U.S. Department
of Transportation

Advanced Public Transportation Systems: The State of the Art, Update '94

January 1994

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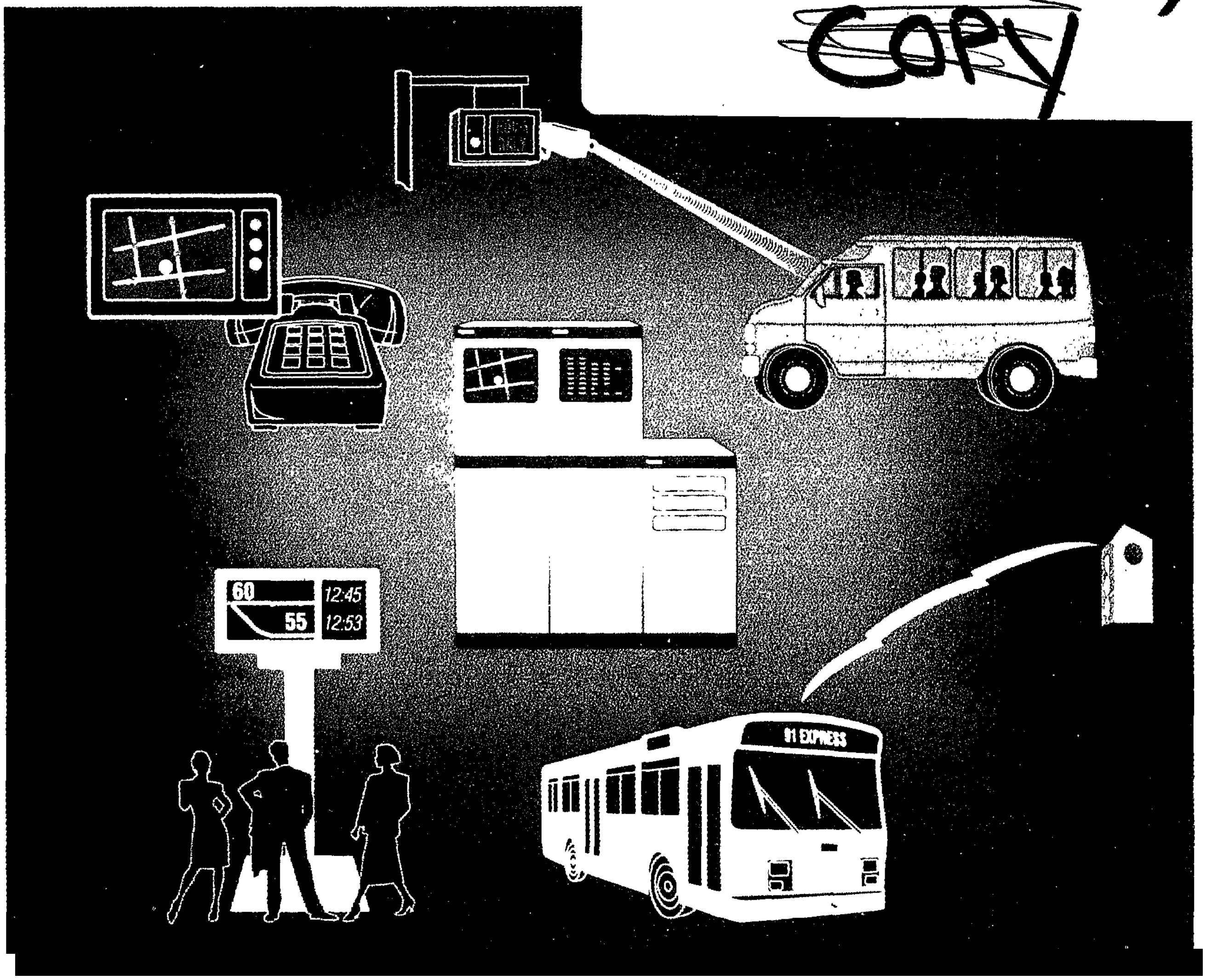

ADVANCED PUBLIC TRANSPORTATION SYSTEMS PROGRAM
A Component of the Departmental IVHS Initiative

Office of Technical Assistance and Safety

Advanced Public Transportation Systems: The State of the Art, Update '94

Final Report
January 1994

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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 and April 1992. 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. Ronald J. Fisher, P.E., director of the Office of Training, Research, and Rural Transportation, 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 the Appendix.

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 hectares (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gr)
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)] ^{o}F ❑ y ^{o}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)
1 hectare (he) = 10,000 square meters (m^2) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 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 milliliters (ml) ❑ 0.03 fluid ounce (fl oz)
1 liter (1) = 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] ^{o}C ❑ x ^{o}F

QUICK INCH-CENTIMETER LENGTH CONVERSION

INCHES: 0 1 2 3 4 5 6 7 8 9 10

CENTIMETERS: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 25.40

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 NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. Cl3 10286.

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LIST OF ACRONYMS AND ABBREVIATIONS USED IN THIS REPORT

AATA	Ann Arbor Transportation Authority
AC Transit	Alameda-Contra Costa Transit District (California)
ADA	Americans with Disabilities Act of 1990
AFC	Automatic Fare Collection
AIBS	Automated Identification and Billing System
APTA	American Public Transit Association
APTS	Advanced Public Transportation Systems
ARTIC	Advanced Rural Transportation Information and Coordination Project
AS1	Applied Systems Institute
ATIS	Advanced Traveler Information Systems
ATM	Automated Teller Machine
AVI	Automatic Vehicle Identification
AVL	Automatic Vehicle Location
AVL/C	Automatic Vehicle Location and Control
AVM	Automatic Vehicle Monitoring
BART	Bay Area Rapid Transit (Northern California)
Baud	Bit per Second
BMT	Brooklyn-Manhattan Transit (New York City Subway)
CAAA	Clean Air Act Amendments of 1990
CAD	Computer-Aided Dispatch
caltrans	California Department of Transportation
CCCTA	Central Contra Costa Transit Authority (California)
CIS	Communication and Information System
COTA	Central Ohio Transit Authority
CTA	Chicago Transit Authority
DART	Dallas Area Rapid Transit
DARTS	Dakota Area Resources and Transportation Services for Seniors (Minnesota)
DHHS	Department of Health and Human Services
DOT	Department of Transportation
DGPS	Differential Global Positioning System
EIS	Executive Information System
FOT	Field Operational Test
FTA	Federal Transit Administration
GIS	Geographic Information System
GO	Government of Ontario
GPS	Global Positioning System
HOV	High-Occupancy Vehicle
ID	Identification
IMI	Information Management International, Inc.
IND	Independent Subway System (New York City Subway)
IRT	Interborough Rapid Transit (New York City Subway)

LIST OF ACRONYMS AND ABBREVIATIONS USED IN THIS REPORT **(con?)**

ITS	Intelligent Transportation System
LACMTA	Los Angeles County Metropolitan Transportation Authority
LIRR	Long Island Rail Road
MBTA	Massachusetts Bay Transportation Authority
MDTA	Metro-Dade Transit Agency (Miami)
MTA	Mass Transit Administration (Baltimore)
MTC	Metropolitan Transportation Commission (Oakland, California)
NICTD	Northern Indiana Commuter Transportation District
NJT	New Jersey Transit
NYCTA	New York City Transit Authority
o c	Operations Controller
OC Transpo	Ottawa-Carleton Regional Transit Commission
PATH	Port Authority Trans-Hudson Corporation (New York/New Jersey)
PATH	Partners for Advanced Transit and Highways
PC	Personal Computer
PCIS	Payment and Control Information System
PCS	Personal Communication Services
PIN	Personal Identification Number
PTT	The Post, Telephone and Telegraph Service
RDS	Radio Data System
RF	Radio-Frequency
RFP	Request for Proposals
RFQ	Request for Qualifications
RTA	Chicago Regional Transportation Authority
RTB	Regional Transit Board (Minneapolis/St. Paul, Minnesota)
RVCOG	Rogue Valley Council of Governments
RVMP	Rogue Valley Mobility Project
STO	The Societe de Transport de L'Outaouais
s v c	Stored Value Card
TIM	Ticket Issuing Machine
TMC	Transportation Management Center
Tri-Met	Tri-County Metropolitan Transportation District (Portland, Oregon)
TRUMP	Transit Universal Microprocessor
TTC	Toronto Transit Commission
TTI	Texas Transportation Institute (Texas A&M University)
TVM	Ticket Vending Machine
VRE	Virginia Railway Express
Volpe Center	Volpe National Transportation Systems Center (of the U.S. Department of Transportation/Research and Special Programs Administration)
WMATA	Washington Metropolitan Area Transit Authority
WSTA	Winston-Salem Transit Authority

EXECUTIVE SUMMARY

This report examines the implementation status of advances in technology in the public transportation industry. The ready availability of low-cost, reliable microelectronics has opened up many new opportunities for enhanced information, communications, and control strategies for transit and ridesharing modes.

Many public transportation agencies have been applying recent technological advancements to improve services. To help develop, evaluate, and publicize these opportunities, the Federal Transit Administration (FTA) has established the Advanced Public Transportation Systems (APTS) Program. FTA's objective 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 report documents a limited investigation of the extent of adoption of advanced technology in the provision of public transportation service primarily in the U.S. and Canada. It is an update to two similar reports published in April 1991 and April 1992. 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 three different types of systems: Smart Traveler Technology, Smart Vehicle Technology, and Smart Intermodal Systems.

SMART TRAVELER TECHNOLOGY

The "Smart Traveler" is a person who has access to real-time and reliable information in order to make travel decisions that involve high-occupancy vehicles and transit. The concept of the Smart Traveler encompasses several technologies including smart cards, audiotex and videotex, telephones, cable television, personal computers, and geographic information systems. Activities are focused on the demand side of transportation supply and demand relationships.

Passenger Information Systems

Passenger information systems provide timely transportation data to trip makers at home, in the office, and enroute, including transportation centers, at wayside stops, and on-board vehicles. The data can be delivered via a variety of conventional and high technology methods, including telephones, direct computer links, and cable television. With links to automatic vehicle location (AVL) methods, advanced passenger information systems can provide real-time updates on expected transit vehicle arrival times, as well as warn transit users and system operators of delays.

The newer pre-trip systems are designed for use by people who are unfamiliar with the city and its bus routes. Some include geographic information system (GIS) map displays of the service area. A few transit systems are also exploring direct computer links and use of cable television information systems which can provide scheduling and routing information. The potential for using personal pagers or hand held computers to supply this information is also being explored. Cities with existing pre-trip information systems include: New York City; Columbus, Ohio; San Diego, Palm Springs, Ventura, San Bemadino, and Riverside County, California; Calgary, Alberta; and Ottawa, Ontario.

In-terminal and wayside information systems are gradually being installed by a number of bus systems. They provide schedule updates and transfer information for passengers already enroute. The systems generally list the next two or three transit vehicles expected at a particular stop, give transfer requirements and provide updates on any unexpected delays. This information can be conveyed through electronic or computer-based display devices. Some cities with AVL systems are planning to have monitors reflect real-time schedule information.

Although there are few American examples to date, several transit agencies have installed or are soon to install free-standing smart kiosks which would convey schedule information, trip planning information, and static files such as the locations of popular restaurants and tourist attractions. Some are interactive, enabling the potential rider to query the computer for ride-specific information. Primary concerns include costs for the kiosks and the potential for vandalism especially in outdoor locations. Examples of existing systems include Los Angeles, California and Halifax, Nova Scotia.

In-vehicle information systems support the transit user enroute, with on-board displays and communication devices which provide information on routes, schedules, and connecting services. There has been extensive development in the last two years, inspired largely by the requirements of the Americans with Disabilities Act of 1991 (ADA), which mandates that all fixed-route transit vehicles provide both visual and audible information to passengers on major intersections and key transfer points. These automated devices remove the responsibility for announcing stops from the drivers, leaving them to concentrate on driving which should result in greater safety for the passengers. Video displays have not yet been installed extensively on buses. Existing examples include: Salem, Oregon; JFK Airport, New York; and Montreal, Quebec.

Real-Time Rideshare Matching

The need for compliance with the Federal requirements of the Clean Air Act Amendments of 1990 has led to renewed interest in carpools and vanpools. Car-pooling and vanpooling is relatively common for fixed groups of people traveling to or from work on a regular basis, but rare for other purposes.

In contrast, dynamic carpooling is multipurpose and can be arranged either in real-time or close to it (near term). Participants pre-qualify and are put into a database. Upon receipt of a trip enquiry, the database is searched for others who are traveling in the same direction at the same time. Participants can not only use this database to carp001 to and from work, but also to a shopping center, medical facility or any other major trip generator.

The concept of dynamic carpooling is new and still in the experimental stage. However, there are some tests of the concept either in the planning stage or in pilot test stages, including applications in: Houston, Texas; Bellevue, Washington; Medford and Portland, Oregon; Sacramento, California; and Northern Virginia.

Multiprovider Trip Reservation and Integrated Billing Systems

Trip reservations utilizing multiple transportation providers allow the traveler to obtain trip reservations and tickets for a trip (portal-to-portal) from a single source. This would be based on ticketing and fare collection agreements by transit, paratransit, and other transportation providers.

An integrated billing system is one in which bills for the purchase of fares for all modes are generated from a central source. For instance, if several different carriers were used for a trip and the fare was purchased by a credit card, the billing for each fare would be generated by the credit card company.

Multiprovider trip reservation and integrated billing systems are being developed in North America, primarily based upon the Mobility Management concept that was developed for FTA. Currently, there are systems being developed in Medford, Oregon; Winston-Salem, North Carolina; and Northern Virginia.

Integrated Fare Media

Integrated fare media are tickets that can be used on more than one mode, such as a magnetic-stripe card that could be used for both bus and subway fares.

There are several North American transit systems that are utilizing integrated fare media that can be used on several modes being operated by different transit agencies. The most common application of integrated fare media involves the use of magnetically-encoded farecards for both bus and rail modes. The only operational system is in Oakland, California. Cities that will soon be testing or installing integrated fare media systems include: Chicago, Illinois; Ann Arbor, Michigan; New York City; and Mississauga and Toronto, Ontario.

Electronic Ticketing and Automated Trip Payment

Electronic ticketing involves the automated generation of tickets and automated fare collection. This can be accomplished with the use of non-cash media, such as credit cards and/or debit (ATM) cards.

Automated trip payments are those payments made without a manual exchange of coins or bills. Often, electronic ticketing provides automated trip payment through the use of magnetically-encoded farecards or advanced card technology, such as smart cards. Advanced card technology typically means plastic cards (credit card size) with a programmable memory chip that can be used for identification, trip payment, and other travel-related functions.

Electronic ticketing and automated trip payment are technologies that are beginning to be utilized by transit agencies throughout North America. Frequently, these two technologies go hand-in-hand (i.e., electronic ticketing often provides automated trip payment through the use of advanced card technology or the more conventional magnetically-encoded cards). Operational systems are located on Long Island, New York; in Northern Virginia; and Niagra Falls, Ontario. Implementation or testing is occurring in Chicago, Illinois; Northern Indiana; and Washington, DC.

SMART VEHICLE TECHNOLOGY

The "Smart Vehicle" incorporates many of the vehicle-based APTS technologies and innovations for more effective vehicle operations and control and fleet planning, scheduling, systems operations, and passenger safety. Whereas Smart Traveler technology focuses on passengers and directly increasing the ease and convenience of using transit (the "demand side"), Smart Vehicle technology focuses principally on the vehicle and improving the efficiency and effectiveness of service provided (the "supply side"). By making transit more efficient and more secure, it should be more attractive to prospective riders.

Automatic Vehicle Location Systems

Automatic Vehicle Location systems are computer-based vehicle tracking systems. The system measures the actual location (real-time position) of each vehicle, which can be compared with its expected position (based on the schedule). This information is relayed to the central base station or dispatching center or can be determined by the vehicle's computer. The potential for improving on-time performance is evident. Data generated over a period of time can be used to plan schedules and routes, collect data for use in maintenance, and prepare management reports.

Real-time vehicle location also provides the basis for additional benefits for a transit operation. A silent alarm can be activated by a driver in an emergency and police (or other emergency services) can be dispatched immediately to the location of the bus. AVL can be linked to Automatic Traveler Information Systems which can convey actual bus locations to the public through pre-trip information systems or through monitors in terminals or at transfer points. The system may be connected to vehicle component probes, so that conditions out of tolerance may be flagged, and dispatch alerted. Bus location information could be combined with automatic passenger count data, and communicated to the dispatch center in real time. Bus location information could also be used for automated actuation of traffic signal preferential treatment for buses.

The primary components of any AVL system are: a method of position determination; a means of communication with the dispatcher in real time; and a central processor capable of storing and using transmitted information. There are several types of AVL systems in existence: Signpost/Odometer; Radio Location (either ground or space-based); and Dead-Reckoning. The most common form of AVL applied to transit is the signpost/odometer system, which involves a series of beacons or tags along the bus routes. These are normally mounted on utility poles and send out a low-powered signal which can be detected by a vehicle fitted with a receiver or are integrated by the vehicle. The signposts each have their own ID and are spread throughout the system. Several cities in North America have installed these systems.

Ground-based radio systems are no longer widely used for intensive real-time vehicle tracking. The Loran-C systems which used ground-based signal triangulation have been largely displaced by the space-based Global Positioning System (GPS). Loran-C radio waves were affected when a vehicle passed a radio station or utility company wires. Florescent lighting on buses creates noise that interferes with the radio signals. As a result, systems based on Loran-C have turned to other position determination methods. 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 serves a variety of clients in several different businesses including package delivery, an ambulance service, a sanitation service, and a transit system.

Global positioning is the technology of preference among an increasing number of transit operations. However, at the time of this publication, no North American city has a fully operational GPS tracking system for its transit operation. Several cities are either planning GPS systems, conducting operational tests, or installing systems. Given the flexibility involved with GPS, it is now possible to consider application to demand-responsive paratransit systems where the primary motive is increased efficiency of service and improved vehicle allocation. Rural public transportation systems are also considering use of GPS to monitor vehicles in remote areas. Transit agencies currently installing GPS AVL systems include those in: Dallas, Texas; Denver, Colorado; and Milwaukee, Wisconsin. GPS systems are also expected to be installed in Baltimore, Maryland; Miami, Florida; Scranton, Pennsylvania; Ann Arbor, Michigan; and the twin cities of Minneapolis and St Paul, Minnesota.

A number of technological issues are being addressed. The U.S. military is employing selective availability, which results in decreasing precision of location. The limited number of radio frequencies available in many urban areas has proven difficult for many transit agencies. The issue of map display systems is one that a number of operations are weighing against cost. The U.S. Census Tiger files, although "free," require considerable editing in order to be usable for transit. A number of innovative solutions are being employed.

Transit Operations Software

Transit operations software usually performs and integrates several operations functions within a transit agency, such as computer-aided dispatching (CAD), computer-aided service restoration, and service monitoring. Service restoration involves the adjustment of vehicle operations based on schedule adherence or scheduled headways, the replacement of a disabled vehicle (which was in revenue service), and the activities necessary to restore the schedule disrupted by a disabled vehicle. Service restoration can involve dispatching a vehicle to replace a disabled vehicle or restoring the vehicle schedule. The vehicle schedule may be restored by adjusting vehicle dwell time at particular stops/locations (e.g., at transfer points), adjusting vehicle schedule/headway, performing traffic signal priority, rerouting the vehicle, or adding a vehicle to the route.

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, schedule/route/headway adherence, estimated time of 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),

Systems that integrate software and hardware have been and are being developed to address the operations functions mentioned above. Most of these systems are being developed for the larger rail properties. The following rail systems are planning, designing, or developing new operations control centers, which will provide real-time control and management:

- Bay Area Rapid Transit (BART),
- Chicago Transit Authority (CTA),
- Los Angeles County Metropolitan Transportation Authority,
- Massachusetts Bay Transportation Authority (MBTA),
- Metro-Dade Transit Agency (Miami),
- New York City Transit Authority (NYCTA),
- Port Authority Trans-Hudson Corporation (PATH),
- Toronto Transit Commission (TTC), and
- Washington Metropolitan Area Transit Authority (WMATA).

Rail systems are more advanced than bus systems in terms of operations automation because rail operations have traditionally been more automated than bus operations. For example, many rail systems have automated vehicle monitoring through the use of technologies such as automatic train control and automatic vehicle identification, whereas most bus systems have not had vehicle location until the recent advent of vehicle location technologies.

Also, many of the AVL systems that have been implemented for bus operations contain real-time control and management features. Existing systems are located in: Ottawa and Toronto, Ontario; and Hull, Quebec. Systems are being developed in Boston, Massachusetts; New York City; Dallas, Texas; Ann Arbor, Michigan; and Dade County, Florida.

Automated Demand-Responsive Dispatching Systems

Automated demand-responsive dispatching systems include scheduling features which assign individuals to demand-responsive vehicles that are operating in a shared-ride mode. The scheduling components accommodate advanced trip reservations, standing orders, and immediate requests. Increasingly, automation is becoming more available for paratransit systems, specifically in the areas of scheduling, dispatching, billing, and accounting and is based on advanced technologies such as radio-frequency (RF) communications in conjunction with on-board computers or mobile display terminals, CAD, location technologies, GIS, and smart cards.

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 Act. The ADA has stimulated the vendors of scheduling and dispatching software to incorporate many new features, such as mapping or GIS software, to assist in the determination of whether an individual’s origin or destination is located within %-mile 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 dispatching systems ranges from minimal (specialized software to assist manual dispatch) to fully automated scheduling and dispatch with the use of advanced communications and/or location technology. Many cities have established automated demand-responsive dispatching systems.

SMART INTERMODAL SYSTEMS

Recently, there has been increasing interest on the part of government, local, state, and Federal, in intermodal transport, i.e., the coordinated use of two or modes to make a single trip. This way, the best aspects of each mode may be isolated for a particular segment of the trip and combined to increase the efficiency and utility of the entire trip. In order to encourage travelers to take this intermodal approach, it must be made attractive. APTS technologies have great potential in this area and are already being applied in several cases.

Traveler Information Systems

Intermodal Traveler Information Systems are intended to entice the single occupant driver out of his or her vehicle and into a carp001 or a transit vehicle for at least a portion of the trip. Although some intermodal systems only present an array of transit or carpooling options, the trend is toward providing information about the level of traffic congestion by the same means as information about various transit or carpooling options. These systems parallel the basic Advanced Traveler Information Systems (ATIS) in that they can provide pre-trip or in-trip information. Information is provided through an interface between real-time traffic management systems and real-time transit or dynamic ridesharing information systems.

Although few fully intermodal systems are operative at this time, they clearly represent the direction for future automated traveler information projects. Examples of intermodal traveler information systems are found in Boston, Massachusetts; and Minneapolis, Minnesota.

Multi-Modal Smart Cards/Payment Systems

As stated above, smart card technology typically means plastic cards (credit card size) with a programmable memory chip that can be used for identification, trip payment, and other travel-related functions. There are three types of smart cards (categorized by how they are used): Contact Cards (require a physical contact between the card and the reader/writer unit), Contactless Cards (use a contactless interface to provide power to the card and for data transfer - using inductive techniques for power and capacitive for data reading), and Proximity Cards (use a contactless interface to interchange data between card and the reader/writer unit - using RF or laser techniques). The multimodal aspect of smart cards and payment systems refers to a smart card that could be used to pay fares across several modes of transportation (bus, rapid rail, light rail, highway, etc.).

No multimodal application of smart cards has been demonstrated as yet in the U.S. A demonstration of a proximity smart card for Metrorail, Metrobus, and transit parking in Washington, DC is planned for 1994. There are, however, several multimodal smart card systems being implemented in Europe, Asia, and Australia.

High Occupancy Vehicle Facility Monitoring

The concept of high occupancy vehicle (HOV) lanes is well established as a means of encouraging single occupant drivers to carp001 and thereby help to relieve congestion. Those traveling in cars with two or more passengers (or in some cases, three or more passengers, depending on the threshold established) are rewarded with a shorter travel time by being permitted to use exclusive travel lanes. Given the benefits of congestion-free travel, there is a temptation for drivers of single occupancy vehicles to use the HOV lanes illegally. Hence, monitoring the use of HOV lanes has become an increasing challenge. The traditional response is to station police cars near ramp entrances, but costs in personnel time and limited effectiveness in monitoring peak hour use of HOV lanes has led to the search for a technological solution to the issue.

To date, a number of HOV lane monitoring devices have been tested but none has proven to be fully effective in operation. Experimental tests are continuing, largely focusing on adapting military surveillance techniques or techniques used in law enforcement for such a purpose. Some metropolitan areas have dismissed technological solutions, noting the costs involved in implementation - an issue which has not been fully explored.

Transportation Management Centers

There are a number of well-established Transportation Management Centers (TMCs) associated with highway monitoring. They use an array of television monitors and cameras to observe congestion levels on limited access highways. Observation of congestion leads to displaying warnings and suggested re-routings on automated highway message boards.

Some of the Transportation Management Centers, like that in Los Angeles, also monitor traffic build up on arterials by using inductive loop detectors imbeddcd in the pavement at intersections. Traffic signals are preprogrammed to respond to high levels of traffic build-up on key arterials by extending the green time.

None of the current TMCs are yet linked to information about a transit alternative. There are, however, plans to feed real-time traffic congestion reporting into traveler information systems that will highlight transit and ride-sharing alternatives in: Bellevue, Washington; Detroit, Michigan; Anaheim, California; and Portland, Oregon. The U.S. Department of Transportation has just issued a request for proposals for public-private partnerships to address the interrelated issue of enroute driver and traveler services information. Operational tests are planned.

Vehicle Guidance Systems

Vehicle guidance systems integrate technologies that laterally and longitudinally control the operation of a vehicle. To date, vehicle guidance technologies that have been demonstrated include: track guidance, electronic guidance, magnetic guidance, and vision systems. Track guidance is mechanical, and electronic guidance consists of wire buried in a roadway that emits a signal to guide a bus. There are developments in new technologies that are being demonstrated in the San Francisco Bay Area, Japan, and the United Kingdom.

1. INTRODUCTION

Purpose of Report

The ready availability of low-cost, reliable microelectronics continues to open up many new opportunities for enhanced information, communications, and control strategies for transit and ridesharing modes. This report describes the implementation status of advances in new technologies in the public transportation industry which have occurred since the last State-of-the-Art report (Update '92).

Background

The 1980s saw rapid advancements in the development of information and communication technologies. During this period, many public transportation agencies have been employing certain of these technologies to improve the services they offer. Automatic vehicle location and monitoring, automated guideway operations, and computerized dispatching were some of the earliest applications of advanced technologies. However, the greatest opportunities for public transportation enhancement through advanced technologies are just unfolding as the private sector development of these technologies accelerates.

In an effort to assist the development and evaluation of these opportunities, the Federal Transit Administration (FTA) has established the Advanced Public Transportation Systems (APTS) Program. Through in-service operational tests, evaluations, and publication of results, FTA's objective is to increase the industry's knowledge of successful applications of advanced technologies with the expectation that this will lead to their widespread adoption. The improved public transportation services that will result should attract more riders to transit and ridesharing modes, thus producing the added public benefits of reductions in traffic congestion, air pollution, and energy consumption. This state-of-the-art update is just one of the initiatives of the APTS program.

Scope

This effort was a short-term investigation of developments and advancements in the adoption of new technology in public transportation services in North America during the past two years. 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. Nevertheless, where North American applications were few or nonexistent, foreign examples were noted if they happened to be known to members of the study team. They were included in this report only for the purpose of indicating advanced technology approaches that are in use elsewhere and, therefore, which could soon be tried in the U.S.

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 three categories: Smart Traveler Technology, Smart Vehicle Technology, and Smart Intermodal Systems. These sections are preceded by an Executive Summary and this Introduction, and are followed by a list of current FTA-sponsored projects and an Appendix containing a comprehensive list of the individuals contacted during this study.

2. SMART TRAVELER TECHNOLOGY

The "Smart Traveler" is a person who has access to real-time and reliable information in order to make travel decisions that involve high-occupancy vehicles and transit. Hence, the technologies involved in "Smart Traveler" programs are focused on the demand (ridership) side of transportation supply and demand relationships. These technologies include Smart Cards, audiotex and videotex, telephones, cable television, personal computers, and geographic information systems. The use of one or more of these technologies can facilitate a traveler's decision to carp001 or take transit.

This chapter describes five applications of Smart Traveler Technology. These are:

- Passenger Information Systems,
- Real-Time Rideshare Matching,
- Multimodal Trip Reservation and Integrated Billing Systems,
- Integrated Fare Media, and
- Electronic Ticketing and Automated Trip Payment.

Each of these is discussed, in turn.

2.1 PASSENGER INFORMATION SYSTEMS

Passenger information systems provide timely transportation data to trip makers at home, in the office, and enroute, including transportation centers, at wayside stops, and on-board vehicles. This information enables travelers to improve their travel decision making, both before they begin the trip and while they are enroute and can include data on transit routes, schedules, transfers, and fares. The data can be delivered via a variety of conventional and high technology methods, including telephones, direct computer links, and cable television. With links to automated vehicle location (AVL) methods, advanced passenger information systems can provide real-time updates on expected transit vehicle arrival times, as well as warn transit users and system operators of delays. Three types of passenger information systems are discussed in this section:

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

2.1.1 Pre-Trip Information

Pre-Trip traveler information systems reach trip makers in their homes or offices and provide timely information on transit routes, schedules, and fares. In some cities, these systems go beyond responding to specific questions regarding appropriate routes and schedule times to provide automated trip planning.

Recently, there has been an increasing number of sites electing not only to provide transit information, but information on other travel modes as well. (These systems will be discussed further in Chapter 4 of this report.) The objectives in using technology in pre-trip information services are to increase efficiency in responding to calls and to improve the accuracy and completeness of information supplied. Efficiency can be increased by using touch tone telephones and/or voice synthesizers to report back information on routes and schedules much as telephone companies do with directory assistance. In this way, many calls, especially those for basic information are pre-screened. A number of transit systems feel that it is important to have a person initially answer and direct the call in order to convey personal interest. Computer data retrieval systems provide quick and accurate information to the operator to respond to the customer's inquiry.

State-of-the-Art Summary

Although the early systems were primarily directed toward riders who knew the basic bus routes and who only wanted to be updated on schedules and transfers, the newer systems are also designed for use by potential new riders, those who do not know routes and the locations of bus stops. Also, the newer systems are designed to be used by operators who are unfamiliar with the city and its bus routes. All the traveler needs to supply are the cross streets of origin and destination. The operator can enter the city-wide data bank where routes and schedules are associated with street locations. Some newer information systems include GIS map displays of the service area. The operator can use these to locate the closest route and stop to the street comer referenced. by the caller and then apply network analysis. Other bus systems use extensive computer data banks which can accomplish trip planning by associating the points of origin and destination supplied by the caller.

A few transit systems are also exploring direct computer links and use of cable television information systems which can provide scheduling and routing information. The potential for using personal pagers or hand held computers to supply this information is also being explored.

With the expanding interest in AVL systems, the potential for providing real-time information on bus arrival and departure times at bus stops system-wide is coming closer to reality. Real-time schedule information can be made available through telephones, computers, televisions, and personal pagers.

Applications

Columbus, Ohio

An automated transit information system designed by Megadyne was introduced in late 1992. It has proven to be a time saver for the Central Ohio Transit Authority's (COTA) customers and customer service representatives. Training time for new customer service representatives has been cut in half and the volume of calls handled has increased considerably.[1]

San Diego, California

An automated trip planning system developed by Tidewater Consultants of Virginia Beach provides a variety of information about bus and trolley systems for a large portion of San Diego County. Travelers may call InfoExpress, a computer-based system, to request information on ways to travel between points. Answers are provided in English or Spanish and include information on routes, schedules, and stop locations. About 20 percent of the incoming calls can be handled with InfoExpress.

Human clerks answer the more complex questions, assisted by a computer-based trip planning system which can identify in a few seconds the optimum routing between any two points in the huge 1,000 square mile service area. Clerks provide a human touch answering the caller in English, Spanish, or Tagalog. The information is retrieved from the computer database, and a computer voice gives the caller the answer. Many more calls are being answered with the

[1] "Columbus Uses Team Effort to Better Serve Customers," *Passenger Transport,* March 29, 1993.

new system. Only about four percent of calls are lost, compared to about 30 percent previously.*

Calgary, Alberta

Calgary Transit provides bus schedule information for prospective passengers. The passenger must know his or her bus stop number before calling from home or work to find out when the next few buses will arrive at that stop. The system is computerized but does not use real-time bus location information. This type of system requires that the caller have knowledge of the bus network. For those who do not know the bus routes, it is still possible to call a customer information number and talk directly to a customer service operator.[3]

New York City, New York

The customer information service provided by the New York City Transit Authority can handle large volumes of calls with the use of a computerized telephone response system designed by Tidewater Consultants. Callers are given the option of talking directly with a customer agent, but only a small number do so. This system supplies intermodal information on how to travel from origin to destination. It can provide schedules and routes of subways, buses, and ferries and transfers between them. Customer agents do not need to know the city personally, since the system includes a Geographic Information System which can identify the caller's origin and destination by street segment. Those segments are linked to transit routes.[4]

Ottawa, Ontario

Ottawa-Carleton Transit has developed an automatic telephone system (called the 560 system) over the last ten years. The entire city has been covered since 1991. This system provides the individual caller with information on the scheduled arrival time of the next two

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[2] "Info Express," *Bus Line*, April 1992.
Theresa Brock, San Diego Transit Corporation.

[3] Fred Warg, Calgary Transit.

[4] Andi Overton, Tidewater Consultants.

buses at a particular stop. Plans call for adding a run plate to the front of the bus. These plates would then be read as the bus leaves or enters the garage and actual and printed schedules could be compared. (See also Section 3.2.)

Washington, District of Columbia

The Washington Metropolitan Area Transit Authority (WMATA) plans to operate paratransit as a feeder to fixed-route service and has recently issued an RFP to have a computer-operated information system designed to respond to requests regarding both fixed-route and paratransit trips. This concept may be of interest to other transit agencies responding to the requirements for complementary paratransit service specified in the Americans with Disability Act.

Other California Sites

Riverside Transit Authority (California), Sunline Transit (Palm Springs), Ventura County Transit Commission, Omni Transit (San Bemadino), and Culver City Transit are currently using an automated telephone traveler information system developed by Transtar. These systems provide the prospective passenger not only with schedules, but also with information on trip length, trip time, and walking distance to the bus stop.’

Germany

Some German cities have introduced innovative telephone-based information systems that permit residents to request rides between any two checkpoints at any time. The rider calls for the trip as needed and supplies the telephone operator with origin and destination checkpoint numbers, requested departure time, number traveling, and special needs. A computer analyzes the request and assigns vehicles to pick up the traveler, generally within seven minutes. Such a concept could be adapted to rideshare.[6]

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[5] Bob Kohl, Transtar.

[6] Behnke, Robert, “The Need for IVHS Technologies in U.S. Public Transportation Systems,” Aegis Transportation Systems, 1993.

2.1.2 In-Terminal and Wayside Information Systems

In-terminal and wayside information systems provide schedule updates and transfer information for passengers already enroute. They generally list the next two or three transit vehicles expected at a particular stop, give transfer requirements and provide updates on any unexpected delays. This information can be conveyed through electronic or computer-based display devices. Although automated displays announcing the arrival of trains and providing updates on airplane schedules are well established, they are still not regular features in bus terminals and transfer points.

State-of-the-Art Summary

In-terminal and wayside information systems are gradually being installed by a number of bus systems. Some transit agencies are also exploring the placement of computer-based monitors at locations that are potential transit generators. Some cities with AVL systems are planning to have monitors reflect real-time schedule. There is some debate, however, regarding the advisability of providing real-time arrival times. If a traveler is informed that the bus is running five minutes late and makes plans accordingly, it is possible that the bus can make up time and arrive at the stop earlier than predicted. This might cause the traveler who relied on the information to miss the bus.

Some transit agencies are considering providing free standing smart kiosks which would convey schedule information, trip planning information, and static files such as the locations of popular restaurants and tourist attractions. Some are interactive, enabling the potential rider to query the computer for ride-specific information. These smart kiosks proved to be successful in connection with the automobile-based TravTec experiment in Orlando, Florida. They could, therefore, be located at potential transit rider generators including hotel lobbies, convention centers, office parks, and park-and-ride lots. They also can be linked to a bus AVL system and provide real-time transit information. Primary concerns include costs for the kiosks and the potential for vandalism especially in outdoor locations. To date, there are few American examples of remote kiosks being used to convey transit information.

Applications

Halifax, Nova Scotia

Video terminals are located in transit terminals and malls. Displays list the Metro Transit routes that stop at that location and the time at which the bus will arrive in real time. To access this information, a traveler punches in a four-digit code number signifying his or her location.

Anaheim, California

Anaheim currently has remote kiosks located at some locations, including the Anaheim Hilton and the Anaheim Stadium, which provide real-time roadway congestion information. Cable TV also provides this information. To date, however, transit information is not provided at these kiosks.[7]

Los Angeles, California

The Los Angeles Smart Traveler program provides pre-trip information on bus schedules and also on kiosks located at Union Station, Arco Plaza, and a shopping mall. Beginning on or about November 1, the kiosks not only were to provide current information on bus, light rail, and heavy rail schedules but also were to include display maps showing congestion on freeways and adjoining arterials. The electronic displays are provided by SilentRadio, a division of Cybernetic Data Products, which has supplied indoor/outdoor LED message displays to AmTrak. The displays are located on station platforms and provide transit arrival information. They are readable in sunlight and equipped with StenoText verbal translation for the hearing impaired. Further, they are weather-proof and are treated with a polycarbonate facia to protect against vandalism. The displays can be programmed and updated from a central location, but are not yet triggered automatically by the vehicles themselves.*

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[7] Jim Paral, City of Anaheim, Public Works-Engineering Department.
FTA, Project Summary, June 1993.

[8] Robert Ratcliff, California Smart Traveler, California Department of Transportation.

Yosemite Park, California

The number of summer visitors to Yosemite National Park has increased to such an extent that the park is frequently congested in the summer months and the limited roadways serving the park are unable to handle the traffic. Travel conditions also change abruptly in the mountain passes due to weather. In an effort to provide dynamic as well as static traveler information, four smart kiosks will be placed at the entrance to the park, five within the park, and five on approaches to the park. These kiosks will provide information on congestion, road and pass conditions, and attractions and lodging information.[9]

Broward County, Florida

Broward County Transit Authority has installed televiewer services in terminals. Similar systems have been installed in Toronto, Kinchener, and Guelph, Ontario, while a Spanish version has been installed in San Juan, Puerto Rico. These viewers, developed by Teleride-Sage, are similar to the monitors used in airports, but have much sharper graphics. They present material on arrivals and departures, detours, delays, cancellations, and fares. The arrival and departure information is real-time since it is based on sensors that are located on the approach to the station. The televiewers also can display advertisements or store promotions.[10]

Minneapolis, Minnesota

As part of the overall Guidestar project, Travlink anticipates providing real-time transit and traffic information by installing smart kiosks at shopping malls and transit stations as well as making information available on terminals at home and at work places. They also hope to indicate the time saved through use of HOV lanes. (See Section 4.1 for a further discussion of Guidestar.)

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[9] Robert Ratcliff, California Smart Traveler, California Department of Transportation.

[10] Brian Kalanda, Teleride-Sage.

Birmingham, England

A very ambitious program is being conducted in Birmingham, England as part of the DRIVE Program. Tests will be run on several types of interactive terminals. A computer system will be provided at the central base station for use by the information operators, which will calculate optimum routes. The system will include a map display, Similar facilities will be provided in self-service terminals on the street. These will have screen-based displays, supplemented by optional print-outs, giving timetables and a map showing recommended walking routes to the nearest bus stop. Five such terminals will be installed for the initial test. In addition, home terminals will provide real-time information on departure times at specified bus stops. Twenty such terminals will be tested initially. Portable hand held terminals are also being developed as part of project PROMISE in the Drive program.

Passive real-time information will be displayed at a sample of bus stops where the arrival times of the next few buses will be posted. An initial test involves fifty buses from three independent operators. Ten stops will be equipped with the displays.

Information also will be provided to automobile drivers. Displays in automobiles will indicate the closest park-and-ride location as well as real-time information on traffic congestion.[11]

2.1.3 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. This is an area which has seen extensive development in the last two years. Much of the inspiration has come from the requirements imposed by the Americans with Disabilities Act (ADA) of 1991. The Act requires that all fixed-route transit vehicles provide both visual and audible information to passengers on major intersections and key transfer points. The new equipment, including enunciators and visual display boards have made the systems more user friendly for all passengers. These

[11] Blackledge, David and Laurie Pickup, "Public Transport Passenger Information Systems: The Potential of Advanced Transport Telematics," *Proceedings of the IVHS America Annual Meeting 1993,* pp. 295-301.

automated devices remove the responsibility for announcing stops from the drivers, leaving them to concentrate on driving which should result in greater safety for the passengers.

State-of-the-Art Summary

Since they operate primarily on exclusive right-of-ways, rail systems are able to provide audio announcements for the various stops with a reasonable degree of accuracy. Bus announcements are more difficult. Some bus systems are preprogrammed to announce stops based on door openings while others respond to sensors placed in the streets. Far more accurate information will come from use of an AVL system which can closely determine position and trigger audio messages. This concept is beginning to spread. Nevertheless, video displays have not yet been installed extensively on buses.

Applications

Salem, Oregon

Four of Salem, Oregon's 54 buses are now equipped with voice enunciators supplied by Digital Recorders. They have been operating for almost a year. These buses announce stops at major intersections and also provide information to passengers on local retailer promotions. They will be used for more general advertising once all 54 buses are equipped. The approach provides an efficient means of complying with the regulations of the Americans with Disabilities Act - passengers receive relevant information without regularly involving the driver. This system runs on a timer that is activated by a button pressed by the driver.[12]

Orange, Osceola, and Seminole Counties, Florida

The LYNX bus system has 47 enunciators on order from Digital Recorders with operation scheduled to begin November 1993. They plan to have 300 to 400 buses equipped by 1996. These will announce each stop in this multi-county system.[13]

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[12] Greg Cook, Salem Transit.

[13] Glenn Parrish, LYNX bus system.

JFK Airport, New York

Caravan operates the ground transportation services for John F. Kennedy Airport in New York. They currently have 36 “talking buses” on line. Inside the bus, the stops are announced; the routes are announced outside the bus at each stop. The same route information is displayed on an LED sign display outside the bus. The system operates automatically but can also be operated manually by the driver. The system, designed by Digital Recorders, is operating effectively and plans call for expansion.[14]

Other cities are also experimenting with “talking bus” enunciators. Wilmington, Delaware has two test units of the talking bus in operation. Atlanta, Georgia is considering using multilingual enunciators during the Olympics.”

Montreal, Quebec

An in-vehicle information system is in use on the Montreal Metro rapid rail system. A bright lighted display developed by Telecite has now been installed in all subway cars. The flat view, high intensity, LED display screen is placed on the side of the individual cars. This display presents not only the name of the next stop but also can relay any retail store promotions associated with that stop. The advertisements are paid for by the stores. The messages are transmitted via a data radio network from one or more control centers to receivers inside the metro cars. Between stops the displays present weather reports, sports reports, news headlines and information on upcoming events. Advertisements and messages are presented in animated cartoon imagery. The system, which benefits the elderly and persons with disabilities, has been very positively received by the general public as well.[16]

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[14] Jeff DeStephano, Caravan Bus Lines.

[15] Carol Schuster, Digital Recorders.

[16] Marshall Moreyne, Telecite, Inc.
“Montreal Tests Visual Communication Network,” *Passenger Transport,* April 19, 1993.

In-Vehicle Passenger Information System Demonstration

At the American Public Transit Association (APTA) Annual meeting and Expo '93 show in New Orleans, in October 1993, Luminator demonstrated its integrated information system which provides next stop information inside the bus and route information outside the bus. Visual displays are also provided in the bus to aid the hearing impaired. It provides a concept that responds to the needs presented by the ADA. The special feature of this system is that the bus will be tracked through a Global Positioning System (GPS) AVL system and thus can identify its location for activation of information messages.[17]

2.2 REAL-TIME RIDESHARE MATCHING

The need for compliance with the Federal requirements of the Clean Air Act Amendments of 1990 (CAAA) has led to renewed interest in car-pools and vanpools. Carp001 matching has generally been accomplished for regular commuting to a work site. The participants in each carp001 agree on a travel schedule. Any variations from the regular, pre-established schedule are with the agreement of the other participants. Vanpools operate similarly, except that they usually represent a considerable agency or company investment in the vehicle which is driven by a designated driver. Carpools and vanpools can reduce the pressure on over-crowded parking lots and play a role in reducing highway congestion in peak hours. In addition, they help to reduce the real cost of the work trip for participants.

In contrast to these pre-established, single purpose carpools, dynamic car-pooling is presented as a mode of transportation that is "ready when you are." They are multipurpose and can be arranged either in real-time or close to it (near term). Participants pre-qualify and are put into a database. Upon receipt of a trip enquiry, the database is searched for others who are traveling in the same direction at the same time. Participants can not only use this database to arrange for carpools to and from work, but also to a shopping center, medical facility or any other trip generator.

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[17] Barbara Lange, Luminator.

State-of-the-Art Summary

The concept of dynamic car-pooling is new and still in the experimental stage. However, there are some tests of the concept either in the planning stage or in pilot test stages. Some vendors like Transtar, which have been active in furthering Automatic Vehicle Information for transit users, are now introducing compatible software for providing information on ride share opportunities.

A related set of technologies involve dynamic scheduling of paratransit systems, a process that links scheduling network software and AVL technologies.

Applications

Houston, Texas

Real-time carpooling is a major element in the Metropolitan Transit Authority of Harris County's Smart Corridor project, funded in part by FTA. The I-10 West corridor and the Post-Oak Galleria area provide the opportunity to test a comprehensive employer-based carp001 matching service. Most commuters in this corridor are suburb-to-suburb travelers and the area is not well served by regular fixed-route bus service. The project is associated with an effort to increase the number of two or three-person carpools on the Katy Freeway HOV lane in the A.M. peak. The initial stages of the project will focus on near-term carp001 arrangements (trips arranged the night before), but longer-term plans call for instant rideshare matching using an interactive program tied into the database. Participants will initially access the database through touch-tone telephones, but videotex systems will be used in the future. Employers have been surveyed to determine their interest in the pilot project which will operate between the Addicks park-and-ride lot and the Post Oak-Galleria area.[18]

[18] Turnbull, Katherine, "The Use of Information Generation from Transit AVL Systems," Proceedings *of the IVHS America Annual Meeting 1993,* pp. 82-88.

Bellevue, Washington

The Bellevue, Washington Smart Traveler project is a major operational test of the concept of dynamic ride sharing. The concept is to use access to real-time traffic information as an incentive to encourage participation in a rideshare pool. Participants will use cellular telephones through which they will receive computerized messages regarding real-time traffic information and bus routes and schedules. An alphanumeric pager will be used to develop near term rideshare matches. The objective is to eventually generate real-time dynamic carp001 matches. Pretests have been completed and an intensive marketing program is underway with major employers. [19]

Medford, Oregon

The Rogue Valley Council of Governments is about to begin a pilot program in which they will test dynamic scheduling of paratransit service. The software, designed by Easy Street, will allow for real-time insertion of trips and rerouting of paratransit vehicles. A dead-reckoning/odometer AVL system will be used to track the location of paratransit vehicles. Vehicle locations will be reported to base where the scheduling program will modify the pre-scheduled trip routing. Plans call for an initial test with clients of four headstart centers in early 1994. Four months later, an additional test will be conducted with the senior volunteer program.[20] (See ***also*** the ***Medford, Oregon*** description in Section 2.3.)

Portland, Oregon

Tri-Met is in the process of negotiating a bid for real-time paratransit scheduling. Information on vehicle location will be fed back to the control center where the schedules will be manipulated to reflect real-time changes in travel conditions.[21]

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[19] Cathy Blumenthal, Bellevue Smart Traveler, Bellevue Transportation Management Association.

[20] Patrick Simmons, Easy Street Software.

[21] Easy Street is in the process of developing dynamic scheduling software for paratransit systems.

Sacramento, California

One of the projects in the California Smart Traveler Program is a real-time rideshare matching system in Sacramento. The concept is to provide rideshare information for single trips, such as to the shopping mall. The program is still in the planning phase.[22]

2.3 MWLTIPROVIDER TRIP RESERVATION AND INTEGRATED BILLING SYSTEMS

Multiprovider trip reservations allow the traveler to obtain trip reservations and tickets for a multimodal trip (portal-to-portal) from the initial carrier through inter-line agreements. This would be based on inter-line ticketing and fare collection agreements by inter-regional carriers, transit and paratransit providers in a metropolitan area.

An integrated billing system is one in which bills for the purchase of fares for all modes are generated from a central source. For instance, if bus, subway, and air fares for one complete trip were purchased by a credit card, the billing for each fare would be generated by the credit card company.

This section differs from Section 4.2, Multimodal Smart Cards/Payment Systems, in that this section describes reservation and ticketing for multiple transportation providers through an integrated system. Section 4.2 describes smart card technologies that can be used for a variety of transportation purposes, such as identification, trip payment, parking payment, etc.

State-of-the-Art Summary

Multiprovider trip reservation and integrated billing systems are being developed in North America, primarily based upon the Mobility Management concept that was developed for FTA.[23] Currently, there are systems being developed in Medford, Oregon, Winston-Salem, North Carolina, and Northern Virginia.

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[22] Robert Ratcliff, California Smart Traveler, California Department of Transportation.

[23] Jeffrey A. Parker and Associates and International Taxicab and Livery Association, **Mobility Management and Market-Oriented Local Transportation,** Final Report, prepared for FTA Office of Technical Assistance and Safety, March 1991, Report No. DOT-T-92-07.

Applications

Medford, Oregon

As described in the **State of the Art** - ***Update 92*** report, the Rogue Valley Council **of** Governments (RVCOG) is developing a mobility management project, called the Rogue Valley Mobility Project (RVMP). The RVMP will demonstrate the use of advanced technologies to provide users with access to information on public and private transportation services in order to make choices among the available modes. The RVMP's objectives are to support the independence of and the competition between providers, and minimize the cost of public and private mass transportation while maximizing patronage.[24]

In the fall of 1992, RVCOG selected a vendor for the RVMP. Phase I of the project, which focuses on subsidized taxi and volunteer transportation services for elderly and disabled individuals, is expected to be implemented in February 1994. The RVMP will consist of the following major components:[25]

- Phone System - Consumers will call one central telephone number to obtain information regarding transportation services and to make trip reservations. The system will use automatic number identification to automatically identify clients of any participating program.

- Software - The software (developed by Easy Street) takes client reservations and registrations, develops routes and schedules, dispatches vehicles and drivers, and generates reports and billings. The software can also monitor vehicle, driver, and client activity, trace vehicle maintenance and availability, and maintain records of driver training and experience.

- Data Transmission - Data transmission between the vehicles and the base site will be accomplished via digital communications. The vehicles will be equipped with on-board computers, or mobile data terminals, and the digital signals will be transmitted from the dispatch center via radio waves or cellular technology. The participants will be able to transmit information to each other via modem and/or local area network.

[24] Rogue Valley Council of Governments Request for Proposals for Mobility Management Project, July 14, 1992, p. 2.

[25] Rogue Valley Council of Governments RVMP Status Report, July 23, 1993.

- Fare Media - Magnetic-stripe cards will be used in place of cash, tickets and coupons. Card readers will be placed in participating vehicles, and all financial transactions between provider and subsidy agencies will be tracked using the cards. Passenger consumption and provider information will be recorded electronically. The software can analyze accounting and financial transactions to determine transportation providers' and subsidy agencies' current accounts. The RVMP system, headquartered at RVCOG's offices, will also electronically administer the system.

In Phase II, RVCOG expects to add fixed-route transportation and possibly expand the paratransit/specialized portion of the RVMP into Josephine County.

Winston-Salem, North Carolina

The Winston-Salem Transit Authority (WSTA) will develop and operationally test a mobility management system for human services transportation. Future plans will involve the fixed-route system. FTA and the North Carolina Department of Transportation, Public Transportation and Rail Division are providing the funding for this project.

WSTA provides human service transportation to the Winston-Salem area through Trans-AID, a 17-vehicle paratransit service. WSTA issued a Request for Qualifications (RFQ) in July 1993 to obtain background information on potential system integrators. A Request for Proposals (RFP) was to have been issued in the fall of 1993.

The scope of this project includes:

- Mobility Management Definition - Identify current system needs, functions, characteristics and performance, refine hardware and software specification, and develop an RFP;

- Mobility Management Acquisition for Human Service Transportation - Advertise the RFP, review and analyze proposals, select a vendor, install and test the hardware and software, conduct training, develop operating procedures, and inform the participating human service providers and their clients on the practical application of mobility management;

- Evaluation of Mobility Management - Monitor and assess the performance of the system, analyze the integration of software (through the North Carolina State University's APTS Computational Laboratory), analyze the hardware, and investigate public-private partnerships for future mobility management activities;

- Conduct Formal Evaluation and Research Program - Install a system to collect data for evaluation, test alternative operating strategies for mobility management, and test optimization routines of the scheduling and dispatching software for system performance and cost impacts; and

- Fixed-Route Mobility Management Planing - Develop plans for an extension of the mobility management from human service transportation to include fixed-route transportation.

Northern Virginia

The Potomac-Rappahannock Transportation Commission has received funding through the IVHS Corridors Program to operate (as a test) an enhanced ridesharing-route deviation transportation system integrated with conventional transit and ridesharing in the Northern Virginia suburbs of Washington, DC (Prince Williams and Stafford Counties). This operational test will begin in 1994 and will last for over 2% years. The Advanced Ridesharing and Traveler Information System will provide on-demand service through an audiotex request system which uses scheduling software similar to that used by the taxi industry. Depending on the needs and preferences of the system user, door-to-door transportation will be provided using both publicly and privately owned vehicles operated by paid and volunteer drivers using vans, minibuses, specialized public vehicles, fixed-route buses, and taxicabs. Users will be charged a standard per-mile rate regardless of the type of vehicle used. System costs not recovered by fares will be covered by the local agencies. Smart cards will be used to process transactions. A dispatch center will be established and the necessary hardware will be installed in fifty vehicles. Technologies are expected to include AVL (GPS-based) and telephones initially. Interactive cable television and electronic bulletin boards are possible future enhancements to the system.

Other participating organizations include:

- Northern Virginia Planning District Commission - providing a geographic information system (GIS) for location/navigation/marketing services and project evaluation services;

- Virginia Department of Rail and Public Transportation - providing project oversight, site selection, and multimodal coordination;

- Gandalf Mobile Systems, Inc. - providing location and communication hardware and software;

- UMA Engineering Ltd. - providing fixed-route/route deviation and demand-responsive scheduling software and integration;

- Aegis Transportation Information Systems - providing route-deviation and single-trip ridesharing system design; and

- SG Associates - providing project management technical assistance.

2.4 INTEGRATED FARE MEDIA

Integrated fare media are tickets that can be used on more than one mode, such as a magnetic-stripe card that could be used for both bus and subway fares.

State-of-the-Art Summary

There are several North American transit systems that are utilizing integrated fare media that can be used on several modes being operated by different transit agencies. The most common application of integrated fare media involves the use of magnetically-encoded farecards for both bus and rail modes. In addition to the systems described below, the Washington, DC and Ann Arbor, Michigan systems, which also use integrated fare media are discussed in Section 2.5.

Applications

Oakland, California

The TransLink program is an effort by Oakland's Metropolitan Transportation Commission (MTC), San Francisco's Bay Area Rapid Transit (BART) District and the Central Contra Costa Transit Authority (CCCTA) to provide a magnetic-stripe farecard that can be used on CCCTA and BART buses and BART subways. The TransLink farecard is an adaptation of the BART magnetic-stripe stored-value farecard. It looks like a BART farecard with a different logo in the center but has two columns - one to record bus values and one to record rail values. The TransLink farecard does not expire.

At the time of the last State-of-the-Art Report, the TransLink program was in an operational test phase. This lo-week test, conducted in early 1992, was declared a success since the equipment only had three valid failures out of approximately 10,500 transactions.[26] Currently, TransLink is fully operational, with all 115 "County Connection" (CCCTA) buses and 45-50 BART Express buses equipped with on-board ticket validators.[27] These buses serve the suburban areas around five BART subway stations.

TransLink farecard distribution is being done manually. Pre-encoded farecards are being sold at supermarkets and banks in the Contra Costa area. Also, there is a sales booth in one of the five Contra Costa BART stations and one CCCTA sales location, which is a public outlet. The farecards cost $75 for $80 worth of rides and $30 for $32 worth. "There are additional discounts including as much as 75C on transfers from BART to BART Express or County Connection buses. "[28]

According to the MTC, new ticket vending machines will be developed and placed in five BART stations and in the major downtown destinations in Berkeley, Oakland, and San Francisco.[29] There will be one or two machines per station, for a total of about two dozen machines. These machines will accept credit cards, debit cards (automated teller machine (ATM) cards), and currency, but will not make change. The prototype machine was delivered in mid-July 1993. MTC is expecting that the final vending machines will be delivered by the end of 1993 or early 1994.

BART has over 300 fare gates, 10% of which are Cubic and the rest are IBM. The Cubic gates are being retro-fitted to recognize the new TransLink farecards, so that all BART fare gates will accept the new tickets.

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[26] "Stored Value Cards Emerging as Cashless Bus Tickets, *Passenger Transport*, November 23, 1992, p. 10.

[27] The on-board ticket validator is made by a French company and was derived from an implementation of the same equipment in Hong Kong.

[28] "San Francisco Bay Area Launches TransLink Joint Ticketing, *Passenger Transport*, May 3 1, 1993, p. 3.

[29] Joel Markowitz, Manager, Advanced Systems Applications.

"With the inauguration of the TransLink ticket, technical barriers to a truly universal ticket that could be valid on any San Francisco-Oakland Bay Area bus, rail, or ferry system have been overcome."[30]

Los Angeles, California

The Los Angeles County Metropolitan Transportation Authority (LACMTA) (formerly the Los Angeles County Transportation Commission) will be demonstrating a stored-value card fare collection system, called MetroCard, which is similar to the TransLink system. The demonstration project is a precursor to implementing a magnetically-encoded farecard to pay for any bus, rail, or transfer trip throughout Los Angeles County.

"Each bus and rail station would have a validator [similar to the validator used for TransLink], which accepts the MetroCard, deducts the appropriate value, prints the trip information, and returns the card to the user. When the fare is deducted from the card, it is recorded on the bus as each trip is taken.

"For continuing trips with transfers between buses in one property, between buses in different properties, or between modes of travel in the same or different properties, the fare deducted for the second and succeeding vehicles will automatically be adjusted in accordance with the fare structure agreements.

"The on-board validator will maintain the records of the fares collected from the cards, and when each bus returns to a garage, would download the recorded data into a personal computer. Each night a central computer would poll each garage to extract the values deducted, which would then be assembled by property and billed to the clearinghouse automatically. A duplicate record would be transmitted back to each property for audit purposes. A similar process would take place for the rail system."[31]

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[30] "TransLink Starts in Contra Costa," *Passenger Transport*, September 21, 1992, p. 4.

[31] "Stored Value Cards Emerging as Cashless Bus Tickets, *Passenger Transport*, November 23, 1992, p. 10.

This project was started in the spring of 1990. A decision was made in March 1991 to implement a magnetic-stripe, stored-value card rather than a smart card.[32] In December 1991, GFI was awarded the contract for the MetroCard system. The MetroCard demonstration will involve three transit agencies: Culver City Municipal Bus Lines, Foothill Transit, and the Southern California Rapid Transit District Pomona Bus Division.[33] In-service qualification tests were to begin in October 1993. One hundred passengers were selected for the sixty-day in-service test. A ninety-day reliability test was scheduled for December 1993. The test involves 315 sets of bus validation units (mounted on the side of the existing fareboxes), including 199 units on Foothill buses, thirty on Culver City buses, seventy on LACMTA buses, and sixteen spare units.

Eventually, it is hoped that MetroCard will be used as a one-ticket ride anywhere throughout the Los Angeles area, including bus, light rail (Blue and Green Lines), subway (Red Line), and commuter rail (Metrolink).

Advanced Fare Payment Media Study, Phase II

Phase I of the Advanced Fare Payment Media Study conducted by Echelon Industries, described in Section 2.5, concluded that various smart card technologies could be used for transit fare payment. Phase II will test several smart card technologies in the California cities of Gardena, Torrance, and Los Angeles, as well as an additional site or sites selected by the California Department of Transportation. As many as 25 vehicles will be equipped with smart card reader/writer equipment, and the vehicles will be operated in a variety of environments, including express and regular fixed route services.

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[32] Volkmer, William, Project Manager, Fare Debitcard Project, LACMTA, "The Los Angeles Metrocard Project: A Status Report - September 11, 1993," presentation to the 1993 APTA Fare Collection & Police/Security Workshop, Chicago, IL, September 11, 1993.

[33] Currently, LACMTA operates 2,300 buses over 200 routes. These buses are equipped with Cubic fareboxes. Foothill Transit operates 199 buses on 12-13 routes in the San Diego valley. These are equipped with GFI fareboxes. Culver City has 34 buses (with GFI fareboxes) that operate on 6 lines.

Ann Arbor, Michigan

A part of the proposed "Intelligent Transportation System" for the Ann Arbor Transportation Authority (AATA) is the development of a smart card system that will provide a dual transit fare/parking card to encourage automobile drivers to ride transit. AATA is recommending the use of a proximity smart card, with the capability of handling multiple fare categories and structures. AATA is proposing that the smart card be capable of handling two payment strategies: cash (value cards) and credit. AATA has proposed that information kiosks that are developed as part of their Intelligent Transportation System include the capability to issue and update smart value cards.

Chicago, Illinois

On September 8, 1993, the Chicago Transit Authority (CTA) board approved the purchase of a new revenue collection system based on magnetic stripe technology.[34] This system features a "stored-value" magnetic-stripe card, similar to that used in the WMATA Metrorail system. This card will be used on both the rail and bus system, and will include the capability to handle transfers.

The system, being installed by Cubic Automatic Revenue Collection Group, will work in the following way:[35]

- Riders purchase the farecards from vending machines that will accept currency and credit cards.

- Riders insert cards into rail turnstiles and bus fareboxes. The cost of the fare will automatically be deducted, and the time will be recorded.

- When riders transfer, the system will know to deduct only the cost of a transfer (30C) based on the time recorded.

- Once the cost of rides totals the purchase price of a card, it is no longer usable.

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[34] "CTA says it is going to hold line on fares in '94-at least for now," *Chicago Tribune,* September 9, 1993.

[35] "CTA plans smarter fareboxes," *Chicago Tribune,* September 8, 1993.

One unique feature of this system will be the ability of the turnstiles to accept coins, tokens, and monthly passes, as well as the new stored-value cards. Two rail stations will be used to test the new system in mid-1994. If the testing is successful, the whole system could be in place by late 1995. When fully installed, the system will cover CTA's 147 rail stations and 2,000 buses.

Also, CTA is considering a smart card system for use by the maintenance personnel who open the vending machines.[36] They would insert a smart card when opening a vending machine, and the time the machine was opened and their identification would be recorded on the card. When they close the machine, the time that it was closed would be recorded as well. CTA is also considering smart cards for their disabled riders.

New York City, New York

The New York City Transit Authority (NYCTA) is in the process of testing and implementing a new automated fare collection (AFC) system which is designed to replace the existing token system.[37] (The token system has been in existence for forty years.)[38] MetroCard, which is the fare media that will be used in the new system, is a plasticized farecard that has a magnetic stripe. The Cubic Automatic Revenue Collection Group's system is a read-and-write system, which allows for both time-based and stored-value transactions.[39] (This will allow the system to be upgraded to smart cards, eventually.) MetroCards will be swiped through the top of the new turnstiles in rail stations and will be accepted on the fareboxes on buses. MetroCards will be sold from the existing token booths and, in the future, will be distributed through vending machines located in the stations (to supplement token booth sales) as well as at outside distribution outlets.

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[36] Joe Simonetti, General Manager, Revenue Equipment Technology and Maintenance, Chicago Transit Authority.

[37] David Weiss, New York City Transit Authority.

[38] "The Coin of the Underground Realm: A Brief History, *The New York Times, Sunday,* July 25, 1993, Section E, p. 5.

[39] Dick Trenary, Vice President and Program Manager for Automatic Fare Collection, New York City Transit Authority.

Cubic was awarded the contract for the AFC system, and installation of the new electronic turnstiles began in October 1992.[40] Between January 20 and February 2, 1992, 1,887 people participated in a test of the system.[41] As of October 1993, the system testing was being expanded. Implementation in the first 69 rail stations has begun and will continue through March 1994. NYCTA is performing the installations, which involve re-powering the stations and modifying the communications system. The remaining 400 rail stations will be equipped beginning in April 1995 and continuing through the end of 1997. The test of the MetroCard system on buses is underway. Bus implementation will begin in June 1995 and be complete by February 1996.

Mississauga and Toronto, Ontario

Mississauga Transit and Government of Ontario (GO) Transit (commuter rail system in Toronto) are performing a demonstration test of electronic integrated fare media in the form of a proximity card. This demonstration test, involving Mississauga Transit buses and GO trains, will be performed in one commuter rail station that has feeder bus service (Clarkson).[42]

2.5 ELECTRONIC TICKETING AN-D AUTOMATED TRIP PAYMENT

Electronic ticketing involves the automated generation of tickets and automated fare collection. Electronic ticketing can be accomplished with the use of non-cash media, such as credit cards and/or debit (ATM) cards. Automated fare collection provides the capability to obtain authorizations for credit/debit card payments and to collect detailed information on revenue, passengers, and origins and destinations.

Automated trip payments are those payments made without a manual exchange of coins or bills. Often, electronic ticketing provides automated trip payment through the use of magnetically-encoded farecards or advanced card technology, such as smart cards. Advanced

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[40] "N.Y .'s First Turnstiles Installed For Automatic Fare Collection," *Passenger Transport*, January 4, 1993, p. 8.

[41] "N.Y. Subway Riders Satisfied With Electronic Fare System, *Passenger Transport*, May 4, 1992, p. 8.

[42] Brendon Hemily, Canadian Urban Transit Association.

card technology typically means plastic cards (credit card size) with a programmable memory chip that can be used for identification, trip payment, and other travel-related functions.

State-of-the-Art Summary

Electronic ticketing and automated trip payment are technologies that are beginning to be utilized in several transit agencies throughout North America. Frequently, these two technologies go hand-in-hand (i.e., electronic ticketing often provides automated trip payment through the use of advanced card technology or the more conventional magnetically-encoded cards).

According to APTA, the use of advanced fare systems is significant as shown in Figures 2.1[43] and 2.2.[44]

Applications

Chicago, Illinois

As reported in **the State-of-the-Art** - ***Update*** '92 document, the Regional Transportation Authority's (RTA) Payment and Control Information System (PCIS), was nearing completion of Phase 1 - system design and development. The system was developed by a team of vendors, lead by Applied Systems Institute, Inc. Phase 1 culminated in a two-week pilot test with 3-4 hand-held computers and smart cards that were kept on the vehicle (rather than issued to riders).

"Instead of recording rides with paper vouchers, PCIS prepares electronic trip records through the interaction of portable terminals carried by drivers and smart cards issued to eligible riders. Once a day, the electronic records stored in the terminals are downloaded to a central computer for reconciliation against the day's reservations. Routine transactions are processed

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[43] APTA, "Transit Fare Summary as of January 1, 1993", April 1993, pp. 20-68 to 20-69.

[44] Ibid, pp. 20-47 to 20-49.

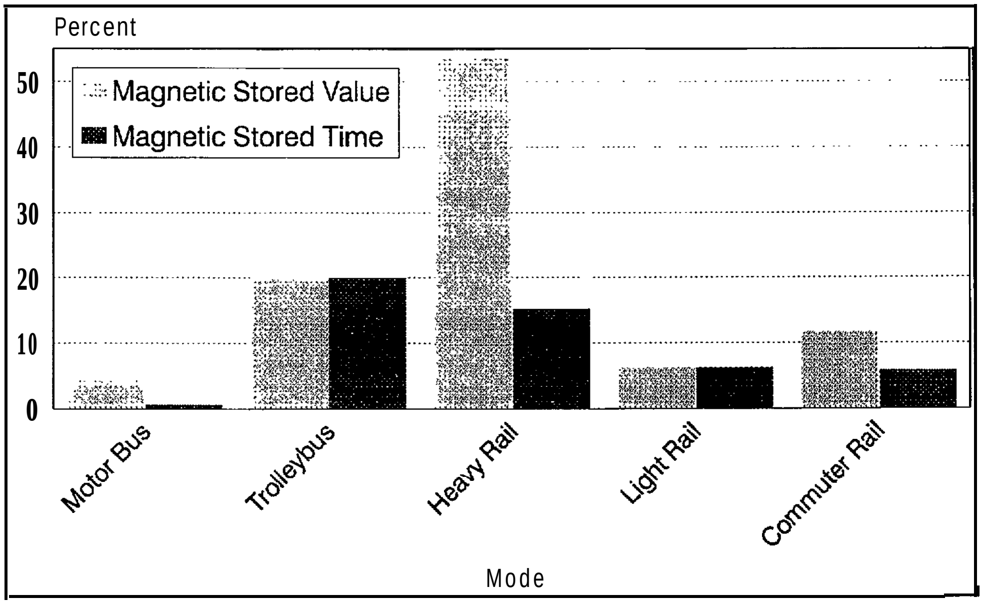

Figure 2.1. Percent of Systems Using Magnetic Farecards

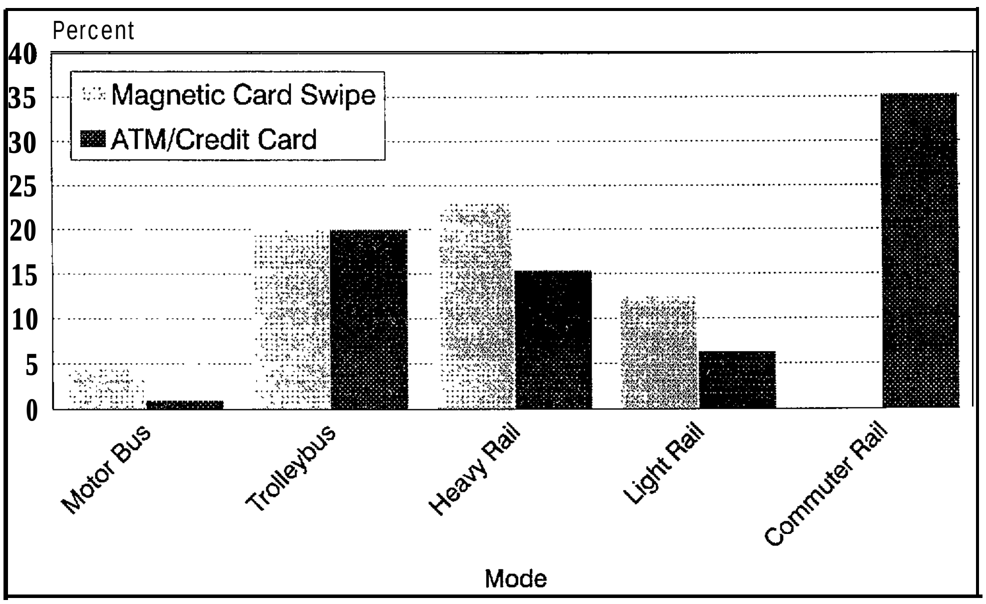

Figure 2.2. Percent of Systems Using Advanced Fare Equipment

for payment; late arrivals or trips without corresponding reservations are handled as exceptions."[45]

Phase II - implementation - began in January 1993 but has been interrupted while problems with the hand-held units are being addressed. In late 1993, RTA was to have a test using one carrier and be monitoring performance of the system.[46]

Washington, District of Columbia

WMATA is currently negotiating with Cubic to demonstrate a "proximity" smart card. This card could be used by holding it near a reader, rather than having to insert it.[47] The card, which will be used in the Metrorail system and on Metrobuses, will have the capability of being updated, and will have the capability to be used in parking lots.

The scope of this demonstration will encompass 5,000 passengers, fourteen Metrorail mezzanines, twenty-one buses, and fifteen parking lanes.[48] The card technology will be a radio-frequency (RF) contactless card which is serialized, battery-powered, and will handle multiple fare types (e.g., regular, student, elderly, disabled and employee fares). The current schedule is for the first rail station installation to take place in April 1994, the first bus installation to take place in August 1994, and the first parking lot installation to take place in November 1994.

Currently, WMATA is in the process of installing new farecard equipment, some of which will accept credit and debit cards. Farecards can be purchased with credit and debit cards at specific vending locations and with debit cards at certain ATMs. "NationsBank, which dispenses fare media for use on WMATA, issues fare media of a predetermined value from a cassette within the ATM."[49]

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[45] Ognibene, Peter J., "Role of Automated Identification and Fare Collection," *Passenger Transport*, July 13, 1992, p. 9.

[46] Rich Mizeria, Chicago Regional Transportation Authority.

[47] Peter Benjamin, Assistant General Manager for Finance, WMATA.

[48] Miller, David, Director, Systems Support, Cubic Automatic Revenue Collection Group, "Uniform Fare Technology Demonstration," presentation to the 1993 APTA Fare Collection & Police/Security Workshop, Chicago, IL, September 10, 1993.

[49] Franklin, Tom, "Fare Distribution Moves into the Next Century," Mass *Transit*, July/August 1993, p. 33.

Also, WMATA Metrorail farecards and Metro Flash Passes are available through TicketMaster. "The TicketMaster service permits customers to charge their purchases to their credit cards, and receive the selected fare media from TicketMaster by mail. An added advantage of the Fares-by-Phone program is that customers can subscribe to continuous, automatic delivery of Metro fare media with just one phone call, providing a level of convenience and accessibility previously unavailable."[50]

Long Island, New York

The Long Island Rail Road (LIRR) has eighty ticket vending machines (TVMs) in operation throughout their system (32 stations). Seven of these machines are manufactured by Agent Systems, and accept only Mastercard or VISA for the purchase of monthly and weekly tickets. They also have a touch screen for ease of use. The other 73 TVMs are manufactured by Scheidt & Bachmann. Most of these TVMS accept debit and credit cards as well as cash. These TVMs sell one-way, monthly and weekly tickets, and NYCTA tokens in groups of five.[51]

San Francisco Bay Area, California

The five new stations to be added to the BART system in 1995 will be equipped with automated Scheidt & Bachmann ticketing machines that accept credit and debit cards and dispense BART's magnetic farecards. Scheidt & Bachmann is also providing TVMs (that accept credit and debit cards) to some existing BART stations in order to add cashless payment options.[52] (See also discussion in Section 2.4 on BART TVMs.)

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[50] "WMATA Riders Can Order Fare Media from TicketMaster,' *Passenger Transport*, March 8, 1993, p. 7.

[51] Swanson, John, Manager, Automated Ticket Sales, LIRR, "Ticket Vending Machine Technology at the Long Island Rail Road," presentation to the 1993 APTA Fare Collection & Police/Security Workshop, Chicago, IL, September 9, 1993.

[52] Bruce Davis, Marketing Director, Agent Systems, Inc.

Currently, BART's disabled customers that need to use the elevators in BART stations are issued proximity cards. This smart card serves as an identification device, and it calls the elevator for the passenger.[53]

Northern Indiana

The Northern Indiana Commuter Transportation District (MCTD), the owner and operator of the South Shore Line, is implementing a ticketing system based on bar codes to replace the 60-year-old manual process of issuing and printing tickets. "New point-of-sale terminals will automate all aspects of the South Shore's ticket agents' duties. The computerized point-of-sale system eliminates the burden of printing and inventory control required with 95 different ticket types for a manual sales system. It also has audit and reporting advantages allowing for daily balancing and instantaneous retrieval of daily activity reports by transaction.

"Ticket identification and printing security are other advantages of computerization, making revenue collection more secure. Counterfeiting is deterred because the point-of-sale hardware controls the printing on each ticket. With the aid of a computer program, each ticket is uniquely identifiable with a bar code imprinted on the ticket at the time of its issue. There is no duplication of this bar code. The bar code identifies who sold the ticket, where it was sold, and other attributes. This makes it impossible for someone to counterfeit the ticket because they would have to know what the security code is at the time of issue. Metallic inks are printed as background on valueless ticket stock providing another means of ticket security.

"The computerized system also enables [MCTD] to monitor conductor remittances and parking fees collected at stations. This provides MCTD's transportation and accounting departments with useful information about railroad activity. It also provides an accurate count of passenger activity between stations. "[54]

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[53] Larry Kozimor, Program Manager, Automatic Fare Collection Systems, BART.

[54] Matakovic, Boris, "Northern Indiana Automates South Shore's Ticket System," *Passenger Transport,* June 7, 1993, p. 25.
Matakovic, Boris, "Collection by Digital Means," *Mass Transit,* Volume XIX, No. 4, July/August 1993, p. 32.

Ann Arbor, Michigan

The Ann Arbor Transportation Authority (AATA) will be developing an Intelligent Transportation System (ITS). The ITS will implement and integrate several advanced transit technologies, such as on-board vehicle and central control systems, farebox, destination sign, enunciator, smart cards, adaptive signal control, and computer-aided dispatching (CAD).[55] As of October 1993, the proposals submitted in response to the request for proposals for the ITS were in the process of being reviewed.

The overall ITS will have the following components:

- Operations Center Information System
  - Communications
  - Information storage and retrieval
  - Computer-Aided Dispatch

- Vehicle System
  - Vehicle Network System
  - Peripheral Devices
  - Vehicle status

- Traveler System
  - Information services
  - Smart cards

The ITS proposes the use of a proximity card as the preferred smart card technology. The smart card will be used for passenger identification as well as fare collection. The card will be capable of handling multiple fare categories, various pricing strategies, two payment options (pre-paid and credit), and changes in fare schedules. In addition, the card will be capable of multi-modal use - parking and transit. This is extremely useful for people who take transit to work some days and drive on others.

[55] JRL, Associates, Inc., "Request for Proposals #276 Intelligent Transportation System," prepared for the Ann Arbor Transportation Authority, pp. 79-82.

Minneapolis/St. Paul, Minnesota

The Regional Transit Board (RTB) is evaluating the potential of smart cards to improve paratransit service. RTB contracted with the Applied Systems Institute (ASI) to perform this study, which began in August 1992. As of September 1993, the project was near completion.

AS1 performed the following tasks as part of this effort:

- Evaluation of Metro Mobility Requirements,
- Review and Evaluation of Available Technologies,
- Definition of Operating and Management Procedures,
- Recommendation of Preliminary System Design,
- Development of Plans and Specifications for System Implementation, and
- Development of Evaluation Plan.

A final report detailing the results of this study was expected to be available in the last quarter of 1993.[56]

Northern Virginia

Since June 1992, the Virginia Railway Express (VRE) has used Schlumberger credit/debit card ticket vending machines (TVM 2000) for fare collection. They have had success with the equipment and a 'proof of payment' fare collection system. Fare evasion was less than 1/4 of one percent, and its automated information and ticket ordering systems produced additional savings.[57]

The VRE currently is testing a pre-production model of Schlumberger's TVM 5000 at Union Station in Washington, DC.[58] (This is the same vending machine that is being installed in Buffalo, Memphis, and Tallahassee.) The TVM 5000, an extension of the TVM 2000, accepts credit and debit cards, coins, and bills.

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[56] Peter Ognibene, Applied Systems Institute, Inc.

[57] Waldron, Thomas R., "Virginia Railway Express Nears First-Year Mark," *Passenger Transport*, April 19, 1993, p. 19.

[58] Cameron Muhick, Supervisor, Ticket Vending, Virginia Railway Express.

VRE, along with Schlumberger, is currently designing the next stage of the TVM 2000.[59] The new TVM 2001 is ADA compliant. It is expected that there will be one TVM 2001 located in each VRE station. It is likely that this ADA compliant machine will give voice instructions along with Braille.[60]

VRE is also examining the possibility of supplementing the TVMs at heavier vending locations with Ticket Issuing Machines (TIMs). TIMs are clerk-operated, countertop machines like state lottery ticket-issuing machines, but with TVM features that the clerk could use to issue tickets to customers. Any fare type and combination could be issued from this machine. VRE is planning to strategically place these machines in each fare zone. It is hoped that the TIMs will be tested during 1994.

Boston, Massachusetts

Within the next two years, the Massachusetts Bay Transportation Authority (MBTA) will be eliminating the use of tokens by implementing an automated fare collection system. This new system will be implemented across the bus, rapid rail, and light rail systems. In May 1993, three different electronic farecard systems were demonstrated at three MBTA rail stations to obtain passenger opinions and other data. The three fare collection systems were:

- Farecard swiped through the top of an electronic turnstile;
- Farecard entered into one end of the turnstile, and it comes out on the other end; and
- Farecard held up to a "proximity reader".[61]

Passenger opinion was favorable on all of these advanced fare collection technologies, although none of them stood out above the others. According to the MBTA,[62] this new system will be seamless between all modes (except commuter rail), will employ read-write entry turnstiles, and will include ticket vending machines.

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[59] Bertrand Moritz, Marketing Manager, Schlumberger Technologies.

[60] Howard Shock, Consultant to the Northern Virginia Transportation Commission.

[61] "MBTA officials will soon choose from 3 automated fare systems," The ***Boston Globe,*** May 9, 1993.

[62] Brown, James, Chief Revenue Officer, MBTA, "Revenue Services Management," presentation to the 1993 APTA Fare Collection & Police/Security Workshop, Chicago, IL, September 11, 1993.

Delaware

The Delaware Department of Transportation has been selected by the U.S. Department of Transportation under the IVHS Operational Test Program for a field operational test of smart cards. The Smart Delaware Authority for Regional Transportation project involves testing smart cards in their entire fleet of 128 urban transit buses. The purpose of this test is to introduce smart cards as fare instruments and as a means for local employers to offer their employees one payment/identification mechanism for a variety of work site services. Employers could offer the smart card to their employees as electronic fare for the bus system (which qualifies for state and Federal tax credits), as an identification device, as an access card (if the work site has limited access locations), as a payment mechanism for cafeteria meals, etc. As a fare payment device, this smart card could be a significant part of the employer's employee trip reduction (employee commute option) program, which must be submitted in January 1994. As of September 1993, three employers had stated their interest in participating.

The employers will make the smart cards available to their employees and will coordinate with the smart card vendor through the transit system. There will be a financial clearinghouse function, and the cards will serve either as a debit or credit card for the transit fare, depending on which option the employer chooses. The fare will be electronically removed from the employee's card. Likewise, an electronic transfer from the employee's account will be used to replenish the card's stored value or to pay for charged trips.

Recent developments in the smart card industry has caused the Delaware DOT to reassess the smart card options. As of September 1993, the selection of smart card technology had not been made. [63]

New Jersey

New Jersey Transit (NJT) has an innovative approach to fare collection on buses that operate out of the Maplewood Bus Garage. At the start of each bus operator's shift, the operator swipes their identification (ID) card through a reader, and enters their employee ID

[63] Wayne Spaulding, Assistant Director, Program Development, Delaware Transportation Authority. Bee Buergler, Senior Associate, JHK & Associates.

number and the route that they will be working. A personal computer (PC) then downloads fare structure information on that particular route to a small module that is physically inserted into the automated farebox on the operator's bus. This unit gives the farebox "intelligence." For example, the farebox knows that if the operator indicates that the person paying the fare is an adult, the correct fare is $1.00. If the farebox receives 90c, it will not allow the bus operator to issue a ticket to the adult until the $1.00 has been deposited into the farebox. Also, the operator communicates with the operations center at the Maplewood facility through a Motorola unit that has a keypad and display unit. The operator indicates to the unit when a run is starting, when a run is finishing, etc. This information is used along with their AVL system to pinpoint exactly where any vehicle is at any given time.[64] (More information on NJT's AVL system is contained in Section 3.1.)

California

The State of California, Department of Transportation (Caltrans), in partnership with the FTA, will develop and implement a field operational test of a computerized system capable of integrating various advanced fare media technologies and processing systems. Echelon Industries' work on the Advanced Fare Payment Media Study, Phase II, is an integral part of this field operational test. (See Section 2.4 for a description of the Echelon project.) Tests will demonstrate on-board electronic transit fare and data collections, and on-site travel support services, such as congestion and parking management. The project will investigate systems applications, fare reciprocity among service providers, and real-time operational funds allocations and transfers. Evaluations of the tests with regard to operational and behavioral characteristics will be conducted by an independent university team.

Following the tests and evaluations, issues and applications will be recommended for further research and problem-solving to increase the potential for a viable inter-agency, multi-modal use of smart cards leading to seamless travel. Future activities include integrating

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[64] Sharish Gupte, Director of Operations System Development, New Jersey Transit

electronic advanced fare media with travel services, consumer choice of payment methodologies, and the development of national or regional travel passes.[65]

Department of Health and Human Services Ride Tracking Project

The Department of Health and Human Services (DHHS) is sponsoring a project to research, develop, and market a universal system for DHHS and urban and rural public transportation systems which would track passenger trips automatically, calculate discount fares, process fares, and transfer data to accounting for billing and market analysis. This "Bide Tracking Project" is being conducted by Information Management International, Inc. (IMI) in cooperation with the International Public Works Federation and several hardware manufacturers. The project uses low-cost technology and is to be compatible with existing fare processing methods (e.g., cash, token, paper tickets, debit cards, and credit cards).

Initially, the project will track DHHS-subsidized trips by persons with physical and mental disabilities and possibly other participants in DHHS programs. The system could ultimately identify vehicle locations, transmit vehicle and passenger data to traffic management, and deliver information to drivers and passengers. The project is in the second of three phases:

- Develop concept and design (conducted from June to December
- Engineer and test prototypes, and
- Commercialize proven products.

As part of this project, IMI developed an electronic identification card that is usable by most transportation systems, whether they employ manual or automated fare collection. Each card includes an identification picture, magnetic stripe (and/or integrated circuit), contact (and contactless/proximity) port, printed and embossed (or Braille) name and expiration date, and orientation detector. Cards issued for general trips can be processed by readers at transportation facilities. Cards issued for special purpose trips must be activated first by readers at service facilities, where users are authorized to obtain services. Security measures include incremental activation so that a card only can be used by one person at a time. The system also handles

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[65] California Department of Transportation, "CALTRANS Automated Transit Pass 'Smart Card' Project," write-up provided on August 11, 1993.

multiple subsidy programs by one or more sponsors. In addition, the system is designed so that it can either be used in conjunction with existing fare processing methods or integrated into health security cards or other new electronic technologies. This system has yet to be applied in regular use.[66]

Transit Cooperative Research Program - Fare Policies, Structures, and Technologies

The Transportation Research Board (TRB) recently awarded a Transit Cooperative Research Program (TCRP) Project on Fare Policies, Structures, and Technologies to Multisystems, Inc. "The objective of this project is to provide guidance for use by large and small transit agencies in developing and implementing fare policies to meet their social, financial, and service needs. This project should produce:

- an evaluation of alternative fare structures;
- a review of current and emerging fare-collection and media-distribution technologies;
- an analysis of relationships between fare policies, structures, and technologies; and
- techniques and guidelines to enable transit agencies to evaluate appropriate structures and technologies in making fare-policy decisions."[67]

Phase I of this project, which involves a "state-of-the-art review," is underway.[68] The product of this phase of the project will be a preliminary analysis and evaluation of the interrelationships among fare policies, structures, and payment/collection technologies.

Canada

Various locations in Canada have implemented or will be implementing electronic ticketing and automated fare payment systems.[69]

- In Niagara Falls, Ontario, Niagara Transit has implemented a magnetic-stripe stored-value card using Cubic's Fast Fare Processor system. This system has an "electronic

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[66] Robert Tanenhaus, President, Information Management International, Inc.

[67] TRB, Transit Cooperative Research Program: Research Project Statement, TCRP Project A-l, FY '92, "Fare Policies, Structures, and Technologies."

[68] Daniel Fleishman, Multisystems, Inc.

[69] Brendon Hemily, Canadian Urban Transit Association.

transfer system, " which uses encoded magnetic-stripe transfer cards, issued on the first vehicle, and validated on the second.

- In Ajax, Ontario, Ajax Transit has a smart tag system that has been in place for two years. This system checks for an ID number that indicates that a monthly transit pass was purchased. In the first year of operation (1991), the system only handled student IDS. Currently, the system has been extended beyond the student population.

- In Burlington, Ontario, Burlington Transit has purchased optical card readers as part of a monthly-pass validation system.

- The Societe de Transport de L'Outaouais in Hull, Quebec is purchasing a proximity card system.

IC/Smart Card and RF Communication Industry Study

The Volpe Center supported a study, Phase I of which was completed in February 1993 that examined the smart card industry. The objectives of this study, which was performed by Coopers & Lybrand, included a review of smart card industry suppliers (including component manufacturers, system developers, and system integrators) and the assessment of smart card technology focusing on the non-contact RF/ID segment.[70]

This study involved the following tasks:

- Assemble background information,
- Segment industry,
- Identify potential product suppliers,
- Establish evaluation criteria,
- Identify issues,
- Conduct interviews, and
- Summarize findings.

The issues and influencing factors suspected to impact system design and operation were divided into four areas in the report, The following issues were covered:

- Technology Component Issues
  - Communications
  - Location of system intelligence

[70] Coopers & Lybrand, **IC/Smart Card and RF Communications Industry Study,** Final Report, prepared for the Volpe Center, March 5, 1993, p. 1.

- Electrical power
- security
- Centralized vs. decentralized
- speed
- Growth

- System Issues
  - System integration
  - Single vs. multiple technology approach
  - Proprietary vs. non-proprietary considerations
  - Developing new solutions
  - Points of failure
  - Availability and maintainability
  - Ease of use
  - Complexity of system

- Application Issues
  - Environmental concerns
  - Route adherence
  - security

- External Influencing Factors
  - Standards
  - Environmental

Each issue was discussed, and several key questions and points were raised for consideration by agencies about to implement systems and for future research.

Multi-Use Remotely Interrogated, Stored-Data Cards for Fare and Toll Payment Study

The FTA, through the Volpe Center, is sponsoring a study of multi-use smart cards for toll and fare payment. This study, which is being performed by Coopers & Lybrand, consists of three tasks:[71]

- Survey of existing stored readable/writable data card systems technology for fare and toll payment or other applications, including:
  - Conducting data card industry research
  - Conducting transit systems and applications research
  - Conducting external factors research

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[71] Coopers & Lybrand, "Multi-Use Remotely Interrogated, Stored-Data Cards for Toll and Fare Payment," presentation to the IVHS America APTS Smart Card/Smart Tag Systems Working Group Meeting, June 29, 1993.

- Analysis and development of system requirements for a stored-data multimodal fare and toll card system, including:
  - Collecting user needs and expectations
  - Performing analysis

- Design of conceptual prototype, including:
  - Prototype system design
  - Design analysis

A draft of the first tasks's final report was submitted to the Volpe Center for review in August 1993.

Advanced Fare Payment Media Study

In 1992, Echelon Industries performed a feasibility study of advanced fare payment media for the public transit industry (under a Small Business Innovative Research Phase 1 grant), This study:

- Reviewed advanced fare media technologies, vendors, and transit and other applications;
- Surveyed the transit industry to determine:
  - Fare collection equipment currently in use,
  - Type and frequency of fare classification surveys,
  - Type of fare media currently used,
  - Type of fare structures in use,
  - Perception of change in ridership with advanced fare payment media,
  - Current average system fare,
  - Current cost of fare collection,
  - Acceptable costs for advanced fare payment media systems,
  - Acceptable transaction times,
  - Importance of data provided by advanced fare payment media,
  - Importance of various operational parameters, and
  - Constraints to implementing an advanced fare payment media system;
- Interviewed several transit and related agencies; and
- Determined a preferred strategy for implementing an advanced fare payment media demonstration.

In the first step of this last task, Echelon recommended that a demonstration be structured such that the technology or system elements that are most questionable are tested, taking into account the defined needs of the industry. Further, four generic applications for advanced fare payment technologies were suggested: the corporate card, the basic card, the advanced fare card, and passenger transaction systems. These alternatives would then be evaluated

In the second step, Echelon suggested that selection of a fare payment system be based on the problems or concerns, rather than on the size or function of the operation. For the most comprehensive demonstration program - a passenger transaction system - Echelon identified subsystem elements (user interfaces, on-bus systems, central control, etc.).

Once the demonstration program and card systems are selected, the specific card type/technology would be selected. Echelon identified fare card technologies (e.g., contact, contactless, RF) and fare cards (corporate, basic, etc.) in terms of transit needs.

The final step in selecting the card type/technology would involve the examination of costs. Echelon identified fourteen subsystems and estimated per unit cost for each subsystem by card type.[72]

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[72] Echelon Industries, **Inc., Advanced Fare Payment Media for Public Transit: A Feasibility Review,** Final Report, prepared for SBIR Phase 1 Contract DTRS-57-92-C-00030, July 1992.

3. SMART VEHICLE TECHNOLOGY

The "Smart Vehicle" incorporates many of the vehicle-based APTS technologies and innovations for more effective vehicle and fleet planning, scheduling, and operations. Whereas Smart Traveler technology focuses on passengers and directly increasing the ease and convenience of using transit (the "demand side"), Smart Vehicle technology focuses directly 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,
- Automatic Vehicle Location,
- Transit Operations Software, and
- Automated Demand-Responsive Dispatching Systems.

3.1 COMMUNICATIONS SYSTEMS

Telecommunications technology development is in a growth period. A major stimulus for this growth is a need to make better use of the crowded electromagnetic spectrum to accommodate ever growing communication needs.

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. The benefits Smart Vehicle concepts will bring to public transportation will depend upon effective communications.

Whether existing communications capabilities and spectrum can support these additional communications requirements is subject to review and analysis at this point.

State-of-the-Art Summary

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

- Bus and control center communications
    - Voice
    - Data - AVL, APC, Mechanical Health
    - Emergency

- Revenue systems
    - Fare payment
    - Auto toll payment

- Park & ride operations

- HOV/Express Bus Lane access

- Adaptive signal systems

- Intermodal communications

- Workplace/home transit & intermodal information

- Wayside/transfer center transit & intermodal information

- On-board information

Presently, public transportation mainly uses conventional land mobile communication services. The additional requirements brought about by the introduction of IVHS technology to public transportation, make it unlikely currently utilized communications and spectrum capability will meet these new requirements. This will be especially true for the transition period when IVHS technology will be phased in, but current operations must continue uninterrupted.

Alternative communication approaches will be necessary for the smart public transit vehicle functions noted. Some of these alternatives include:

o 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 radio data system (RDS): Traffic and other information can be transmitted in frequency sidebands of commercial FM radio stations.

- Personal communication services (PCS): PCS services are 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.

Of all the APTS functions noted which will require communications, by far the most critical function is the bus/control center link. Most systems which radiate energy must be licensed by the Federal Communications Commission in terms of their use of the electromagnetic spectrum. Many of the functions can be satisfied by low power unlicensed electromagnetic devices. However, the bus/control center link requires communications coverage over a metropolitan area, which dictates a licensed service.

The bus/control center communication requirement for traffic advisories may be satisfied by broadcast services instead of direct dedicated communications links. Typically, 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 RDS. Such approaches, while operational in Europe, are for the most part only at the conceptual stage in this country.

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

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 smart 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 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 example of this approach. 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 3 to 15 times for digital cellular systems.

Applications

Other than trunked communications systems, current applications of new communication technologies are limited. Such activity is expected to grow in the future.

3.2 AUTOMATIC VEHICLE LOCATION SYSTEMS

Automatic Vehicle Location (AVL) systems are computer-based vehicle tracking systems. Initially used for military purposes, they are now used extensively to monitor transit and trucking fleets and are beginning to be used to monitor police cars and ambulances. In transit applications, the system measures the actual location (real-time position) of each vehicle. The actual location can be compared with its expected position (based on the schedule) and this information relayed to the central base station or dispatching center. The potential for improving on-time schedule performance and data collection is evident. Data generated over a period of time can be used to adjust schedules and routes and be used for planning and management activities. This should result in more efficient and reliable transit service.

Real-time vehicle location also provides the basis for additional benefits for a transit operation. A silent alarm can be activated by a driver in an emergency and police (or other emergency services) can be dispatched immediately to the location of the bus. AVL can be linked to Automated Traveler Information Systems by providing exact updates on the location of the vehicles. This can be conveyed through pre-trip information systems (e.g. automated telephone), or through monitors in terminals or at transfer points. The system may be connected to vehicle component monitoring, so that conditions out of tolerance may be flagged, and dispatch alerted. This allows a bus in danger of breaking down to be removed from service before costly repairs are required or passengers are inconvenienced. Bus location information could be combined with automatic passenger count data, and communicated to the dispatch center in real time. The dispatch center could include the approximate load of the next couple of buses to arrive, along with their arrival times, in wayside passenger information systems.

Passengers could then choose to wait for a less-crowded bus. Bus location information could also be used for automated actuation of traffic signal preferential treatment for buses so late buses can be granted priority to catch-up to schedule.

Rail services have been using a form of AVL for many years. Given fixed guideways and uniformity of vehicle size it is possible to identify vehicles when they pass points where sensors have been located. Communications are also simplified with rail since there is a dedicated right-of-way in which to place wires and therefore no need for complicated radio systems. For buses, conversely, the task of tracking buses along city streets and in urban canyons is far more difficult.

The primary components of any AVL system are:

- A method of position determination,
- A means of communication with the dispatcher in real time, and
- A central processor capable of storing and using transmitted information.

Addressing each of these components involves a number of critical decisions that must be made in light of the objectives of an individual bus system, what it wishes to gain from an AVL system, and the level of resources available, both financial and human. In response to a survey conducted in February 1993 by Trimble Navigation, most transit authorities indicated an interest in the following:

- Improved schedule adherence,
- Maximum driver and passenger safety,
- Better vehicle utilization, and
- Real-time rerouting capability.

These can be addressed with AVL. However, the cost of an AVL system is a major concern, especially' for small and medium-sized systems.

State-of-the-Art Summary

There are several types of AVL systems in existence (categorized by location technology):

- Signpost /Odometer,
- Radio Navigation/Location, and
- Dead-Reckoning.

The most common form of AVL applied to transit continues to be the signpost/odometer system, which involves a series of beacons along the bus routes. These are normally mounted on utility poles and send out a low-powered signal which can be detected by a vehicle fitted with a receiver. The signposts each have their own ID, so when the vehicle relays each signpost's ID to the control center, the dispatcher knows the position of the vehicle. The signposts are spread throughout the system and the vehicles' progress between them is calculated, using an odometer that measures wheel rotation.

This 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, which limits the potential for making major changes in bus routes or could require the installation of a large number of signposts. Several major bus systems are in the process of installing signpost/odometer systems, primarily because of the reportedly lower cost of the equipment involved.

Ground-based radio systems include Loran-C (Long Range Aid to Navigation). 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. Baltimore, which has a Loran-C system operating, is now moving to GPS. Champaign-Urbana, Illinois, which had an early Loran-C system, abandoned it four years ago.[73]

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

[73] Jim Dhom, Champaign-Urbana Mass Transit District.

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.

An increasing number of transit operations are moving towards the space-based Global Positioning System (GPS). 24 U.S. Defense Department GPS satellites have been deployed, and are available for civilian purposes. Three are test satellites and will soon be lost; however, they will be replaced. There is no charge for use of the satellite signals. This technology offers the flexibility which is not available with signposts. The concern with this type of system rests primarily with the newness of the application to large scale transit operations. To date, no North American city has a fully operational GPS tracking system for its transit operation. Several cities are either in the planning phase, conducting operational tests, or installing such systems system-wide. Given the flexibility involved with GPS, it is now possible to consider application to demand-responsive paratransit systems where the primary motive is increased efficiency of service and improved vehicle allocation. Rural public transportation systems are also considering use of GPS to monitor vehicles in remote areas.

A number of technological issues are being addressed. These include: the level of accuracy required and provided, reliability of position reporting, frequency of polling, selection of communication devices, and selection of display systems. With the U.S. military employing selective availability (SA) of the satellites, which results in decreased position accuracy, a number of transit operations are considering 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. Concerns about consistency of SA with GPS in "urban canyons" is leading transit systems to add dead-reckoning to supplement GPS tracking systems.

The limited number of radio frequencies available in many urban areas has proven difficult for many transit agencies. This has dictated polling rates for AVL systems and led some transit systems to consider "exception reporting," i.e., the bus will only report its position to central dispatch if it is off schedule. Otherwise, the dispatcher assumes the bus is on schedule.

The issue of map display systems is one that a number of operations are weighing against cost. The U.S. Census Tiger files, although "free," require considerable editing in order to be usable for transit. The number of map production companies and GIS software vendors continues to increase. The challenge is to select a viable system that will display the vehicle position and still fit within the agency's budget.

Applications

Table 3.1 contains a listing of known transit AVL systems or plans in North America, as of September 30, 1993. A representative sample of applications using the various technologies follows.

A. Signpost/Odometer

Halifax, Nova Scotia

Metro Transit has all 168 of its vehicles equipped with magnetic wheel sensors that respond to a signpost AVL system. This AVL system has been operating since 1987. Location data is generated every eighth rotation of a tire, is gathered by an on-board microprocessor, and is transmitted to the dispatch center by way of radio relay every thirty seconds during peak time. Two radio frequencies are available: one for digital data, the other for voice. The system also has the capability of providing for passenger counting and monitoring the buses' mechanical systems.[74]

[74] Moss Mombourquette, Metro Transit, City of Halifax, Nova Scotia.

Table 3.1 North American Transit AVL Systems

City, State/Province	Vehicles	$M	Status (as of 9/30/93)	Principal Contractor	Location	Freq.	Poll
Ann Arbor, MI	*67/67*		*In Bid Process*				
Baltimore, MD	*235/1200*		*RFP Out*		GPS		
Urbana, IL	69/69		*Abandoned*	II Morrow	LC		
Chicago, IL	*?/*1900		*In Second Round of Bidding Process*			8	
Dallas, TX	*1200/1300*		*Resolving Software Issues*	ElectroCom	GPS	*8/3*	*
Denver, CO	*833*/833	10.4	Installation/Resolving Additional Issues	Westinghouse	GPS	?/2	*
Fort Lauderdale, FL	192/192	2.3	*System Installed/Resolving Issues*	Motorola	SO	2/1	*
Halifax, Nova Scotia	168/168	1.0	In Regular Use	(agency)	SO	1/1	30
Hamilton, Ontario	284/284	6.0	In Regular Use/*Resolving Additional Issues*	RMS Ind Controls	DR	3/1	30
Houston, TX	1000/1000		Designing/Building System	(agency)	GPS		
Hull, Quebec	162/162		*In Regular Use*	(various)	SO		
Jacksonville, FL	*0*/180		*Withdrew Plans for AVL*				
Kansas City, MO	*275/275*	2.1	In Regular Use/*Under Re-assessment*	F & M Global	SO	1/1	15-30
Louisville, KY	*300/300*	*2.5*	*Installation to begin early 1994*	*Glenayre*	*SO*		*40*
Miami, FL	*550/550*		*Install. about to begin/Operational late '95*	*Frederick R. Harris*	GPS		*120*
Milwaukee, WI	550/550		*Under Installation*	Westinghouse	GPS	2	*
New Jersey Transit	1900/1900	*8*	*Pilot Test in Progress with 300 Buses*	Motorola	SO	*25/3*	

Sources: the agencies; Pekilis, B. and G. I-leti, Automatic Vehicle Location and Control Systems for Small and Medium Ontario Transit Properties: Phase I Report (Final), Transportation Technology and Energy Branch, Ontario Ministry of Transportation, January 1992.

Text in italics represents new information since the last state-of-the-art report.

Key:

Vehicles - Number equipped/Number owned

$M - System cost in millions of $, when purchased. US Agencies - US$, Canadian Agencies - Canadian $.

Location - The location technology: SO - Signposts + Odometer; ***LC*** - LORAN-C; ***GPS*** - Global Positioning System; ***DR*** - Dead Reckoning + signposts; GBR - Other Ground-Based Radio.

Freq. - The number of frequencies dedicated: numbers in the format ***a/b,*** indicate ***a*** voice channels and ***b*** data channels.

Poll - Time between polls (seconds). * = exception reporting strategy employed.

Table 3.1 (con't) North American Transit AVL, Systems

City, State/Province	Vehicles	$M	Status (as of 9/30/93)	Principal Contractor	Location	Freq.	Poll
Norfolk, VA	151/151	2.0	In Regular Use	F & M Global	SO		40
Ottawa, Ontario	*825/825*		*Testing*	Amtech	SO	*Phne*	*
Palm Beach, FL	*59/74*	1.2	*In Regular Use*	Motorola	SO/*Teletrc*	3/1	60
San Antonio, TX	531/531	3.7	In Regular Use / Examining Pot. Upgrades	General Rwy Signal	SO (GPS?)	2	60
San Mateo, CA	320/320		*Final Testing*	Motorola	SO	3/1	
Santa Monica, CA			*In Regular Use*	*Teletrac*	*GBR*		
Scranton, PA	*30/30*		*To Begin Installation Soon*	*AutoTrac*	*GPS*		
Seattle, WA	1341/1341	17	*In Regular Use/Resolving Additional Issues*	Frederick R Harris	SO	2	
Sheboygen, WI	20/33	0.1	In Regular Use	II Morrow	LC	3	10-20
Tampa, FL	162/162	1.6	*In Regular Use/Fine Tuning*	Motorola	SO	3/1	*120**
Toronto, Ontario	2300/2300	38	In Regular Use	Bell Radio	SO	11/31	6

Sources: the agencies; Pekilis, B. and G. Heti, Automatic Vehicle Location and Control Systems for Small and Medium Ontario Transit Properties: Phase I Report (Final), Transportation Technology and Energy Branch, Ontario Ministry of Transportation, January 1992.

Text in italics represents new information since the last state-of-the-art report.

Key:

Vehicles - Number equipped/Number owned

$M - System cost in millions of $, when purchased. US Agencies - US$, Canadian Agencies - Canadian $.

Location - The location technology: SO - Signposts + Odometer; ***LC*** - LORAN-C; ***GPS*** - Global Positioning System; ***DR*** - Dead Reckoning + signposts; ***GBR*** - Other Ground-Based Radio.

Freq. - The number of frequencies dedicated: numbers in the format ***a/b,*** indicate ***a*** voice channels and ***b*** data channels.

Poll - Time between polls (seconds). * = exception reporting strategy employed.

Kansas City, Missouri

The Kansas City Area Transportation Authority, which has had a signpost/odometer system installed since 1989, has experienced considerable benefit from the system. Schedules have been fine tuned, and on-time performance has increased substantially to over 90 percent. Yet the system has also had its share of challenges. The cost in personnel time required for system installation and the continuing cost of maintenance of the individual beacons on utility poles has been considerable. Most vexing has been software maintenance since the vendor which installed the system (F&M Global Communications) is no longer in business. Kansas City is currently reassessing its system and existing options.[75]

Norfolk, Virginia

A similar system is operating in the Tidewater Transportation District in Norfolk, Virginia. Like Kansas City, the system was developed by F&M Global Communications and uses a signpost/odometer system. The 151 vehicles in the fleet are polled every forty seconds and information is transmitted over dedicated radio frequencies to the central control facility. The system also includes a silent alarm and monitors brake air pressure, engine temperature, and oil pressure.[76]

San Antonio, Texas

The VIA Metropolitan Transit System uses a signpost/odometer system on all 531 fixed-route buses in its fleet but not on its paratransit vans. The system, which has been in operation for six years, uses two radio channels for voice and data and polls each vehicle at sixty second intervals. Buses have emergency notification systems but no passenger counters. VIA is concerned about the heavy maintenance expenses associated with their system and its software.

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[75] John Dobies, Director of Transportation, Kansas City Area Transportation Authority, presentation at Midwest Regional IVHS Conference, September, 1993.

[76] Turnbull, Katherine, "The Use of Information Generated from Transit AVL Systems," *Proceedings of the IVHS America Annual Meeting 1993*, pp. 82-88.

They plan to install GPS on the complementary paratransit system and, subsequently, reevaluate the fixed-route system as to potential conversion to GPS.[77]

Ottawa-Carleton, Ontario

The Ottawa-Carleton Regional Transit Commission AVL system is in the post-prototype phase, but is still under development. The system uses signposts with sensors installed on all 825 buses. Detectors are located on utility poles along an exclusive transit way. Signals are sent to the depot via telephone lines. The depot does not poll the vehicles on a regular basis; rather, the system operates by "exception reporting," whereby a vehicle only reports its location if it is not running on time. Otherwise the central computer assumes the vehicle is at its scheduled location. Drivers are notified via radio if their bus is running late, which is the only action taken. Ninety of the buses are equipped with passenger counters that include microprocessors and infrared light beam detectors to record passenger boardings and alightings. Although they do not report passenger count data to the dispatch in real time, the data are used in scheduling activities.[78]

New Jersey

New Jersey Transit, a state-wide operation, has just installed a signpost/odometer system. All 1,900 buses are equipped, although only 300 are included in the current operational pilot test. The entire project is estimated to cost $27 million. Twenty-two frequencies are allocated to the system in northern New Jersey (two for digital data and twenty for voice). In southern New Jersey, one frequency is dedicated to digital communication and five for voice. The system has experienced some software problems that are currently being addressed. Nevertheless, the information received seems accurate. Data is transmitted either every time a signpost is passed or every ten minutes, whichever is shorter.[79] Similar signpost/odometer systems are in the implementation phase in Albany, New York and San Mateo, California.

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[77] Kevin Stanush, VIA Metropolitan Transit, San Antonio.

[78] Helen Gault, Ottawa-Carleton Regional Transit Commission.

[79] Mark Revis, New Jersey Transit (Bus Operations).

Hull, Quebec

The Societe de Transport de L'Outaouais (STO) has a well-established SAGEPAS automated bus fleet management system. The system operates by using in-vehicle microprocessor-based control units developed by Gandalf Technologies. These respond to the proximity signposts which are located strategically along the fixed routes. Buses pass an average of two signposts on each run. In the next polling sequence the on-board unit informs the base station that it passed a signpost, and the position is updated. A transmission odometer which is mechanically connected to the wheels is used to estimate the position of the bus between signposts. Drivers have displays with time of day and early or late indicators. Bus location is indicated at the base station on a stylized graphic indicating the portion of the route completed. The system does not use GIS mapping. The STO vehicle locator system interfaces with INFOBUS, an automatic telephone answering system which provides real-time bus arrival information. Other integrated system modules handle timekeeping, payroll, and scheduling and run-cutting functions."

Louisville, Kentucky

The Transit Authority of River City, which serves Louisville and surrounding suburbs, is in the process of installing a signpost/odometer system to improve scheduling and data collection. Infrared passenger counters and mechanical alarms are being installed in the initial phase. A major focus of the project will be on providing real-time schedule information to travelers who telephone for information. Customer service operators will continue to answer the telephone but they will be supplied with real-time information on the location of each bus as it passes a signpost. No base station display is planned, but drivers will receive feedback on on-time status from dispatch through a lighted panel system. The system, which is being developed by Glenayre, will operate with about 95 signposts which will cover the full system and be reinforced by odometer readings. Polling will be every forty seconds for all 292 fixed-

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[80] Pekilis, Barry, P.Eng., and G. Heti, **Automatic Vehicle Location and Control Systems for Small and** Medium **Ontario Transit Properties,** Phase I *Report* (final), Ministry of Transportation, Canada, January 1992.
Interviews at ST0 administrative offices.

route buses. Cost was a major factor in electing to proceed with the signpost/odometer system. The full system installed on all 300 buses will cost $2.5 million. Installation of the AVL system will begin in early 1994.[81]

B. Radio Navigation/Location

Dallas, Texas

Phase I of the Dallas Area Rapid Transit (DART) AVL project is completed. ElectroCom has equipped 1,200 of the 1,300 DART buses with GPS receivers. Three radio frequencies are dedicated for data collection, one for tracking control, and eight for voice communications. DART has had considerable difficulty with the software, and feels it is not working up to specification. As of October 1993, exception reporting is working, and the paratransit dispatch system is on-line. However, no polling system has been put into effect. The fixed-route system is not yet operational.[82]

Denver, Colorado

The Denver Regional Transportation District is in the process of installing a GPS-based AVL system on 833 buses, eleven light rail vehicles, and 28 supervisory vehicles. The system, designed by Westinghouse, will provide vehicle and schedule monitoring. Map displays showing each vehicle's location will aid the dispatcher in monitoring the system. In the event of an emergency, a silent alarm will be used to notify the dispatch center and emergency vehicles will be directed to the bus. As of December, the system was being tested, using 82 fixed-route buses. Some implementation issues are being worked out.[83]

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[81] John Woodford and Bill Mason, Transit Authority of River City, Louisville, Kentucky.

[82] Chris Patrick, Dallas Area Rapid Transit.

[83] FTA Project Summaries, June 1993.

Milwaukee, Wisconsin

Milwaukee County Transit System is in the process of implementing a GPS system which is similar to that in Denver. Like Denver, Milwaukee is using a system developed by Westinghouse Electric Corporation. Milwaukee Transit is involving a private sector consortium to assist in implementing the system. Expectations are that it will be operational within the year.[84]

Baltimore, Maryland

The Baltimore Mass Transit Administration (MTA) now has an RFP out for a GPS system that will eventually track all of its buses and trains. An RFP is now circulating for an initial test, involving the tracking of 200 buses and 35 light rail trains. The system is, however, being sized to accommodate 1,200 vehicles, including all 800 buses, the light rail system, and their commuter rail line. The RFP also contains the requirement for installation of 25 automatic passenger counters and the software capability to revise schedules. The goal is to award a contract by mid-February 1994.

The MTA has had a fully functional Loran-C system on fifty buses with GIS real-time route tracking maps installed on base station monitors. Reasons for the change to GPS rest with the need for greater accuracy in tracking.[85]

Lackawanna County, Pennsylvania

Lackawanna County Transit System, which operates 30 buses in the Scranton, Pennsylvania area, has just offered a contract to AutoTrac of Dallas, Texas to install a differential-based GPS system. The system will operate with mobile data terminals on the buses and will use Motorola Spectra radios, and Rockwell Navcor V tracking units. Initially, the

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[84] Turnbull, Katherine, "The Use of Information Generated from Transit AVL Systems," *Proceedings of the IVHS America Annual Meeting 1993*, pp. 82-88.

[85] Ray Caroll, Mass Transit Administration.

system will help to insure on-time schedule adherence. It will also include an on-board enunciator system. A silent alarm could be added later.[86]

Denmark

Nysteel is a paratransit system with ten vehicles in a small city in Denmark. They currently monitor their fleet using a differential GPS system, designed by TeknoGuide. The system uses a Phillips GPS receiver and transmits location over a telephone line. Printouts of updated schedules are provided to drivers in their cars. The AVL is used both for real-time dynamic scheduling and vehicle location information. It is also linked to the home health service and emergency system, so that help can be dispatched directly to an emergency.[87]

Heinsburg, Germany

Heinsburg, Germany has an integrated Automatic Vehicle Management system, developed by Intelligent Transportation Systems. The system integrates GPS vehicle location, fleet monitoring, CAD, connection protection (for "guaranteed" transfers), and a service restoration system.[88]

Santa Monica, California

An alternative form of fleet location system is available in the Los Angeles area. Teletrac, a fleet management company, has built a system using a network of transmitting and receiving antennas owned by its parent company, Pacific Telesis. The Santa Monica Municipal Bus Lines is one of over 900 companies using the system which is noted for its low cost and simplicity. Subscribers to the Teletrac system purchase a PC-based workstation equipped with a 2400-baud (bit per second) modem from Teletrac. They also receive an Etak Map with a detailed database of the streets and addresses in the Los Angeles Area, together with Teletrac

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[86] Pat Friend, AutoTrac.

[87] Peter Soelberg, TeknoGuide.

[88] Gerland, Horst, "ITS Intelligent Transportation System: Fleet Management," *Proceeding of the IEEE-ZEE Vehicle Navigation and Information Systems Conference VNZS '93*, Ottawa, pp. 606-611.

communications and control software. The workstation communicates with the Teletrac control center through standard telephone lines. The control center is linked with Teletrac's network of transmitting and receiving antennas. To poll a vehicle, an operator enters a command on the Teletrac workstation. The request is then routed through the Teletrac transmitting towers to a small transceiver in the vehicle. This "Vehicle Locator Unit" responds by sending a signal back through the system to the operator's computer screen, showing the vehicle's location.[89] Teletrac has offices in Chicago, Detroit, Dallas/Fort Worth, Houston, and Miami and is available for transit subscribers in those areas as well.

The system works well for situations in which a dispatcher needs to locate a particular vehicle of fleets that do not require frequent or continuous position location. The cost would be prohibitive for continuous polling of entire vehicle fleets.

Melbourne, Australia

In Melbourne, Australia, 1,000 government buses and trams are being monitored through an Automatic Vehicle Monitoring (AVM) System that has been installed over a number of years. The system features management information on passengers, vehicle location, emergency and silent alarms, in-vehicle display, remote public address, and real-time information for prospective passengers. The system is in the process of installing late-vehicle priority for buses and trams at traffic signals.[90]

C. *Dead-Reckoning*

Hamilton, Ontario

The Hamilton Street Railway Company has operated a fully implemented dead-reckoning tracking system since 1991. The system operates with periodic corrections provided by signposts. This allows the 37 routes to be completely covered by only sixty beacons. On board

[89] Wells, Jesse, "Fleet Management Advances Through Digital Mapping Technology," Etak, Inc., 1993.

[90] Aplin, Neil, "Overview of IVHS Activities in Australia, *Proceedings of the IVHS America Annual Meeting 1993,* pp. 286-290.

the 284 buses are signpost receivers, odometer sensors and a silent alarm. A common radio is used for both voice and data communications. The system was gradually phased in from a pilot project in 1987, but there are still issues to be resolved, including: end-of-the-line tracking, polling rates, hardware maintenance, and ability to affect route modifications.[91]

D. Systems Still in the Process of Choosing Technology

Ann Arbor, Michigan

The Ann Arbor Transportation Authority plans to award a contract in mid-December for a GPS system using smart vehicles. At project completion, ***70*** buses will be fully equipped. Initial installation will include 30 buses that will use on-board computers to verify schedule adherence. They will initially operate autonomously. Radio communication for exception reporting to central control will be a second step. When fully implemented, the central system will service an accompanying information system, including Cable TV and information kiosks.‘* (See also Section 2.5.)

Chicago, Illinois

The Chicago Transit Authority has devoted considerable time to developing a bid package that would best respond to the interrelated transit needs of the city. They envision a full AVL system including an automated bus service-restoration system. The bid package did not specify a particular location technology. Hence, finalists include vendors proposing signposts and GPS. The CTA is now in the second round of the bidding process. The costs submitted with initial bids were much higher than anticipated and higher than available funding. Funding limitations may require installing the AVL system on less than the full fleet of buses, at least initially.[93]

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[91] Pekilis, Barry, P.Eng., and G. Heti, **Automatic Vehicle Location and Control Systems for Small and Medium Ontario Transit Properties,** *Phase Z Report (final),* Ministry of Transportation, Canada, January 1992.

[92] Michael Bolton, General Manager, Ann Arbor Transportation Authority.

[93] Ronald Baker, Chicago Transit Authority.

Northern Minnesota

The Advanced Rural Transportation Information and Coordination Project (ARTIC), which will be operated by the Minnesota DOT, will bring AVL and advanced traveler information systems to the area near Duluth, Minnesota. Plans call for using GPS for paratransit fleet management and control. This will interface with a central vehicle information system and an automatic dispatch system at the base station.

Traveler information will be provided through a toll-free regional telephone transit information system featuring audiotex capabilities. ARTIC will still maintain a telephone operator to provide information directly to rural residents.[94]

Houston, Texas

The Metropolitan Transit Authority of Harris County is still evaluating technologies for the entire system. The agency has experimented with dead-reckoning, signpost/odometer, and GPS technologies. They are currently using a PacTel Teletrac system on 150 paratransit vehicles. In any future RFP, Houston will emphasize adherence to the proposed standards for communication between systems in transit vehicle applications. The proposed FTA and IVHS APTS standard for a Vehicle Area Network is based on the Society of Automotive Engineer's SAE J-1708 document entitled "Serial Data Communications Between Microcomputer Systems in Heavy Duty Vehicle Applications." Adherence to this standard will enable interchangeable components and flexibility for expansion and technology advancements.[95]

Minneapolis, Minnesota

The Guidestar project is in the process of developing an AVL system for the I-394 corridor. The original scope of the project (installation on 100 buses) is being revised, since cost projections were too high. Current efforts include developing public-private partnerships to share costs and benefits. No specific technology been selected, as yet. They expect that this

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[94] Chris Hill, Castle Rock Consultants.

[95] Darryl Puckett and William Kronenberger, Metropolitan Transit Authority of Harris County.

system will contribute directly to the real-time transit information system.[96] (See also Section 2.1.2.)

Dakota County, Minnesota

The Dakota Area Resources and Transportation Services for Seniors (DARTS) and the Minnesota DOT are involved in a study assessing the feasibility of implementing advanced technologies in the DARTS demand-responsive paratransit operation. They expect that AVL can improve responsiveness and service to users, enhance the personal interface between provider and user, and increase the capacity of the system to accommodate more requests and riders.[97]

Peter Pan Buslines

A new dimension in AVL applications is to be pursued by Peter Pan Buslines, an intercity bus company with 150 vehicles operating out of two terminals in Massachusetts, one in Southern Connecticut, and one in Washington, DC. (Their headquarters are in Springfield, Massachusetts.) The system will employ GPS and is experimenting with Rockwell International Tripmasters. The first batch of GPS receivers will arrive in early 1994 with the full system to be operational in 1996. The system is planned not only to provide bus location information, but also to enable the company to track mileage within the various states its vehicles traverse.[98]

3.3 TRANSIT OPERATIONS SOFTWARE

Transit operations software usually performs and integrates several operations functions within a transit agency, such as computer-aided dispatching, computer-aided service restoration, and service monitoring functions. Integration of service components like fixed-route services with paratransit and demand-responsive services is in the early development and operations stages. Service restoration involves the adjustment of vehicle operations based on schedule

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[96] Ibid.

[97] Benson, Jeffrey, "Paratransit and the Promise of Advanced Technologies: The Smart Darts Case Study," *Proceedings of the IVHS America Annual Meeting 1993,* pp.295301.

[98] Lloyd Jack, Peter Pan Buslines.

adherence or scheduled headways, the replacement of a disabled vehicle (which was in revenue service), and the activities necessary to restore the schedule disrupted by a disabled vehicle. Service restoration can involve the following strategies:”

- Restore vehicle schedule
  - Adjusting vehicle dwell time at particular stops/locations (e.g., at transfer points)
  - Adjusting vehicle schedule/headway
  - Performing traffic signal priority
  - Rerouting the vehicle
  - Adding vehicle to route

- Dispatch vehicle to replace 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 of 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).

State-of-the-Art Summary

Systems that integrate software and hardware have been and are being developed to address the operations functions mentioned above. Most of these systems are being developed for the larger rail properties. The following rail systems are planning, designing, or developing new operations control centers, which will provide real-time control and management:

- Bay Area Rapid Transit,
- Chicago Transit Authority,
- Los Angeles County Metropolitan Transportation Authority,
- Massachusetts Bay Transportation Authority,
- Metro-Dade Transit Agency (Miami),
- New York City Transit Authority,
- Port Authority Trans-Hudson Corporation (PATH),

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[99] In order to implement these strategies, a vehicle monitoring system with AVL and communications is necessary.

- Toronto Transit Commission (TTC), and
- Washington Metropolitan Area Transit Authority.

Further, many of the AVL systems that have been implemented for bus operations contain real-time control and management features.

Applications

Boston, Massachusetts

On March 6, 1992, the MBTA awarded a turnkey system contract to Union Switch and Signal to develop and install a state-of-the-art operations control center which will provide central control for the bus, light rail, and rapid rail systems. It is expected that this system, which is a good example of integrating service components, will be fully operational by February 1996. The following paragraphs describe features of the new control center as they relate to each mode.

Bus dispatch will be centralized at the new operations control center. Each bus dispatcher will have a console that contains three elements:

- Event management system, which is an expansion of the existing automated dispatcher log, (located on the left side of the console),
- Graphic presentation, which contains route and tracking displays, (located in the center of the console), and
- Voice control, which handles the radio, public address, and telephone communication, (located on the right side of the console).

In the graphic presentation portion of the console, the route and tracking display will be on a geographically-encoded map of the service area overlayed with bus stops and landmarks. Although the system is not initially planned to have an AVL component, some bus locations will be plotted, based on voice reports and schedule information. The dispatcher will be able to make an inquiry to obtain information by bus number, route number, bus stop, landmark, or street intersection. This graphic display can be updated dynamically to show things like detours but will not show bus movements, since there is no AVL system. However, for the future, the MBTA is looking into a GPS-based computer-aided dispatch and AVL system, for all revenue and non-revenue surface vehicles (buses, service vehicles, police vehicles, commuter rail, light rail, and paratransit vehicles).

Currently, the MBTA's light rail operations include 33 automatic vehicle identification (AVI) readers placed at 22 key points throughout the system. Nine of these units automatically set the switches. The only information available through this technology is the passage of a train by a point where an AVI unit is located. This information can be captured on a display screen, and queries as to which train has passed which key point can be made in real-time. As part of the new control center project, AVI will be expanded to 65 key locations.

The MBTA has three rapid transit (heavy rail) lines with control for each line performed from a different location. All rapid transit revenue service control will be relocated to the new control center project. The rapid transit consoles will be similar to the bus consoles.

The new control center will have a 106-foot long by seven-foot wide graphic display board. The rapid rail systems will be projected onto this display. Automatic capabilities will permit following a train throughout the system, scanning the entire system, and viewing all signal switch indicators.

Controllers at the consoles will have the ability to de-energize the power on track sections by clicking with a mouse. Also, if there is an emergency at a particular location, functions such as calling police and/or fire departments, or turning fans on intake or exhaust will be controlled from the console. Any call from a vehicle will be automatically recorded by the system. Further, the new system will prioritize queue transactions, so that an emergency would go to the top of the queue.

A factory test of the system is planned to occur in February 1995. The MBTA currently has a functioning model (prototype), with the train graphics and event management defined.[100]

New York City, New York

The NYCTA is in the process of developing a new central operations control center, similar to the MBTA effort, but much larger in scope (there are a total of 469 rapid transit

[100] Robert Clark, Massachusetts Bay Transportation Authority.

stations). Currently, the NYCTA operations[101] are de-centralized and the dispatchers have total, direct control over their portion of the system. If an incident occurs (there are 200 incidents per day), it is reported to the cognizant command center by radio.

The new control center will centralize all routing, dispatching, monitoring, and train control. They will be adding a passenger information system that will coincide with an upgrade to the public address system. This system, like the MBTA's system, will have state-of-the-art display technology. The IRT division will be implemented first (consists of 150 miles) and then the BMT division. The IND division will not be part of this new system. Other projects related to the new control center include an improved radio system, an upgrade to the communications systems, and emergency response systems.

By April 1994, the specifications for the new control center will be ready for bid, and NYCTA is expected to make an award in early 1995 to do the final design, installation and implementation. By 1999, the IRT division will be operated from the new control center. A skeleton BMT division will be operating from the facility as well.[102]

Ottawa, Ontario

Although there are many transit agencies that have employed AVL systems, not all have an explicit control function that assists dispatchers/controllers in making operational decisions based on the data generated by the AVL system. Two Ontario transit systems that have implemented automatic vehicle location and control (AVL/C) systems are featured to illustrate the automation of operations using AVL/C technologies.

The Ottawa-Carleton Regional Transit Commission (OC Transpo) has an AVL/C system that "consists of a real-time AVL module capable of monitoring the passage of all buses at specific locations. Buses are identified by a unique tag which can be read at strategic locations in the service area."[103] "Real-time bus location monitoring is an exception based process in

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[101] NYCTA rapid transit operations consists of three divisions: Interborough Rapid Transit (IRT), Brooklyn-Manhattan Transit (BMT), and Independent Subway System (IND).

[102] David Weiss, New York City Transit Authority.

[103] OC Transpo, AVL/C *Phase ZZ Pilot Test: Results*, August 1992, p. 3.

which the actual arrival times of buses at key points throughout the system are checked against their schedules. "[104] Schedule adherence and headways are reported to the controllers. The controllers then take action manually based on the data supplied by the AVL/C system by either calling the bus driver on the radio and asking him/her to change speed or introducing another vehicle into the system.

Actions that controllers can take are built into the service control module of the AVL/C. Each of the twelve control actions is displayed on a screen. Also displayed with each control action is related data, such as schedules, in order to facilitate a decision by the controller. (See also Section 2.1.1.)

Toronto, Ontario

The Toronto Transportation Commission's Communications and Information System (CIS) involves "2,000 transit vehicles, which operate out of three districts further divided into ten separate garage divisions. Each division has its own control center, which monitors and controls the vehicles operating on the routes within its service area. TTC's main control center oversees the overall CIS system and fleet performance. "[105] TTC's AVL technology is a signpost-based system.

A Transit Universal Microprocessor (TRUMP) is installed on each vehicle. The TRUMP consists of a microcomputer, UHF radio, cellular telephone, handset, microphone, driver display screen, and user keypad. Through this equipment, the driver can communicate with the appropriate control center via either voice or data. "Inspectors at each Division Control Center monitor three-color screens displaying the scheduled and actual locations of every vehicle assigned to them. The displays are both graphical and textual tables and charts. All vehicles on all routes being monitored by a division are shown. Inspectors also have a keyboard, CIS

[104] OC Transpo, *AVL/C System Scope and Concept*, February 1989, p. 12.

[105] Pekilis, B. and G. Heti, *Automatic Vehicle Location and Control Systems for Small and Medium Ontario Transit Properties: Phase 1 Report (Final)*, published by Transportation Technology and Energy Branch, Ministry of Transportation of Ontario, Revised January 1992, Report No. TCT-91-02, p. 75.

handset, and conventional telephone for communicating with the vehicles through either text messages or voice communications."[106]

Dallas, Texas

The Dallas Area Rapid Transit system initiated the implementation of a GPS-based AVL system in July 1992 "as part of a comprehensive tracking and communication system to keep a closer eye on its 1,430 buses, transit police cars, and other vehicles. DART's bus and van network carries more than 175,000 people each weekday in an urban/suburban network covering 700 square miles."[107] As with other AVL/C systems mentioned previously in this section, the control features of DART's system will be based on the data generated from the AVL system.

Information generated by DART's AVL system will be used on-line "for tracking and post-service use by transportation and fleet division managers to check and document performance during certain operational periods, such as morning and afternoon rush hours. It also will compile and store information on the status of the dispatch consoles, dispatchers, and accuracy of bus route time points. These reporting features will provide an invaluable tool for management of vehicles, personnel, fleet performance, and scheduling. The reports [that will be generated from the system] will provide aggregate information to document late or early bus times, diverted routes, and other on-time performance for schedules and route review with bus service planners and for community review.

"The AVL system will be an integral part of the integrated radio system, especially for locating vehicles in emergency or off-route conditions. In each case, the system will immediately start tracking the vehicles and will alert dispatchers to a vehicle's condition for further action. (The system will watch route parameters and time points, and will notify the control center if travel distances are shortened or diverted.) It also will serve to offer real-time vehicle monitoring and tracking of all transit vehicles for schedule adherence. This function, performed from the control/dispatch facility, will be more cost-efficient than stationing

[106] Ibid, p. 77.

[107] Ledwitz, Paul "DART AVL Hits Transit Bull's-Eye with GPS," *GPS World*, Volume 4, Number 4, April 1993, pp. 29 and 32.

employees along routes or following buses to determine performance. "[108] (See also Section 3.1.)

Ann Arbor, Michigan

The Ann Arbor Transportation Authority's Intelligent Transportation System (See also Section 2.5 and Section 3.1.) includes a computer-aided dispatch function. The CAD portion of the ITS will have the following components:

- Visual Display;
- Vehicle Management; and
- Motor Coach Operator Management.

In the Vehicle Management portion of the CAD system, graphic displays will provide information to the Operations Controller (OC) on vehicle routes, locations, and status conditions. Status information could include schedule adherence, wheelchair lift and lockdown utilization, and the mechanical condition of specific bus components. Transfer coordination is proposed to be fully automated, with transfer requests being sent to the specific vehicle. When there is an indication of an emergency, the vehicle's location will be displayed, and the OC will be prompted to perform a set of activities pertinent to the particular situation.

Flexible routing refers to both the fixed-route and paratransit operations. It is proposed that the ITS be capable of dynamically re-routing paratransit vehicles in real time based on trip additions and cancellations. It is also proposed that the ITS be capable of modifying fixed routes in real time (e.g., route deviation).

The motor coach operator management software handles driver assignment. This includes check-in, check-out, relief, and extra assignment.

Pinellas County, Florida

Even though the use of CAD by an emergency services company (LifeFleet) in Pinellas County is not a transit application, it is important to note here since advanced technology is

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[108] Ibid, p. 34.

being employed. This CAD system was developed by EAI Systems, Inc. Dispatchers are provided with the real-time location and status of each vehicle (available, en-route, on-site, etc.) on color-coded maps which show streets and geography. Further, "each vehicle is equipped with an Etak Navigator@ map display and driver guidance system, an on-board computer that displays a dynamic, digitized street map showing both the vehicle's present position and the destination as provided by the dispatch center. Every one-tenth of a mile, the Etak Navigator(R) automatically transmits its coordinate data, determined from the map, through an on-board modem and radio to the [dispatch center]."[109]

This dispatch system is capable of automatically dispatching vehicles, even though it is being done manually based on the data from the CAD system. However, if dispatch is not performed within forty seconds of an emergency call, the system will automatically dispatch the closest vehicle.

Dade County, Florida

Dade County, Florida will be implementing a mobile communications system, which includes computer-aided dispatching. Frederick R. Harris, Inc., contractor to Ericsson GE Mobile Communications, will be installing the system which will link fire fighters, police, transit employees and public works employees via mobile voice and data communications. The system, which includes AVL and computer-aided dispatch, is GPS-based and will be capable of tracking about 800 buses, rail cars, and other transit vehicles both on and off-route. The system will also monitor the status of on-board conditions, such as engine temperature and tire pressure.[110]

Hull, Quebec

The Societe de Transport de L'Outaouais (STO) in Hull, Quebec has a comprehensive AVL/C-based system that provides real-time monitoring and control of their bus fleet. Further, it is integrated with their two automated information systems (one for customers to telephone for

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[109] Wells, Jess, ETAK, Inc., "Fleet Management Advances Through Digital Mapping Technology," undated white paper, p. 3.

[110] Inside IVHS, Volume 3, No. 17, August 16, 1993, p. 14.

real-time bus stop arrival times, and one for telephone agents to answer various information inquiries including trip planning), their payroll system, and their scheduling system. Further, STO has an executive information system (EIS) that interfaces with the AVL/C system to provide exception reports to management. [111] (See also Section 3.1.)

3.4 AUTOMATED DEMAND-RESPONSIVE DISPATCHING SYSTEMS

Automated demand-responsive dispatching systems include scheduling features which assign individuals 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 orders, or real-time dispatching can be accommodated through the use of radio frequency (RF) communications with on-board computers. Information from scheduling and dispatching can be integrated into management information, billing, and accounting functions of the transportation provider.

State-of-the-Art Summary

Automation is being increasingly applied to the scheduling, dispatching, billing, and accounting functions of demand-responsive vehicles. This automation is based on advanced technologies such as RF communications in conjunction with on-board computers or mobile display terminals, CAD, global positioning systems or other location technologies, GIS, and smart cards.

Another innovation in scheduling and dispatching systems is the ability to dynamically reschedule and re-route paratransit vehicles, based on 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 Act. The ADA has stimulated the vendors of scheduling and dispatching software to incorporate many new features, such as mapping or GIS software, to assist in the determination

[111] Brendon Hemily, Canadian Urban Transit Association.

of whether an individual's origin or destination is located within %-mile 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 dispatching 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 the scheduling and dispatching software.

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

Applications

In order to determine the extent to which automated scheduling and dispatching software is actually being successfully used in the paratransit industry, both paratransit agencies and vendors were contacted. Since information on specific vendors and their products can be found in the APTS ***Vendor Catalog,*** published by IVHS America in October 1993, this section focuses on the users of the software.

This section includes information on automated or computer-assisted scheduling and dispatching systems. Table 3.2 shows a sample of the 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 3.3 lists the manufacturers of each system, as a further reference. A detailed table is included as table A.2 in the Appendix. One particularly innovative application, Delaware County, Pennsylvania, is described in detail. Other users are identified, along with the systems they employ. Also included in this section are several important research projects that have been or will be accomplished to determine the "state of the art" of automated scheduling and dispatch systems in the paratransit industry.

Even though there are many automated scheduling and dispatching systems available for paratransit operators, not all have been successfully implemented. It is important for prospective buyers of these systems to carefully evaluate software and 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.

Table 3.2 Automated Paratrausit Scheduling and Dispatching Systems

User	Location	Automated System
Mayflower Contract Services	Fresno, CA	Rides Unlimited
Mayflower Contract Services	Hemet, CA	Rides Unlimited
Hartford Transportation Services	Hartford, CT	MIDAS
Manatee County Area Transit	Bradenton, FL	EMTRACK™
Greater Pinellas Transp. Mgmt Svc., Inc.	Clearwater, FL	EasyTrips™
Paratrausit service	Deland, FL	COMSIS Trip Planning System
Jacksonville brokerage	Jacksonville, FL	COMSIS Trip Planning System
Honolulu Public Transportation Authority	Honolulu, HI	EasyTrips™
Mayflower Contract Services	Honolulu, HI	Rides Unlimited
Belleville Area College Senior Citizens Center	Belleville, IL	QUICK-ROUTE,
Madison County Transit	Granate City, IL	QuoVadis
Ace Cab (Shared-ride and Dial-a-Ride)	Indiana	CADMOS-Pro +
Aid Ambulance	Indianapolis, IN	EMTRACK™
Des Moines Metropolitan Transit Authority	Des Moines, IA	CADMOS-Pro +
Washington-Hancock Community Agency	Maine	(Bar Harbor Software, Inc.)
Germantown Taxi	Germantown, MD	CADMOS-Pro +
DAVE Transportation Services, Inc.	Cambridge, MA	MIDAS
Southeastern Regional Transit Authority	New Bedford, MA	DISPATCH-A-RIDE
Veterans Transportation Services	Waltham, MA	DISPATCH-A-RIDE

Table 3.2 (con't) Automated Paratransit Scheduling and Dispatching Systems

User	Location	Automated System
TWC Ambulance	Long Island, NY	EMTRACK™
Mecklenburg County Dep. of Social Svcs	Charlotte, NC	EasyTrips™
Gaston County Coordinated Transportation	Gastonia, NC	EasyTrips™
Greensboro Specialized Transportation	Greensboro, NC	DISPATCH-A-RIDE
Project Sparkplug - Canton Reg. Transit Auth.	Canton, OH	QUICK-ROUTE™
Sioux Falls Paratransit	Sioux Falls, SD	DISPATCH-A-RIDE
K-TRANS	Knoxville, TN	DISPATCH-A-RIDE
Beaumont Nutrition and Service for the Elderly	Texas	Paratransit Scheduling Package
Kaufman County Senior Citizen Service	Texas	Paratransit Scheduling Package
SPAN	Texas	Paratransit Scheduling Package
Dallas Area Rapid Transit	Dallas, TX	MIDAS
El Paso Para Transit Department	El Paso, TX	QuoVadis
VIA Metropolitan Transit	San Antonio, TX	QuoVadis
Salt Lake City Aging Service	Utah	Paratransit Scheduling Package
American Contracting Management	Virginia	CADMOS-Pro +
Paratransit Services	Bremertown, WA	Rides Unlimited
Clallam Paratransit	Port Angeles, WA	Rides Unlimited
Mason County Dial-A-Ride	Shelton, WA	Rides Unlimited
Spokane Transit Authority	Spokane, WA	QUICK-ROUTE™
BC Transit	British Columbia	Rides Unlimited
Toronto Transit Commission	Toronto, Ontario	GIRO/ACCES
Montreal Urban Community Transport Comm.	Montreal, Quebec	MIDAS

Table 3.3 Scheduling and Dispatching System Vendors

Automated System	Vendor
CADMOS-Pro +	Micro Dynamics Corporation
COMSI Trip Planning System	COMSI Corporation
DISPATCH-A-RIDE	Multisystems
EMTRACK™	Automated Dispatch Services, Inc.
EasyTrips™	Easy Street Software, Inc.
MIDAS	Multisystems
Paratransit Scheduling Package	Philip G. Dorcas and Associates
QUICK-ROUTE™	Decision Sciences, Inc.
QuoVadis	UMA Engineering Ltd.
Rides Unlimited	Paratransit Systems International, Inc.

Delaware County, Pennsylvania

Community Transit of Delaware County currently is developing and will implement an automated system that includes sophisticated scheduling and financial management software integrated with an automated identification and billing system (AIBS).[112] Community Transit is a private, non-profit transit service that enables Delaware County citizens to travel within the county. The operation is demand-responsive, shared-ride, with advanced reservations and door-to-door service. Community Transit provides an average of 1,400 one-way trips per day, including shuttle service to Delaware County employers.

The system that Community Transit is developing involves the automated scheduling and dispatching software, on-board computers, RF communications, and automated identification cards (see Figures 3.1 and 3.2).

[112] Judith McGrane, General Manager, Community Transit.
Community Transit of Delaware County, "Preliminary Functional Description for the Community Transit APTS Demonstration Project: Automated Identification and Billing System," prepared for Federal Transit Administration, Office of Technical Assistance and Safety, Project PA-26-0006, March 19, 1993.

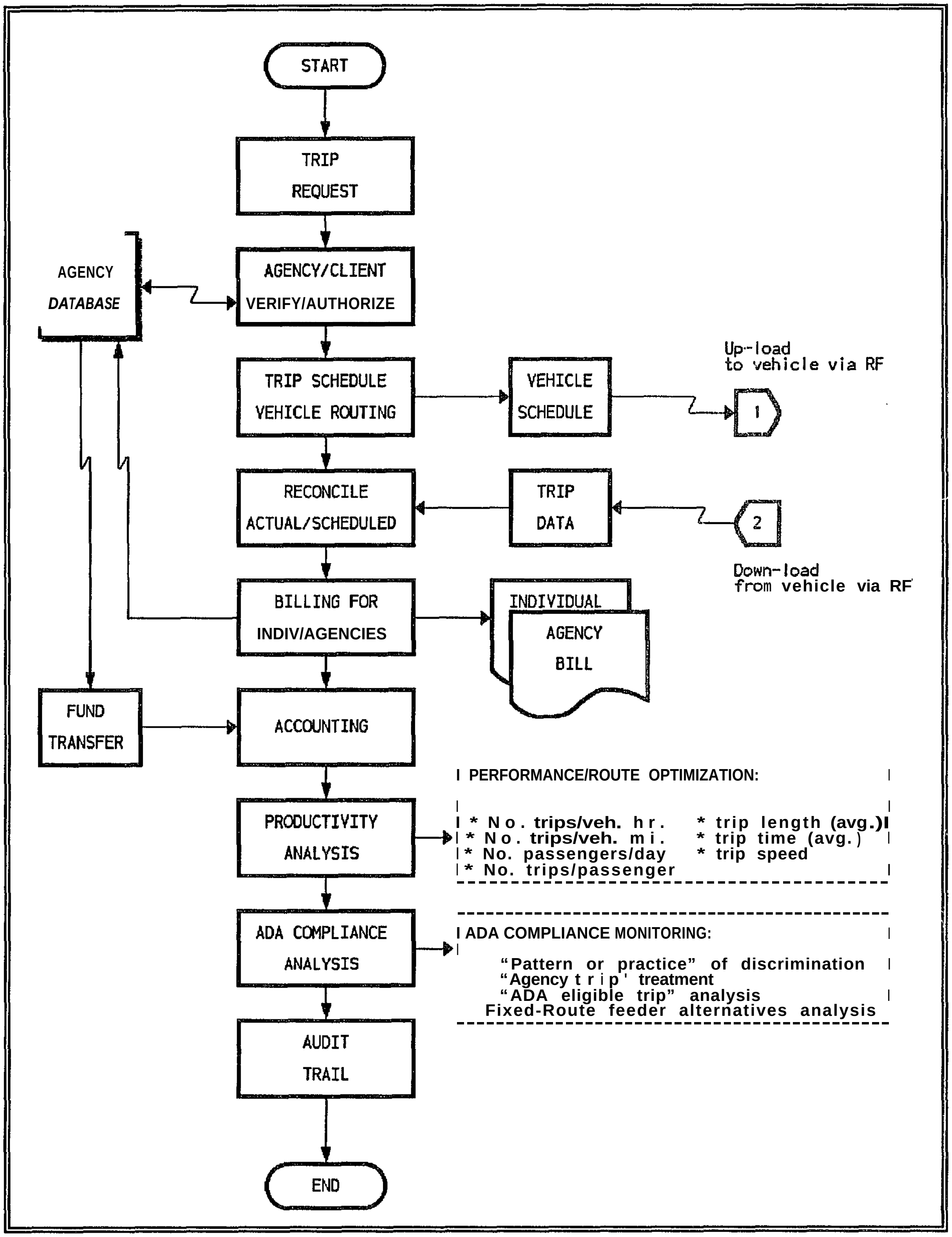

Figure 3.1. Community Transit Integrated System

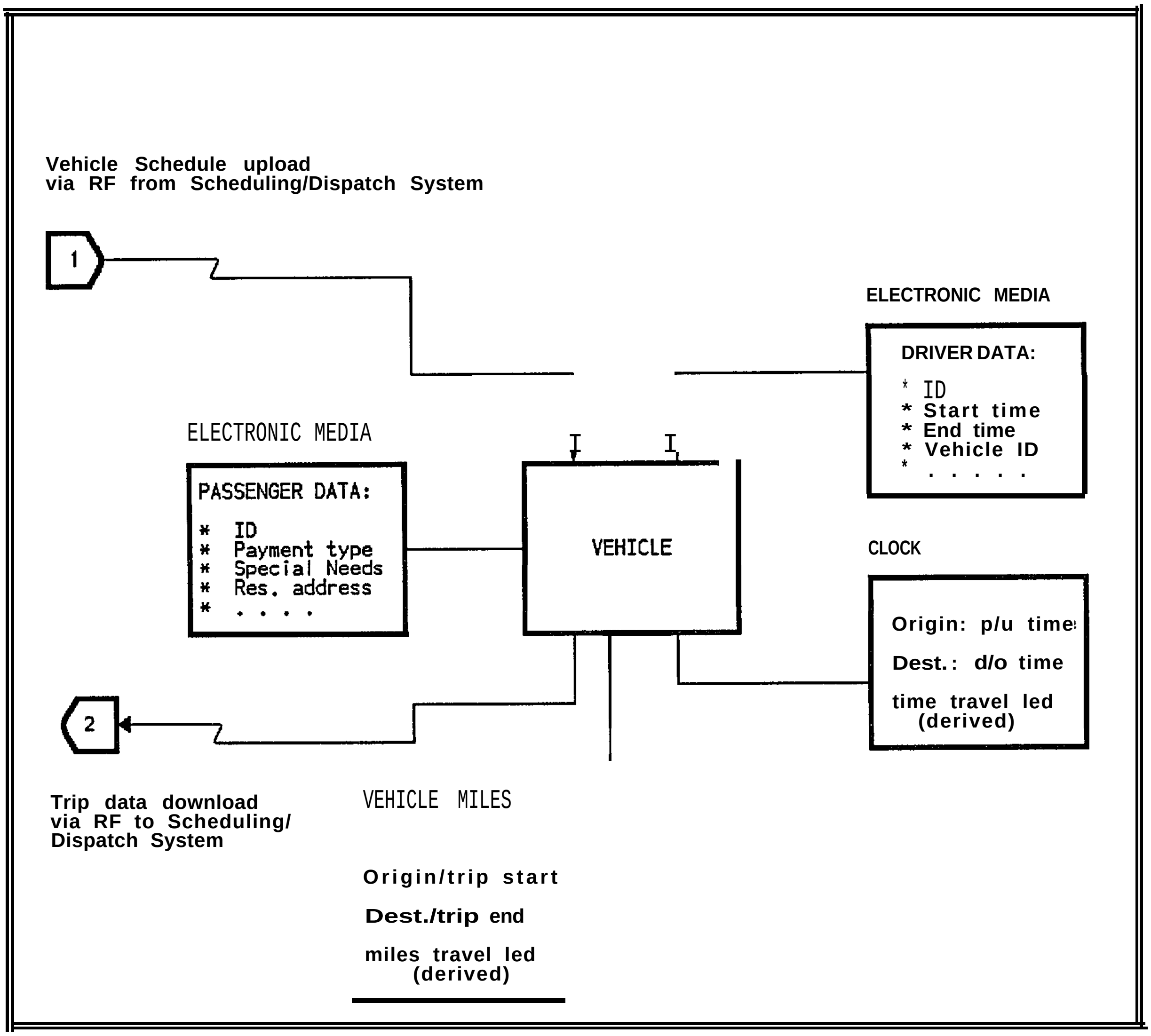

Figure 3.2. On-Board Data Collection (part of AIBS)

The primary goal of the AIBS portion of the project is to significantly improve the identification of passengers (in terms of reliability, eligibility, and security), the data collected on each passenger trip (which will subsequently be used for accounting and billing purposes), and the reporting required for agency coordination and for internal performance monitoring. Additional benefits will include increased operational productivity and maximum use of limited vehicular and personnel resources.

Specifically, the AIBS will be capable of:

- Automated passenger identification and trip eligibility validation;
- Automated fare calculation for various billing schemes (diversified fare structure);

- Interactive acceptance and recording of trip data, including passenger travel time, trip length, and fare; and

- Automated transfer of trip and performance data to Community Transit's accounting and performance analysis systems.

A direct link between the AIBS and the scheduling and dispatching system will ensure the transfer of trip and passenger data between these two systems. In addition, the overall system will have the capability to receive and transmit data over RF for both the AIBS and the scheduling and dispatch system at the same time.

Assessment of Computer Dispatch Technology in the Paratransit Industry

Computer scheduling and dispatching in the paratransit industry was the focus of a study performed by the Institute of Transportation Research and Education at the University of North Carolina. Through on-site and telephone interviews with many taxi and paratransit operators and many software vendors, this study determined the following:[113]

- Current operating capabilities of computer dispatch systems;
- The costs and economic benefits of these systems;
- The suitability of computer dispatch technology for the Mobility Manager concept; and
- Future technological directions for computer dispatch.

This study showed that the improvement in response time when using computer dispatch technology was significant. With manual dispatching in the taxi industry, it could take 30 minutes or more to assign a vehicle to a request. Conversely, it takes only 30-45 seconds if computer dispatch technology is employed. In terms of costs and economic benefits, the study showed that while computer dispatch technology is not inexpensive, the costs can be easily recouped through reduced operations costs. Further, the benefits include travel time savings to passengers. The study concluded that computer dispatch technology is an integral part of the Mobility Manager concept, and that for it to be most successful, it must provide real-time scheduling and dispatch. Finally, the study discussed the future direction of computer dispatch

[113] Stone, John R., Gorman Gilbert, *and* Anna Nalevanko, *Assessment of Computer Dispatch Technology in the Paratransit Industry,* Final Report, prepared for Federal Transit Administration, Office of Technical Assistance and Safety, March 1992, Report No. DOT-T-92-23.

in terms of the ADA requirements and the integration of this technology with several other technologies that are increasingly being implemented by paratransit operators.

Paratransit Scheduling and Dispatching Systems: Overview and Selection Guidelines

This study, an update and follow-on to the previously mentioned study identified the capabilities of paratransit scheduling and dispatch software, and developed guidelines for the selection of automated paratransit management software. Also, the costs of scheduling and dispatching software and hardware were examined, yielding the following:

> "Total system costs will vary depending on the size of the system and the options acquired. Paratransit software averages about $30,000 depending on available functions. Hardware costs vary depending not only on the products purchased, but also on the number of vehicles and personnel locations that the items serve. According to vendors, it will cost up to $4,000 to install APTS equipment in paratransit vehicles and up to $65,000 for the operations center. The costs include:

VEHICLE HARDWARE AND SOFTWARE		OPERATIONS CENTER HARDWARE AND SOFTWARE	
In-vehicle computer & application software	$1,750-2,000	Communications software and hardware	$10,000
GPS receiver unit and antenna	800	Database reporting software	5,000
Smart card reader/writer	300	AVL software	10,000
RF modem (depends on type of radio system)	400-900	Scheduling/dispatching software	30,000
		Additional computer hardware	10,000
Total per vehicle cost	$3,250-4,000	Total operations center cost	$65,000

> An automated scheduling and dispatching package represents about half of the total APTS system cost."[114]

[114] Stone, John R., "Paratransit Scheduling and Dispatching Systems Overview and Selection Guidelines, prepared for and presented at the 1993 IVHS America Annual Meeting, April 14-17, 1993, Washington, DC.

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

In April 1993, the Transportation Research Board announced several transit research projects as part of the Transit Cooperative Research Program. Included was a $200,000 project called "Computerized Paratransit Dispatching." "The objective of this research is to determine the current state of the practice in computerized demand-responsive scheduling/dispatching and to compare the state of the practice with the current capabilities of software and hardware for demand-responsive transit scheduling/dispatching. This will involve examining experiences in the U.S. and abroad. The further objective of the research is to assess the cost-effectiveness and service quality implications of moving from the software typically used to computerized systems with improved capabilities. "[115] A request for proposals for this project was to be issued in late 1993.

Advances in Paratransit Scheduling and Dispatching Related to the ADA

Many of the commercially-available routing and scheduling programs developed for the paratransit industry have recently been upgraded to include features that address ADA information needs and requirements. These packages typically include client information modules as well as trip files, scheduling algorithms, reporting routines, and other functions designed to offer full support in all aspects of paratransit operation.[116]

Some of the common features that have been developed for ADA paratransit operation include:

- ADA Paratransit Eligible Customer Information: Individuals who are determined to be ADA paratransit eligible can be distinguished from other riders. Conditions and limitations of eligibility and/or the regulatory categories under which riders are eligible can be displayed. If ADA paratransit eligible persons are also eligible under other programs, this multiple eligibility information can also be displayed.

  To be of immediate use to schedulers, the above client information can be displayed in "real time," meaning that it can be immediately accessed as part of a scheduling routine.

[115] TRB, "Transit Cooperative Research Program Announcement of Transit Research Projects," April 1993.

[116] Thatcher, Russell, *Americans with Disabilities Act (ADA) Paratransit Eligibility Manual,* Final Report, prepared for FTA Office of Grants Management, September 1993, DOT-T-93-17, pp. 122-133.

- Relationship of Desired Trip to the Fixed-Route System: The ADA regulations require transit providers to offer complementary paratransit service to eligible individuals in an area defined by corridors 3/4 of a mile to each side of fixed routes plus to other areas within a "core service area." In determining if a requested trip is eligible, transit providers will need to check the geographic relationship of the origin and destination to the fixed-route service. In addition, customers may be able to get to and from bus stops up to a certain distance (e.g., up to 1/4 of a mile) but are eligible for paratransit when they would need to travel a greater distance to and from bus stops.

  Several scheduling systems are now capable of incorporating geographic information on the fixed-route system. ADA paratransit service corridors can be displayed and calculations of distances from origin or destination to the closest fixed route can be made. More accurate systems will develop these calculations by using exact latitude/longitude coordinates or street centerlines. Trip eligibility can then be determined using this information.

- Visitors Information: The regulations require that ADA paratransit systems accommodate visitors to the area. Visitors are to be provided with 21 days of service over a reasonable period of time if they have been determined eligible by another transit agency or if they claim to be eligible. After 21 days of service, the person can be required to go through the local eligibility determination process.

  Several paratransit scheduling programs are able to process visitor requests, track the days of service provided to a visitor, and display this information as part of the scheduling routine.

- Documenting Compliance: In addition to assisting with determining individual and trip eligibility, these systems are also capable of providing data and developing reports that can assist in assuring compliance with the regulations. For example, the ADA regulations require that complementary paratransit service, when fully implemented, cannot have capacity constraints. Examples of capacity constraints are an excessive number of trip denials, late pick-ups, and long trips. Trip requests are to be considered denials if they cannot be scheduled within one hour of the requested pick-up time. Additionally, the regulations limit subscription trips ("standing orders") to no more than 50 percent of total trips when capacity constraints exist.

  Several software systems allow users to track and analyze capacity constraints and subscription trips.

As part of the preparation of FTA's ***Americans with Disabilities Act (ADA) Paratransit Eligibility Manual,*** information about the availability of the above features was requested from 30 of the leading paratransit software companies. Twelve companies responded and indicated that one or more of these features was either currently available or in development. Tables contained in the aforementioned manual summarize this information.

Out of the twelve software systems offered by the companies that responded to the request for information, eight can display ADA service area corridors, and origins and destinations. The other four have this capability under development. Five can make real-time calculations of distance from routes to origins and destinations. Seven use latitude/longitude as the basis of distance calculations; one uses zonal-based centroids; one uses street centerlines; and the rest have the option of using any of these methods.

Ontario

"Over the years, the Ontario Ministry of Transportation has funded the acquisition and implementation of scheduling software for transit systems for the disabled. Although there are a few systems in use in Ontario, they all require long lead times for trip reservations, usually one or two days in advance. This is due to the lack of an on-line automatic scheduler."[117]

Currently, UMA Engineering is developing and will be implementing a demonstration of a fully automated, on-line routing and scheduling system for specialized transit operators typically of less than thirty vehicles. The status of this project is that testing of the system is being completed in Burlington (single user) and Kitchener (multi-user). Parallel evaluation and acceptance testing by the Ministry's Transportation Technology and Energy Branch is also being conducted.[118]

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[117] Transportation Control Technology and System Office, Transportation Technology and Energy Branch, Ontario Ministry of Transportation, "Automatic On-Line Scheduling/MIS System for Paratransit," Fact Sheet No. 37.

[118] Ontario Ministry of Transportation, "MTO Project Summaries - June 1993," p. 4.

4. SMART INTERMODAL SYSTEMS

The goal of smart intermodal systems is to increase the efficiency and effectiveness of transit for both system operators and trip-makers. The concept involves sharing information systems and other technology between and among modes. The overall objective is to decrease congestion by encouraging the use of alternatives to single occupancy vehicles. APTS technologies have great potential in this area and are already being applied in several cases. The following types of applications of smart intermodal systems are discussed in this chapter:

- Traveler Information Systems,
- Multimodal Smart Cards/Payment Systems,
- High-Occupancy Vehicle (HOV) Facility Monitoring,
- Transportation Management Centers, and
- Vehicle Guidance Systems.

4.1 TRAVELER INFORMATION SYSTEMS

Intermodal Traveler Information Systems are intended to entice single occupant drivers out of their vehicles and into a carp001 or a transit vehicle for at least a portion of the trip. Although some intermodal systems only present transit or carpooling options, the trend is toward providing information about the level of traffic congestion by the same means as information about various transit or carpooling options. These systems parallel the basic ATIS systems in that they can provide pre-trip or enroute information.

State-of-the-Art Summary

Although few fully intermodal information systems are operative at this time, they clearly represent the direction for future automated traveler information projects. These trends are evident from the following application examples.

Applications

Portland, Oregon

The Tri-County Metropolitan Transportation District is in the process of bidding an automated trip planning system which will interface with the City of Portland's smart corridor project and its highway monitoring system. This will insure that telephone information operators have real-time information on congestion levels. [119]

Los Angeles, California

A California Smart Traveler project being pursued in the Los Angeles basin incorporates pre-trip planning. A prospective passenger can dial a 900 telephone number and use a 7-digit code identifying his or her point of origin and preferred destination. Multi-modal information is provided which could include bus, light rail and/or heavy rail itineraries.[120]

San Francisco, California

The design of a broad based regional traveler information system (TravInfo) for the San Francisco Bay Area is almost complete. Travel information will be provided through touch-tone telephones. Callers will select among a menu of possible types of information, including highway congestion reports and updated schedules for the various transit systems operating in the Bay Area including Bay Area Rapid Transit (BART), the ferry systems, Muni, commuter rail, and several bus operations. The regional carpooling ride-matching program, RIDES, is also a participant in TravInfo. The concept includes an open access architecture that can accommodate both multiple data sources and a variety of different types of requests for transportation information. An initial pilot multimodal information telephone system will be tested shortly. A traveler will have one basic number to call for all travel information and the call will be routed to the appropriate provider though a switching mechanism currently staffed by 26 operators. The private sector will be involved in developing kiosks displaying dynamic and static information at transit centers.

TravInfo is directed both at marketing travel information systems to the ultimate user and a computer-based data system to the many transportation providers in the Bay Area. The system is an example of a public-private partnership. It has an advisory group of over 100 individuals from local firms, major automobile manufacturers, local governments, and state government

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[119] Ken Turner, Portland Tri-Met.

[120] Robert Ratcliff, California Department of Transportation.

agencies. The large advisory group has four steering and working committees. The legal committee is currently tackling the issue of liability. A management board includes the Metropolitan Transit Commission, the California Department of Transportation - District 4, and the California Highway Board.[121]

Boston, Massachusetts

Travelers in the Boston area can obtain real-time traffic information over a computerized telephone information service every day except Saturday. The system is called "Smart Routes." It also provides information on bus, light and heavy rail, and commuter rail. The system lists certain roads and highways and asks the traveler to select one or to select information about transit modes. If the caller selects transit, he or she is guided through a menu to information on specific routes and given the status of the route.[122]

Minneapolis, Minnesota

Minnesota DOT has developed an integrated motorist information program (Guidestar) in cooperation with the University of Minnesota, Motorola, and the Federal Highway Administration. Several elements of this comprehensive information system are already in place with others planned or under contract. An advanced motorist information system incorporates cable TV, teletex, and audiotex elements into a single LAN-based arrangement. Cable TV includes a real-time graphics map showing traffic flow on all currently instrumented freeways and live video from on-line closed-circuit television cameras. Radio traffic broadcasts are also supplemented with this information. Audiotex allows for information retrieval with touch-tone telephone, while teletex uses personal computer communication software packages to interactively retrieve traffic information. Automatic facsimile will be added later. The Genesis project, which begins in Fall 1993, will test the use of personal communication devices to deliver real-time traffic and transit information services. Devices to be evaluated include an

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[121] Melanie Crotty, Metropolitan Transportation Commission.

[122] *Boston Globe,* Jan. 13, 1993.

intelligent hand-held unit with two-way wireless communications and a touch or pen-based screen, an alphanumeric pager, and off-the-shelf dedicated traffic information-only devices.

In Fall 1994, traffic congestion and bus information will be added to pager functions. The Travlink project will test the impacts of various advanced information transfer and automated vehicle location systems on transit ridership and traveler behavior. This project will involve audiotex and videotex services in delivering real-time transit and traffic information. Estimates of travel time savings for HOV use will be provided.‘”

ARTIC, a developing rural-based project of the Minnesota DOT, will offer automated dispatching and advanced rideshare matching for demand response transportation providers operating in multiple counties in northeastern Minnesota. The system is expected to accommodate standing orders and single trip requests with limited advance notice. As such it will aid in the formation of real-time, single-trip carpools.[124]

4.2 MULTI-MODAL SMART CARDS/PAYMENT SYSTEMS

As stated in Section 2.5, smart card technology typically means plastic cards (credit card size) with an integrated circuit microprocessor chip that can be used for identification, trip payment, and other travel-related functions. Generally, “there are three types of smart cards:

- Contact Cards - require a physical contact between the card and the reader/writer unit. Data interchange occurs via ‘touching fingers’ in the unit. The Gemplus card used for the Chicago Regional Transportation Authority’s (RTA) Payment and Control Information System (PCIS) Project is an example.

- Contactless Cards - use a contactless interface to provide power to the card and for data transfer. This is done using inductive techniques for power and capacitive techniques for data reading. AT&T’s card is an example. This card is available for use in AT&T’s 2000 telephones, toll roads, and for other applications.

- Proximity Cards - use a contactless interface to interchange data between card and the reader/writer unit. This is done using radio frequency (RF), or laser techniques. Power may be supplied by a battery built into the card or by means of received magnetic

[123] Minnesota DOT, 1993
Melanie Brawn, Minnesota DOT, Transit Division.

[124] Minnesota DOT, 1993.

energy. Westinghouse-Cubic's "Touch and Pass" card used in a trial for London Underground is an example. "[125]

The multi-modal aspect of smart cards and payment systems refers to a smart card that could be used to pay fares across several modes of transportation (bus, rapid rail, light rail, highway, etc.).

This section differs from Sections 2.3 and 2.4 in that it describes smart card technologies that can be used for a variety of transportation purposes, such as identification, trip payment, parking payment, etc. Section 2.3 describes reservation and ticketing for multiple transportation providers through an integrated system. Section 2.4 describes fare media that can be used on more than one mode, such as magnetic-strip cards that could be used for both bus and subway fares.

State-of-the-Art Summary

In Sections 2.3, 2.4, and 2.5 of this report, applications of smart cards and multimodal fare payment are presented. However, none of these applications in North America have demonstrated the use of multi-modal smart cards as yet. The planned 1994 demonstration of a proximity smart card for Metrorail, Metrobus, and transit parking in Washington, DC (See section 2.5 for description.) is the only North American demonstration of multimodal smart cards expected in the very near future.[126] There are, however, several multimodal smart card systems being implemented in Europe, Asia and Australia. A few of these systems are described below.

Applications

Manchester, England

Progress is being made in Great Britain on "the world's first fully-integrated multi-modal ticketing system based on contactless smart card technology"[127] This system is being

[125] Joshi, Ashok, J.W. Leas & Associates, "Get Electronic Card Smart," prepared for the 1993 APTA Fare Collection and Police/Security Workshop, Chicago, IL, September 10, 1993, p. 2.

[126] There are other smart card applications, but they are not multimodal (e.g., Chicago RTA).

[127] "Manchester *Gets Smart,* " *International Railway Journal,* May 1993.

implemented in Manchester. When completed in 1995, "it will enable cardholders to travel on regional rail, Metrolink light rail and bus networks in the area."[128]

The Greater Manchester Passenger Transport Executive has contracted with AES Scanpoint for the £10 million system. The smart card, based on a contactless smart card developed by GEC Card Technology, has an antenna which receives signals from the card reader in order to add or subtract funds. The card can either touch the reader or pass within close proximity. The card has an effective range of one-two centimeters, and a transaction time of 300 milliseconds.

"The system will begin in early 1994 with 300 buses, two depots and up to 10,000 passenger smart cards. All post offices in the service area and twenty newspaper outlets and convenience stores will also participate in this first phase."[129]

Ultimately, card readers and ticket machines will be installed at 350 British Rail and Metrolink locations. The cards will be issued at more than twenty locations, and over 800 agents will be able to add funds to the cards. It is expected that electronic fund transfer kiosks will enable cardholders to add value to their cards. Approximately 500,000 cards will be issued.

New South Wales, Australia

Although the fate of this project has yet to be determined, the New South Wales Government is seeking an operator for a smart card system that will not only cover the public rail, bus, and ferry systems, but will cover many other services, such as fast food, convenience stores, and parking. Called the "Stored Value Card" (SVC), this smart card would be purchased at participating merchants for fixed values (e.g., $20, $50 and $100). The SVC system would be operated as shown in Figure 4.1.

The following government and private sector service providers have committed to join the SVC system:

- Public Transportation - rail, buses and ferries;
- Pay Telephones - Optus Communications;
- Fast Foods - McDonald's, Kentucky Fried Chicken;

[128] Ibid.

[129] Joshi, Ashok, J.W. Leas & Associates, "Get Electronic Card Smart," op. cit., p. 13.

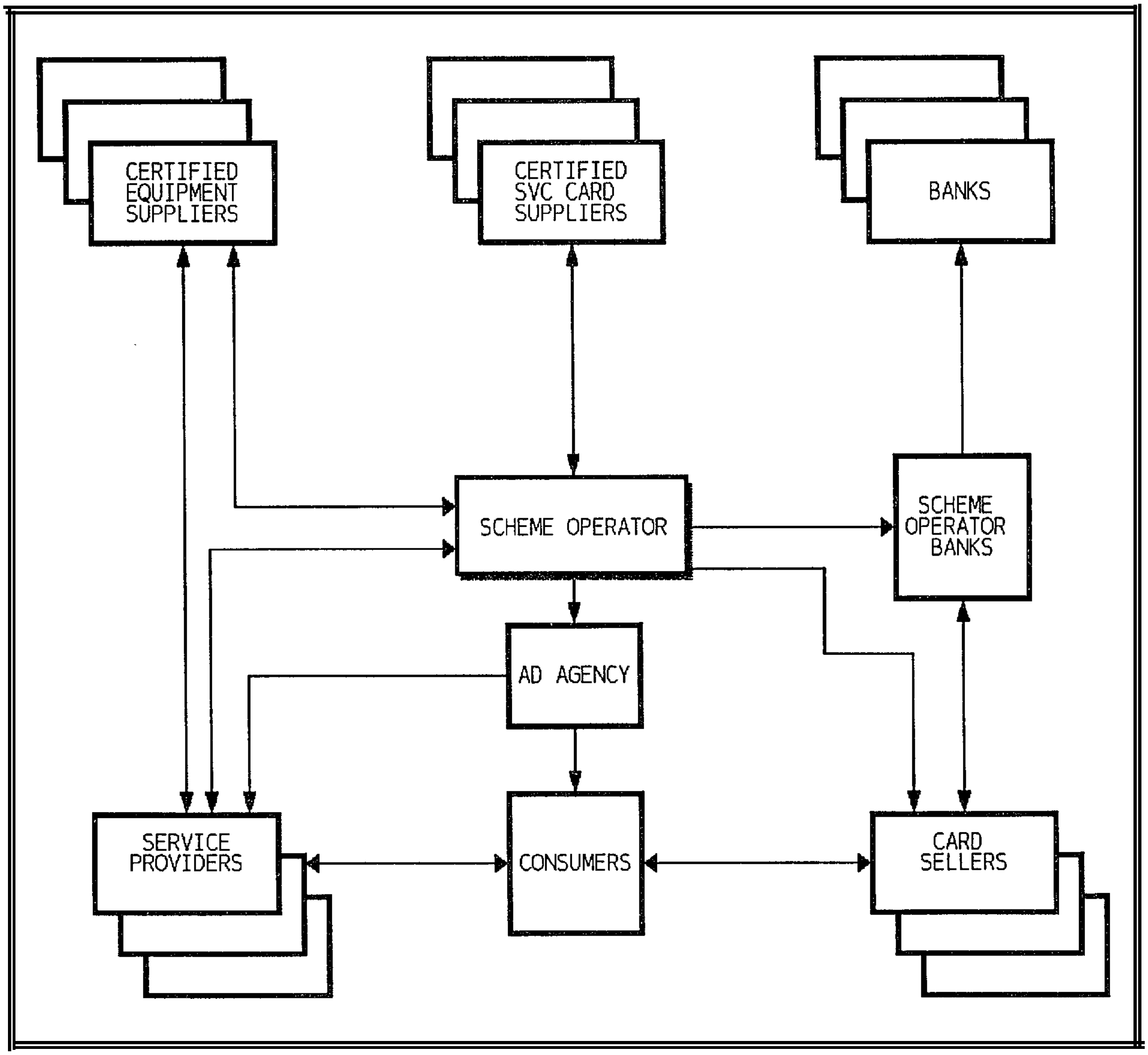

Figure 4.1 Stored Value Card Scheme

- Vending - Coca-Cola, The Smith's Snackfood Company;
- Parking - Wilson Parking Australia 1992 P/L;
- Convenience Stores - Food Plus;
- Taxi - Cabcharge Australia Pty Ltd;
- Entertainment - Village Roadshow Corporation;
- Gasoline - BP Australia;
- Hotels - Jacksons on George and Woolloomooloo Bay Hotel;
- Registered Clubs - Dee-Why RSL Club and Canterbury-Bankstown Leagues Club; and
- Private Bus Operators - 6 x NSW Bus Lines and 2 x QLD Bus Lines.

Trials are expected to begin early in 1994 following a six to nine month evaluation of tender documents. They plan to introduce the card in late 1994.[130]

Denmark

Denmark is implementing a national smart card system in which consumers can pay for telephone service, train and bus service, parking meters and items from vending machines. The contact smart cards will be in denominations of 30, 50 and 100 krone, and will not be capable of being replenished. This system was to be introduced in Copenhagen in December 1993.[131]

Switzerland

The Post, Telephone and Telegraph service (PIT) in Biel, Switzerland is in it's third year of experimenting with contact smart cards for purchasing a variety of services and products. Currently, 30,000 people are using this "POSTCARD" system. POSTCARDs "can be used:

- In ten Ascom ticket vending machines to purchase single and multiride bus tickets for the local bus system;
- In 32 PTT public pay telephones;
- In 25 readers/writers in stores to pay for goods and services;
- In three hot and cold drink vending machines; and
- In readers/writer at the post office to pay for electric and telephone bills and to buy stamps." [132]

4.3 HIGH OCCUPANCY VEHICLE FACILITY MONITORING

The concept of high occupancy vehicle (HOV) lanes is well established as a means of encouraging single occupant drivers to carp001 and thereby help to relieve congestion. Those

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[130] Briefing Document on Stored Value Card Project, prepared by Commercial Services Group, New South Wales Government, Australia, July 1993.
Morris, Linda, "Plastic Cash Card for Trial," ***Telegraph Mirror,*** May 6, 1993.

[131] Joshi, Ashok, J.W. Leas & Associates, "Get Electronic Card Smart," op. cit., p. 11.

[132] Ibid, p. 10.

traveling in cars with two or more passengers (or in some cases, three or more passengers, depending on the threshold established) are rewarded with a shorter travel time by being permitted to use exclusive travel lanes. Given the benefits of congestion-free travel, there is a temptation for drivers of single occupancy vehicles to use the HOV lanes illegally. Hence, monitoring the use of HOV lanes has become an increasing challenge. The traditional response is to station police cars near ramp entrances, but costs in personnel time and limited effectiveness in monitoring peak hour use of HOV lanes has led to the search for a technological solution to the issue of HOV lane monitoring.

State-of-the-Art Summary

To date, a number of HOV lane monitoring devices have been tested but none has proven to be fully effective in operation. Surveillance cameras have been used in several locations, but they are not accurate in recording the presence of children or an individual lying down in the automobile. They are also not usable in darkness. Infrared beams are turned aside by tinted windshields. Automatic Vehicle Identification (AVI), where vehicles are equipped with transponders which are read by wayside sensors, will verify compliance even if the vehicle does not have the requisite passengers on a given trip. Experimental tests are continuing, largely focusing on adapting military surveillance techniques or techniques used in law enforcement for such a purpose. Some metropolitan areas have dismissed technological solutions, noting the costs involved in implementation - an issue which has not been fully explored.

Applications

Portland, Oregon

In an ongoing operational test, car-pools and buses use by-pass lanes to avoid ramp-metering queues when entering the HOV facility. Registered carpools are issued vehicle ID cards, which are displayed in the windshield and are read at the ramp. More permanent ID tags are affixed to buses. The number of registered carpools is extensive, since Tri-Met has been managing a carp001 matching program for several years. The Oregon Department of

Transportation is developing a smaller version of the tag which can be attached to its vehicles using velcro.

The Oregon DOT is now accepting proposals for a study to test the relative effectiveness of using law enforcement personnel, compared to capital investments such as cameras or signs, for monitoring HOV violation rates.

Dallas, Texas

The Texas Transportation Institute (TTI) has initiated a study that will assess the applicability of various types of automated enforcement technologies for the East R. L. Thornton HOV lane. The study will focus on two basic types of automated enforcement technologies - AVI and imaging technologies. The AVI approach would use a small in-vehicle device that will identify the vehicle to an electronic reader via radio frequency. Imaging technologies would use video or other visualization techniques to distinguish individual vehicle passengers remotely. Initial contacts are being made with vendors who might provide necessary software. Implementation will occur if any of the alternative technologies examined are judged to be feasible.[133]

Houston, Texas

Houston is experimenting with use of AVI to monitor congestion on HOV lanes, rather than as a surveillance device. One thousand tags have been distributed to commuters who travel on I-10, I-45, and US 290. Radio frequency antennas are mounted overhead on existing signs and bridges and will continuously scan the lanes looking for tags on vehicles that are serving as congestion probes. Actual trip times are compared with expected trip time and the level of congestion assessed.

Similar tags are being used for electronic toll collection on the Sam Houston and Hardy toll roads as well as in highways in Oklahoma, Dallas, Hong Kong, and London. To date, over 400,000 AVI tags have been distributed for revenue collection.[134] No plans have been

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[133] Lomax, project statement, September 1993.

[134] AmTech, Backscatter, summer 1993.

announced to use tags to identify registered carpools or to use the same antennas for monitoring the number of passengers in vehicles on an HOV lane.

Georgia Institute of Technology

At the Georgia Institute of Technology, a unique set of experiments in advanced monitoring systems for HOV lanes are being performed. Prototype scanning radiometers are being field tested. These use electromagnetic radiation as a means of reading inside a vehicle to determine the number of passengers. Since humans raise the heat of a seat by about six degrees, it is claimed to be possible to detect exactly how many people are in a vehicle. This concept would be successful in detecting the use of dummies as vehicle passengers and will report the presence of children or individuals who are lying down and who might not be seen by a camera. Earlier studies using infrared were quickly abandoned since the windshield blocks infrared light. The concept awaits funding for an operational test.[135]

Camera Surveillance

The Minnesota Guidestar project is experimenting with the use of autoscope, an advanced area-wide vehicle directional and automatic vehicle surveillance system invented at the University of Minnesota. The autoscope looks for changes in vehicle speeds and volumes and then analyzes video imagery and generates traffic flow information. To date, however, it is not being used to monitor the number of passengers in cars on the HOV lanes.[136]

Jackson, Michigan and National City, California police are using camera-based advanced traffic enforcement systems developed by U. S. Public Technologies to enforce speed limits, red lights, and stopping at railroad crossings. The system has not been tested on HOV lanes except with spot checking using cameras.[137]

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[135] Gene Greneker, Professor of Engineering, Georgia Institute of Technology.

[136] Minnesota DOT, 1993
Melanie Brawn, Minnesota DOT, Transit Division.

[137] Zev Fogel, U.S. Public Technologies.

The cities of Portland, Oregon, Boca Raton, Florida, and San Jose, California are all using Colby Monitoring Products for remote monitoring of traffic signals and parking areas. These systems involve using a standard touch-tone telephone to access remote video monitors and to transmit video pictures. Options include zoom and pan, tilt, and infrared detectors and cellular phone access. The system has not been used for HOV monitoring as yet.

4.4 TRANSPORTATION MANAGEMENT CENTERS

A number of well-established Transportation Management Centers (TMCs) are associated with highway monitoring. They use an array of television monitors and cameras to observe congestion levels on limited access highways. Observation of congestion leads to displaying warnings and suggested re-routings on automated highway message boards.

Some of the Transportation Management Centers like that in Los Angeles also monitor traffic build-up on arterials by using inductive loop detectors imbedded in the pavement at intersections. Traffic signals are preprogrammed to respond to high levels of traffic build up on key arterials by extending the green time. On Century Boulevard in Los Angeles, for example, the traffic signals are configured to respond to the level of traffic expected at sporting events at the Los Angeles Coliseum.

Examples of TMCs are: the Inform project in Long Island, New York; the Washington, DC Metropolitan Traffic Management Facility; the Minnesota Department of Transportation Interstate Highway Monitoring System; and the California Department of Transportation system for monitoring the Los Angeles freeways.

State-of the-Art Summary

None of the current TMCs are yet linked to information about a transit alternative. There are, however, plans to feed real-time traffic congestion reporting into traveler information systems that do highlight transit and ride-sharing alternatives, as was discussed earlier. The U.S. Department of Transportation has just issued a request for proposals for public-private partnerships to address the interrelated issue of enroute driver and traveler services information. Operational tests are planned.

Applications

One type of application is the provision of traffic signal preemption or extension of green time for buses that are running late because of congestion levels. The following are examples of some attention being afforded to transit operations, although most do not involve a Transportation Management Center.

Detroit,. Michigan

Plans for the Detroit Transportation Center Transit Information System call for an eventual multi-modal information system which would link transit information with highway congestion information. Under the plan, real-time traffic information generated by the interstate traffic management system will be relayed to the transit authority. The transit authority is currently supplied with information on congestion points, but not yet in real time.[138]

Anaheim, California

The Anaheim Traffic Management Information and Fleet Operation Coordination project has an extensive freeway monitoring program for Orange County, based in Anaheim, but no transit component is operational yet. [139]

Portland, Oregon

A pilot project is underway in traffic signal preemption for one corridor, Route 9, Powell Street. This is managed by the City of Portland. They are using vehicle ID cards and inductive loop detectors imbedded in the pavement. A related project sponsored by the Oregon DOT is considering the potential for ramp monitoring on the Sunset Highway. Both use the same bus ID cards.[140]

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[138] Janet D'Ignazio, Michigan DOT.
Doreen Tyrell, Detroit DOT.

[139] Jim Paral, City of Anaheim.

[140] Ken Turner, Portland Smart Vehicle.

Toronto, Ontario

The city of Toronto now has thirty intersections which have adaptive signal control for street cars in the Queen Street corridor. There are also ten intersections that have adaptive signal control for buses.[141]

Chicago, Illinois

The CTA is in the process of negotiating a contract with an integrator for a system that would not only include automatic vehicle location for the majority of its fleet but would also include adaptive signal control for transit vehicles operating on major arterials.[142]

Saarbruecken/Oldenburg, Germany

There are several examples of effective traffic signal preemption operations in Europe. For example, in Saarbruecken, Germany, an autonomous vehicle control monitoring system features management of on-board electronics/peripherals and traffic signal preemption, connection protection, and active passenger signs. The system, designed by Intelligent Transportation Systems, also features cashless payment via smart cards. In Oldenburg, Germany, traffic signal preemption is also integrated with the use of smart cards. Both systems use GPS and GIS mapping in their tracking systems. [143]

London, England

A bus priority system is being tested in London within the SCOOT traffic-responsive UTC system. SCOOT currently is operating 450 intersections; 5,000 buses are equipped with transponders. The system uses selective detection of buses, based upon bus transponders and inductive loop detectors. SCOOT features the regular optimization of cycle time and the use of

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[141] Brandon Hemily, Canadian Urban Transit Association.

[142] Ronald Baker, Chicago Transit Authority.

[143] Gerland, Horst, "ITS Intelligent Transportation System: Fleet Management," *Proceedings of the IEEE-ZEE Vehicle Navigation Systems Conference, VNIS '93,* Ottawa pp. 606-611.

frequent but small changes in these signal timings to respond to changing network traffic conditions.[144]

Turin, Italy and Gothenburg, Germany

Turin has a well established approach to bus priority using automated vehicle monitoring equipment associated with the city's trams and buses. Forty intersections are involved and soon the entire fleet of 1,300 vehicles will be equipped. The system uses journey time prediction methods to provide the information necessary to give priority to the public transportation vehicles. A similar system is being introduced in Gothenburg where adaptive control is based on automatic updating at central control and modified by SPOT units at the local level. Most intersections have the system installed with priority given to trams. However, the granting of priority does not consider the level of congestion.[145]

4.5 VEHICLE GUIDANCE SYSTEMS

Vehicle guidance systems integrate technologies that laterally and longitudinally control the operation of a vehicle. To date, vehicle guidance technologies that have been demonstrated include: track guidance, electronic guidance, magnetic guidance, and vision systems. Track guidance is mechanical, and has been used in bus systems in Rochefort, Belgium; Essen, Germany; Adelaide Australia; and Birmingham, United Kingdom. Electronic guidance consists of wire buried in a roadway that emits a signal to guide a bus. This technology is operating in Furth, Germany. Magnetic guidance and vision systems are described below.

State-of-the-Art Summary

In the ***State-of-the-art Update '92*** report, the aforementioned guided bus systems were reviewed. Since then, there has been no further development in these specific systems.

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[144] Burton, Robert and Nicholas Hounsell, "Bus Priority and UTC Systems: The PROMPT Project," *Proceedings of the IEEE-IEE Vehicle Navigation Systems Conference, VNIS '93,* Ottawa pp. 602-605.

[145] Ibid.

However, there are several developments in new technologies that are being demonstrated in North America, England and Japan.

Applications

United Kingdom

A bus system similar to that in Furth, Germany was to be operating in the English Channel Tunnel, probably by the end of 1993. This system has electronic guidance, which consists of wire (buried in the road) that emits a signal which is used by a transducer on the bus to control the steering system.

San Francisco Bay Area, California

The Partners for Advanced Transit and Highways (PATH) has a test track which uses a guidance system based on magnets. PATH has been experimenting with this concept since 1987, and is currently testing the technology with automobiles. This technology consists of permanent magnets buried in the center of the road three to five feet apart. The magnets, which have a one inch diameter and are four inches long, would be dropped into holes drilled into a road and then covered with pavement (so they would not be detectable to the eye).[146]

This "magnetic marker reference system is used to provide vehicle lateral displacement and the upcoming road radius of curvature to the vehicle. The road geometric information (curvature, start and end points) are obtained off-line and stored in an on-board database. The absolute position is transmitted to the vehicle, which is then used to extract the road curvature information."[147]

PATH is discussing the potential for bus implementation with the Alameda-Contra Costa Transit District (AC Transit). PATH is working with Honeywell on the magnets, with TRW

[146] Weibin Zhang, Research Specialist, Partners for Advanced Transit and Highways (PATH).

[147] Peng, Huei, Weibin Zhang, Steven Shladover, Masayoshi Tomizuka, and Alan Arai, "Magnetic-Marker-Based Lane Keeping: A Robustness Experimental Study," prepared for the 1993 SAE Congress, September 27, 1992, p. 2.

on the steering actuation, and with Gillig on the buses themselves. PATH anticipates a full demanstration of this technology in three to five years.

Japan

In Japan, the vision system of guidance has been demonstrated with automobiles and a small Nissan bus. The vision system recognizes vehicle lateral and longitudinal position, and traffic signs. "Vision-based systems have the potential to be used for a wide variety of vehicle control purposes, e.g., obstacle detection, collision warning, lane keeping, adaptive cruise control, etc."[148] The demonstration, which was supported by the Japan Ministry of International Trade and Industry, was performed at low speeds and used six to eight videocameras. This system could be a potential guidance technology for transit in fifteen to twenty years.

[148] Ibid.

5. 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 (FOT) 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 5.1. 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:

Ronald J. Fisher
U.S. Department of Transportation
Federal Transit Administration (TTS-30)
Room 6102
400 Seventh Street, SW
Washington, DC 20590
(202) 366-4995

Table 5.1
Current FTA-Sponsored APTS Field Operational Tests and Research[149]

Title	FTA Contact	Local Agency	Local Contact
SMART' TRAVELER			
Bellevue Smart Traveler	Ronald Boenau (202) 366-o 195	Municipality of Metropolitan Seattle Seattle, Washington	Cathy Blumenthal (Bellevue TMA) (206) 453-0644
California Smart Traveler	Ronald Boenau (202) 366-O 195	California DOT, Div of New Tech. & Research Sacramento, California	Robert Ratcliff (9 16) 323-2644
Houston Smart Commuter	Denis Symes (202) 366-0232	Metropolitan Transit Authority of Harris County Houston, Texas	Darryl Pucket (7 13) 7396093
Twin Cities Smart Traveler	Sean Ricketson (202) 366-6678	Regional Transit Board of St. Paul St. Paul, Minnesota	Howard Blin (612) 292-8789
Rogue Valley Mobility Manager	Ronald Boenau (202) 366-0195	Rogue Valley Council of Governments Central Point, Oregon	Gary Shaff (503) 664-6674
Advanced Ridesharing and Traveler Information System	Ronald Boenau (202) 366-0195	Potomac-Rappahanoc Transportation Commission Northern Virginia	Eric Marx (703) 490-4811
New York City Travel Info	Denis Symes (202) 366-0232	New York City Transit Authority Brooklyn, New York	Isaac Takyi (718) 694-3652
Winston-Salem Mobility Manager	Ronald Boenau (202) 366-0195	City of Winston-Salem Winston-Salem, North Carolina	John Stone (NC State U) (919) 515-7732
SMART VEHICLE			
Portland Smart Bus	Ronald Boenau (202) 366-0195	Tri-County Metropolitan Transportation District Portland, Oregon	Park Woodworth (503) 238-4879
Denver Smart Bus	Denis Symes (202) 366-0232	Regional Transportation District Denver, Colorado	Lou Ha (303) 299-6265
Baltimore Smart Bus	Denis Symes (202) 366-0232	Mass Transit Administration Baltimore, Maryland	Ray Carroll (410) 333-3430

[149] Based on information provided by FTA, Office of Technical Assistance and Safety.

Table 5.1 (continued)
Current FTA-Sponsored Field Operational Tests and Research

Title	FTA Contact	Local Agency	Local Contact
Dallas Smart Bus	Denis Symes (202) 366-0232	Dallas Area Rapid Transit Dallas, Texas	Paul Ledwitz (214) 749-2837
Milwaukee Smart Bus	Sean Ricketson (202) 366-6678	Milwaukee County Milwaukee, Wisconsin	Jim Mackey (414) 278-4931
SMART INTERMODAL SYSTEMS			
Traffic Management Information and Fleet Operation Coordination	Denis Symes (202) 366-0232	City of Anaheim, Public Works-Engineering Dep. Anaheim, California	Jim Paral (714) 254-5183
Detroit Transportation Center Transit Information	Sean Ricketson (202) 366-6678	Michigan Department of Transportation Michigan	Janet D'Ignazio (517) 373-2834
Ann Arbor Smart Intermodal	Sean Ricketson (202) 366-6678	Ann Arbor Transportation Authority Ann Arbor, Michigan	Michael Bolton (313) 973-6500
Chicago Smart Intermodal	Sean Ricketson (202) 366-6678	Chicago Transit Authority Chicago, Illinois	Jim Blanchard (312) 245-9170
Chattanooga Smart Card	Sean Ricketson (202) 366-6678	Chattanooga Are Rapid Transit Authority Chattanooga, Tennessee	Art Barnes (615) 698-2749
Delaware County Ridetracking	Sean Ricketson (202) 366-6678	Delaware County Community Transit Delaware County, Pennsylvania	Judy McGrane (215) 532-2900
PROGRAM EVALUATIONS AND RESEARCH			
IVHS Institutional Issues	Ronald Fisher (202) 366-4995	George Mason University Fairfax, Virginia	Roger Stough (703) 993-2280
Advanced Fare Payment Media II - Phase II	Sean Ricketson (202) 366-6678	Echelon Industries Incorporated Diamond Bar, California	Ray Rebeiro (714) 594-1891
Transit Network Decision Aid	Sean Ricketson (202) 366-6678	University of Michigan Ann Arbor, Michigan	Chip White (313) 763-1332

Table 5.1 (continued)
Current FTA-Sponsored Field Operational Tests and Research

Title	FTA Contact	Local Agency	Local contact
Operational Test Evaluation	Ronald Fisher (202) 366-4995	Volpe National Transportation Systems Center Cambridge, Massachusetts	Robert Ow (617) 494-2411
Technology Research	Denis Symes (202) 366-0232	Volpe National Transportation Systems Center Cambridge, Massachusetts	Robert Ow (617) 494-2411

APPENDIX

TABLE A.1 List of Contacts[150]

Organization	Contact	Phone
Trimble Navigation California	Jeff Jacobs, Product Manager	(408) 481-2865
U.S. Public Technologies California	Zev Fogel	(619) 558-8778
City of Anaheim Anaheim, California	Jim Paral, Public Works-Eng. Department	(714) 254-5183
University of California Berkeley, California	Ted Chaval Wei-Bin Zhang, Research Specialist	(510) 642-3559 (510) 231-9538
SilentRadio Chatsworth, California	Cameron Katrai	(800) 753-4888
Mayflower Contract Services Fresno, California	Elizabeth Diaz	(209) 291-2555
Mayflower Contract Services Hemet, California	Chet Bor	(909) 766-8781
Etak, Inc. Menlo Park, California	Jess Wells	(415) 328-3825
Caltrans, Public Transportation Branch Los Angeles, California	Margaret Moilov	(213) 897-0188
Commuter Transportation Services, Inc. Los Angeles, California	Bob Kohl	(213) 380-7750

[150] The following provided input for the report.

Contacts are ordered alphabetically, first by state, then by city within each state, then by organization name within each city. U.S. organizations are listed first, followed by Canadian organizations, followed by all others. An alphabetical list of people immediately follows as Table A. la

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TABLE, A. 1. (continued) List of Contacts

Organization	Contact	Phone
Los Angeles County Metropolitan Transportation Authority Los Angeles, California	William Volkmer, Project Manager, Fare Debitcard Project	(2 13) 244-6976
Bay Area Rapid Transit District Oakland, California	Larry Kozimor	(5 10) 287-4723
Metropolitan Transportation Commission Oakland, California	Joel Markowitz, Mgr., Adv. Sys. Applications Melanie Crotty	(5 10) 464-7760 (5 10) 464-7760
California Smart Traveler Sacramento, California	Robert Ratcliff	(9 16) 654-8367
Cubic Automated Revenue Collection Group San Diego, California	David Miller, Mgr-Customer Svcs.&Training	(6 19) 627-4662
San Diego Transit Corporation San Diego, California	Theresa Brock	(619) 238-0100, x468
San Mateo County Transit San Mateo, California	John Griffith	(415) 5086200
Denver Regional Transportation District Denver, Colorado	Lou Ha	(303) 299-6265
Hartford Transportation Services Hartford, Connecticut	David Vozzolo	(203) 722-8480
Delaware Transportation Authority Delaware	Wayne Spaulding, Assistant Director, Program Development	(302) 739-4593
Applied Systems Institute, Inc. Washington, District of Columbia	Peter Ognibene, Vice President	(202) 371-1600
Information Management International, Inc. Washington. District of Columbia	Robert Tanenhaus, President	(202) 797-00 13
Washington Metropolitan Area Transit Authority Washington, District of Columbia	Peter Benjamin, Ass. Gen. Manager-Finance	(202) 962-1200

TABLE A.1. (continued) List of Contacts

Organization	Contact	Phone
LYNX bus line of Orange, Osceola and Seminole Counties Florida	Glen Parrish	(407) 84 1-2279
Monarch Electronics, Inc. (Colby Monitoring Products) Florida	Marv Stuart	(305) 866-l 885
Manatee County Area Transit Bradenton, Florida	Chuck Firestone	(813) 749-7144
Greater Pinellas Transp. Mgmt Svc., Inc. Clearwater, Florida	Bud Williams	(813) 586-2811
Paratransit service Deland, Florida	Buffy Hunt	(904) 7366411
Broward County Division of Mass Transit Fort Lauderdale, Florida	Glen Margolis Bruce Coleman	(305) 357-839 1 (305) 357-839 1
Jacksonville brokerage Jacksonville, Florida	Joyce O'Brien	(904) 396-1814
Jacksonville Transportation Authority Jacksonville, Florida	Joseph Mistrot	(904) 650-3 153
Automated Dispatch Services (ADS), Inc. Miami, Florida	David Brown	(305) 471-0441
Metropolitan Dade County Transportation Authority Miami, Florida	Louis Revas Richard Jones	(305) 375-3203 (305) 637-37 17
Hillsboro Area Regional Transit Authority Tampa, Florida	Steve Roberts	(8 13) 623-5835
Palm Beach County Transportation Authority West Palm Beach, Florida	Jerry Bryan	(305) 233-l 114
Georgia Institute of Technology Georgia	Gene Greneker, Professor of Engineering	(404) 528-7744

TABLE A.P. (continued) List of Contacts

Organization	Contact	Phone
Honolulu Public Transportation Authority Honolulu, Hawaii	James Burke	(808) 523-4445
Mayflower Contract Services Honolulu, Hawaii	Mike Kopaczewski	(808) 8414322
Decision Sciences, Inc. Illinois	Charles Jones, President	(708) 965-158 1
Belleville Area College Senior Citizens Center Belleville, Illinois	Rudy Muzzerelli	(618) 277-7964
Champaign-Urbana Mass Transit District Champaign-Urbana, Illinois	Jim Dhom	(217) 384-8188
Chicago Transit Authority Chicago, Illinois	Joe Simonetti, General Manager, Revenue Equipment Technology and Maintenance Ronald Baker, General Manager, Communications Implementation Task Force	(312) 521-1415 (312) 664-7200, x4105
Regional Transportation Authority Chicago, Illinois	Rich Mizera, Dir., PCIS and PRT Projects	(312) 917-0799
Madison County Transit Granate City, Illinois	Todd Plesko	(618) 797-0660
Ace Cab (Shared-ride and Dial-a-Ride) Indiana	Mike Personnette	(219) 295-6886
Northern Indiana Commuter Transportation District Indiana	Boris Matakovic, Systems Analyst	(2 19) 926-5744
Micro Dynamics Corporation Evansville, Indiana	Paul Buroker	(8 12) 477-3090
Aid Ambulance Indianapolis, Indiana	Rick Archer	(317) 546-1581

TABLE A.1. (continued) List of Contacts

Organization	Contact	Phone
Iowa !&ate University Ames, Iowa	Mary Kihl	(5 15) 294-0734
Des Moines Metropolitan Transit Authority Des Moines, Iowa	Tom Blair	(515) 283-8111
Transit Authority of River City Louisville, Kentucky	John Woodford Bill Mason	(502) 561-5104
Washington-Hancock Community Agency Maine	Barbara Donovan	(207) 546-7544
Bar Harbor Software, Inc. Bar Harbor, Maine	Doug Lee	(207) 667-8007
Germantown Taxi Germantown, Maryland	Mike Salmany	(301) 990-7000
Mass Transit Administration Baltimore, Maryland	Ray Carroll David Hill	(410) 333-3430 (410) 333-3430
Coopers & Lybrand Boston, Massachusetts	Robert Ropp, Senior Associate	(617) 621-3619
Massachusetts Bay Transportation Authority Boston, Massachusetts	James T. Brown, Chief Revenue Officer Mike Francis, Sup. of Central Control Alan Casteline Robert Clark	(617) 722-5728 (617) 722-5758 (617) 722-573 1 (617) 722-3493
Smart Routes, Hot Line Boston Area, Massachusetts	---	(617 or 508) 574-1234
DAVE Transportation Services, Inc. Cambridge, Massachusetts	David Naiditch	(617) 491-0941
Multisystems Cambridge, Massachusetts	Daniel Fleishman, Dir, Transit Policy Anal. Kurt Dossin	(617) 864-5810 (617) 864-5810

TABLE A.1. (continued) List of Contacts

Organization	Contact	Phone
Southeastern Regional Transit Authority New Bedford, Massachusetts	Jane Kirby	(508) 997-6767
Peter Pann Buslines Springfield, Massachusetts	Lloyd Jack	(413) 781-3320
Veterans Transportation Services Waltham, Massachusetts	JoAnn Zebal	(617) 899-7433
Michigan Department of Transportation Michigan	Janet D'Ignazio	(5 17) 373-2834
Ann Arbor Transportation Authority Arm Arbor, Michigan	William Hiller Michael Bolton, General Manager	(3 13) 973-6500
Detroit Department of Transportation Detroit, Michigan	Doreen Tyrell	(313) 223-2121
3M Corporation Minnesota	Robert Johnson, Marketing Specialist for Opticum	(612) 733-0647
Minnesota DOT Minnesota	Melanie Brawn, RSI (Transit) Division Dick Stehr, Planning Development and Traffic	(6 12) 282-2474 (612) 297-3532
Castle Rock Consultants (Minnesota Guidestar, rural prjcts) Eagan, Minnesota	Chris Hill (in Minnesota)	(612) 686-6321
Kansas City Area Transportation Authority Kansas City, Missouri	John Dobies, Director of Transportation	(816) 346-0216
AT&T, IVHS Communications New Jersey	Peter Skareynski	(908) 658-6650
New Jersey Transit New Jersey	Mark Revis, Bus Operations	(201) 491-7277
Caravan Bus Lines New York	Jeff DeStephano	(718) 453-3800

TABLE A.1. (continued) List of Contacts

Organization	Contact	Phone
New York City Transit Authority Brooklyn, New York	Dick Trenary, VP and Program Mgr for AFC Dave Weiss, Prjct Mgr for Control Ctr Project	(7 18) 694-5273 (718) 694-3690
TWC Ambulance Long Island, New York	Al Iguiori	(516) 431-4569
Long Island Rail Road New York, New York	John Swanson, Manager, Automated Ticket Sales	
Digital Recorders, Inc., (Talking Bus) North Carolina	Bruce Thomas, V. P. Sales Carol Schuster	(800) 222-9583 (919) 361-2155
Mecklenburg County Department of Social Services Charlotte, North Carolina	Vincent Withers	(704) 336-4546
Gaston County Coordinated Transportation Gastonia, North Carolina	Sheila Courtney	(704) 866-3 107
Greensboro Specialized Transportation Greensboro, North Carolina	Donnie Funderburk	(919) 275-9100
Easy Street (Dynamic Scheduling Software) Raleigh, North Carolina	Art Stratemeyer Patrick Simnons	(9 19) 848-999 1 (9 19) 848-999 1
Project Sparkplug - Canton Regional Transit Authority Canton, Ohio	Clark Hart	(216) 454-6132
Rogue Valley Council of Governments Central Point, Oregon	Gary Shaff Jon Deason	(503) 664-6674 (503) 6646674
Portland Smart Vehicle, Tri-Met Portland, Oregon	Ken Turner	(503) 238-49 18
Salem Area Transit Salem, Oregon	Greg Cook, General Manager	(503) 588-2885
Sioux Falls Paratransit Sioux Falls, South Dakota	David Braun	(605) 339-7 183

TABLE A.1. (continued) List of Contacts

Organization	contact	Phone
J.W. Leas & Associates Pennsylvania	Ashok Joshi, Senior Transportation Engineer	(215) 525-1952
Community Transit of Delaware County Philadelphia, Pennsylvania	Judith McGrane, General Manager	(2 15) 532-2900
COMSIS Corporation Pittsburgh, Pennsylvania	Marcia DeJulio	(412) 279-9110
Beaver County Transit Authority Rochester. Pennsylvania	Bruce Ahern, General Manager	(4 12) 728-4255
K-TRANS Knoxville, Tennessee	Paulette Lay	(6 15) 546-3752
Beaumont Nutrition and Service for the Elderly Texas	Elaine Shellenberger	(409) 8924455
Kaufman County Senior Citizen Service Texas	Doris Jenkins	(214) 563-1422
Scientific Systems Texas	Pete Schumacher	(8 17) 467-5555
SPAN Texas	Sharon Olafson	(2 14) 434-2466
Texas Transportation Institute College Station, Texas	Katherine Turnbull, Program Manager	(409) 845-1535
Agent Systems, Inc. Dallas, Texas	Bruce David, Director of Marketing	(2 14) 630-0400
AmTech Dallas, Texas	Frank Dorrence	(214) 7336045
AutoTrac Dallas, Texas	Pat Friend	(214) 480-8145

TABLE A.l. (continued) List of Contacts

Organization	Contact	Phone
Dallas Area Rapid Transit Dallas, Texas	Donnie Thompson Paul Ledwitz Chris Patrick, Communications Systems Mgr	(214) 828-6628 (214) 749-2837 (214) 828-6779
El Paso Para Transit Department El Paso, Texas	Robin Stone	(915) 533-1220
Philip G. Dorcas and Associates Fort Worth, Texas	Phil Dorcas	(817) 921-9704
Metropolitan Transit Authority of Harris County Houston, Texas	Gloria Stoppenhagen William Kronenberger	(713) 739-6595 (713) 739-6013
Luminator Plano, Texas	George Picket Barbara Lange	(214) 424-6511 (214) 424-6511
VIA Metropolitan Transit San Antonio, Texas	Stephen Thomas Kevin Stanush	(210) 227-5371 (210) 227-5371
Salt Lake City Aging Service Utah	Scott McBeth	(801) 468-2753
American Contracting Management Viginia	Jim McCleary	(703) 960-2264
Castle Rock Consultants Virginia	Chris Hill (in Virginia)	(703) 771-0020
JHK & Associates Virginia	Bee Buergler, Senior Associate	(703) 370-2411
Northern Virginia Transportation Commission Virginia	Cameron Muhick, Supervisor, Ticket Vending Howard Shock, Automatic Fare System Cons.	(703) 642-3808 (703) 524-3322
Potomac and Rappahannock Transportation Commission Virginia	Brad Miller	(703) 490-4811

TABLE A.l. (continued) List of Contacts

Organization	Contact	Phone
Schlumberger Technologies, Parking & Transit Systems Chesapeake, Virginia	Bertrand Moritz, Marketing Manager	(800) 523-2114
Tidewater Consultants Virginia Beach, Virginia	Andi Overton	(804) 497-895 1
Bellevue Smart Traveler Bellevue, Washington	Cathy Blumenthal	(206) 453-0644
Paratransit Systems International, Inc. Bremerton, Washington	Jeff Forville	(800) 926-2345
Paratransit Services Bremertown, Washington	Bruce Barrett	(206) 377-7 176
Clallam Paratransit Port Angeles, Washington	Dan Lucas	(206) 452-l 397
Mason County Dial-A-Ride Shelton, Washington	Dan Morrissey	(206) 427-5033
Spokane Transit Authority Spokane, Washington	John Matthews	(509) 3256033
Sheboygen Transit System Sheboygen, Wisconsin	Ray Ann Brunette	(4 14) 459-328 1
Calgary Transit Calgary, Alberta, CANADA	Fred Warg	(403) 277-97 16
BC Transit Kamloops, British Columbia, CANADA	Anita Sevard	(604) 376-7525
BC Transit Kelowna, British Columbia, CANADA	Arly Dawson	(604) 762-3278
BC Transit Nanaimo, British Columbia, CANADA	Brian Warner	(604) 390-3000

TABLE A.l. (continued) List of Contacts

Organization	Contact	Phone
BC Transit Victoria, British Columbia, CANADA	Peter Ganyon	(604) 479-3 111
Metro Transit, City of Halifax Halifax, Nova Scotia, CANADA	Moss Mombourquette	(902) 42 l-2647
UMA Engineering Ltd. Mississauga, Ontario, CANADA	Fran Fendelet, Marketing Manager	(416) 238-0007
Ottawa-Carleton Regional Transit Commission Ottawa, Ontario, CANADA	Helen Gault, P.Eng., Dir., Systems Planning	(613) 7416440
Canadian Urban Transit Association Toronto, Ontario, CANADA	Brendon Hemily	(416) 365-9800
Ontario Ministry of Transportation Toronto, Ontario, CANADA	Barry Pekilis, Research Engineer	(416) 235-3455
Teleride-Sage Toronto, Ontario, CANADA	Brian Kalanda, Director of Marketing	(416) 596-1940 x210
Toronto Transit Commission Toronto, Ontario, CANADA	Agnes Csors	(416) 393-2631
GIRO Montreal, Quebec, CANADA	Nigel Hamer	(514) 383-0404
Montreal Urban Community Transport Commission Montreal, Quebec, CANADA	Serge Belanger Mr. Rousse	(514) 280-5829 (514) 280-6308
Telecite, Inc. Montreal, Quebec, CANADA	Marshall Moreyne	(514) 695-7517
TecknoGuide Hillerod, DENMARK	Peter Soelberg	(45) 45-25-07-77

TABLE A.la List of Contacts - Alphabetical Person Index

Contact	Organization
Bruce Ahern	Beaver County Transit Authority Rochester, Pennsylvania
Rick Archer	Aid Ambulance Indianapolis, Indiana
Ronald Baker	Chicago Transit Authority Chicago, Illinois
Bruce Barrett	Paratransit Services Bremertown, Washington
Serge Belanger	Montreal Urban Community Transport Commission Montreal, Quebec, CANADA
Peter Benjamin	Washington Metropolitan Area Transit Authority Washington, District of Columbia
Tom Blair	Des Moines Metropolitan Transit Authority Des Moines, Iowa
Cathy Blumenthal	Bellevue Smart Traveler Bellevue, Washington
Michael Bolton	Ann Arbor Transportation Authority Ann Arbor, Michigan
Chet Bor	Mayflower Contract Services Hemet, California
David Braun	Sioux Falls Paratransit Sioux Falls, South Dakota
Melanie Brawn	Minnesota DOT Minnesota
'Theresa Brock	San Diego Transit Corporation San Diego, California
David Brown	Automated Dispatch Services (ADS), Inc. Miami, Florida
James T. Brown	Massachusetts Bay Transportation Authority Boston, Massachusetts
Ray AM Brunette	Sheboygen Transit System Sheboygen, Wisconsin
Jerry Bryan	Palm Beach County Transportation Authority West Palm Beach, Florida
Bee Buergler	JHK & Associates Virginia

TABLE A.la (continued) List of Contacts - Alphabetical Person Index

Contact	Organization
James Burke	Honolulu Public Transportation Authority Honolulu, Hawaii
Paul Buroker	Micro Dynamics Corporation Evansville, Indiana
Ray Caroll	Mass Transit Administration Baltimore, Maryland
Alan Casteline	Massachusetts Bay Transportation Authority Boston, Massachusetts
Ted Chaval	University of California Berkeley, California
Robert Clark	Massachusetts Bay Transportation Authority Boston, Massachusetts
Bruce Coleman	Broward County Division of Mass Transit Fort Lauderdale, Florida
Greg Cook	Salem Area Transit Salem, Oregon
Sheila Courtney	Gaston County Coordinated Transportation Gastonia, North Carolina
Melanie Crotty	Metropolitan Transportation Commission Oakland, California
Agnes Csors	Toronto Transit Commission Toronto, Ontario, CANADA
Bruce David	Agent Systems, Inc. Dallas, Texas
Arly Dawson	BC Transit Kelowna, British Columbia, CANADA
Jon Deason	Rogue Valley Council of Governments Central Point, Oregon
Marcia DeJulio	COMSIS Corporation Pittsburgh, Pennsylvania
Jeff DeStephano	Caravan Bus Lines New York
Jim Dhom	Champaign-Urbana Mass Transit District Champaign-Urbana, Illinois
Elizabeth Diaz	Mayflower Contract Services Fresno, California

TABLE A.la (continued) List of Contacts - Alphabetical Person Index

Contact	Organization
Janet D'Ignazio	Michigan Department of Transportation Michigan
John Dobies	Kansas City Area Transportation Authority Kansas City, Missouri
Barbara Donovan	Washington-Hancock Community Agency Maine
Phil Dorcas	Philip G. Dorcas and Associates Fort Worth, Texas
Frank Dorrence	AmTech Dallas, Texas
Kurt Dossin	Multisystems Cambridge, Massachusetts
Fran Fendelet	UMA Engineering Ltd. Mississauga, Ontario, CANADA
Chuck Firestone	Manatee County Area Transit Bradenton, Florida
Daniel Fleishman	Multisystems Cambridge, Massachusetts
Zev Fogel	U.S. Public Technologies California
Jeff Forville	Paratransit Systems International, Inc. Bremerton, Washington
Mike Francis	Massachusetts Bay Transportation Authority Boston, Massachusetts
Pat Friend	AutoTrac Dallas, Texas
Donnie Funderburk	Greensboro Specialized Transportation Greensboro, North Carolina
Peter Ganyon	BC Transit Victoria, British Columbia, CANADA
Helen Gault	Ottawa-Carleton Regional Transit Commission Ottawa, Ontario, CANADA
Gene Greneker	Georgia Institute of Technology Georgia
John Griffith	San Mateo County Transit San Mateo, California

TABLE A.1a (continued) List of Contacts - Alphabetical Person Index

Contact	Organization
Lou Ha	Denver Regional Transportation District Denver, Colorado
Nigel Hamer	GIRO Montreal, Quebec, CANADA
Clark Hart	Project Sparkplug - Canton Regional Transit Authority Canton, Ohio
Brendon Hemily	Canadian Urban Transit Association Toronto, Ontario, CANADA
Chris Hill	Castle Rock Consultants (Minnesota Guidestar, rural prjcts) Eagan, Minnesota *and* Virginia
David Hill	Mass Transit Administration Baltimore, Maryland
William Hiller	Ann Arbor Transportation Authority Ann Arbor, Michigan
Buffy Hunt	Paratransit service Deland, Florida
Al Iguiori	TWC Ambulance Long Island, New York
Lloyd Jack	Peter Pann Buslines Springfield, Massachusetts
Jeff Jacobs	Trimble Navigation California
Doris Jenkins	Kaufman County Senior Citizen Service Texas
Robert Johnson	3M Corporation Minnesota
Charles Jones	Decision Sciences, Inc. Illinois
Richard Jones	Metropolitan Dade County Transportation Authoirity Miami, Florida
Ashok Joshi	J.W. Leas & Associates Pennsylvania
Brian Kalanda	Teleride-Sage Toronto, Ontario, CANADA
Cameron Katrai	SilentRadio Chatsworth, California

TABLE A.la (continued) List of Contacts - Alphabetical Person Index

Contact	Organization
Mary Kihl	Iowa State University Ames, Iowa
Jane Kirby	Southeastern Regional Transit Authority New Bedford, Massachusetts
Bob Kohl	Commuter Transportation Services, Inc. Los Angeles, California
Mike Kopaczewski	Mayflower Contract Services Honolulu, Hawaii
Larry Kozimor	Bay Area Rapid Transit District Oakland, California
William Kronenberger	Metropolitan Transit Authority of Harris County Houston, Texas
Barbara Lange	Luminator Plano, Texas
Paulette Lay	K-TRANS Knoxville, Tennessee
Paul Ledwitz	Dallas Area Rapid Transit Dallas, Texas
Dan Lucas	Clallam Paratransit Port Angeles, Washington
Glen Margolis	Broward County Division of Mass Transit Fort Lauderdale, Florida
Joel Markowitz	Metropolitan Transportation Commission Oakland, California
Bill Mason	Transit Authority of River City Louisville, Kentucky
Boris Matakovic	Northern Indiana Commuter Transportation District Indiana
John Matthews	Spokane Transit Authority Spokane, Washington
Scott McBeth	Salt Lake City Aging Service Utah
Jim McCleary	American Contracting Management Virginia
Judith McGrane	Community Transit of Delaware County Philadelphia, Pennsylvania

TABLE A.la (continued) List of Contacts - Alphabetical Person Index

Contact	Organization
Brad Miller	Potomac and Rappahannock Transportation Commission Virginia
David Miller	Cubic Automated Revenue Collection Group San Diego, California
Joseph Mistrot	Jacksonville Transportation Authority Jacksonville, Florida
Rich Mizera	Regional Transportation Authority Chicago, Illinois
Margaret Moilov	Caltrans, Public Transportation Branch Los Angeles, California
Moss Mombourquette	Metro Transit, City of Halifax Halifax, Nova Scotia, CANADA
Marshall Moreyne	Telecite, Inc. Montreal, Quebec, CANADA
Bertrand Moritz	Schlumberger Technologies, Parking & Transit Systems Chesapeake, Virginia
Dan Morrissey	Mason County Dial-A-Ride Shelton, Washington
Cameron Muhick	Northern Virginia Transportation Commission Virginia
Rudy Muzzerelli	Belleville Area College Senior Citizens Center Belleville, Illinois
David Naiditch	DAVE Transportation Services, Inc. Cambridge, Massachusetts
Joyce O'Brien	Jacksonville brokerage Jacksonville, Florida
Peter Ognibene	Applied Systems Institute, Inc. Washington, District of Columbia
Sharon Olafson	SPAN Texas
Andi Overton	Tidewater Consultants Virginia Beach, Virginia
Jim Paral	City of Anaheim Anaheim, California
Glen Parrish	LYNX bus line of Orange, Osceola and Seminole Counties Florida

TABLE A.la (continued) List of Contacts - Alphabetical Person Index

Contact	Organization
Chris Patrick	Dallas Area Rapid Transit Dallas, Texas
Barry Pekil is	Ontario Ministry of Transportation Toronto, Ontario, CANADA
Mike Personnette	Ace Cab (Shared-ride and Dial-a-Ride) Indiana
George Picket	Luminator Plano, Texas
Todd Plesko	Madison County Transit Granate City, Illinois
Robert Ratcliff	California Smart Traveler Sacramento, California
Louis Revas	Metropolitan Dade County Transportation Authoirity Miami, Florida
Mark Revis	New Jersey Transit New Jersey
Steve Roberts	Hillsboro Area Regional Transit Authority Tampa, Florida
Robert Ropp	Coopers & Lybrand Boston. Massachusetts
Mr. Rousse	Montreal Urban Community Transport Commission Montreal, Quebec, CANADA
Mike Salmany	Germantown Taxi Germantown, Maryland
Pete Schumacher	Scientific Systems Texas
Carol Schuster	Digital Recorders, Inc., (Talking Bus) North Carolina
Anita Sevard	BC Transit Kamloops. British Columbia. CANADA
Gary Shaff	Rogue Valley Council of Governments Central Point, Oregon
Elaine Shellenberger	Beaumont Nutrition and Service for the Elderly Texas
Howard Shock	Northern Virginia Transportation Commission Virginia

TABLE A.1a (continued) List of Contacts - Alphabetical Person Index

Contact	Organization
Patrick Simmons	Easy Street (Dynamic Scheduling Software) Raleigh, North Carolina
Joe Simonetti	Chicago Transit Authority Chicago, Illinois
Peter Skareynski	AT&T, IVHS Communications New Jersey
Peter Soelberg	TecknoGuide Hillerod, DENMARK
Wayne Spaulding	Delaware Transportation Authority Delaware
Kevin Stanush	VIA Metropolitan Transit San Antonio, Texas
Dick Stehr	Minnesota DOT Minnesota
Art Stratemeyer	Easy Street (Dynamic Scheduling Software) Raleigh, North Carolina
Robin Stone	El Paso Paratransit Department El Paso, Texas
Gloria Stoppenhagen	Metropolitan Transit Authority of Harris County Houston, Texas
Marv Stuart	Monarch Electronics, Inc. (Colby Monitoring Products) Florida
John Swanson	Long Island Rail Road New York, New York
Robert Tanenhaus	Information Management International, Inc. Washington, District of Columbia
Bruce Thomas	Digital Recorders, Inc., (Talking Bus) North Carolina
Stephen Thomas	VIA Metropolitan Transit San Antonio, Texas
Donnie Thompson	Dallas Area Rapid Transit Dallas, Texas
Dick Trenary	New York City Transit Authority Brooklyn, New York
Katherine Turnbull	Texas Transportation Institute College Station, Texas

TABLE A.la (continued) List of Contacts - Alphabetical Person Index

Contact	Organization
Ken Turner	Portland Smart Vehicle, Tri-Met Portland, Oregon
Doreen Tyrell	Detroit Department of Transportation Detroit, Michigan
William Volkmer	Los Angeles County Metropolitan Transportation Authority Los Angeles, California
David Vozzolo	Hartford Transportation Services Hartford, Connecticut
Fred Warg	Calgary Transit Calgary, Alberta, CANADA
Brian Warner	BC Transit Nanaimo, British Columbia, CANADA
Dave Weiss	New York City Transit Authority Brooklyn, New York
Jess Wells	Etak, Inc. Menlo Park, California
Bud Williams	Greater Pinellas Transp. Mgmt Svc., Inc. Clearwater, Florida
Vincent Withers	Mecklenburg County Department of Social Services Charlotte, North Carolina
John Woodford	Transit Authority of River City Louisville, Kentucky
JoAnn Zebal	Veterans Transportation Services Waltham, Massachusetts
Weibin Zhang	University of California Berkeley, California

TABLE A.2. Paratransit Contacts and Their Suppliers

User (Paratransit Agency Name)	Contact Name	Phone	Automated System Being Used (Vendor)
Mayflower Contract Services Fresno, California	Elizabeth Diaz	(209) 291-2555	Rides Unlimited (Paratransit Systems International Inc.)
Mayflower Contract Services Hemet, California	Chet Bor	(909) 766-8781	Rides Unlimited (Paratransit Systems International Inc.)
Hartford Transportation Services Hartford, Connecticut	David Vozzolo	(203) 722-8480	MIDAS (Multisystems)
Manatee County Area Transit Bradenton, Florida	Chuck Firestone	(813) 749-7144	EMTRACK™ (Automated Dispatch Services, Inc.)
Greater Pinellas Transp. Mgmt Svc., Inc. Clearwater, Florida	Bud Williams	(813) 586-2811	EasyTrips™ (Easy Street Software, Inc.)
Paratransit service Deland, Florida	Buffy Hunt	(904) 736-6411	COMSIS Trip Planning System (COMSIS Corporation)
Jacksonville brokerage Jacksonville, Florida	Joyce O'Brien	(904) 396-1814	COMSIS Trip Planning System (COMSIS Corporation)
Honolulu Public Transportation Authority Honolulu, Hawaii	James Burke	(808) 523-4445	EasyTrips™ (Easy Street Software, Inc.)
Mayflower Contract Services Honolulu, Hawaii	Mike Kopaczewski	(808) 841-4322	Rides Unlimited (Paratransit Systems International Inc.)
Belleville Area College Senior Citizens Center Belleville, Illinois	Rudy Muzzerelli	(618) 277-7964	QUICK-ROUTE™ (Decision Sciences, Inc.)
Madison County Transit Granate City, Illinois	Todd Plesko	(618) 797-0660	QuoVadis (UMA Engineering Ltd.)
Ace Cab (Shared-ride and Dial-a-Ride) Indiana	Mike Personnette	(219) 295-6886	CADMOS-Pro + (Micro Dynamics Corporation)
Aid Ambulance Indianapolis, Indiana	Rick Archer	(317) 546-1581	EMTRACK™ (Automated Dispatch Services, Inc.)

TABLE A.2. (continued) Paratransit Contacts and Their Suppliers

User (Paratransit Agency Name)	Contact Name	Phone	Automated System Being Used (Vendor)
Des Moines Metropolitan Transit Authority Des Moines, Iowa	Tom Blair	(515) 283-8111	CADMOS-Pro + (Micro Dynamics Corporation)
Washington-Hancock Community Agency Maine	Barbara Donovan	(207) 546-7544	(Bar Harbor Software, Inc.)
Germantown Taxi Germantown, Maryland	Mike Salmany	(301) 990-7000	CADMOS-Pro + (Micro Dynamics Corporation)
DAVE Transportation Services, Inc. Cambridge, Massachusetts	David Naiditch	(617) 491-0941	MIDAS (Multisystems)
Southeastern Regional Transit Authority New Bedford, Massachusetts	Jane Kirby	(508) 997-6767	DISPATCH-A-RIDE (Multisystems)
Veterans Transportation Services Waltham, Massachusetts	JoAnn Zebal	(617) 899-7433	DISPATCH-A-RIDE (Multisystems)
TWC Ambulance Long Island, New York	Al Iguiori	(5 16) 43 l-4569	EMTRACK™ (Automated Dispatch Services, Inc.)
Mecklenburg County Department of Social Services Charlotte, North Carolina	Vincent Withers	(704) 336-4546	EasyTrips™ (Easy Street Software, Inc.)
Gaston County Coordinated Transportation Gastonia, North Carolina	Sheila Courtney	(704) 866-3107	EasyTrips™ (Easy Street Software, Inc.)
Greensboro Specialized Transportation Greensboro, North Carolina	Donnie Funderburk	(919) 275-9100	DISPATCH-A-RIDE (Multisystems)
Project Sparkplug - Canton Regional Transit Authority Canton, Ohio	Clark Hart	(216) 454-6132	QUICK-ROUTE™ (Decision Sciences, Inc.)
Sioux Falls Paratransit Sioux Falls, South Dakota	David Braun	(605) 339-7 183	DISPATCH-A-RIDE (Multisystems)
K-TRANS Knoxville, Tennessee	Paulette Lay	(6 15) 546-3752	DISPATCH-A-RIDE (Multisystems)

TABLE A.2. (continued) Paratransit Contacts and Their Suppliers

User (Paratransit Agency Name)	Contact Name	Phone	Automated System Being Used (Vendor)
Beaumont Nutrition and Service for the Elderly Texas	Elaine Shellenberger	(409) 892-4455	Paratransit Scheduling Package (Philip G. Dorcas and Associates)
Kaufman County Senior Citizen Service Texas	Doris Jenkins	(214) 563-1422	Paratransit Scheduling Package (Philip G. Dorcas and Associates)
SPAN Texas	Sharon Olafson	(214) 434-2466	Paratransit Scheduling Package (Philip G. Dorcas and Associates)
Dallas Area Rapid Transit Dallas, Texas	Dotie Thompson	(214) 828-6628	MIDAS (Multisystems)
El Paso Para Transit Department El Paso, Texas	Robin Stone	(915) 533-1220	QuoVadis (UMA Engineering Ltd.)
VIA Metropolitan Transit San Antonio, Texas	Stephen Thomas	(5 12) 227-537 1	QuoVadis (UMA Engineering Ltd.)
Salt Lake City Aging Service Utah	Scott McBeth	(801) 468-2753	Paratransit Scheduling Package (Philip G. Dorcas and Associates)
American Contracting Management Virginia	Jim McCleary	(703) 960-2264	CADMOS-Pro + (Micro Dynamics Corporation)
Paratransit Services Bremertown, Washington	Bruce Barrett	(206) 377-7 176	Rides Unlimited (Paratransit Systems International Inc.)
Clallam Paratransit Port Angeles, Washington	Dan Lucas	(206) 452-1397	Rides Unlimited (Paratransit Systems International Inc.)
Mason County Dial-A-Ride Shelton, Washington	Dan Morrissey	(206) 427-5033	Rides Unlimited (Paratransit Systems International Inc.)
Spokane Transit Authority Spokane, Washington	John Matthews	(509) 325-6033	QUICK-ROUTE TM (Decision Sciences, Inc.)
BC Transit Kamloops, British Columbia, CANADA	Anita Sevard	(604) 376-7525	Rides Unlimited (Paratransit Systems International Inc.)

TABLE A.2. (continued) Paratransit Contacts and Their Suppliers

User (Paratransit Agency Name)	Contact Name	Phone	Automated System Being Used (Vendor)
BC Transit Kelowna, British Columbia, CANADA	Arly Dawson	(604) 762-3278	Rides Unlimited (Paratransit Systems International Inc.)
BC Transit Nanaimo, British Columbia, CANADA	Brian Warner	(604) 390-3000	Rides Unlimited (Paratransit Systems International Inc.)
BC Transit Victoria, British Columbia, CANADA	Peter Ganyon	(604) 479-3 111	Rides Unlimited (Paratransit Systems International Inc.)
Toronto Transit Commission Toronto, Ontario, CANADA	Agnes Csors	(4 16) 393-2631	GIRO/ACCES
Montreal Urban Community Transport Commission Montreal, Quebec, CANADA	Serge Belanger Mr. Rousse	(514) 280-5829 (514) 280-6308	MIDAS (Multisystems) GIRO/ACCES

TABLE A.3 Systems Discussed in State of the Art, Update ‘94*

Agency, Project or Location	Automated Transit Information	Real-Time Rideshare Matching	Multimodal Trip Reservation/Billing	Integrated Fare Media	Automated Ticketing and Payment	Automated Vehicle Location	Operations Software	Demand Responsive Dispatching	Multimodal Traveler Information	Multimodal Electronic Fare Payment	High Occupancy Vehicle Monitoring	Transportation Management Centers	Vehicle Guidance
Bay Area Rapid Transit, CA					X		X						
City of Anaheim, CA												X	
Culver City Transit, CA	X												
Los Angeles, CA	X			X				X	X				
MTC/Bay Area, CA				X					X				
Omni Transit, CA	X												
PATH, CA													X
Riverside TA, CA	X												
Sacramento, CA		X											
San Diego Transit, CA	X												
Santa Monica Mun. BL, CA						X							
Sunline Transit, CA	X												
Ventura Co. TC, CA	X												
Denver RTD, CO						X							
DOT, DE					X								
WMATA., DC	X				X								
Broward Co. TA., FL	X												
Dade Co., FL							X						
LYNX , FL	X												
Pinelas Co., FL							X						
Chicago TA, IL				X		X	X					X	
Regional Transp. Auth., IL					X								
No. Indiana Comm. TD, IN					X								
TA of River City, KY						X							
Baltimore MTA, MD						X							
MBTA, MA					X		X						
Peter Pan Buslines, MA						X							
Smart Routes, MA									X				
Ann Arbor TA, MI					X	X	X						
Detroit., MI.												X	

* Systems arranged by country, and alphabetically by state or province and by implementing agency, project name or location within states, provinces, or countries

TABLE A.3 (Continued) Systems Discussed in State of the Art, Update '94

Agency, Project or Location	Automated Transit Information	Real-Time Rideshare Matching	Multimodal Trip Reservation/Billing	Integrated Fare Media	Automated Ticketing and Payment	Automated Vehicle Location	Operations Software	Demand Responsive Dispatching	Multimodal Traveler Information	Multimodal Electronic Fare Payment	High Occupancy Vehicle Monitoring	Transportation Management Centers	Vehicle Guidance
Adv. Rural Trans. Info., MN						X							
Dakota Area Res. & TS, MN						X							
MN DOT/Guidestar, MN	X					X			X				
Kansas City Area TA, MO						X							
New Jersey Transit, NJ					x	X							
JFK Airport, NY	X												
Long Island Railroad, NY					x								
New York City TA, NY				X			X						
Winston-Salem TA, NC			X										
Central Ohio TA, OH	x												
Cleveland TS, OH	x												
Portland, OR											X		
Rogue Valley COG, OR		x	X										
Salem Transit, OR	X												
Tri-Met, OR		x							X				
Community Transit, PA								X					
Lackawana Co. TS, PA						x							
Dallas Area RT, TX						x	X						
Houston, TX											X		
Metro. TA of Harris Co., TX		x				x							
VIA Metro. TS, TX						x							
Potomac-Rappahan. TC, VA		x	X										
Tidewater Transp. Dist., VA						X							
Va. Railway Express, VA					X								
Bellevue TMA, WA		X											
Milwaukee Co. TS, WI						x							
Metro Transit, Nova Scotia	X					x							
Ajax Transit, Ontario					x								
Burlington Transit, Ontario					x			x					
Hamilton St. Railway, Ontario						X							
Kitchener, Ontario								x					
Mississauga Transit, Ontario				X									
Niagra Transit, Ontario					X								
Ottawa-Carleton RTC, Ontario						X	X						

TABLE A.3 (Continued) Systems Discussed in State of the Art, Update '94

Agency,Project or Location	Automated Transit Information	Real-Time Rideshare Matching	Multimodal Trip Reservation/Billing	Integrated Fare Media	Automated Ticketing and Payment	Automated Vehicle Location	Operations Software	Demand Responsive Dispatching	Multimodal Traveler Information	Multimodal Electronic Fare Payment	High Occupancy Vehicle Monitoring	Transportation Management Centers	Vehicle Guidance
Toronto TC, Ontario							X					X	
Hull, Quebec					X	X	X						
Montreal Metro, Quebec	X												
Melbourne, Australia						X							
New South Wales, Australia										X			
Copenhagen, Denmark										X			
Nysteel, Denmark						X							
Birmingham, England	X												
England													X
London, England												X	
Manchester, England										X			
Gothenburg, Germany												X	
Heinsburg, Germany						X							
Turin, Italy												X	
Japan													X
Biel, Switzerland										X			

*U.S. G.P.O.:1994-301-717:80541

NOTICE

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TECHNOLOGY SHARING

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