysis of the complete system suggested the need for it. Similarly, by splitting the amplifier into two stages the headphone/speaker output selector could be integrated into the "Sound Input & Output Controller," with the pre-amplifier providing sufficient output to drive the headphones. Both the independent and the integrated architectures meet all the system goals, but the integrated one provides the sensible sharing of speakers and amplifier, which are some of the most costly elements.

The system architecture development can also go one step further and specify a *physical* architecture, which indicates which functions should be co-located. These decisions are based on issues like communications costs, functional needs, or other factors. For a typical home stereo system, the radio receiver, compact disk player, and cassette player are packaged separately to allow users to purchase only functions they desire. Everything else is packaged as a single component because these components are needed by all other components. The speakers are separate because they may be large and would be impractical to pack with the electronics components. More importantly, the customer may purchase his components from any manufacturer, confident they will work well together, thanks to the "architecture" of the home stereo system. If an architecture is so helpful to a simple home stereo system, it becomes absolutely essential for an extremely complex system such as the Intelligent Transportation System.

The National ITS System Architecture Development

Central to the successful realization of a national Intelligent Transportation System is the establishment of a unifying national ITS architecture. If carefully designed, 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 national ITS architecture will "...allow stakeholders to adopt the elements of ITS in the manner and time frame of their choosing, enable these elements to be supplied by multiple vendors, serve as the foundation for standards that can reduce duplication of effort by stakeholders, speed the introduction of ITS products and services and reduce the risk for the private sector developing these products and services."[C-1]

Recognizing the ITS program's need for a system architecture, the US DOT initiated the National ITS Architecture Development Program. The US DOT selected contractor teams to produce alternative architectures for a 20-year planning horizon (1992-2012). The program was divided into two phases. The first phase began in September 1993 with four teams, led by Hughes Aircraft, IBM-Loral, Rockwell International, and Westinghouse Electric, competing to produce the best architectures. Phase II began in February 1995 with two selected teams, Loral and Rockwell International, working together to merge and refine their architectures into a national standard. The architecture is scheduled to be completed by the end of February 1996 with a national review of the architecture scheduled for June 1996.

The foundation of the ITS system architecture is the set of 29 User Services. The services are listed in Table C. The user services address a broad spectrum of services including advanced vehicle systems, transportation management, and electronic payment services. The goal of the National ITS System Architecture Program is to unify and organize the user services and promote standards that assure seamless operation of the system from coast-to-coast.

The 29 ITS User Services have been grouped into seven "bundles" of services that are related in some way, either by the common users of those services (such as Commercial Vehicle Operations), or by the similarity in technologies and functions (such as Travel and Transportation Management). (See Table C.) Transit, or Public Transportation, is represented by the grouping labeled Public Transportation Operations.[C-2]

[C-1] **ITS Architecture Development Program: Interim Status Report**, ITS America, Washington, D.C., April 1994.

[C-2] David L. Caskey and Philip D. Heermann, Sandia National Laboratories, Albuquerque, New Mexico.

Table C ITS User Services

TRAVEL AND TRANSPORTATION MANAGEMENT En-Route Driver Information Route Guidance Traveler Services Information Traffic Control Incident Management Emissions Testing and Mitigation	**COMMERCIAL VEHICLE OPERATIONS** Commercial Vehicle Electronic Clearance Automated Roadside Safety Inspection On-Board Safety Monitoring Commercial Vehicle Administrative Processes Hazardous Materials Incident Response Freight Mobility
TRAVEL DEMAND MANAGEMENT **Pre-Trip Travel Information** **Ride Matching and Reservation** Demand Management and Operations	**EMERGENCY MANAGEMENT** Emergency Notification and Personal Security Emergency Vehicle Management
PUBLIC TRANSPORTATION OPERATIONS **Public Transportation Management** **En-Route Transit Information** **Personalized Public Transit** **Public Travel Security** **ELECTRONIC PAYMENT** **Electronic Payment Services** (APTS-Related Services in Bold Type)	**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 Systems

Transit Involvement in the System Architecture Program

The Federal Transit Administration has tasked the Volpe National Transportation Systems Center and Sandia National Laboratories to assist the architecture development teams and to identify transit-specific requirements. A major product of this work was the development of a set of information flow charts. These flow charts present the logical information flows that satisfy the needs of the APTS user services. The flow charts, together with a narrative description, have been provided to the architecture teams as well as members of the transit community.

In addition to the development of the transit architecture requirements, the Volpe Center and Sandia National Laboratories have conducted outreach activities to inform the transit community of the national architecture development program and its benefits to the industry.[C-3]

Standards Development

As indicated above, a national architecture facilitates the development of necessary ITS and APTS standards. One of the first ITS standards was an APTS standard, namely the standard for bus vehicle area networks, SAE J1708. This standard was developed through the efforts of the ITS America's APTS Committee/Bus Vehicle Area Network Working Group.

On the international front, the International Standards Organization has established Technical Committee (TC) 204 to develop standards for Transport Information and Control Systems. Due to U.S. leadership in both Intelligent Transportation Systems (ITS) technologies and development of internationally recognized ITS standards related to transit, the U.S. has been designated the International Secretariat of TC 204. The formal structure of TC 204 consists of 16 international Working Groups. Working Group 8 for Public Transport and Emergency Services is one of these groups.

The U.S., in support of these international Working Groups, has set up a parallel U.S. committee structure to provide the technical expertise which can be used to provide U.S. input to the Technical Committee 204 Working Groups. Therefore, a U.S. Working Advisory Group (WAG) 8 is being developed to support TC 204 Working Group 8. The WAG 8 Administrator is the Volpe Center; WAG 8 membership is being assembled from highly-qualified private industry and transportation agency sources. The WAG will serve as a source of experts for nomination to TC 204/Working Group 8.[C-4]

[C-3] Robert S. Ow, Volpe National Transportation Systems Center, Cambridge, Massachusetts.

[C-4] Elisabeth Carpenter, Volpe National Transportation Systems Center, Cambridge, Massachusetts.

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