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The State of the Art

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16. Abstract

This report documents one of the early initiatives of UMTA's Advanced Public Transportation Systems (APTS) Program, a program structured to undertake research and development of innovative applications of advanced navigation, information, and communication technologies that most benefit public transportation.

This report 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 focused on some of the most innovative or comprehensive implementations, categorized broadly under the APTS program elements of Market Development, Customer Interface, Vehicle Operations and Communications, and High Occupancy Vehicle Facility Operations. The objective of this effort was to increase the industry's knowledge of successful applications of advanced technologies with the expectation that this will lead to their widespread adoption.

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PREFACE

This report contains the results of a limited investigation of the extent of adoption of advanced technology in the provision of public transportation service in North America. The objective of this effort was to increase the industry's knowledge of successful applications of advanced technologies with the expectation that this will lead to their widespread adoption.

This research was conducted by the Volpe National Transportation Systems Center of the United States Department of Transportation, Research and Special Programs Administration, and was sponsored by Ronald J. Fisher, P.E., director of the Office of Training, Research, and Rural Transportation, Urban Mass Transportation Administration.

Appreciation goes to all of the researchers and professionals who supplied information for this report, most of whom are listed as contacts in Appendix C.

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)

$[(x-32)(5/9)]$ ^{0}F □ y ^{0}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 (l) = 2.1 pints (pt)

1 liter (l) = 1.06 quarts (qt)

1 liter (l) = 0.26 gallon (gal)

1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)

1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

$[(9/5) y + 32]$ ^{0}C □ x ^{0}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
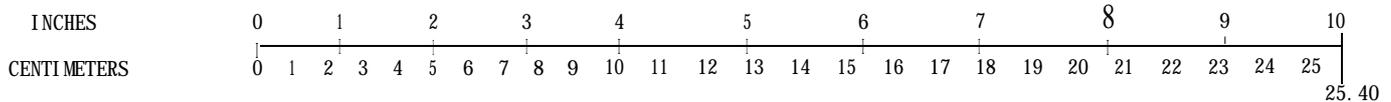
QUICK FAHRENHEIT-CELSIUS TEMPERATURE CONVERSION

^{0}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°
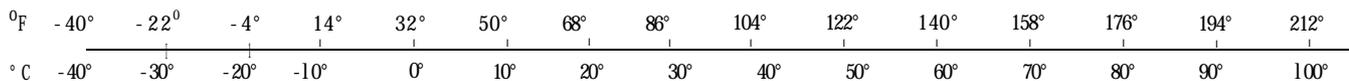
For more exact and or other conversion factors, see NBS Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50. SD Catalog No. C13 10286.

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EXECUTIVE SUMMARY

This report examines the implementation status of advances in new technologies 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. UMTA has established the Advanced Public Transportation Systems (APTS) Program. UMTA'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 one of the early initiatives of the APTS program, a limited investigation of the extent of adoption of advanced technology in the provision of public transportation service in North America. It was not an exhaustive search of every city or transit authority which has tested, planned. or implemented an advanced technology concept. Rather, it focused on some of the most innovative or comprehensive implementations. categorized broadly under the APTS program elements of Market Development. Customer Interface, Vehicle Operations and Communications, and High Occupancy Vehicle Facility Operations.

MARKET DEVELOPMENT

Market development projects are aimed at increasing the utilization **of** high occupancy vehicle modes. By providing travelers, especially regular commuters, with traffic and transportation service information prior to embarking on their trips, travelers can make the most informed choices of modes and routings.

Pre-Trip Passenger Information

Pre-trip passenger information systems provide transit users, in their home or office, with appropriate and timely data to improve travel decision making. Combined with automatic vehicle location methods. pre-trip traveler information systems can provide real-time updates on system status and expected arrival times.

Basic telephone-based schedule and fare information systems are common at North American transit operations. while concept development or planning activities have been

initiated in only a few transit systems for the more complex technologies such as direct computer links and cable TV.

Implementation of telephone-based information systems include computerized databases that provide agents with detailed information to use in reply to telephone inquiries (Washington, D.C.; Miami; Denver; Southern California;. Boston; and Hull, Quebec). Touch tone telephone systems with voice-synthesized responses automate many or all of the functions previously accomplished by an operator (Long Island Railroad: Portland, Oregon; Salt Lake City; Baltimore; and Ottawa/Carleton, Ontario).

Several North American transit systems have incorporated data generated by their automatic vehicle location systems to enhance the information available to transit users. Transit systems in Halifax/Dartmouth (Nova Scotia), Hull (Quebec), San Antonio, Columbus (discontinued), and Baltimore (planned), among others, have implemented systems that provide specific real-time bus location information to transit users via telephone. A few transit agencies (including Ann Arbor and Portland) are also planning to use real-time vehicle data to improve the level **of service** provided to paratransit users.

Several transit agencies, including those in Ann Arbor, Champaign/Urbana, Houston, **and** Baltimore, are experimenting with the use **of** public access cable TV as a medium to provide information on current bus location, direction, and estimated arrival time at key stops. A similar method is employed in teletext information systems that are common in Western Europe, but not the U.S. (updated traffic information is being reported in this way in Los Angeles). They operate by invisibly encoding alphanumeric data onto conventional television signals, which are then read by a decoder attached to the TV set.

Real-Time Rideshare Matching

Real-time rideshare matching features an automated system for requesting and responding immediately to a request from a traveler for a trip in a carpool or vanpool. In recent years, ride matching has become a highly automated process in which people wishing to join or form a car-pool or vanpool can do so by a telephone call (or sometimes via personal computer) to a matching service. This match. however, is usually for a trip that is regularly taken (e.g., home-work-home trip. 5 days a week).

"Real-time" matches also could be made for travelers wishing a ride for a single one-way or round trip on a one-time, short-notice basis. This type of real-time ride matching is not currently available in North America. but is being considered in

Houston, Texas and several cities in California with assistance from UMTA's APTS program. In Houston. the proposed <u>Smart</u> <u>Commuter</u> Demonstration Project will examine the potential for encouraging greater utilization of high occupancy modes such as buses. cat-pools, and vanpools. The technologies being examined to provide the real-time ride matching service include the following:

o telephone-based systems (live operator. voice synthesis, voice recognition, voice mail).

o television-based systems (commercial television traffic reports, cable television, interactive cable television).

o videotext-based systems (dumb terminals or smart terminals).

Different combinations of these technologies will be considered, as will the use of different methods at the home and at the work site.

Integrated Fare Media

Integrated fare media are tickets that can be used for all modes, 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 could be used on different modes operated by a one or more transit operators. Current examples include:

o the TransLink system demonstration (UMTA-funded) which is a prelude to a universal transit ticket for the entire San Francisco/Oakland Bay Area.

o SamTrans (Burlingame. CA) honors adult (daily. weekly, and monthly) passes from San Francisco Municipal Railway, San Francisco Bay Area Rapid Transit District, Alameda-Contra Costa Transit District. CalTrain, and Santa Clara County Transit District.

o San Francisco Bay Area Rapid Transit District ran a demonstration using the AC/BART Plus **MUNl** ticket following the October 1989 earthquake - the multiple ticket was usable on Alameda-Contra Costa Transit District, BART. and the San Francisco Municipal Railway.

o BC Transit - Vancouver Regional Transit System uses the same fare media for its bus system, ferry system (SeaBus) and AGT system (SkyTrain).

o Port Authority Trans-Hudson Corporation and New Jersey Transit Corporation riders can use QuickCard, a magnetically-encoded farecard, for fares on both systems.

Multimodal Trip Reservations and Integrated Billing Systems

Multimodal trip reservations would allow a traveler to obtain trip reservations and tickets for an entire multimodal trip (portal-to-portal) from the initial carrier through interline agreements. An integrated billing system is one in which bills for the purchase of fares for all modes are generated from a central source.

There are no known multimodal trip reservation systems or integrated billing Systems Operating in North America, with the exception of the airline and passenger rail industry.   Currently. UMTA is researching a related concept called Mobility Manager. The Mobility Manager would operate a clearinghouse network consisting of multimodal trip reservation and integrated billing as well as integrated fare collection, shared ride travel inforrnation, coordinated dispatching, and management of funds and transaction documentation,

CUSTOMER INTERFACE

Customer interface provides services to the passengers of a system to make their travel easier.   This includes information on arrival times, the general condition of the system, and simplified methods of payment.   Each of the strategies is designed to make the user's trip easier, from the point of departure to arrival at the 'destination.

In-Terminal Information Systems

In-terminal information systems consist of electronic and computer display devices located at transit stations and/or en route stops, providing up-to-date travel information on delays, cancellations, reroutings, and terminal layout and services.   These systems may involve interactive traveler inputs, and can be designed to accommodate handicapped travelers.

Only a few transit agencies in North America have begun the process of installing or upgrading in-terminal information systems.   The most widely employed type is a video monitor, similar to those commonly encountered in airports and train stations.

o Columbus, Ohio - Closed-circuit TV monitors at downtown express bus stations provide information on scheduled arrival and departure times. The system is not updated in real time, but significant anticipated delays can be input.

o San Francisco Bay Area, California - Passenger information displays at a few BART stations provide information on scheduled departure times and locations for the next two departing buses on each route that serves the transit stop.

o Houston, Texas - A pilot program is planned at transit facilities and central business district locations.   The information provided will include time and location data on the next buses scheduled to depart.   When their AVL system is operational. estimates of arrival and departure times will be updated automatically in real time.

Several other systems in North America and Europe use real-time data from automatic identification and vehicle tracking systems to support in-terminal displays.

o Tampa. Florida - curbside LCD displays and bus shelter TV monitors are used to provide real-time bus order and arrival time information to passengers in the downtown transit mall.

o Halifax/Dartmouth. Nova Scotia - speaker phones at a few high volume bus stops, and video monitors at several shopping center locations, provide real-time information from their bus tracking system.

o Ottawa/Carleton. Ontario - TV monitor displays at downtown bus stops provide real-time information on the order and stop location of arriving buses.

o Oslo, Norway - an automatic vehicle identification system identifies buses arriving in the main bus terminal and simultaneously assigns them to an open bay while displaying arrival time and stop location on the in-terminal monitors.

User interactive terminals with touch-sensitive screens are currently being planned or implemented in a few' North American systems including Houston, Baltimore, and Hull, Quebec.   The travel information systems provide instructions on how to access the transit system. estimated travel times, applicable routes, schedules, transfers, and fares. Similar systems are more commonly available in Europe to provide general. purpose travel directions and guidance.

In-Vehicle Information Systems

In-vehicle information systems consist of technological innovations supporting the transit user and vehicle operator.   Travelers are aided by information displays and on-board communications devices providing current information on seating availability, routes, schedules, and connecting services.   Additional information available to vehicle operators includes correctable schedule deviations, and requirements to wait for connecting services.

Information indicating upcoming transit stops and connections are typically provided on fixed rail and some specialized bus systems (e.g., at airports) by means of announcements over a public address system.   These approaches are not commonly found in the North American urban bus environment, even though the technology appears completely transferable. A few European and Japanese systems are implementing more technologically advanced on-board information systems involving use of synthesized voice messages, dot matrix signs, or video displays located at strategic locations within the vehicle.

Information generated from an automatic vehicle location system may be provided to drivers in the form of simple dashboard displays that indicate deviations from the schedule. Several transit agencies with AVL systems have chosen this approach, which is proving effective in reducing run-time variations.

Although they offer considerable potential benefits, few transit systems are currently Contemplating the use of on-board navigation or route guidance systems. An exception is the Ann Arbor Transit Agency which is in the process of implementing an on-board navigation system on their paratransit buses.

Electronic Ticketing and Automated Trip Payment

Electronic ticketing involves the automated generation of tickets and automated fare collection, allowing for the collection of detailed information on revenue, passengers, and origins and destinations. Automated trip payments are those payments made without a manual exchange of cash. Often, electronic ticketing provides automated trip payment through the use of either magnetically-encoded farecards or Smart Cards.

Electronic ticketing and automated trip payment are technologies that are beginning to be utilized in several North American transit agencies. These two technologies frequently go hand-in-hand, electronic ticketing often providing automated trip payment through the use of Smart Cards or magnetically-encoded (stored-value) cards. Current examples include:

o Chicago Regional Transportation Authority's development of a Payment and Control Information System using Smart Cards and portable card readers as a fare payment mechanism and to collect information on passengers, trips, and fares.

o Port Authority of Allegheny County (Pittsburgh) demonstration of Smart Cards as monthly passes and Smart Boxes as devices to collect information about the trips taken.

o Virginia Railway Express's cashless (credit card ticket vending machines) proof-of-payment ticketing system.

o Port Authority Trams-Hudson's QuickCard, a magnetically-encoded farecard which can be purchased using a credit card or cash.

o WMATA farecards, which can be purchased at Automated Teller Machines.

o TransLink for the San Francisco Bay Area, which uses a magnetically-encoded debit card, purchased through credit card ticket vending machines, for fare payment.

o City of Phoenix Transit System's test of magnetically-encoded passes.

VEHICLE OPERATIONS AND COMMUNICATIONS

The principal goal of vehicle operations and communications techniques is improved management of existing fleet resources through technological innovation without adding new vehicles or significantly restructuring old ones.

Automatic Vehicle Location

Automatic Vehicle Location (AVL) is a means of monitoring the movement of a fleet of vehicles. Transit agencies have been using AVL for rail operations for several years to control operations and to help maintain a schedule. The technology is now available to do the same with buses.

AVL is now being tested and implemented extensively by transit agencies throughout the world. Although more widespread in Europe. there are several AVL implementations and tests in progress throughout North America. including the following.

o The Tidewater Transportation District Commission in Norfolk, VA has equipped 15 I buses with a signpost-based system that also includes three remote bus component alarms: engine temperature, low air (brakes), and oil pressure.

o VIA Metropolitan Transit in San Antonio, Texas has equipped 537 buses and streetcars with a signpost-based system. The system also includes bus component alarms and a security alarm.

o The Ann Arbor Transit Authority in Ann Arbor, MI has equipped 67 buses with a dead reckoning system that also includes an emergency alarm. The agency also wishes to broadcast bus positions via cable TV for passenger information.

o The Mass Transit Administration in Baltimore has equipped 50 of their 900 buses with a LORAN-C system in "phase two" of their test. Computer Aided Dispatch is included to aid in necessary adjustments to operations.

o The Toronto Transit Commission is in the midst of a phased implementation of a signpost system on all of their 2,300 buses and streetcars, Their operation also includes Automatic Passenger Counters on 10% of their buses.

There are more than a dozen other systems in North America, and many in the rest of the world, either in operation or planned. The principal location technology used is signposts and odometers, but there are a few examples of dead reckoning and LORAN-C. The Global Positioning System (GPS), a satellite-based locating system, is planned for use by the transit agency in Houston, Texas.

Bus Operations in Suburban Areas

UMTA is sponsoring a project in Portland, Oregon which will examine the technical and economic feasibility as well as the hardware and software requirements of a variety of automated information. control. and dispatching techniques for suburb-to-suburb transportation service. Techniques may include computerized dispatching of flexible route paratransit service, in-vehicle information displays for drivers and passengers. out-of-vehicle information for transit riders and carpoolers. automatic vehicle location, automated passenger counters. smart farecards. and single trip carpooling.

There are no locations in North America where more than one or two of these techniques have been tested or implemented. An assessment of a West German implementation of several of these techniques is being conducted and is expected to provide valuable information for the development of the Portland project.

Transit Operations Software

Transit operations software performs and integrates network and operations planning, vehicle and crew scheduling, marketing, and management and administration.

Currently, there are no examples of real-time integrated operations software being used in North America. However, there are several examples of limited operations software in European locations that control transit operations through the collection, analysis, and transmission of critical operations information in real time.

Automated Demand Responsive Dispatching Systems

Automated demand responsive dispatching systems include scheduling features that assign individuals to demand responsive vehicles operating in a shared-ride mode. The scheduling systems would accommodate advanced reservations, standing orders, and immediate (or real-time) requests. Information from scheduling and dispatching functions would be integrated into the management information, billing, and accounting functions of the provider.

There are several automated demand-responsive dispatching systems operating in the U.S., including the following:

o Metro-Dade County (Florida):

  - Automated Dispatch Services Inc., provides sophisticated real-time automated scheduling and dispatching for both specialized transportation services and Medicaid transportation. The system incorporates a geo-coded street network.

  - Metro Taxi is one of several providers of paratransit service. Each cab in taxi operations is outfitted with a terminal through which the driver communicates with the central computer which also monitors system performance.

o Tri-Met (Portland) uses an automated scheduling system which incorporates geo-coding for client addresses. Eventually. real-time data will be available to determine if the client has been picked up, if that client has paid their bill. etc. Also. a client will be able to make a request remotely through a PC over a Novell network.

o Southeastern Pennsylvania Transportation Authority uses a proprietary prescheduling system which is refined manually. Dispatching is also a manual process.

o **WHEELS, Inc.,** (Philadelphia) uses custom-designed software to automate client eligibility checks, trip requests and manifests, verification of charges, and collection and distribution of reimbursements.

HOV FACILITY OPERATIONS

High occupancy vehicle facility operations include those technologies designed to improve the flow of high occupancy vehicles (HOVs) by giving preference to these vehicles on existing facilities. or by constructing special guideways to control their movement.

Signal Pre-Emption

In the context of APTS. signal pre-emption involves giving preferential treatment to HOVs. including buses, vanpools, and car-pools.   This strategy increases passenger throughput.

Signal pre-emption has not been widely implemented in the U.S. Though it improves passenger throughput at an intersection, it has been argued that signal pre-emption disrupts traffic flow.   Many traffic professionals feel that signal coordination and progression are more effective tools than pre-emption on heavily traveled arterials. It is also difficult to give preference to buses in mixed flow traffic, especially under congested conditions.

There are only a few planned or operational tests in the U.S. One is in Los Angeles where each bus is equipped with a pulsing infrared emitter that flashes at receivers mounted on traffic signals.   If the pre-emption conditions are satisfied, pre-emption is granted.   There also are plans in Chicago to test signal pre-emption for buses running behind schedule on a major arterial.

High Occupancy Vehicle Lane Access Control

HOV lanes are often used by vehicles not carrying the required number of passengers.   These violators diminish the utility of these lanes. The lanes often are patrolled by police, who count the number of people in each vehicle manually, which is an effective. but expensive means of enforcement.

APTS has the capability to reduce the number of violators through two separate strategies.   The first is to restrict access to the lanes by means of a barrier which would open to allow only rightful users to pass.   Rightful users would have their cars fitted with transponders to identify themselves.   Applications of access control in the U.S. thus far have been limited to low-speed applications. primarily at airport parking lots such as Washington National Airport.

The other automatic enforcement strategy would be to place cameras at a strategic location to view the interior of the vehicle.   The images would then be processed by

artificial intelligence software, capable of "counting" the passengers. Violators would be recorded and prosecuted. To date, this system has not been implemented, nor is it planned. The software is not yet available, and tests in the Seattle and Los Angeles areas have shown that it is difficult to get an accurate picture of the vehicle's interior.

Automatic Toll Collection

The advantages of automatic toll collection are several. Cars need not stop to pay a toll, and may even be able to go through without slowing down, thus increasing throughput and reducing the number of toll lanes needed. The user need not pay in cash, so less cash will be handled. Automatic collection gives toll flexibility, and allows for rates which vary by time of day and day of the week, with less danger of confusion. Finally, there is labor cost savings: since tolls are collected automatically, there is less need for personnel.

Unlike the other types of HOV facility operations, automatic toll collection is gaining popularity in the U.S., and new implementations are quite common. Virtually all of the current applications work using a transponder on subscribing vehicles and detection equipment at the toll booths. A separate account is maintained for each user, and prepayment is common. Some U.S. applications are:

o the 'Lincoln Tunnel (New York City - New Jersey) - on a contra-flow lane, for buses o n l y .

o the Goethals Bridge (New York City - New Jersey) - a 6-month test involving 850 vehicles of varying types: cars, buses, and trucks.

o the Verrazano Narrows Bridge (New York City) - a test similar to the one at the Goethals Bridge with the same equipment at both sites and over 1,000 vehicles.

o the Crescent Connection Bridge (New Orleans) - full operation, over 14,000 transponders issued.

o the Dallas North Tollway - full operation, over 28,000 transponders issued.

Automatically Guided Transit Buses

Automatic guidance for transit buses has been investigated as a means of increasing the speed, volume, and boarding capability of transit buses in urban settings. It enables high-speed, high-volume, level-boarding operation typically associated with rail systems and permits operation in a narrower right-of-way than is needed for manually steered buses.

Automatic guidance for transit buses consists of two basic technologies: mechanical and electronic. Mechanical guidance systems use guide rollers attached to either the

front axle or all axles of the bus to control the lateral movement between two rigid guiderails. Electronic guidance systems use a transmitting antenna in the surface of the roadway to guide buses equipped with a receiving antenna and an electronic control system along the desired path.

There are currently no automatically guided transit bus services in North America, but the concept of automatic guidance is under investigation at the University of California as part of the Program on Advanced Technology for the Highway (PATH), Researchers there are beginning a study of applying it to HOVs in an HOV lane. There are, however, a few foreign applications of guided bus technologies.

o The "O-Bahn" is a front axle. mechanical guidance system developed in the mid-1970s. With this system, a transit operator can begin with a conventional bus system operating on public roads and construct guideways in segments. Applications include:

 - a successful demonstration in Essen, (West) Germany, begun in 1980, proving that this technology is safe. reliable, and feasible.

 - a fully operational 0-Bahn system in Adelaide, Australia, open since 1986 which is 12 kilometers in length and served by 92 buses.

o Mechanically guided double-decker buses are operating in a demonstration in Birmingham. England, including a 600 meter segment of guideway which includes raised platforms that allow access by disabled persons.

o Electronically guided buses have been run on a test track in downtown Furth, Germany since May 1984. The system reduces road space requirements by as much as 20 percent and does not require the concrete guideway used in mechanically guided bus systems.

1. INTRODUCTION

Purpose of Report

This report examines the implementation status of advances in new technologies 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. The extent to which these advanced technologies are being adopted by the public transportation industry is documented in this report.

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. Automated vehicle location and monitoring, automated guideway operations, and computerized dispatching were some of the earliest applications of advanced technologies. Yet, 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, UMTA has established the Advanced Public Transportation Systems (APTS) Program. Through in-service operational tests, evaluations, and publication of results, UMTA'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 investigation is one of the early initiatives of the APTS program.

Scope

This effort was a limited investigation of the extent of adoption of advanced technology in the provision of public transportation service in North America. It was not an exhaustive search of every city or transit authority which has tested, planned, or implemented an advanced technology concept. Rather. it focused on some of the most innovative or comprehensive implementations of new technology approaches.

Further, 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 the structure of UMTA's recently announced Advanced Public Transportation Systems Program. Applications of advanced technologies are described in turn, under the APTS categories of Market Development, Customer Interface, Vehicle Operations and Communications, and High Occupancy Vehicle Facility Operations, respectively. These sections are preceded by an Executive Summary and this Introduction, and are followed by Appendices containing more detailed listings of applications of certain concepts and a comprehensive list of the individuals contacted during this study.

2. MARKET DEVELOPMENT

Market development projects are aimed at increasing the utilization of high occupancy vehicle modes. By providing travelers, especially regular commuters, with traffic and transportation service information prior to embarking on their trips, they can make the most informed choices of modes and routings. If provided with transportation service information, especially in real-time, it is anticipated that many travelers will choose to make their trips in high occupancy vehicles rather than in single occupant vehicles. Marketing strategies also include projects to make buses, cat-pools, and vanpools more convenient or easier to use.

Market development includes such activities as pre-trip traveler information systems, real-time rideshare trip matching, integrated fare media, multimodal trip reservation, and integrated billing. Each of these activities is discussed, in turn, in this chapter.

2.1. PRE-TRIP PASSENGER INFORMATION

Pre-trip traveler information systems provide timely transportation data to the home or office of trip makers which will enable them to improve their travel decision making. This information can include data on transit routes, schedules, transfers, and fares. Passenger information can be offered 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 traveler information systems can provide real-time updates on expected transit vehicle arrival times, as well as warn transit users and system operators of delays.

State-of-the-Art Summary

A considerable number of North American transit properties are considering or are actually in the process of installing enhanced pre-trip information methods. Coverage varies from extensive implementation for basic telephone-based service and fare information systems to a few in the concept or planning stage for direct computer link and cable television information systems. As greater numbers of AVL systems are installed, it is likely that the use of higher technology methods for information dissemination will increase significantly.

North American Applications

Many North American transit properties operate some form of information system for transit pre-trip planning. The major types of pre-trip planning systems discussed in this section include:

- o Telephone-based systems
- o Cable television
- o Computer information systems

The most common types of advanced information systems are outgrowths of standard operator supported telephone information services that every property maintains and are efforts to present the schedule and fare information in a more efficient manner. The most common improvements include computerized databases to provide agents with detailed information to use in reply to specific telephone inquiries as in Washington, D.C. [1], and touch-tone telephones eliciting voice-synthesized responses as in the case of The Long Island Railroad [2], Portland, Oregon [3], Salt Lake City [4], Baltimore [5], and Ottawa/Carleton, Ontario [6].

The more advanced systems automate many or all of the functions previously accomplished by an operator. Fully automated inquiry systems generally employ a computer-generated voice which greets the caller and lists the different types of information which are available. The caller may then make a selection by using a touch-tone telephone pad. He or she generally must also indicate the specific service area and time period in question. This type of service enhancement often accompanies an increase in telephone trunk service, so that the prospective traveler would notice a significant improvement in call response time **and** the amount and accuracy of information provided. These automatic telephone systems are expected to become quite common in the transit industry, with many systems already installed and others in the planning stages.

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[1] The Washington Metropolitan Area Transit Authority Automated Information Directory System (AIDS).

[2] A. Kanazaro, Long Island Railroad Teletrip Automated Travel Information System.

[3] P. Woodworth, Tri-County Metropolitan Transit District.

[4] J. Inglish, Utah Transit Authority, Salt Lake City. Utah.

[5] Rohit Patel, Mass Transit Administration, Baltimore, Maryland.

[6] L. P. van der Kloot, Ottawa-Carleton Regional Transit Commission.

A somewhat higher level of service can be provided by using voice recognition technology, in which audible responses made by the telephone inquirer are interpreted by the computer system. This alleviates the need for touch-tone telephone equipment and speeds up the rate at which responses to inquiries can be processed. The technology needed to support voice recognition systems is much more complex and, with few exceptions, has not been adopted in the North American transit industry, An exception is at the Dade County Transit Authority in Miami [7], where a passenger information system employing integrated voice response and voice recognition is being installed that provides information about routes, schedules, fares, and types of service. The system also incorporates an improvement that aids prospective travelers by generating advice on how to access and use the transit system.

Less sophisticated systems offering access and use information are operating in Denver [8], Southern California [9], Boston [l0], and Hull, Quebec [ll] [12]/ These are telephone operator assisted information systems that generate information on alternative transit routings to desired destinations. They are based on a custom-digitized database of transit services (including routes, schedules, and bus/rail stop locations), and street address, intersections, or landmark names. The systems generate information on possible paths through the transit network, taking into account traveler preferences (e.g., for shortest travel time, maximum use of rapid rail, intermediate stops, etc.). The telephone operator has a map display of the service area and computer software to calculate the closest access points and alternative shortest path routings. Information is passed between the operator and traveler by a combination of techniques, including normal speech, touch-tone telephone, computer-synthesized speech (Los Angeles and Miami), and voice recognition (Miami).

[7]   L. Revas, Dade County Transit Authority, Miami, Florida.

[8]   D. Hulse, Regional Transit District, Denver, Colorado.

[9]   D. Anderson. Southern California Rapid Transit District.

[10]   J. Bottari, Massachusetts Bay Transportation Authority, Boston. Massachusetts.

[11]   Sallah Barj, Commission de transport de la Communaute regionale de I'Outaouais, Hull. Quebec.

[12]   The systems being implemented in American cities (i.e.. the PARIS software product) were developed by Megadine Information Systems of Santa Monica. California. The Canadian system (i.e., HASTINFO) was developed by GIRO, Inc. of Montreal.

Several North American transit systems have incorporated data generated by their automatic vehicle location systems to enhance the information available to transit users. Transit Systems in Halifax/Dartmouth, Nova Scotia [13], Hull, Quebec, San Antonio, Texas [14] [15] [16], Columbus, Ohio [17] (discontinued), and Baltimore (planned) are among those that have implemented systems which provide specific real-time bus location information to transit users over the telephone. In these systems, the traveler accesses the system by calling a unique telephone number associated with a specific bus stop (Or set of stops) and is given, by synthesized speech, up-to-date estimates of the expected arrival time of the next several buses to arrive at that stop. The system in Halifax also incorporates speaker phones at a few high traffic locations. Similar systems in Salt Lake City and Ottawa/Carleton, Ontario provide only scheduled bus arrival information, updated only for significant delays. A drawback of this type of system is that they are primarily useful to dedicated transit users who are familiar with transit services.

A few transit operators, including those in Ann Arbor, Michigan [18] and Portland, Oregon, are planning to use real-time vehicle data to improve the level of service provided to paratransit users. Traditionally, paratransit operators have required long reservation lead times (often one day or more in advance). With the use of AVL systems, the amount of advance time needed for scheduling demand responsive services can be greatly reduced. In addition, with real-time knowledge of the exact location of paratransit vehicles, it becomes feasible to call back scheduled passengers a few minutes prior to actual, as opposed to scheduled, pickup times.

Another manner in which real-time vehicle location information is being provided to transit users is through cable television. Several properties, including those in Ann Arbor, Champaign/Urbana, Illinois [19], Houston [20], and Baltimore) are experimenting

[13]   Kenny Silver, Metropolitan Transit Commission, Halifax-Dartmouth, Nova Scotia Gotime Traveler Information System.

[14]   Jerry O' Neil, "VIA Looks to the Future With AVM System," **METRO Magazine,** May/June, 1989, pp. 36-39.

[15]   "On *Time Performance Improves:* VIA Installs New Technology." **Passenger Transport,** January 30, 1989.

[16]   Dennis Perkinson, VIA Metropolitan Transit, San Antonio, Texas.

[17]   R. Parker, Central Ohio Transit Authority. Columbus. Ohio.

[18]   Mike Bolton, Ann Arbor Transit Authority, Ann Arbor, Michigan.

[19]   R. Patton, Champaign-Urbana Mass Transit District, Urbana, Illinois.

with the use of public access cable TV as a medium to present information on current bus location and expected arrival times.   None of these transit systems have finalized details of their cable TV operation.   However, they expected that information will be available periodically throughout the day in the form of schematic diagrams of each route, the location and direction of all buses, and their estimated arrival time at all key stops.   The displays will be designed to scroll through each route in turn, so that travelers will need to wait until the route of interest to them is presented. For smaller transit systems this does not present a problem, but for larger systems, as in Baltimore, with extensive route structures, sequential display of all transit services would not be practical. In those situations, the cable displays could be segmented geographically, with each sector limited to one set of routes.   An issue identified in Ann Arbor is whether transit systems can utilize free public access cable TV channels or whether paid time needs to be purchased.

Another technology which would be used in a similar fashion to cable TV is teletext information systems.   These services are common in Western Europe, but not the U.S.   (Updated <u>traffic</u> information is being reported in this way in Los Angeles. [21]) They operate by invisibly encoding alphanumeric data onto conventional television signals, which are then read by a decoder attached to the TV set.   Teletext systems offer considerable potential for presenting transit pre-trip planning information, especially in areas not connected to cable TV.

Harris County Metro plans to integrate information on transit services with other available highway traffic data to provide travelers with a more comprehensive and useful picture of the transportation system, although they are still refining the concept. This information might be made available through in-home video terminals as well as cable TV.

Videotext systems, such as Prodigy (U.S.) and Teletel (France), offer a variety of 'general-purpose information services to subscribers.   These systems have great potential to provide specific, tailored, up-to-date information on transit routes, schedules, and fares.   They could also be utilized to make reservations on paratransit services or make car-pooling arrangements and. combined with other related information (e.g.,

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[20]   D. Puckett, Harris County Metropolitan Transit Authority. Houston. Texas - Houston Smart Commuter Demonstration Project.

[21]   Reid, P.. California Department of Transportation (CALTRANS), "Los Angeles Commuters Get Their Own Television Network," **AASHTO Quarterly,** July 1990.

highway congestion), would support a significantly improved travel decision-making environment. Videotext systems include application and communications software to provide a user friendly link between the subscriber's personal computer and a variety of different services and information sources (e.g., travel information, home shopping, and on-line encyclopedias). The videotext systems incorporate two-way communications, allowing the user to tailor the types of information selected and initiate transactions, such as making reservations or purchasing tickets.

Although no transit properties were identified that had current plans to provide computer-based travel information, there is a pilot project in the Boston area [22] to collect and report real-time highway traffic information using computer links. The developers expressed interest in augmenting the system with transit data, if these became available.

2.2. REAL-TIME RIDESHARE MATCHING

Real-time rideshare matching features an automated system for requesting and responding immediately to a request from a traveler for a trip in a carpool or vanpool.

State-of-the-Art Summary

Many rideshare matching services provide quick matches for commuters. That match is usually for a trip that is regularly taken, however (i.e., home-work-home trip, 5 days a week). Real-time matches could also be made for travelers wishing a ride for a single one way or round trip on a one time, short notice request. This type of real-time ride matching is not currently offered in North America, but is being considered in several locations.

Applications

Ridesharing has been promoted over the past two decades as a means of reducing congestion. It was first introduced in the 1970s as a Transportation System Management (TSM) strategy. As the terminology has changed, it is now mentioned under the heading of Transportation Demand Management (TDM) techniques. 'In any case, ridesharing created the need for trip takers. particularly regular commuters, to arrange their rides using a process called ride matching.

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[22]   Enroute Systems, Inc., Cambridge, Massachusetts.

In recent years, ride matching has become a highly automated process in which people wishing to join or form a carpool (or vanpool) can do so with one phone call to a matching service. In some cases, a phone call is not even necessary - a person can request a match by using a personal computer (PC) linked to a ride matching system [23]. Many of these automated ride matching systems can provide "real-time" matches. That is. when you request a match from a matching service, they can provide you with one while you are on the phone.

The currently available automated ride matching services provide matches primarily for commuter, or home-work-home trips by carpool or vanpool. These services are provided via telephone or PC. The software capable of ride matching in this fashion includes the following packages:

BRAND NAME	DEVELOPER/DISTRIBUTOR
TRANSMAX	C > Systems
CAPRA	CAPRA Software
RTDESTAR	Commuter Transportation Services, Inc.
SUPERPOOL, RIDETECH, RIDESHARE	CommuteTech
MICROCRIS	COMSIS Corporation
POOLMATCH	Crain & Associates Systems
RIDEMATCH	Spokane Ridesharing
EASYRIDER	STW Communications

However, real-time matches also could be made for travelers who decide that ridesharing would be the appropriate mode choice for the trip they wish to make. This decision would be made on the basis of information provided to the traveler regarding real-time traffic conditions, transit service availability, and other pertinent factors. This information could be provided through a variety of media, such as cable television, PC (at work or at home), or other advanced technologies (see Section 2.1 for a discussion of pre-trip planning information). While not currently operational in North America, this type of real-time ride matching is being considered in California and Texas with assistance from UMTA's APTS program.

In California, audiotext and videotext will be the key components of several automated traveler information projects in which UMTA is assisting the California

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[23] The Nuclear Regulatory Commission, located in Montgomery County, Maryland, provides walk-up information on an easy-to-use PC that is centrally located for employees to obtain information regarding the many commute alternatives available to them. Through this menu-driven system, employees can easily apply for ridesharing through the Washington, D.C. Council of Governments ridesharing service.

Department of Transportation in establishing real-time ridesharing in suburban environments. [24]

In Houston, the proposed Smart Commuter Demonstration Project will examine the potential for encouraging greater utilization of high occupancy modes, such as buses, carpools. and vanpools. through the application of innovative approaches using advanced technologies. [25]

One component of this demonstration focuses on encouraging a work trip mode shift from driving alone to carpooling through the application of a real-time rideshare matching program.   The hypothesis is that carpooling will increase when individuals are provided with a way to obtain a match either the same day or the evening before for a single trip.   This concept will be tested through the implementation and evaluation of an operational test project focusing on commuters living in the West Belt, Addicks, Kingsland, and Katy park-and-ride lot market areas and working in the Post Oak/Galleria area.   This represents a suburban-to-suburban travel market not well served by regular-route transit. The Katy to Post Oak/Galleria market was selected based on a relatively high concentration of origins and destinations, the lack of extensive direct regular route bus service, available space at many of the park-and-ride and park-and-pool lots, the travel time savings provided to carpools using the HOV lane, and the 3 or more peak hour vehicle occupancy requirement on the Katy HOV lane.   In addition, the Katy HOV lane is complete and all major agencies are participating in funding for the different elements.

The technologies being examined for the provision of the real-time carpool matching service include the following:

> o Telephone-based systems (live operator, voice synthesis, voice recognition, voice mail)
>   - touch-tone telephones
>   - cellular telephones
>
> o Television-based systems
>   - traffic reports as part of commercial stations programming
>   - cable television
>   - interactive cable television

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[24]   Robert W. Behnke. President, Aegis Transportation Information Systems. Inc., Portland, Oregon, and Honolulu, Hawaii.

[25]   The following text contains excerpts from a working paper entitled "Houston Smart Commuter Demonstration Project, Bus and Carpool Concept Definitions." February 199 1, which provides a description of the concepts for both the bus and real-time carpool components of the Smart Commuter Demonstration Program.

o   Videotext-based systems (smart terminals, such as microcomputers, or dumb terminals)
 - U.S. videotel
 - Prodigy
 - AT&T

Different combinations of these technologies will be considered, as will the use of different methods at the home end and at the work end.   Also, the technologies used in the carp001 program may evolve over time.

Suggested criteria for evaluating the different technologies for the real-time carp001 element of the <u>S</u>mart <u>C</u>ommuter Demonstration Program include the following:

o   Preference/ranking from focus groups

o   Ease of access by users

o Ability to provide two-way (interactive) communication

o   Ability to provide information at both trip ends (home and work)

o Ability to deliver needed traffic and transit information (both short and long term)

o   costs
 - initial capital costs
 - ongoing operating costs
 - long-term capital costs (system expansion and upgrading)
 - cost to user

o   Compatibility with long-term Metro and SDHPT efforts

o   Potential for private sector involvement and participation
 - R&D involvement
 - Cost sharing

There are a number of different ways of implementing real-time carp001 matching that would be effective.   In addition, there are a number of issues associated with real-time carp001 matching.   The different approaches and issues, which are currently being researched, are briefly described below.

First, approaches to matching potential carpoolers are being explored. Different software programs, including the system currently used by Houston Metro, are being examined along with the hardware and supporting equipment needed to operate the systems.   Also being examined is the potential initially to utilize a relatively simple approach based on existing technologies. while a more sophisticated system based on geographical and real-time ride matching algorithms is being developed.   Such a sophisticated system would be based on a three-dimensional matrix comprised of the trip origin, the trip destination,- and the desired trip time.

Second, a variety of arrangements would be possible for the actual formation of the real-time carpools. For example, matched individuals could meet at park-and-ride (or park-and-pool) lots, or one individual could pick the others up at their residences. Due to the need to provide information on the address and possibly directions to the other residences, it is anticipated that. initially, the demonstration may focus on a common meeting location, with home-based matches provided at a later state. Ultimately, the potential for in-vehicle information systems could be used to obtain both match information and directions to the meeting location. The results from the focus groups will assist in identifying the approach users prefer.

In addition, matching for the return trip will be needed. This could be accomplished either by matching both ends of the trip with the initial request or by making a subsequent match request for the return trip. Some type of program, such as a guaranteed ride home program, must be available to ensure that no individual is stranded at work without a way to get home.

A number of other potential issues or concerns are also being explored including:

- o   Liability of drivers and Metro in case of accident or incident
- o   Comfort level of cat-pooling with possible strangers
- o   Potential for crime or other incidents
- o   Registration requirements

These concerns will be considered in the final concept design and implementation plan.

It is anticipated that, if the assessment indicates the cat-pool element of the Smart Commuter Demonstration Project is viable, the demonstration would last for at least a 3-year period. This duration is based on the realization that it takes time for individuals to change their travel behavior. The 3-year period allows for the introduction of the concept, building awareness among potential users; and allowing individuals to become comfortable using the services. The results of the demonstration will be used to determine the future use of the approach, including possible expansion to other corridors.

It is anticipated that a variety of methods and techniques would be used to monitor and evaluate the results of the carp001 component of the Smart Commuter Demonstration Project. These may include monitoring match request calls, the number of matches provided, utilization levels at the park-and-ride and park-and-pool lots, carpool levels on the Katy HOV lane, surveys of carpoolers, surveys of

participants in the real-time car-pool database, monitoring of carp001 activities on other Houston HOV lanes and freeway corridors, and monitoring of possible confounding variables such as changes in price and availability of gasoline. Some of these elements are currently being conducted as part of other ongoing monitoring efforts in the Houston area. while other elements would be undertaken specifically for the demonstration. A comprehensive evaluation program would be developed as part of the overall Study Design and Implementation Program.

2.3 INTEGRATED FARE MEDIA

Integrated fare media are tickets that can be used for all modes, 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 operators. Most of the current applications of such technology involve the use of magnetically encoded farecards for both bus and rail modes.

Applications

In the San Francisco **area,** there are three examples of integrated fare media that can be used on both bus and rail modes of different transit agencies. The first example is the TransLink demonstration program. Under this program, a magnetic debit card will be used as a single ticket for both rail and bus fare. The TransLink system uses vending machines that will accept credit cards and automatic teller cards for dispensing the tickets. The Central Contra Costa Transit Authority's (CCCTA) and the San Francisco Bay Area Rapid Transit District's (BART) TransLink system is one of the first tests of a truly automated universal transit ticket program using magnetic strip technology in the United States. CCCTA, BART, and the Metropolitan Transportation Commission in Oakland developed the program which is being funded by a demonstration grant from UMTA.

The project has involved the development of computer hardware and software to provide total regional multimodal transfers with a single ticket and bus discounts of varying amounts. Travelers can purchase one pass good for BART Express buses, BART trains, and CCCTA buses. In the initial phase. equipment was installed on approximately 111 CCCTA buses and 45 BART Express buses which serve 10 BART

stations in the East Bay. In the second and third phases, the Alameda-Contra Costa Transit District (AC Transit) in Oakland and the San Francisco Municipal Railway (MUNI) were added to the system. [26]

A second example of integrated fare media in the Bay area is in San Mateo County, where San Mateo County Transit District (SamTrans) buses will accept passes from several San Francisco Bay area transit systems. Out of the 27 transit systems operating in the Bay area, SamTrans will honor daily, weekly, and monthly passes from the following agencies (single-ride tickets and transfers are not included) [27]:

- o MUNI
- o BART
- o AC Transit
- o CalTrain (A Commuter Rail Service from San Francisco - San Jose)
- o Santa Clara County Transit District (County Transit)

The purpose of this program is to encourage fare coordination between San Francisco Bay area transit systems. The program went into effect on January 1, 1991 and is being subsidized by SamTrans until joint revenue-sharing agreements can be finalized with the major transit operators.

Another Bay Area example is a multiple ticket program that was conducted in San Francisco from October 1989 (the earthquake) to June 30, 1990. Under the program, the multiple ticket could be used on AC Transit, BART, and MUNI. The ticket, good for a 2-week period, has stored value for use in the BART fare gates and was shown as a "flash pass" when used on MUNI and AC Transit. [28]

In Vancouver, British Columbia, the bus, ferry and AGT systems use integrated fare media. On the bus system, exact change fare or a FareSaver ticket is accepted. On SeaBus (ferry) and SkyTrain (AGT), FareSaver tickets are inserted into validators at each station. The ticket is retained as proof-of-payment and acts as a transfer. [29] Another fare medium for SeaBus and SkyTrain is the ticket sold in SeaBus and SkyTrain Ticket Vending Machines, which has the date of issue on it.

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[26] "Bay Area Ticketing Reaches Milestone." **Passenger Transport.** August 27, 1990, p. 12.

[27] "SamTrans To Accept Passes From Other Bay Area Systems." **Passenger Transport,** December 10, 1990, Vol. 48, Num. 50. p. 1.

[28] "BART Authorizes Demo Program," **Passenger Transport.** February 19. 1990, p. 6.

[29] "Fare System Integration in Greater Vancouver," **Passenger Transport,** June 11, 1990, p. 4.

The Port Authority Trans-Hudson Corporation (PATH), in an effort to establish a "seamless" transportation network for the New York-New Jersey region, [30] developed the QuickCard, a magnetically encoded farecard which can be used on PATH and New Jersey Transit. Also, there is a joint-ticketing arrangement between New Jersey Transit and Hoboken-Battery Park City ferry service. QuickCards can be purchased in denominations of 10, 20. or 40 trips, valid for 3 months. with cash or credit cards. QuickCards are also available automatically by mail. This joint ticketing program now allows passengers of both systems to take care of their monthly commuting requirements with one purchase.

2.4 MULTIMODAL TRIP RESERVATIONS & INTEGRATED BILLING SYSTEMS

Multimodal 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 interline 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 trip were purchased by a credit card, the billing would be generated by the credit card company.

State-of-the-Art Summary

Even though these technologies are not currently available in North American transit agencies, they have been suggested in recent documentation, such as UMTA's Office of Technical Assistance and Safety's Concept Paper entitled "Development of a Local Mobility Manager," dated November 1990.

Potential Application

The Mobility Manager concept includes the linkage of all local transportation modes by electronic means, allowing the participating modes to retain their individual identities, policies, and subsidies. The Mobility Manager would operate and administer a clearinghouse network, accomplishing the following functions:

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[30] "PATH Strives for 'Seamless' Network. " Passenger Transport, October 1. 1990, p. 56.

o   Integrated fare collection (see Section 4.2 for current examples)

o   Information on shared ride travel options from a single point of contact

o   Coordination of dispatch allowing providers to be contacted through a
    cen tral source

o   Integrated billing

o   Management of funds (public and employer subsidies) and documentation
    of transactions for subsidy agents

The Mobility Manager would provide information on competitive alternatives to single occupant automobile travel, and would provide special population groups greater mobility by matching transportation supply and demand, and providing a clearinghouse for financial transactions.

Work is continuing on this concept and its associated technologies. Currently, UMTA is researching the Mobility Manager.

3. CUSTOMER INTERFACE

Customer interface provides services to the passengers of a system to make their travel easier.   This includes information on arrival times, the general condition of the system, and simplified methods of payment.   Each of the strategies is designed to make the user's trip easier, from the point he or she first begins the trip, to his or her arrival at the destination.

System information and automated ticketing are described in this chapter. First, in-terminal information systems are discussed, wherein information is provided to passengers at major transfer points and downtown terminals. This generally consists of the scheduled and/or actual arrival times of each bus.   In-vehicle information systems follow.   In these, information is provided on-board and enroute, usually consisting of next-stop information and estimated arrival times.   The chapter finishes with electronic ticketing and automated trip payment.   This is both a labor-saving measure and a means of giving the passenger greater service and flexibility in payment.

3.1. IN-TERMINAL INFORMATION SYSTEMS

In-terminal information systems consist of electronic and computer display devices located at transit stations and/or enroute stops providing up-to-date travel information on delays, cancellations, reroutings, and terminal layout and services. These systems may involve interactive traveler inputs, and can be designed to accommodate handicapped and other travelers.

The systems vary in complexity from simple closed circuit television monitors providing scheduled vehicle arrival and departure information to large-format, touch-sensitive map displays combined with sophisticated algorithms to assist travelers to find the best routes to their desired destinations.   Specific applications may be linked to automatic vehicle location or vehicle identification systems to provide real-time updates on transit system status.

State-of-the-Art Summary

The availability of enhanced technology for providing in-terminal travel information to passengers greatly exceeds the level of installation of these methods.   Only a few agencies in North America have begun the process of upgrading in-terminal information systems.   The lack of installed automatic vehicle location (AVL) systems and the relatively high costs of some interactive terminals may have hindered implementation of

these systems in larger transit stations, while security and maintainability issues may have been considered problems for more remote sites.   As in pre-trip planning methods, the implementation of a greater number of advanced in-terminal information systems may be contingent on the acceptance and introduction of AVL technology in the transit industry.

Applications

This section contains information on two major types of in-terminal transit information displays:

o Monitors and closed-circuit television

o Interactive video

The most conventional form of in-terminal information system is the video monitor commonly encountered in airports and train stations.   These types of information displays have recently become available at some high-volume rapid transit and bus terminals in North America and overseas.   In Columbus, closed circuit TV monitors have been installed at two high volume downtown express bus stations to provide information on the scheduled arrival and departure times. [31]   Although the system is not updated in real-time, significant anticipated delays in service can be input into the system, overriding the fixed schedule information.   The display also includes paid advertizing to defray the cost of the system.

In the Bay area, passenger information displays are implemented in four Bay Area Rapid Transit (BART) stations (with plans for six or seven more) that are transfer points for connecting bus service. [32]   Information is provided on the scheduled departure times for the next two departing buses on each route that serves the transit stop.   The system uses a local minicomputer and TV monitor (as opposed to central computer control) to keep the installation hardware cost to a minimum.   Changes in the schedule are input by reading a diskette which must be carried to each location.   The information displayed on the monitors is keyed to a large map showing the physical features of the transit station, with emphasis on the location of connecting bus service.

Houston Metro is about to embark on a pilot program to provide similar information to travelers at two transit facilities and at two central business district

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[31]   R. Parker, Central Ohio Transit Authority, Columbus, Ohio.

[32]   R. Hueng, Bay Area Rapid Transit, Oakland, California.

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locations. [33]   Plans call for an increase in the number of locations served after the concept has been successfully demonstrated.   Initially. the information provided will include time and location (bay) data on the next buses scheduled to depart.   D a t a   t o operate the displays will be downloaded from the main computer-based scheduling system. with significant operating delays and ad hoc changes to the standard schedules input manually.   When the AVL system is operational, estimates of arrival and departure times will be updated automatically in real-time.   In addition to transit data, the monitor displays also will include public service information.

Several other systems in North America and Europe use real-time data, from automatic identification and vehicle tracking systems, to support in-terminal displays. Halifax/Dartmouth, Nova Scotia Transit has implemented speaker phones, connected to their real-time bus information system, at a few high volume bus stops, and video monitors at 15 shopping center locations. [34]   In Ottawa/Carleton, Ontario, TV monitor displays are installed at 12 downtown extended bus stops with high ridership (over 8000 passengers per hour). [35]   Real-time information, derived from a deployed AVL system, is provided on the order and within-terminal location of buses to arrive during the next two minutes.   Since bus boarding areas are quite limited for space, fixed sites are not preassigned, but arrival/departure locations are determined by the order that buses arrive at the transit station.   Arriving buses are positioned in the next available spot (up to four in a row) in several designated linear boarding areas. The information provided on the in-terminal displays assists passengers to queue at appropriate locations along boarding platform areas.

Similar information is provided to public transportation passengers in the nine block long transit mall in downtown Tampa, Florida. [36] Bus boarding locations at long, linear transit stops are dynamically assigned according to the order of arrival of buses at the entrance to the transit mall.   Buses are identified via interrogation of attached radio frequency transponders.   Television monitors located in bus shelters provide information on the route number, name and expected arrival time of buses at

[33]   D. Puckett, Harris County Metro Transit Agency, Houston. Texas: Houston Smart Commuter Demonstration Project.

[34]   Kenny Silver, Metropolitan Transit Commission, Halifax-Dartmouth. Nova Scotia: GoTime Traveler Information System.

[35]   L. P. van der Kloot, Ottawa-Carleton Regional Transit Commission. Ottawa, Ontario.

[36]   S. Roberts, Hillsborough Area Regional Transit Authority, Tampa, Florida.

each stop, while curbside LCD displays inform waiting passengers of the next four buses expected at each boarding location. Although designed to be fully automated, there has been a continuing requirement for on-site transit personnel to assist users who have problems becoming familiar with the system or reading the displays. Improvements are planned to provide refined information on bus location and schedule adherence and to better serve visually impaired transit users.

The passenger information system implemented in main bus terminal in Oslo, Norway employs an extensive set of over 50 computer-controlled video monitors and displays. [37] The system automatically identifies arriving buses optically from their windshield tags, and simultaneously assigns them to an open bay while displaying arrival time and location information on the in-terminal monitors. Other in-terminal passenger information systems in the United Kingdom and the Continent provide similar functionality, but operate using data derived from automatic vehicle location systems. [38]

A different approach to in-terminal transit information display, incorporating user interactive terminals, is currently being planned or implemented in a few North American systems, including Houston, Baltimore, [39] and Hull, Quebec [40]. These applications involve providing specific directions on how to use the transit system to reach user-specified destinations within the service area. Desired travel locations are input by keying in addresses, commonly used site names, or picking items off, a menu (e.g., downtown hotels). All three travel information systems provide instructions on how to access the transit system, estimated travel times, applicable routes, schedules, transfers, and fares. In addition, prospective travelers can obtain paper copies of pertinent information. In Europe, the systems often incorporate coin-operated ticket dispensers.

The technology employed in Houston is patterned after a travel information system (SITU) adopted in several French cities. [41] In Europe, the systems are used more generally to help travelers find their way around the areas using many modes of

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[37]   "State of the Art Electronics Guide Passengers and Buses at the New Oslo Bus Terminal," **Bus Ride,** July 1989.

[38]   "Assessment of Advanced Technologies for Transit and Rideshare Applications." *Draft Final Report,* Castle Rock Consultants, November 1990.

[39[Rohit Patel, Mass Transit Administration. Baltimore, Maryland.

[40]   Sallah Barj, Commission de transport de la Communaute regionale de I'Outaouis.

[41]   SITU equipment. manufactured by Societe d'Etude pour l' Information sur les Transports Urbains, is operating in Paris, Caen, Names, Valenciennes. and Nimes.

transportation, including walking.   The SITU system uses a keypad for data entry, but interactive audio (voice recognition) and touch sensitive screens are also possible. The system deployed in downtown Houston (and two other sites to be operational shortly) permits the user to select destinations from a large-scale (3x4 foot), touch-sensitive video map of the transit service area.   The city map does not include all features at the same scale. but emphasizes major points of interest.   The Houston system operates on stand-alone computer processor. so that the information currently dispensed is based on fixed transit schedules.   In the future, the system could be connected via telephone modems to the main computer to obtain updated (real-time) travel information.   Plans call for eventual implementation of many such terminals in Houston area, provided that the pilot program demonstrates that the benefits of this approach are worth the $20,000 to $30,000 cost per installation.

The in-terminal information system concept being developed for key transit stations in Baltimore incorporates a microwave or leased telephone line link to a central computer to provide real-time information on the location of transit vehicles.   Thus, the routing information dispensed to travelers will take into account current data on delays and service interruptions.   The "Travel Assistance Network" terminal will include a 19- to 27-inch screen, an ATM-like keyboard, and a thermal strip (2-inch) printer. Plans call for initial implementation in about 2 years.

3.2 IN-VEHICLE INFORMATION SYSTEMS

In-vehicle information systems consist of technological innovations supporting the transit user and vehicle operator.   Travelers are aided by information displays and on-board communications devices providing current information on seating availability, routes, schedules, and connecting services, as well as, remote telephone and computer connection capabilities.   Additional information available to vehicle operators might include displays and communication systems indicating correctable schedule deviations, requirements to wait for connecting services, and on-board mapping and GIS support.

State-of-the-Art Summary

In-vehicle passenger information displays have not been seriously considered by transit properties in North- America.   Although some of the simpler systems could easily be adapted for use in bus operations, it appears that most transit operators do not consider the addition of on-board information aids to be a high priority. As one offrcial expressed it, bus displays do not offer as much benefit in attracting and keeping riders

as improvements in other areas, such as in safety and reliability. In-vehicle information systems have been implemented to a limited extent in Europe and Japan.

Although they offer considerable potential benefits for paratransit operations, on-board navigation systems are viewed as experimental and expensive. Consequently, only a few transit systems are currently contemplating their use. Wider implementation in the transit market will probably follow the maturation of the technology.

Applications

Application of on-board information systems in North American public transit systems is negligible. although some experimentation and early implementation of these types of systems has occurred overseas. The main categories of on-board information systems include:

> o signs and displays
> o navigation and guidance systems

Information indicating upcoming transit stops and connections are typically provided on fixed rail and some specialized bus systems (e.g., at airports) by means of announcements over **a** public address system. In some cases, this process is completely or partially automated using prerecorded messages. These approaches are not commonly found in the North American urban bus environment, even though the technology seems completely transferable. However, a small number of European and Japanese systems are beginning to implement more technologically advanced on-board information systems involving use of synthesized voice messages, dot matrix signs, or video displays located at strategic locations within the vehicle. [42] These systems are used to provide information on seating availability, expected arrival times at next stops, and projected waits for connecting services (the latter two require an AVL communications link). The MARIA system (Japan), designed primarily for automobile use - but adaptable for transit, can provide information on tourist sites and places of interest using data stored on a read-only compact disk.

Information generated from an AVL system might also be made available to transit drivers. Several transit properties with implemented AVL systems have included simple driver dashboard displays (lights) that show whether the vehicle is on time. early

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[42] Examples of these types of systems included the Focon Electronic System for the Danish State Railway and the Mitsubishi Advanced Real-Time Information Autosystem (MARIA).

or late [see section 4.1]. This unsophisticated approach is proving effective in helping transit drivers reduce run-time variations.

On-board navigation systems include mapping and route guidance systems. On-board mapping systems show the current location of the vehicle (obtained from an AVL system) superimposed on a detailed street map of the area. The versions of these systems applicable to transit are not significantly different to those that are becoming available for the small vehicle (e.g., taxi, police, etc.) market. A complicated enhancement is the addition of route advice and guidance. [43] This type of information might be particularly beneficial for paratransit services operating on varied routes unfamiliar to the drivers. Application of this technology for fixed route bus systems might also aid new or substitute drivers, but is probably not cost effective. The Ann Arbor Transit Agency is in the process of implementing an on-board navigation system in its paratransit buses. [44] This location benefits from a recently fielded AVL system that employs dead-reckoning and map matching. The same map data and algorithms needed for this type of AVL are also required for on-board mapping, and were more easily adapted to provide input to the required displays.

3.3 ELECTRONIC TICKETING AND AUTOMATED TRIP PAYMENT

Electronic ticketing involves the automated generation of tickets and automated fare collection, allowing for the collection of 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. Advanced card technology typically describes plastic cards (credit card size) with a programmable memory chip that can be used for identification, trip payment, and other travel-related functions.

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[43]   Although algorithms for finding shortest paths in networks are readily available. the accuracy required of location systems and the amount of extra detailed geographic data needed (e.g., intersection turn prohibition) make these systems much more difficult to implement.

[44]   Mike Bolton, Ann Arbor Transit Authority, Ann Arbor, Michigan.

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 (stored-value) cards.

Applications

The Chicago Regional Transportation Authority's (RTA's) development of a Payment and Control Information System (PCIS) for Special Services includes the use of identification cards and portable card readers to collect information on passengers, trips, and fares. [45]   This information will be used at a central location to facilitate the audit, approval, and payment for a completed trip. [46]   The PCIS will be capable of identifying certified users of Special Services transportation, and interactively accepting and recording trip and fare information for transfer to the transportation agency's accounting system.   The PCIS will record and validate trips for reporting and authorization of payment.

One key element of the PCIS is the use of Smart Cards, a type of advanced card technology, primarily for client identification and fare payment.   The Smart Card contains a programmable chip (also called electrically erasable programmable read-only memory (EEPROM)) that can perform several. functions, including: hold instructions, monitor itself, hold a value, and create an electronic billing record.   In this case, the Smart Cards will have the client's picture on it and an expiration date.   A client would board the vehicle, enter his/her Smart Card into a hand-held unit [47] to verify the client and to verify that there is enough money stored in the client's "account" to pay for the trip.   (The Smart Card could be used with or without value if there is no value on the card, the client would have to pay the fare on the vehicle; if there is value on the card, the fare will be taken from the client's account on the card.) The client will be

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[45]   Special Services are transit services that are provided by contract carriers to particular target user groups.   In the Northeastern Illinois region, these services are for severely mobility limited individuals who cannot use accessible mainline service.

[46]   Regional Transportation Authority, "Special Services Payment and Control Information System," Request for Proposals, RFP #6335.

[471   This type of Smart Card is a "contact" Smart Card, since it is physically entered into a reader for verification.

able to send a check in to the transportation agency and, in turn, the transportation agency would send the client a letter stating the client's code. This code would be entered into the hand-held unit by the client when they take their next ride, and the check's value would be credited to their card (similar to Pitney-Bowes postage machines).

RTA's contractor (Applied Systems Institute, Inc.) is proposing a hand-held unit made by Telxon Corporation. The PTC 710 is about the size of a calculator, has a programmable chip (EEPROM), and will have a 25-pin RS-232 cable on the end for peripheral connection. The unit will be fully portable and held by the driver. The units will have an internal clock, which will be the official time clock and may be used to monitor on-time performance. At night, the units will be put into a cradle, which will charge the unit and download the data in the unit to a central computer,

For one month during the summer of 199 1, the Smart Cards and hand-held units will be tested in service. One of the five Special Service carriers (with about 400 regular clients) will be testing this equipment. Twenty units will be employed in the test.

The overall PCIS development project is scheduled to take 3 years - 1 year for implementation of the system on all the carriers, and 2 years for running and maintaining the system. Full implementation will use 330 units and 30,000 Smart Cards.

The Port Authority of Allegheny County (PAT) (Pittsburgh, Pennsylvania) demonstrated the use of Smart Cards from February 1, 1990 to July 3 1, 1990 on 1.5 buses covering three routes. A special farebox, called SmartBox and manufactured by Schlumberger Technologies, was installed in the 15 buses to read the Smart Cards. The SmartCards, also made by Schlumberger Technologies, are similar to those described earlier - they use an EEPROM embedded in a plastic card which is the size of a credit card. This technology has been used throughout Europe for transit fares, public parking lots, and telephones.

The Smart Card was inserted into the SmartBox by the user, and the SmartBox verified if the card was valid. Data collected by the equipment included the Smart Card number (which could be correlated with the user's name and address), time of boarding, trip destination, and other associated trip information.

During the 6-month test, each Smart Card. which represented an unlimited monthly pass, sold for $50, a reduction of $5 from the regular price of a monthly pass. Schlumberger paid that $5 difference, as well as provided all the equipment to

PAT free of charge. This demonstration was very successful in terms of proving the feasibility of using such a Smart Card based system for transit applications.

A relatively new concept in ticketing is being developed for the Virginia Railway Express (VRE), a new commuter rail start-up that is scheduled to open in late October 1991. The VRE will have two lines: Fredericksburg to Washington, DC and Manassas to Washington, DC. They will be using the Ticket Vending System made by Schlumberger as a proof-of-payment or honor system (there will be no fare collection per se). A unique feature of this system is that it will be a cashless system - it will only accept credit cards (and eventually debit or bank cards) for payment. This will eliminate the need for coin vaults and cash processing personnel.

The self-service Ticket Vending Machine will take the rider's credit card, and the rider will enter the station origin and destination, and the ticket type. Three ticket types will be available on VRE:

- o Single-ride
- o Multirides (e.g., lo-ride ticket)
- o Unlimited rides for a month (monthly pass)

Ticket sales for cash will be available off-site and potentially in station parking lots. Tickets sold for cash will be low-value/high-cost (i.e., a penalty for paying cash).

Port Authority Trans-Hudson's (PATH) QuickCard, a magnetically-encoded farecard, can be purchased using a credit card or cash. The QuickCard, which was discussed in the Integrated Fare Media section of this report, can be used for both New Jersey Transit and PATH fares. It is inserted in a turnstile (very similar to those used in the Washington Metropolitan Area Transit Authority (WMATA) system), the magnetic strip on the card is read, and the card is returned to the user after the fare has been decremented. QuickCards are being offered in l0-, 20- or 40-trip denominations and are valid for 3 months.

Currently, WMATA farecards can be purchased at selected Automatic Teller Machines (ATMs). These ATMs can dispense pre-encoded Metro farecards ($10 or $20 cards), and can also dispense cash that can be used in the farecard vending machines (e.g., specific denomination bills). This ATM equipment is built by Cubic Western.

The TransLink demonstration program in San Francisco is another example of electronic ticketing and automated trip payment. Under this program, a magnetic debit card will be used as a single ticket for both rail (BART) and bus (CCCTA and BART Express) fare. TransLink is one of the first tests of a truly automated universal transit ticket program using magnetic-strip technology in the United States. The TransLink

system is cashless - it uses vending machines that will accept credit cards and automatic teller cards for dispensing the tickets.

In the initial phase of the TransLink demonstration, approximately 111 CCCTA buses and 45 BART Express buses which serve 10 BART stations in the East Bay were equipped with the card readers. In the second and third phases, Alameda-Contra Costa Transit District in Oakland and San Francisco Municipal Railway were added to the system.

The City of Phoenix Transit System has begun a test of magnetically encoded passes on four East Valley express routes as a potential method of bus fare payment for monthly pass holders. If successful, it will serve as the foundation for "magcard" implementation systemwide sometime during 199 1. It could eventually lead to a debit card or credit card fare payment plan for transit service valleywide. [48]

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[48]   "Phoenix Begins Magcard Test," **Passenger Transport,** October 1, 1990, p. 6.

4. VEHICLE OPERATIONS AND COMMUNICATIONS

The principal objective of Vehicle Operations and Communications is the better management of existing fleet resources through technological innovation. . In the case of a fleet of transit vehicles, for example, these innovations improve the performance and productivity of the fleet without adding new vehicles or significantly restructuring the old ones. Further, the focus is on innovation, using existing technology in new applications, rather than on invention and giant leaps in technology.

The are many types of Vehicle Operations and Communications, the most innovative of which are described in this chapter. The first is Automatic Vehicle Location (AVL), which leads to better fleet control through knowledge of each vehicle's current position and comparison to where the vehicle would be if it were on schedule, This comparison is greatly facilitated by Transit Operations Software in real-time operation, which is discussed next. The software also may provide strategies for alleviating schedule deviation and improving operations overall. The discussion of Transit Operations Software is followed by Dial-A-Ride Dispatching Systems and their application to demand-responsive service. These have great potential to improve the efficiency and effectiveness of this service.

4.1. AUTOMATIC VEHICLE LOCATION

Automatic Vehicle Location (AVL) is a powerful tool for use by companies and agencies to dispatch and control a fleet of vehicles. It is used extensively by trucking companies to control their fleet and to improve just-in-time delivery and minimize penalties incurred due to late or early deliveries. Transit agencies also want their vehicles to depart and arrive each stop on time, for they too suffer costs incurred by late or early vehicles. With AVL, the agency's central control can know exactly where each vehicle is at any given time, and using this knowledge, can either send the vehicles where they are needed or adjust their operation so that they stay on schedule. This information can also be recorded to provide better base data for later scheduling. Finally, other "extras" such as passenger information systems. automatic passenger counters, vehicle condition monitors, and real-time security can be added to the system either as initial equipment or as new additions.

An AVL system works by first measuring the position of each vehicle and then reporting that position to the computer at central control. This position can be compared to the vehicle's expected position based on schedule information, and a status

can be assessed based on schedule adherence.   This information is valuable for a number of reasons.   For example, the driver might be given specific instructions, based on the information. which will improve real-time system performance, or the information can be stored and then used to aid future planning and scheduling.   Knowledge of the bus' location also aids in security, as it will shorten police response time to an emergency situation.   Finally, this status can be provided to the public, so that they can minimize waiting time at the stop, or to the driver so that he or she can adjust operation to better meet the schedule.

A type of AVL system has been in place for many years in rail operations at many transit agencies.   Location of light and heavy rail cars is greatly eased, since the guideway is fixed and exclusive to transit vehicles, the vehicles are of uniform dimensions, and following distances are more controlled than in normal traffic. The system can then locate vehicles when their wheels pass points where sensors are located. Because of the uniformity of the vehicles and the regulated following distances, there is little danger of counting two trains as one or one as two, even when multicar trains are employed, and trains of different lengths are in service simultaneously.

Communications are also greatly facilitated, because there is already infrastructure in place along which communication lines may be laid.   Because there are rails, and there is power supplied to the vehicle from the substation, there are convenient paths for wires, so there is no need for complicated radio systems. Since AVL for rail is not really "new, " and since it can be implemented without sophisticated and innovative technologies, the following discussion will focus exclusively on bus operations.

There are many pieces in any AVL system, some of which are essential components for operation, others useful additions to the basic system.   Many different technologies are available for performing the functions of each component. The basic components and possible additions are described first, followed by descriptions of existing systems, during which the technologies chosen for each piece are discussed.

Components

There are certain components necessary for any AVL system. including a method for vehicle location, a means of communicating that information to central control in real-time, and a central processor capable of storing and using. that information.   If any of these are missing, the system will not perform all of the functions basic to AVL.

As its name suggests, the vehicle location component measures the position of each vehicle within a certain tolerance.   The tolerance is dependent on the technology

chosen, how that technology is implemented, and the environment in which the system is operating. This position is then either retained by a storage device on the bus for a time before transmission or transmitted immediately to central control.

Two-way, real-time communication between the bus and central control is essential. In addition to standard voice communication, the position data generated by the vehicle location subsystem must also be transmitted from the bus to central control. The technology used for this component partly depends on the position technology selected, but most combinations are viable.

Once the data has reached headquarters, it must be processed before it can be used effectively. The data is simply the current position of each bus, so without comparison to the schedule or the positions of the other buses in operation, the dispatcher can make only very limited decisions about control. Further, if this data is not recorded, there is no database for later planning and schedule modification, While the system would be marginally operational without this component, it would not have the full capability of an AVL system.

Added Features

In addition to the components listed above, there are a number of additional components that can be added to an AVL system that will enhance its capabilities. Each of these are described in turn, below.

Automatic Passenger Counters (APCs) are a means of counting boardings and alightings for a vehicle at each stop. Each APC must include a counting device, recording equipment, a method of determining current location, and a means of transferring the stored data.

There are a number of technologies available for each of these components. The counting device is either a pair of infrared beams across the door-well or pressure sensitive mats on the stairs. Interrupting the beams or pressure on the mats indicates activity, and the order in which the beams or mats are triggered indicates whether it is a boarding or an alighting. The recording equipment is simply a media capable of storing computer data, which can be shared with the AVL if the media has sufficient capacity. The AVL itself determines the location of the bus throughout the route, so it can also determine where each boarding and alighting has occurred. APC data can be transferred on the same link along with the AVL data real-time. or it can be transmitted separately and less often, such as once a day. when the bus pulls in for the night.

In addition to reporting vehicle location. the communication system can report the condition of the vehicle. Many aspects of vehicle performance and condition are already monitored and displayed to the driver, and many more are available to a mechanic who needs simply to plug the engine into a diagnostic computer. These aspects, or some relevant subset, can be measured and reported to the dispatcher, who can remove the bus from service before it breaks down or at least have a bus ready to replace it.

As will be discussed in the next chapter, a High Occupancy Vehicle Preference and Verification System requires the location and identification of the transit or other high occupancy vehicle (HOV) to determine when to give preferential treatment. AVL provides a splendid opportunity to provide just this information to the actuating equipment with little additional equipment,

Security is a concern for many agencies and bus drivers, because there is little protection for the driver or his passengers along the route. First, the transit agency has to identify that there is a problem. Then, the police have to be notified and find the bus, before they can take action. This can take a long time, especially if the bus has been taken off the route.

A great feature of an AVL system is its ability to incorporate a silent alarm. The driver is provided with a switch in a discrete location and needs only press it if he or she is in danger. Activating the switch initiates a number of activities. Central control is notified via the communication link that there is an emergency and that the police should be called. All communication to the bus is cut off, so that the assailant is not made aware an alarm has been activated. Central control can hear everything occurring on the bus and thus can further assess the situation or discount it as a false alarm. Finally, if it is included in the package, a transmitter is activated on the bus, much like in some stolen cars, greatly facilitating the police's efforts to locate the bus, especially if it is off-route.

In addition to the options described above, there are a number of other extras which can be included in an AVL system. The most prevalent of these is Passenger Information Systems. Since the position of each bus is known. this information can be passed on to the public, who can now better plan their travel by transit. This was described in detail in previous sections.

State-of-the-Art Summary

Automatic Vehicle Location is now being tested and implemented extensively by transit agencies throughout the world. Although more widespread in Europe, there are

several AVL implementations and tests in progress throughout North America. There is a large amount of variation from city to city in the complexity **and** the uses of the systems. There is also a large amount of variation in the technologies chosen for the basic components: location, communication, and processing equipment and strategy.

There are also examples of each of the added features in operation in North America. it is rare for all of them to be present in a single operation. Rather, one or two are typically used by each agency, and their choice depends **on** factors specific to the agency and the area.

The agencies who have tested AVL systems are generally pleased with them. Although initial problems with new installations are quite common, these problems are typically attributed to the need for tuning and calibration. Most agencies report that it is crucial to choose the system that best fits the environment in which the system operates. This includes the size of the operation and the size, demographics, and weather of the area served. Future plans vary among agencies, but most of those who have implemented or rigorously tested AVL have plans to initiate, continue, or expand their implementation.

Current & Future Applications

There are a number of AVL systems planned or implemented in the U.S. and in Canada. Several of these systems are described in detail, each chosen to highlight the most innovative systems and to give a representative cross section of the available technologies. Summary details are provided for each system in North America in Appendix A.

The Tidewater Transportation District Commission (TTDC) of Norfolk, Virginia has just installed an AVL system recently acquired from F & M Global. The **cost** for equipping their fleet of 15 1 buses (I 15 peak) was approximated at \$2 million.

Location referencing is accomplished with signposts and the bus' own odometer, and each bus maintains a record of its own position. Each of the signposts continuously broadcasts its location over an area with a radius of about 100 feet. Passing buses read this information, using it to update their recorded position. Between signposts, which can be several miles apart, the bus uses its own odometer to measure distance from the last signpost it passed, and the central computer uses that to determine the bus' exact location.

Communication is via dedicated radio frequencies. which poll each bus every **40** seconds. To poll the bus, the central processor will ask the bus to report its

position, via a radio frequency, and the central computer will then use the information to update the information available to the dispatcher.   The central computer will compare this position information to the schedule for the route to determine whether the bus is on time, early, or late.   This information is then reported to the dispatcher who can then take action to keep the bus on schedule.   It is also sent back over the radio frequency to the driver via an on-board display, so that the driver can monitor his or her own performance and make corrections, independent of the dispatcher.

In addition to general location, the dispatcher also receives information about bus condition.   There are three mechanical "alarms" which may sound: Low Air (Brakes), Engine Temperature, or Oil Pressure. If any of these alarms sound, the dispatcher knows that there is a problem and can immediately send a replacement bus and a mechanic with information about the condition of the bus. This saves time and helps reduce deviations from schedule.

This system is a relatively new installation.   It has been operating well so far, save for a few initial adjustments.   They plan to equip their trolleys in the future. [49]

VIA Metropolitan Transit in San Antonio, Texas has a signpost system similar to the one in Norfolk.   The agency purchased a system from General Railway Signal for their 537 buses for a total cost of about $3.7 million.   Location is by the signposts, which continuously broadcast their location to the bus, and by the bus' own odometer, which interpolates along the route between signposts.   The central computer polls each vehicle once a minute via dedicated radio frequencies, during which time it collects their positions.   The computer will compare this information to schedule data to determine on-time performance, and it will send the information back to the driver.

In addition to the basic components described above, the system includes mechanical alarms and a security alarm.   The mechanical alarms are similar to those in Norfolk, monitoring specific engine components and allowing for problems to be addressed before they become serious.   The security alarm is in the form of a panic button (in a discrete location) furnished to the driver.   If there is a problem involving the safety of the driver or passengers, this button may be pressed, and a silent alarm is activated.   The dispatcher is alerted immediately that there is a problem and may give the position of the bus to the police.   In addition. all communication to the bus is shut off, so that the criminal will not be made aware of the alarm.

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[49]   M. L. Sheldon, Tidewater Transit District Commission, Norfolk, Virginia.

This system was implemented over several years and passed final acceptance over 2 years ago. [50] [51] [52] [53]

The Ann Arbor Transit Authority (AATA) is currently testing a system purchased from General Railway Signal. The overall cost for equipping their fleet of 67 buses was approximated at $300,000 in 1990 dollars.

Location referencing is accomplished using "dead reckoning" with corrections made by map matching and a few signposts. The bus has a record of its current location and direction. and uses odometer readings to measure distance traveled to update that record. It qualifies that update by sensing changes in direction greater than a specified tolerance, for which it takes a compass reading to determine the new direction. This position is constantly compared to a road map stored on cassette tape to determine if it is indeed still on a road, and the position is corrected to ensure that. The location is further corrected at the garage and at a few other key locations by taking a reading from a signpost which constantly broadcasts its location. This is similar to the signpost and odometer method used in Norfolk and San Antonio, but this method relies primarily on bus equipment, the odometer, turn sensor; compass, and road maps, rather than the signposts, which are for gross corrections only. This system of location was chosen both for its accuracy and for the limited amount of hardware needed to be placed in the open, where it cannot easily be protected from the weather and vandals.

The communications are by dedicated two-way radio frequencies in the 900 megahertz region. Polling is every 13 to 14 seconds, and the agency feels that polling at least this often is essential for reasonable accuracy. Given an average speed of 15 miles per hour, the bus will travel slightly over 300 feet in 14 seconds. Less frequent polling will result in greater distances traveled before. the central computer receives an update on the bus' position and greater uncertainty.

[50] **O'Neil,** Jerry, "VIA Looks to the Future with AVM System." **METRO Magazine,** May/June, *1989,* pp. 36, 38, 39.

[51] *"On-Time Performance Improves:* VIA Installs New Technology." **Passenger Transport,** January *30, 1989,* p. 7.

[52] **TransitMaster:** *Fleer Management. Communication, and Control System.* a General Railway Signal Promotional Pamphlet.

[53] Dennis Perkinson, VIA Metropolitan Transit, San Antonio Texas.

Once the position information is received in central control, it is displayed on a full-color video display, and it is used for several service control procedures and for passenger information. The video display shows each vehicle on the city street network as a block at the vehicle's current position. and the block is color-coded according to its on-time status, and the type of vehicle it is, (fixed route bus in service, bus not in service. or supervisory vehicle). The position information is then used to help keep buses on schedule and to facilitate timed transfers. A bus might be told to wait up to 5 minutes so that passengers may make a transfer from another bus. The system also generates "exception data" of deviations from schedule and makes reports for later use in planning and scheduling.

Since central control knows the location of each bus at any given time, the agency wishes to pass this knowledge on to the public. The public would then not need to rely on schedule information and the sometimes faulty assumption that the bus is running on time: they would know exactly when the bus would reach their stop. This inspires greater confidence in public transportation. Passenger Information Systems were described earlier in this report.

The system also includes a silent alarm for emergency use. The driver need only push a button, and central control is notified that there is a problem, and the police should be sent to investigate. There has been a relatively high incidence of false alarms, but this has been mitigated with a "listen in" feature. When the alarm activates, it establishes a one-way communication link from the bus to central control, so that central control can hear everything occurring on the bus but can transmit nothing back to the bus. If there is indeed no emergency, the police will not be sent, and the alarm simply will be reset.

The agency is quite enthusiastic about their AVL system and have found it to be quite useful. for all the tasks just described. They have only had a few equipment problems: the radios tend to fail in bad weather, and the tapes with the street map information tend to wear out every 6 weeks. They have no current plans for the radios, but they are looking at replacing the tape media with ROM chips, containing the same information. [54]

The Mass Transit Administration (MTA) in Baltimore is currently testing an AVL system purchased from Westinghouse. using a phased implementation. They are currently in phase 2, which includes 50 of their 900 fixed route buses and 4 supervisory

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[54]   Mike Bolton. Ann Arbor Transit Authority, Ann Arbor, Michigan.

vehicles. Baltimore has paratransit service, but this is not included in the AVL implementation. Phase 3. if approved by the policy committee, will include all 900 buses, 100 maintenance and supervisory vehicles, and automatic passenger counters (APCs) for 10 percent of the fleet. If implemented, phase three will bring the total system cost to about $11 million.

Location referencing is by LORAN-C, a location system developed for the U.S. Coast Guard. Several ground-based transmitters are already in place, each emitting a signal, and covering nearly all of North America. The buses are equipped with LORAN receivers, which decode the signals, determine the direction from where they originate, and use this information from two or three transmitters to triangulate their position. Further refinements are made using the bus' own odometer and map matching in much the same way as in dead reckoning and signpost methods.

LORAN-C has the advantage that it requires no equipment to be placed outside of the buses and headquarters and that it works anywhere in the city, not just on the assigned routes. It is not as accurate as other methods, however, giving positions to within 100 meters, or about 300 feet under adverse conditions, usually due to large buildings or natural features, which can distort the signals from the transmitters.

Communications are similar to those described for TTDC, VIA, and AATA: dedicated radio frequencies poll each bus every 20 seconds, and the bus' position information is transmitted to central control. The information is then used to generate a digital map for real-time operational control using Computer Aided Dispatch (CAD) and for planning information. The digital map gives a color display of the location of each bus, bus stop, time point, and landmark on the urban street network. Each bus is colored by status: on-time, early, late, off-route, needs maintenance, or has an emergency. It is further equipped with tools to zoom in on portions of the map and to locate desired items and can play back and print previously recorded data.

The dispatcher can then use the information and CAD to improve operations. These improvements include improving schedule adherence and reducing bunching of buses by controlling their speed. The system will also prioritize radio messages and reduce radio traffic in general by partially replacing voice communication with faster, digital means. The system can also suggest detours, based on shortest path or shortest time algorithms. The information is also recorded for use by planners.

Further implementation of the system includes several possible additions and requires approval of the policy committee. This will include an extension of AVL to all the buses and 100 of the maintenance and supervisory vehicles run by the agency.

It will also include automatic passenger counters and passenger information systems. [55] [56]

The Toronto Transit Commission (TTC) runs a very large operation, containing 2,300 buses and streetcars. in addition to several subway lines. They are currently implementing an AVL system purchased in 1988 from Bell Radio (now called National Mobile Radio Communication Inc.), for about $17 million (Canadian Dollars). Adding communications equipment brings the cost to about $38 million (Canadian Dollars). The implementation is proceeding garage-by-garage and the whole system will be equipped by the end of 1991.

Except for the size of the system. this operates in much the same manner, and is used in much the same way as described in other cities. Location referencing is by microwave signposts and odometer and operates in the same manner as in Norfolk, Virginia. Data transmission is over dedicated two-way radio channels.. Forty-two have been reserved, 11 for voice and 3 1 for data. and buses are polled once every 6 seconds. The information received is used for real-time control, as well as planning.

Toronto also has an extensive implementation of Automatic Passenger Counters (APCs), which are not fully integrated with the AVL system. The APCs use the same signposts used by the AVL. but the count information is not transmitted in real time, and only 150 of the 1,500 buses are equipped with APCs. Since APC information is generally for planning and scheduling purposes and not for real-time operations, the agency need only take a sample of the buses o n a route. Further, the data is not needed immediately, and can wait until the end of the day to be unloaded. These two aspects are important, because equipment is expensive and radio frequencies are typically scarce. If additional information needs to be sent each time the bus is polled, the communication will take longer, and either more frequencies will be required, or polling must occur less often. [57]

The Chicago Transit Authority (CTA), who also runs a very large operation (1 ,800 buses carrying 1.5 million passengers during the peak), is currently preparing specifications for an extensive AVL system. The agency is also planning for the system to include many extras, when complete. including Automatic Passenger Counters. a

[55]   Patel, Rohit H.. **A Primer on MTA's Automatic Vehicle Location (AVL) System.** Mass Transit Administration, Baltimore, Maryland, January 1991.

[56]   Rohit **H.** Patel, Mass Transit Administration, Baltimore. Maryland.

[57]   John Panyan (AVL) and Chris Seewald (APC), Toronto Transit Commission, Toronto, Ontario.

Passenger Information System, Engine Probes, a Silent Alarm, Signal Preemption, Computer Aided Dispatch, and Electronic Driver Identification using Smart Cards. They also feel a need to update their communications system, so the two will be implemented in concert, with a goal of completely eliminating voice communication.

Location referencing will be either by signposts or inductive loop detectors. The inductive loop detectors will work essentially the same way as signposts, but will transmit the location via an electric field to an antenna mounted below the bus. The agency feels that it is essential to know the position of the bus every block, because they run headways as low as 90 seconds on the most heavily traveled routes during the peak period.

Close headways create other operational problems. Since the downtown area is a dense network of streets and there are many traffic signals, there is a high probability that the bus will be delayed by red lights. This can delay the bus up to 30 seconds each, or one-third of a headway, creating uneven headways and secondary effects, such as uneven loading, which contributes to a greater disparity in headways and bunching of buses. A solution lies in the AVL system: the bus following the one which was delayed would be told to wait for a few seconds, and the effects of the traffic signal delay would be mitigated somewhat.

Bunching can also be prevented through signal preemption. The agency is currently talking with the city of Chicago to arrange signal preemption for buses which are running late. A demo has been arranged for the summer at one signal, and will operate through the same signposts or loops that report location. Through preemption, buses can maintain the schedule.

The system also will include a silent alarm, but this will be separate from the regular location system. For this, the agency is planning to use the technology currently used to locate stolen cars. Each bus will be equipped with a transmitter linked to a cellular telephone., and when there is an emergency, the police can locate the bus simply by tracking the signal. This method will work, regardless of how far the bus is off-route, and will not be hampered by failures in the regular system. This is part of the overall system that will be employed during the first phase.

There is also talk of including sophisticated engine probes in the system. These probes would be akin to those used by mechanics for diagnosing engine problems. In this way, the dispatcher should be able to predict engine problems before they occur and will be able to replace the bus before it breaks down and disrupts service. This

will also benefit the overall fleet by fixing problems before they can do serious damage to the bus.

Passenger information systems at bus stops are also being considered, as are automatic passenger counters. These would be standard APCs, but the information would be transmitted in real-time to central control. The goal is to use the information to improve instructions given by the dispatcher and to qualify passenger information. The dispatcher would know the load on the bus and could tell the driver to skip stops, Further, passengers would not be told a bus was coming if that bus was already full and they would be unable to board when it arrived.

Finally, there will be a security card check-in/log-in system for drivers, When arriving at work, the driver will swipe his card through the reader at the garage, and once again when signing in on the bus. There will also be a scanner for each bus in the garage. Since there are so many buses in operation and so many drivers, it is difficult for the agency to know when a bus has been removed for maintenance or when a driver has failed to appear for work, even when that driver has called in sick. With this system, central dispatch will know immediately when there is no driver to operate a bus or no bus for him or her to drive. It will also enhance security and ensure that the bus is under normal operation.

The system is designed to be modular and its implementation in stages. First will come the silent alarm/stolen vehicle technology, as it is viewed as very important for safety and security, and it will stand on its own. Next will come the foundation elements of the main system -- the computer platform, the communications platform, and the fiber-optic backbone -- each of which is necessary to support the rest of the system. The rest of the equipment will follow. [58]

In addition to the several applications described in detail above, there are a number of other applications throughout the U.S. and Canada. These are summarized in Appendix A, which include information about size of fleet, system status, location referencing technology, manufacturer, polling interval, and an estimate of the overall cost of each system.

In addition to the North American applications listed in Appendix A. there are a number of AVL installations throughout the world. Experiments began as early as 1958 in about ten cities in South Africa, Japan, Australia. and Europe. Now there is evidence of active systems in the United Kingdom. France. Germany. Switzerland,

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[58]   Ronald J. Baker, Chicago Transit Authority, Chicago, Illinois.

Austria, The Netherlands, Spain, Belgium, and Italy. These are listed by city in Appendix B, along with manufacturer. [59] [60]

Developing Technology

In addition to the technology currently used, civilian satellite systems for object location' are about to be widely available. Since they are not yet available, they are not currently in use by any agency. Metropolitan Transit Authority of Harris County in Houston, Texas is planning to use the Global Positioning System (GPS), one of the available systems, in the AVL system they are currently planning to test. The accuracy of GPS is not proven, but should be somewhere between that of signpost/odometer systems and LORAN-C. GPS has the advantage that it can cover large areas solely with on-bus equipment and satellites already in place. However, it has difficulty locating vehicles in "urban canyons," areas where the streets are lined with tall buildings. [61]

4.2 BUS OPERATIONS IN SUBURBAN AREAS

UMTA is sponsoring a project in Portland, Oregon which will explore a variety of automated information, control, and dispatching techniques for improving suburb-to-suburb public transportation services. The technical and economic feasibility as well as the hardware and software requirements of these techniques will be assessed prior to implementation decisions.

Potential components of the Portland project include: computerized dispatching of flexible route paratransit service using regular buses, minibuses, and taxis; in-vehicle display of routing for drivers of fixed route and paratransit services: in-vehicle display of stop information for riders; in-vehicle automated announcement of next-stop information; automated vehicle location; automated notification of drivers of significant departure from the schedule; automated passenger counters; and smart farecards. Single trip carpooling and audiotext and videotext information systems to provide out-of-vehicle passenger information on transportation services also will be explored. While there

[59]   Britton, Francis E. **K., Automatic Vehicle Monitoring: Survey of World Developments and Prospects,** EcoPlan International, Paris, April 198 I.

[60]   Gilles, David, **The French Experience with Automatic Vehicle Location in Urban Transportation Systems,** Centre D'Etudes Des Transports Urbaines, Ministere de Transports et da la Mer, France, presented at the *international Conference on Automatic Vehicle Location in Urban Transit Systems,* Ottawa, Ontario, Canada, September 1988.

[61]   Bob Griffen, Metropolitan Transportation Authority of Harris County, Houston., Texas.

have been North American applications of some of these components, there has not been any site that has implemented more than one or two. A West German location has tested many of these components and will provide valuable information for the Portland project. [62]

4.3 TRANSIT OPERATIONS SOFTWARE

Transit operations software is software that performs and integrates the following functions:

   o Network and operations planning
   o Vehicle and crew scheduling
   o Marketing
   o Management and administration

Individual programs for any of these functions, such as the Run Cutting and Scheduling System (RUCUS) and HASTUS, are not discussed in this section. Only real-time integrated operations software is included.

State-of-the-Art Summary

Many computer software packages have been developed to address each individual aspect 'of transit operations and planning mentioned above. However, there are few software packages available today that integrate these functions into a comprehensive transit operations automation system that works in real-time. Currently, there are no known real-time operations software systems implemented in North America.

Applications

There are, however, several examples of real-time operations software being used in Europe. In Hamburg, Germany, an operational control system manages, monitors, and controls the U-Bahn network through the automation of train and station data that was previously collected and processed manually. [63]

This overall monitoring and control system, called Betrebsfuhrungssystem (BFS), was developed by Hamburger Hochbahn AG. It began operation on one section of the

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[62]   Robert W. Behnke, President, AEGIS Transportation Systems. Inc., Portland. Oregon and Honolulu, Hawaii.

[63]   Burmeister, Peter and Gunter Sassmannshausen, "Controlling Hamburg's Underground Network," **Railway Technology International 1989,** pp. 141-144.

U2 line in the U-Bahn network in 1989. Apart from the transmission and display of information, the BFS is gradually to take over control functions on a timetable basis. These include control of train destination indicators in stations and the setting of routes in the networks according to plan. It is also intended to have instructions transmitted to the train driver in his cab. Based on late or missed schedules registered by the BFS, these instructions are intended to help bring the train back on schedule as soon as possible, or. if it. is running on schedule, to help energy consumption to be reduced to a minimum.

The same company developed an automated real-time system to ensure proper rail and bus connections. [64] This system, called ASS, is an automatic computer-controlled system which informs the bus driver whether and/or how long he should wait for passengers from a train that is about to arrive or has just arrived at the station, using information about the location and timetable of the trains stored in the metropolitan railway operations control systems. It coordinates this information in its own computer with the programmed departure times of certain bus lines and vehicles from selected stations and indicates how long the bus should wait before leaving the bus-stop. ASS has been in prototype operation since 1986.

The ASS system ensures that during off-peak periods with very little traffic, programmed interconnections between rail and bus service are maintained as far as possible. It avoids the situation where rail passengers get off a train and see that a bus has just left.

The TRANSMATION system, developed by Philips, is a real-time transit operations system that has been implemented at several sites in Europe. "TRANSMATION is an integrated system that collects and exchanges local information, transmits relevant information to strategic points, initiates actions on the basis of the information and gathers all information at a central point of further processing or analysis. " [65]

[64] Burmeister, Peter and Gunter Sassmannshausen, "Ensuring Rail and Bus Connections." Railway **Technology International 1989,** pp. 145-147.

[65] "TRANSMATION Automation for Progressive Public Transport." Philips Telecommunicatie en Informatie-Systemen B.V., June 1988, marketing brochure.

VECOM wi or VETAG [67] systems, also developed by Philips, are important components of TRANSMATION since they provide communications and vehicle identification information, VECOM provides two-way communication between vehicles and the control center, allowing for not only information and data to be gathered from vehicles on route, but also information to be sent to the vehicles. VETAG is also a communications system, the predecessor to VECOM (they are fully compatible systems), VETAG has been installed at the following North American sites as well as at many locations in Europe:

- o Calgary, Alberta, Canada (Automatic vehicle routing and identification for the Light Rail Transit system)
- o Philadelphia, Pennsylvania (Automatic switchpoint control)
- o Santa Clara County, California (Automatic trackswitch control)

4.4 AUTOMATED DEMAND-RESPONSIVE DISPATCHING SYSTEMS

Automated demand-responsive dispatching systems include scheduling features which assign individuals to demand-responsive transit vehicles that are operating in a shared-ride mode. The scheduling systems would accommodate advanced reservation trips, standing orders, and immediate (or real-time) requests. Immediate trip orders (dispatching) would be accommodated from base to mobile with onboard digital displays or onboard hard copy printouts. Information from scheduling and dispatching functions would be integrated into the management information, billing, and accounting functions of the provider.

State-of-the-Art Summary

Even though demand-responsive (or dial-a-ride) transit accounted for less than 1% of the U.S. domestic travel in 1987 [68] it will become a more significant form of public transportation as people continue to move away from the areas currently served by traditional transit, and as more severely disabled persons seek a higher level of mobility. Advanced technology to date in the realm of demand-responsive transit has

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[66] "Philips Vecom Management and Control System for Public Transport." Philips Telecommunicatie en Informatie-Systemen B.V., marketing brochure.

[67] "A Trip Around the World with Philips VETAG," Philips Telecommunicatie en Informatie-Systemen B.V., May 1987, marketing brochure.

[68] Statistic calculated from U.S. Department of Transportation. **National Transportation Strategic Planning Study,** March 1990, pages 5-7.

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focused on the automation of scheduling and dispatching demand-responsive vehicles, and of billing and associated accounting functions.

As early as 1972, demand-responsive services were being delivered with the help of computers. [69]   In the early 1980s. many demand-responsive transit systems performed scheduling, dispatching, and/or billing with the use of specially designed computerized packages.

With the availability of low-cost, powerful microcomputers, between the mid-1980s and the present, the computerization in operating demand-responsive transit became more sophisticated.   However, there are few packages available today that completely automate demand-responsive transit operations.   Of the packages available now, most automate only one aspect of operations, such as scheduling.

Applications

A representative sample of organizations using computer packages in 1981 included:

> o Ann Arbor (Michigan) Dial-A-Ride
> o Cleveland (Ohio) Community Responsive Transit
> o Fort Collins (Colorado) CARE-A-VAN
> o Kansas City (Missouri) Share-A-Fare
> o Orange County (California) Dial-A-Lift and Dial-A-Ride
> o Sacramento (California) Social Service and Handicapped Transportation System

In 1985, a survey of demand-responsive software [70] revealed that there were ten public-domain software packages available at that time.   These packages differed greatly as to which functions they automated, and the degree to which they automated the functions.   Many **of** these packages are still available and being used today. The packages listed in the Bower survey concentrated on one of two functions: scheduling and dispatching, or service monitoring and reporting.

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[69]   Metropolitan Dade County, Office of Transportation Administration and TRANSMAX.' Inc.. **Computer Assisted Routing, Scheduling, Dispatching and Management Information System (CARSD/MIS) Project,** prepared for UMTA. July 1981. page 55.

[70]   Bower, Daniel J.. "Currently Available Software for Paratransit Applications." **Time Capsule** (Newsletter of the Transit Industry Microcomputer Exchange). Volume 4. Numbers 1 and 2, Fall/Winter 1985, pp. 12-17.

An examination of current packages used in demand-responsive transit services shows the same functional emphasis. However, there is an attempt to integrate these functions. Before describing some of the systems being used currently, it is important to note that the degree to which a particular demand-responsive agency automates its operation depends greatly on the following factors:

0 Volume of service

o Nature of provider (public agency, contractor, private provider, etc.)

o Complexity of required reporting (due to multiple-agency funding)

o Diversity of service

o Level of service desired

o Expected growth

o Staffing level and availability

o Financial support for automation

The agencies contacted as part of this study are very diverse in terms of the factors mentioned above. One of the most sophisticated scheduling and dispatch systems is being used in Metro-Dade County, Florida by Automated Dispatch Services Inc. (ADS). ADS provides scheduling and dispatching for both specialized transportation services and Medicaid transportation through their dispatch center in Miami. ADS developed the proprietary system called EMTRACK(TM), which is used in Miami. This system has the following general features [71]:

o Microcomputer based (IBM-compatible)

o Novell Local Area Network (LAN) software

o Fully automated dispatching

o Fully geo-based (using geographically referenced data)

o Open architecture programming

o Ability to interface with popular software products

o Supports all automatic vehicle locator products and mobile digital terminals.

Specific features include:

o Prescheduled patient subscription control and future reservation module

o Geo-based route planning taking into account customer pickup and delivery time windows

o Route assignment to vehicles

[71] "State-of-the-Art Fleet Management: EMTRACK(TM)." Automated Dispatch Services marketing literature.

o   On-demand sorting of pending calls in time sequence by priority, facility, common pickup, or destination

o   Printing of driver stop lists including pickup and delivery estimated times' of arrival (ETAs)

o Real-time insertion of new or canceled calls into prescheduled itineraries

0   "Tagging" capability to allow batch call assignment

o Paratransit fleet management reports to identify vehicle and driver productivity, isolate patient cancellation problems, and improve fleet utilization

o   Interfaceable to government agencies to accept batch download of contracted prescheduled calls

The system operates as follows. When a call comes in, the ADS software automatically verifies the pickup and delivery addresses through geo-coding (which takes into account factors including street type and direction). Calls are then sorted by several factors (such as whether the client is ambulatory or nonambulatory), and the client's preference as to sedan or van. Optimal routes are then calculated based on pickup times (there is a 20-minute window on pickup times) and multiloading (no clients will stay on the vehicle over a certain period of time). This process requires a geo-base, which is a topological network which includes street links, directions, and other pertinent network information (like expected congestion on certain links). The system then schedules the vehicle trips. Approximately 20% of the calls become exceptions, so human intervention is required to resolve those calls. Once those are resolved, the system's schedule is available to the dispatchers. A display shows the dispatcher the schedule 1 hour in advance.

EMTRACK(TM) Program Modules that perform the functions mentioned in the previous paragraph include:

o Order Entry Workstation:

- Address Verification: EMTRACK(TM) automatically verifies and locates each incident address before dispatching a call.

- Patient Recall: Patient-related data is easily recalled.

- Prescheduled Trips and Reservations: Prescheduled, standing orders and reservations can be entered into the computer a year or more in advance.

o Dispatch Workstation:

- Vehicle Locating and Routing: EMTRACK(TM) uses advanced dead-reckoning techniques, as well as instantaneous point-to-point routing to accurately locate the vehicle.

- Batch Routing and Scheduling

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- Vehicle Tracking: EMTRACK(TM) tracks and displays the status of all vehicles, both graphically and textually.

- Transaction Tracking: EMTRACK(TM) tracks and displays each call's progress, alerting the dispatcher when vehicles are overdue.

- Candidate Selection: When the dispatcher wishes to assign a transaction, the vehicles are displayed ranked in order of preference. Ranking is done by distance from pickup, availability, vehicle type as well as a number of factors.

- Graphic Display: EMTRACK's graphic map displays the entire service area with symbols to identify landmarks, such as state and interstate highways, facilities, and other commonly used locations. Information regarding the pickup and destination location of the current call. as well as vehicle position and projected itinerary are then overlaid on the basic map.

- Information Accessibility: At the end of the day, EMTRACK(TM) hands off vehicle, crew, time stamp and billing information to the operations and accounting systems, eliminating expensive rekeying of business operations data.

o Mobile Digital Communications: EMTRACK's Mobile Communications Module completely eliminates the need for voice communications. Information that was entered at order entry and assigned to a vehicle at dispatch can be made available to the driver of the vehicle via an on-board terminal.

o Operations Management: EMTRACK(TM) includes a report generator that allows the production of statistics about calls that have been run. Various reports can be run, including Demand Analysis, Exception Report, Dispatch Log, No Transport, Origin-Destination, and Reconciliation.

Another very sophisticated scheduling and dispatch system is the Motorola system used by Metro Taxi in Miami, Florida, Red Top Cab in Arlington, Virginia, and Super Shuttle at Los Angeles International Airport. Metro Taxi is one of the several providers of paratransit service for Metro-Dade County. In this role, they provide both regular taxi trips and paratransit (prescheduled) trips. For the regular taxi trips, they use the Motorola system.

This system consists of a terminal in every taxi which is linked to a central computer system. When a call for a trip comes in, the telephone operator types the address of the person requesting the trip into the computer. The computer determines what zone [72] the address is in and it beeps cabs that are signed in to that zone [73].

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[72] Every address in Dade County is in the computer. and each address is associated with a particular zone (determined originally by Metro Taxi). There are 100 zones defined in the Metro-Dade County area.

A driver can at that point either accept or reject the trip (through the terminal). If a driver chooses to accept the trip, he/she has 10 minutes to get to the pickup address. If the driver hasn't arrived at the pickup address in 10 minutes, the computer asks the driver if he/she still wants the trip. If so, the driver indicates that through the terminal, and the computer gives him/her another 10 minutes to arrive at the pickup address. If the driver still hasn't arrived after a total of 20 minutes, the computer sends a message to the supervisor and the driver, so that an appropriate action can be taken. Once the driver has arrived at the pickup address, he/she checks in by indicating the arrival to the central control computer (through the terminal).

This system also has several other dynamic features. Calls can be put into the computer for advance trips. For instance, if someone calls for a trip to the grocery store at 9 a.m. tomorrow morning, the operator enters that info into the computer, and tomorrow morning, the computer will beep cabs in the zone of the pickup address (just as if the call had just come in). Also, if a trip is canceled, the operator cancels that trip in the computer, and the cab that was going to pick up that trip is free to pick-up other trips in that zone. At any time, the taxi driver is free to look at all the jobs in a particular zone on his terminal.

For paratransit trips, Metro Taxi receives about 2,000 calls per day for trips. These calls, along with subscription trips, are entered into the computer, and the computer does the routing.

Metro-Dade County itself does some scheduling for paratransit trips. For instance, one of their services is for Medicaid patients to get to medical appointments. The telephone operator at Metro-Dade County takes the call for a Medicaid trip, and verifies that person's eligibility for the trip. The computer then schedules the trip, using an in-house scheduling package. The night before the trip is to take place, Metro-Dade's computer electronically transmits the schedule for the following day (including that trip) to the service provider(s). The provider(s) routes and dispatches the trip according to their in-house dispatching system. After the trip is completed, the provider(s) sends in the trip ticket to Metro-Dade County for billing purposes.

Another sophisticated automated system for scheduling and dispatching is being used at Tri-Met in Portland, Oregon. Recently, they began using a COMSIS scheduling

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1731   When a taxi driver reports to work, he/she must enter his/her taxi license number and the zone in which he/she will be operating into the terminal in the taxi. It is possible for the driver to change zones during the day.

system for their paratransit operations. Client data for this system is in the process of being updated using an automated geo-coding system. Their previous scheduling was done by hand.

Tri-Met currently uses a Novell network to operate their COMSIS software. In the future, they envision clients requesting a ride through a Personal Computer (PC) that could be tied-in remotely through this network. They are currently selecting the hardware for this remote access capability, which will be on-line with the central dispatch center through the Novell network.

When fully operational, the COMSIS system at Tri-Met will first look at client registration to determine if that client is registered for accessible transit. Then it will check the client's address in relation to accessible fixed-route bus service to determine if fixed-route service could be used for the complete trip or for a feeder to/from demand-responsive service. Also, real-time data will be available in the system through modifications to the basic COMSIS software. These data will include time of client pickup, client bill payment, the number of trips made by each client during the last few weeks, etc.

Tri-Met will be installing an Automatic Vehicle Location (AVL) system for their paratransit system that will tie into the COMSIS system, Also, in the next few years, information from the AVL system will be tied into the local Metropolitan Planning Organization's (MPO's) Geographic Information System (GIS). This GIS uses Topologically Integrated Geographic Encoding and Referencing (TIGER) files to represent the Oregon Department of Transportation's highway grid. Tri-Met's fixed-route transit service will be overlayed on the highway grid.

Another future application of automated technology at Tri-Met is the trip notification telephone system. They are currently using a ROME system, which ties into the IBM mainframe computer for voice-messaging. Eventually, Tri-Met would like the phone system to automatically call a client to tell the client that the bus will arrive to pick them up in 5 minutes.

Wheels, Inc. in Philadelphia, Pennsylvania is using a custom-designed system developed by Solutions Systems, Inc. to support almost all facets of its paratransit operations. Wheels, Inc. is the coordinator of Medicaid-funded transportation for all of the City and County of Philadelphia through its Medical Assistance Transportation

Program (MATP) [74]. In a unique collaboration with the software developer (Solution Systems, Inc.), the complex processes required to provide and administer MATP have been automated [75] These processes include:

> o Client eligibility check
> o Trip requests/scheduling and production of manifests
> o Verification of transportation charges
> o Collection/distribution of reimbursements to carriers and individuals

The Southeastern Pennsylvania Transportation Authority (SEPTA) is using a pre-scheduling system developed by ALEPH Systems.   When a trip request comes in, the system makes an immediate search for available vehicles, their capacity, and their location.   If the system can schedule a vehicle for that trip request, it produces a confirmation.   If the system cannot accommodate the trip, the operator can suggest a different time for the trip, and another check is made by the system as to vehicle availability, etc.   After the schedule is completed by the system, there is a manual review of the schedule to refine the results.   That "massaged" schedule becomes the final schedule.   This system is not dynamic in that it cannot reschedule for trips that are canceled the same day that the trip is to take place.

Many other automated tools for demand-responsive transit operations are available today.   However, they do not provide real-time scheduling or dispatching, as several of the above examples.   A list of commercial software that is currently available for paratransit operations can be found in PCs in Transportation Software Directory, put together by the PC-TRANS resource center at the University of Kansas Transportation Center. It is updated periodically.

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[74]   Axworthy, Suzanne and Neil Kleeman, "Flexibility Within Complexity: Design of Automation by Solution Systems, Inc. for Wheels, Inc. of Philadelphia."   paper based on presentation at the 12th National Conference on Specialized Transportation in Sarasota. Florida, October 28-3 1, 1990.

[75]   Solutions Systems conducts all data processing and operates the system on its mainframes.

5. HOV FACILITY OPERATIONS

High Occupancy Vehicle Facility Operations includes those technologies designed to improve the flow of high occupancy vehicles (HOVs) by giving preference to these vehicles or by constructing special guideways to control their movement.   In the first case, they give preference to HOVs, including buses, vanpools. and carpools, who share the right-of-way with conventional traffic.   In the second case. special guideways are constructed to control the HOV's lateral and/or longitudinal movements, thereby reducing headways and required lane widths because vehicle control is increased.

Several different types of HOV Facility Operations are discussed below, starting with those that give preference, and continuing on to those which provide movement control.   Each, in turn, is first defined by its general concept, and then further described through specific examples which either were carried out in the past, are current applications, or are planned for the near future. This is followed by a summary of the state of the art and current applications.

A number of strategies are discussed.   Preemption of traffic signals for HOVs at urban intersections is first.   Following that are two strategies for enforcement of occupancy restrictions in HOV lanes: a barrier that opens automatically only to rightful users of the lane, and a method of detecting violators automatically,   Automatic Toll Collection is discussed next, along with its benefits to HOVs.

The discussion then proceeds to vehicle guidance and control and the capability of these systems to provide it.   The chapter finishes with automated guidance. both lateral and longitudinal, for transit buses.

5.1. SIGNAL PREEMPTION

Traffic signals are usually timed so that each movement through the intersection is given green time proportional to the number of cars who want to make that movement.   In addition, a series of signals at intersections along an arterial often will be timed in concert so that a platoon of vehicles travelling at or near the speed limit will arrive at each intersection as the light is turning green.   These strategies allow for maximum throughput of vehicles but do not necessarily provide for the maximum throughput of people.

Vehicle occupancy varies widely between a passenger auto and a bus. and even between a single occupancy auto and a cat-pool or vanpool. Therefore, maximizing the throughput of people requires that high occupancy vehicles (HOVs) experience less

waiting time than single occupancy autos. One way to accomplish this is to give HOVs preferential treatment at traffic signals using signal preemption, a technique in which a participating vehicle is given a green signal when it might otherwise have to wait. This is already in use in many cities for emergency vehicles, such as police and fire. This section discusses signal preemption and its applications in the U.S., including old experiments and new applications.

For this system to be effective, it must be capable of identifying participating HOVs as they approach the intersection and then effecting the preemption. If all the participating vehicles have similar characteristics and are distinct from the rest of the traffic stream (such as buses in a stream of mixed traffic), the sensing equipment might consist of relatively simple technology, such as inductive loop detectors or piezoelectric axle sensors. Together, these would be able to single out the buses. If this is not the case, however, and participating vehicles blend in more readily with' general traffic, more sophisticated technology may be required, such as Automatic Vehicle Identification, including transponders attached to the participating vehicles, and readers on or near the signals.

Once the vehicle is identified, the preemption must be effected, under the specified control strategy. The control strategy defines under what conditions and for what duration to grant the preemption and can range from unconditional on both, to only for a limited extension during certain parts of the cycle. The equipment and strategy can be implemented as an extension to the standard control equipment for the signal.

State-of-the-Art Summary

Signal preemption has the capability to decrease HOV travel times and reliability in many cases, but also has some difficulties, which in part have hindered implementation. For this reason, it has not been widely implemented in the U.S., despite having gained some popularity in Europe. Though it improves the throughput of passengers through an intersection, it has been argued that signal preemption disrupts traffic flow. Many traffic professionals have found that signal coordination and progression are more effective tools on heavily traveled arterials than preemption. There is also the difficulty that it is difficult to give preference to buses (or HOVs in general) in mixed flow traffic, especially under congested conditions. The bus tends to remain stuck in traffic, unless other vehicles are allowed to clear the approach. Finally,

coordination between traffic and transit agencies is essential in most cases for this strategy, which is sometimes difficult.

previous Tests

During the 1970s there were a number of tests of signal preemption for buses on local arterials. At least four of these tests were in cities in the U.S.: Kent, Ohio, Louisville, Kentucky, Miami. Florida. and Washington. DC. [76] These are all very similar, so they are described below in brief, and emphasis is placed on the unique aspects of each.

In Kent, Ohio, a study was conducted by Kent State University for the Urban Mass Transportation Administration (UMTA), between 1969 and 1971. They installed equipment in three signals along a 4-mile section of East Main Street near the university. The sensing equipment consisted of a floor switch on the bus which, when pressed, activated an infrared beam. similar to that in a remote control or garage door opener, and alerted the signal to the presence of the bus. The signal would then implement the preemption strategy: if the signal was green, the green would be extended for 7 seconds, if red, it would turn green after the minimum green time for the other direction.

The results matched expectation: the buses experienced higher average speeds and shorter delays at intersections, and the traffic on the cross streets experienced a decrease in average speed. However, the average speed of traffic on the main street also decreased slightly, a phenomenon which was not explained. The project was eventually terminated because of a lack of communication between the two key players: the agency and the city. [77]

Louisville, Kentucky had a system manufactured by Minnesota Mining and Manufacturing (3M) Company, which was quite similar to the one in Kent, with a few differences. In Louisville, the routes on which the system was implemented were express routes, and the identifying beam was continuous and not driver activated. This took advantage of a feature of an express route: since an express bus does not stop to pick up or discharge passengers, there was no danger that the signal would effect a

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[76]   **Lovett. C. D.. Overview of Experimental Bus Priority Systems.** National Technical Information Service, Springfield, VA, March 1975.

[77]   **Joe** Fiola, Kent State University.

preemption when one was not required, and the driver needed not be burdened with an additional task.   As demonstrated in Kent, bus travel times decreased significantly.

Miami was the scene of an extensive test of signal preemption, signal progression, and an exclusive bus lane. Signal progression is defined here as coordinating the timing of successive signals so that traffic proceeding at the speed limit will reach each signal as it turns green.   The base condition was a series of uncoordinated signals. The test site was a 7-mile segment, northwest-bound, of 7th Avenue, between River Drive and Golden Gate Exchange.   Several, but not all of the signals were equipped with preemption equipment similar to that just described.   The preemption strategy was the same as in Kent and Louisville: on 7th Avenue, green signals were extended and red signals were truncated after minimum green time for the opposing flow had expired. Preemption was tested alone in mixed trafftc, then an exclusive bus lane was built, and preemption and progression were tested in turn.

The results demonstrate the relative effects of preemption, progression, and exclusive bus lanes to the travel times of cars and buses on the arterial.   preemption in mixed traffic significantly reduced travel time for both buses and cars travelling NW on 7th Avenue in the test area.   Adding an exclusive bus lane decreased the travel time further for buses, but had no significant effect on the travel time for autos. Progression with an exclusive bus lane greatly reduced auto travel times over botb the base and preemption cases, and it produced roughly the same travel time for buses as preemption. Thus, progression gave the shortest travel time for autos and tied with preemption for buses in this environment, in which there are a great number of signals in a short stretch of an urban arterial. [78]

Washington, D.C. contracted Sperry Rand Corporation and experimented with a more ambitious control strategy and used a different detection technology. In this case, antennas were mounted in the undercarriage of the buses, and inductive loop detectors buried in the pavement near the intersections.   Using near-field radio or UHF radio (they experimented with both), the bus signalled its presence through the antenna to the loop.   Then, preemption would be granted as an extended green if there would be a net decrease in overall passenger delay at the intersection.   This proved largely ineffective, so the preemption strategy was replaced with the one described above,

[78]   Wattleworth, **J. A.** et al., **I-95/NW 7th Avenue Bus/Car Pool Systems Demonstration Project:** *Report I-I: Evaluation of the NW 7th Avenue Express Bus and Bus Priority Systems. Final Report,* Transportation Research Center, University of Florida, September 1978.

except that preemption would not occur if the cross street was highly congested or if preemption was already being granted to the other direction.

In addition to the early experiments listed above, there were several European applications found. Descriptions of systems in Leicester and Derby, England and Bern, Switzerland are also contained in the report referenced above.

Current and Planned Applications

Currently, signal preemption for HOVs is relatively uncommon in the U.S. It is especially uncommon for buses and other vehicles who do not have a fixed, dedicated guideway, even one concurrent with a city street. A few cities do have preemption equipment for their light rail lines. The Southeastern Pennsylvania Transportation Authority (SEPTA) in Philadelphia, the Santa Clara County Transit District (County Transit) in San Jose, California. and the Southern California Rapid Transit District (SCRTD) in the Los Angeles area are three examples. In each case, the streetcars are given priority at each grade crossing, which is facilitated by the fixed guideway. Information about location, speed, and next stop may be transmitted easily, so it is easy to determine when the vehicle will reach the signal.

SCRTD also has equipment installed for signal preemption on two bus routes along Ventura Boulevard, the #424 (local) and #425 (limited). Ventura Boulevard is an arterial running from downtown Los Angeles. Each bus is equipped with a pulsing infrared emitter, manufactured by Minnesota Mining and Manufacturing (3M), which flashes at upcoming signals. If the emitter is within 500 feet of the signal, the signal will employ a selective preemption technique: a green signal for the approach on which the bus is travelling will be extended up to 10 seconds, and a green signal on the other approach will be terminated as much as 10 seconds early. The system was taken off-line fairly soon after implementation, due to highway construction, but will be reactivated as soon as the construction is complete. The agency found a certain amount of benefit to the system before it had to be shut down, especially for the limited bus route, but they have not yet had opportunity to test the system fully. [79]

Two other agencies, the Chicago Transit Authority and Broward County Division of Mass Transit in Fort Lauderdale, Florida are also discussing signal preemption as part of Automatic Vehicle Location (AVL) systems they are currently planning or implementing (see Section 2 .) In each case. the bus would be located and identified

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[79]   Richard Anderson, Southern California Rapid Transit District (SCRTD).

by the AVL system, which would then notify the traffic signal, Both of these implementations are still in the early planning stages. so control strategies have not been discussed in great detail, except that, in the case of Chicago, preemption would be only for those buses running behind schedule. [80] [81]

In addition to the U.S. applications, there are a number of signal preemption schemes in the rest of the world. Phillips, a Dutch company, has supplied equipment to several agencies throughout the Netherlands for use on their buses and streetcars. Alcatel, a French company, has supplied similar systems to several agencies in France.

5.2. HIGH OCCUPANCY VEHICLE LANE CONTROL

High occupancy vehicle lanes have been established for several years in many U.S. cities as a means of encouraging motorists to cat-pool or take the bus. These have been very effective for better utilization of the existing highway network. Sometimes, however, those carrying less than the specified number of passengers use the HOV lanes, and diminish their utility to rightful users. In an effort to reduce the rate of violators, the lanes often are patrolled by police, who manually count the number of people in each vehicle as it travels the HOV lane. While this is an effective method of identifying violators, it is manpower intensive and therefore expensive.

APTS has the capability to reduce the number of violators using the facilities, through two separate strategies. The first of these is to restrict access to the lanes by means of a barrier which would open to allow rightful users to pass and remain closed to the potential violators. The other strategy is to use cameras and image processing technology to count the number of passengers in each vehicle and to report violators automatically. Each one of these strategies is discussed in turn, below.

Access Control

Access to the HOV lanes may be restricted through the use of a moveable barrier, which would open only to rightful users, allowing them to pass into the HOV lane. This strategy has the benefit of acting before violations ever occur, saving on enforcement because there are no violators.

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[80]   Ronald J. Baker, Chicago Transit Authority.

[81]   Glenn Margolis, Broward County Division of Mass Transit, Ft. Lauderdale, Florida.

Access control may be achieved in much the same way as signal preemption. Registered HOVs are equipped with identifying equipment, and the barrier with a sensing and an actuating apparatus. A properly registered vehicle identifies itself automatically to the barrier, which then opens to permit passage of the vehicle.

There have been few instances of this type of access control located in the U.S. To date, there have only been low-speed applications. One is at Washington National Airport, where there is a shuttle bus serving the parking lots and the terminals. To ease the bus' progress through the parking lot. it is equipped with a transponder which identifies it as the shuttle bus to the actuating equipment. and the gate opens. [82]

Automatic Enforcement

As an alternative to access control, violators may be discouraged from using the HOV lanes through automatic enforcement. If a potential violator knows that he will be caught, or has a very good chance of being caught, he will be less likely to use the lane. Currently, it is difficult to provide this assurance. because manual enforcement requires a large amount of manpower that is often needed elsewhere. Through automatic detection of HOV lane violation, this enforcement may be enacted relatively cheaply and effectively.

The major components of the system are cameras to view the interior of each vehicle, recording equipment to provide a permanent record, and artificial intelligence based software to "count" the passengers and determine each vehicle's occupancy. This number may then be compared with the minimum number of passengers required to determine violations and to take legal action.

To date, the above system has not been implemented, nor is it planned. A more manual application was tested both in the Seattle area and in the Los Angeles area. In each case, a number of video cameras were used, and the resulting tapes were later viewed manually. This was not very effective, because it was difficult to see inside and determine its occupancy, even with four video cameras in a single location. Further, this fails to solve a major problem of manual enforcement: a large amount of

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[82]   Chuck Pillar, Washington National Airport.

manpower is still required to view the tapes manually.   Finally, this is not yet a legal method of enforcement in most jurisdictions. [83] [84] [85]

5.3. AUTOMATIC TOLL COLLECTION

Automatic Toll Collection. as the name suggests. is the collection of tolls via automatic means.   The advantages of this are several.   First, manual toll collection requires the vehicle to stop for payment and perhaps wait for a time as change is made.   Automatic Toll Collection has the potential to operate at highway speeds, thus reducing delays and increasing throughput.   The second advantage is customer convenience: the user need not pay in cash.   Third, this gives toll flexibility and allows for rates which vary by time of day and day of the week, with less danger of confusion.   Fourth, a reduced handling of cash reduces the amount of funds lost. Finally, there is labor cost savings: since tolls are collected automatically, there is less of a need for personnel.

Automatic Toll Collection requires a system that can identify participating vehicles as they approach, calculate the appropriate toll. notify the onboard system, transfer the funds. and maintain a record of monies owed or credits available.

State-of-the-Art Summary

Unlike the other types of HOV Facility Operations, Automatic Toll Collection is gaining popularity in the U.S. and new implementations are quite common. It has been recognized as an effective means of reducing manpower requirements and money handling and increasing traffic throughput.   There are several examples throughout the U.S. of these systems which have been implemented, are under review, or are being considered.

Current & Planned Applications

As just stated, there are several U.S. examples of Automatic Toll Collection. The Port Authority of New York and New Jersey (PATH) operates several toll bridges

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[83]   **Rutherford, G. Scott** et al, **HOV Compliance Monitoring and Evaluation of the Hero Hotline Program,** Transportation Northwest. Department of Civil Engineering. University of Washington, Seattle, WA, February 1990, pp. 54-65.

[84]   Mark Hallenbeck, University of Washington.

[85]   Ron Colusa. California Department of Transportation, Los Angeles office.

and tunnels across the Hudson River between northern New Jersey and New York City. There is a contra-flow lane in operation during the morning peak period at the Lincoln Tunnel for the exclusive use of buses. This lane is also equipped with an automatic vehicle identification (AVI) "tag reader," and buses participating in the program have relatively cheap transponders, or "tags," attached to their roofs. Each time the bus uses the lane. the standard toll is debited from the company's account, and each company is billed once a month. PATH maintains all the records. To participate in the program, the bus companies must maintain 2 months' worth of estimated tolls in their account. Violators are videotaped, and the tapes are later viewed to determine whether it is an actual violation or it is a reader error.

PATH has a similar program at the Goethals Bridge, currently under a 6-month test, using 850 vehicles of varying types: cars, buses, and trucks. If the results are favorable, the program will be opened to more vehicles. [86] Linked to this, there is a similar test in progress by the Tri-borough Bridge Authority of New' York at the Verrazano Narrows Bridge, which connects Staten Island with Brooklyn, within New York City. Tri-borough is using the same equipment that PATH is using at the Goethals Bridge and plans to register over 1,000 vehicles for their test. The agencies are maintaining separate accounts. [87]

In addition to the New York City area projects, there are several others. These include plans for systems on the New Jersey Turnpike and the Dulles Toll Road in Northern Virginia. A Request for Proposals is expected from the New Jersey Turnpike Authority in May 199 1. [88] The Virginia DOT plans to implement a system on the Dulles Toll Road in the metropolitan Washington, DC area. They hope to increase the throughput of the toll booth from 700 or 800 vehicles per hour to about 2,000 vehicles per hour, the capacity of a lane on a limited access highway. [89]

Automatic Toll Collection is also being considered in connection with some new toll highways planned as part of the Toll Facilities Pilot Program, authorized by

[86]   Bob Eliot. Charley Fausti. Mark Schaff. Port Authority of New York and New Jersey.

[87]   Ron Colusa, Tri-borough Bridge Authority of New York.

[88]   **The Urban Transportation Monitor,** March 15. 1991. p. 5.

[89]   Ed DeLozire, Dulles Toll Road.

Congress.   The projects in California. Georgia, Pennsylvania. and Texas specifically mention collection by automatic means as a possibility. [90]

There are a few full implementations in the U.S. These include the Crescent City Connection Bridge in New Orleans. for which over 14.000 transponders have been issued to users. and the Dallas North Tollway. for which over 28,000 transponders have been issued. [91]

A different approach was recently demonstrated on the Massachusetts Turnpike by AT/Comm incorporated.   The main feature of the system is that the accounts are maintained by the user in the removable In Vehicle Component (IVC) modules which fit into the vehicle's permanently installed hardware.   The IVCs contain encrypted information about the vehicle type for determining the correct toll and records of the account. including the balance.   The balance is automatically debited by the collection system, and can be increased with payments to an agent who fits the IVC into a machine authorized to increase the amount.   This arrangement has the benefit of assuring the user privacy concerning his or her travel habits. [92]

5.4 AUTOMATICALLY GUIDED TRANSIT BUSES

Automatic guidance for transit buses has been investigated as a means of increasing the speed, volume, and boarding capability of transit buses in urban settings. The use of a guidance system with buses exploits some of the advantages of rail transit, without a number of its limitations.   Bus guidance enables high-speed, high-volume, level-boarding operation typically associated with rail systems and permits operation in a narrower right-of-way than is needed for manually steered buses. [93]

Automatic guidance for transit buses consists of two basic technologies: mechanical and electronic.   Mechanical guidance systems use guide rollers attached to either the front axle or all axles [94] of the bus to control the lateral movement between two rigid

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[90]   **The Urban Transportation Monitor,** February 15, 1991, p, 9.

[91]   Chris Hill, "Electronic Tolls and Traffic Management." **The Urban Transportation Monitor,** October 12, 1990. p. 2.

[92]   AT/Comm Incorporated System Description Flyer.

[93]   Ruprecht. Gary F. and Larry S. Englisher, Multisystems. **Bus Guidance** Technology: A *Review* of *Current Development,* prepared for UMTA. December 1983. UMTA Report No. UMTA-IT-06-0247-84-1, p. 2.

[94]   Few details are available on the first all-axle guidance system that began revenue service in June 1988 in Rochefort. Belgium.

guiderails. Electronic guidance systems use a transmitting antenna in the surface of the roadway to guide buses equipped with a receiving antenna and an electronic control system along the desired path. The control system measures the vehicle's deviation from the path of the cable(s) in the roadway and corrects the bus by means of a servo motor or hydraulic actuator linked to the steering system.

State-of-the-Art Summary

There are no automatically guided transit bus services operated in North America. There is research, however, at the University of California investigating the applicability of automatic guidance for High Occupancy Vehicles in the HOV lane. This research is in the early stages, and it, along with some foreign systems, is discussed below,

Applications

As part of its Program of Advanced Technology for the Highway (PATH), a program sponsored by the California DOT (Caltrans), UMTA, FHWA, and several private companies. researchers at the University of California are investigating the applicability of Automatic Guidance for vehicles traveling a limited-access highway. To start with a smaller and more controlled environment, they are first investigating guidance, both lateral and longitudinal, with HOVs operating in the HOV lane. They are still in the very early stages of this aspect of the research and expect preliminary findings later this year. [95]

In the mid-1970s, Daimler-Benz and M.A.N. jointly developed a front-axle mechanical guidance system. A demonstration of this technology in Essen, (West) Germany, which started in the summer of 1980, was successful in proving that this technology is safe, reliable, and feasible for implementation. Daimler-Benz named this mechanical guidance system the "O-Bahn" concept, in which a transit operator can begin with a conventional bus system operating on public roads and construct guideways when operating conditions require and as budgets permit. Because the buses can continue to operate on the street, the operation of the transit system is not interrupted during construction and operations can benefit from the completion of even small segments.

Currently, there is a fully operational 0-Bahn system in Adelaide. Australia. Opened in 1986, it is the only revenue service application of this technology outside of Germany. This system is 12 kilometers in length. and is served by 92 Mercedes Benz

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[95]   Ted Chavala, Institute of Transportation Studies, University of California, Berkeley.

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buses (5 1 of those are articulated).   One unique aspect of this system is that part of the guideway was constructed in a riverbed with little disruption of the environment.

The first mechanically guided double-decker buses are operating in a demonstration in Birmingham, England.   This experiment is being conducted on a 600-meter segment of guideway which includes bus floor-level platforms that allow access by disabled persons.   The hardware manufacturer for this demonstration is Metro-Cammell.

In terms of electronically guided buses, the world's first was tested in Furth, Germany.   The demonstration was started in May 1984 on a test track located in downtown Furth.   The system reduces road space requirements for the guided bus by as much as 20% and does not require the concrete guideway used in mechanical guided bus systems. [96]

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[96]   "Electronic Guided Bus Now Operates in Germany," **Urban Transport Abroad,** Fall 1984.

APPENDIX A
NORTH AMERICAN AVL SYSTEMS/a

Abb.	City	Vehicles/b	Cost/c	Status
AATA	Ann Arbor, MI	60/67	0.3	In Final Testing
MTA	Baltimore	900/900	11.0	Phase II of IV
FtL	Ft. Lauderdale	192/192	2.3	Awaiting Delivery
MTD	Halifax, N. S.	170/170	1.0	In Regular Use
HSR	Hamilton, Ont.	275/275	6.0	In Regular Use
Hou	Houston	1000/1000		Designing/Building System
CTCRO	Hull, Que.	162/162		Testing
KCATA	Kansas City, MO	275/275	2.1	In Regular Use
Miami	Miami	520/520		Preparing Specifications
Mil	Milwaukee	??/550		Preparing Specifications
TTDC	Norfolk, VA	1601160	2.0	In Regular Use
PBF	Palm Beach, FL	74/74	1.2	Awaiting Delivery
VIA	San Antonio, TX	537/537	3.7	In Regular Use
SAMTR	San Mateo, CA	320/320		Installing Equipment
METRO	Seattle	1291/1291	17.0	Testing
HART	Tampa	1831183	1.6	Awaiting Delivery
TTC	Toronto	1000/2300	38.0	Phased Implementation

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[a]   Based on information supplied by the agencies.

[b]   Vehicles are in the format: # equipped/# owned by the agency.

[c]   Cost is in millions of dollars. *All costs are approximate..* are the total spent. and are the amounts spent when the system was purchased. not current dollars. Costs for US agencies are in US dollars, and for Canadian agencies, Canadian dollars.

NORTH AMERICAN AVL SYSTEMS (cont'd)

Abb.	Manufacturer/d	Location Referencing	Polling Interval/e
AATA	GRS	Dead Reckoning	13-14 seconds
MTA	Motorolla	LORAN-C	20 seconds
FtL	Motorolla	Signposts + Odometer	
MTD	(agency)	Signposts + Odometer	30-40 seconds
HSR	RMS Indus. Controls	Dead Reckoning	60 seconds
Hou	(agency)	GPS	
CTCRO	(various)	Signposts + Odometer	
KCATA	F & M Global	Signposts + Odometer	3-4 seconds
Miami		LORAN-C or Signposts	
Mil		LORAN-C or GPS	
TTDC	F & M Global	Signposts + Odometer	40 seconds
PBF	Mo torolla	Signposts + Odometer/f	60 seconds
VIA	General Railway Signal	Signposts + Odometer	60 seconds
SAMTR	Telleryde-Sage	Signposts + Odometer	
METRO	Harris Corporation	Signposts + Odometer	3 minutes
HART	Mo torolla	Signposts + Odometer	
TTC	'Bell Radio	Signposts + Odometer	6 seconds

[d]   "Manufacturer" refers to the principal contractor.

[e]   "Polling Interval" refers to the time between successive polls of the same bus.

[f]   LORAN-C will be used for dial-a-ride and emergency operations

APPENDIX B
AVL SYSTEMS OUTSIDE NORTH AMERICA/g,h

Country	City	Supplier
United Kingdom	Nottingham	Phillips
Sweden	Stockholm	Datasaab/Sorno
Switzerland	Zurich Berne Basle Geneva	Hani-Prolectron Hani-Prolectron Hani-Prolectron Hani-Prolectron
Austria	Salzburg Graz	Hani-Prolectron Hani-Prolectron
Germany	Hamburg Darmstadt Regensburg Dusseldorf Munich Wiesbaden	Prodata Hani-Prolectron Siemans Hani-Prolectron Hani-Prolectron Siemans
Italy	Rome	Italtel
The Netherlands	The Hague	HTM
Belgium	Bruselles	Hani-Prolectron
Spain	Barcelona Madrid	Alcatel/Dimetronics Alcatel

[g]   Sources: Britton, Francis E. **K., Automatic Vehicle Monitoring: Survey of World Developments and Prospects,** EcoPlan International, Paris. April, 1981: and

[h]   Gilles, David. **The French Experience with Auotmatic Vehicle Location in Urban Transportation Systems,** Centre D'Etudes Des Transports Urbaines. Ministere de Transports et de la Mer, France, presented at the *International Conference on Automatic Vehicle Location in Urban Transit Systems,* Ottawa, Ontario, Canada, September, 1988.

Country	City	Supplier
France	Aixen Provence	Thompson
	Angers	Alcatel
	Angouleme	Alcatel
	Annecy	Alcatel
	Besancon	Thompson
	Bres t	Socrie
	Caen	Thompson
	Claremont-Ferrand	Matra
	Evrevx	Alcatel
	Grenoble	Alcatel
	Le Mans	Socrie
	Lyon	Alcatel
	Marseille	Alcatel
	Montbeliard	Socrie
	Montpellier	Alcatel .
	Nancy	Alcatel
	Nantes	Alcatel
	Orleans	Alcatel
	Reims	Alca tel
	Sobrieve	Thompson
	Strasbourg	Alcatel
	Toulon	Alcatel
	Tours	Thompson .
	Valienciennes	Sema-Metta

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Champaign-Urbana Mass Transit District
Champaign/Urbana, IL

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Jacksonville Transportation Authority
Jacksonville, FL

Carmen Lewis (616) 385-8201
Kalamazoo-Metro Transit System
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Vertis Park (301) 333-3674
Rohit Pate1 (301) 333-3438
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Baltimore, MD

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Ann Arbor, MI

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Atlanta, GA

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