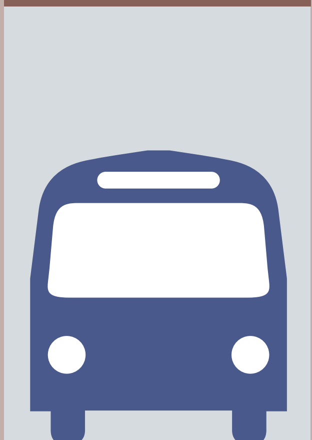
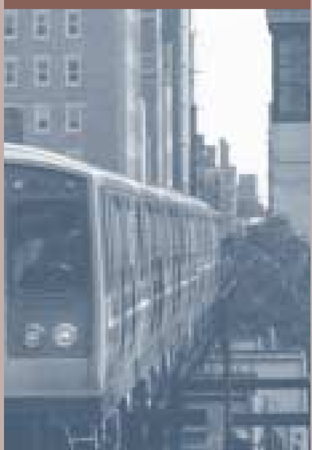
chapter 5





WHAT HAVE WE LEARNED ABOUT ADVANCED PUBLIC TRANSPORTATION SYSTEMS?

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EXECUTIVE SUMMARY

This paper discusses advanced public transportation systems (APTS) technologies, assesses the extent of their deployment, and judges their degree of success. While it covers APTS technologies in use by bus and demand-response service operations, rail and ferryboat services are beyond its scope.

The primary source of deployment-level information is a 1998 survey by the John A. Volpe National Transportation Systems Center (Volpe Center) that encompassed 525 transit agencies operating fixed-route bus and/or demand-response services (Casey 1999). This data source differs from that used in other chapters of this report (78 metropolitan areas as opposed to transit agencies) and, consequently, deployment levels for a technology here could differ from those determined in other chapters for the same technology. Using the selected deployment level standards outlined in Chapter 1,[1] APTS technologies have reached the deployment levels shown in Table 5-1.

Table 5-1. APTS Summary Table

Technology	Deployment Level	Limiting Factors	Comments
Automatic vehicle location	Moderate Deployment	Cost, fleet size, service type, staff technological competence	**Successful**—use continues to grow, new systems principally use GPS technology but usually augmented by dead reckoning
Operations software	Widespread Deployment	N/A	**Successful**
Fully-automated dispatching for demand response	Research & Development*	Still in research and development stage	**Jury is still out**
Mobile data terminals	Moderate Deployment*	Most frequently deployed with automatic vehicle location systems	**Successful**—reduces radio frequency requirements
Silent alarm/covert microphone	Moderate Deployment*	Most frequently deployed with automatic vehicle location systems	**Successful**—improves security of transit operations
Surveillance cameras	Limited Deployment*	Cost	**Holds promise**—enhances on-board security. Deters vandalism
Automated passenger counters	Limited Deployment	Cost	**Holds promise**—provides better data for operations, scheduling, planning, and recruiting at lower cost

[1]The three different deployment levels used in this paper are defined as follows: Deployed in fewer than 10 percent of the 525 transit agencies surveyed = Limited Deployment; Deployed in between 10 percent and 30 percent of the 525 transit agencies surveyed = Moderate Deployment; Deployed in more than 30 percent of the 525 transit agencies surveyed = Widespread Deployment.

Table 5-1. Continued

Technology	Deployment Level	Limiting Factors	Comments
Pre-trip passenger information	Widespread Deployment	N/A	**Successful**—improves customer satisfaction
En-route and in-vehicle passenger information	Limited Deployment	Cost, lack of evidence of ridership increases	**Jury is still out**
Vehicle diagnostics	Limited Deployment	Cost, lack of data on benefits	**Jury is still out**
Traffic signal priority	Limited Deployment	Institutional issues, concerns about impacts on traffic flows	**Holds promise**—reduces transit trip times. May reduce required fleet size
Electronic fare payment	Limited Deployment	Cost	**Holds promise**—increases customer convenience

**Quantitative deployment tracking data not available. Deployment level determined by expert judgment.*

All the above technologies have been proven to work and are in full operation at varying numbers of transit agencies. Agencies have reported benefits resulting from implementation of each of these technologies. Although some benefits have been quantified, most of those reported herein are claims or statements from deploying agencies. In spite of the lack of quantified benefits, transit agencies that have deployed or will soon deploy APTS technologies have concluded that potential benefits of the added functions and services that these technologies provide outweigh the capital and operating expenses. Several transit agencies have stated that a principal reason for installing APTS technologies is to help them provide better service for customers and safer service for both customers and vehicle operators.

Despite measured benefits and other benefits realized but not measured, many agencies are not considering APTS technologies. Possible reasons include cost (although some less sophisticated, low-cost APTS systems are available),[2] a lack of awareness of benefits, small fleet size, type of service provided, resistance to change, and absence of personnel knowledgeable about APTS. Nevertheless, a comparison of results from the most recent Volpe Center survey and a previous survey (Casey and Labell 1996) revealed that APTS technology deployments increased substantially between 1995 and 1998. Deployments are expected to continue to increase faster for those making up the more basic elements of APTS deployments (e.g., automatic vehicle location [AVL], operations software, mobile data terminals, silent alarms, and covert microphones). Also, greater use of AVL data is expected in the areas of real-time service adjustments, scheduling changes, route planning, and customer information.

[2] Some less sophisticated, low-cost APTS systems are available for purchase, as evidenced by the figures in the lower end of cost ranges contained in the technology discussions. However, these systems will not provide the functionality many transit agencies desire.

INTRODUCTION

The Federal Transit Administration created the Advanced Public Transportation Systems program as its part of the U.S. Department of Transportation's (U.S. DOT's) National Intelligent Transportation Systems (ITS) Program. The APTS program was established to encourage use of current and emerging technologies in the fields of electronics, information processing, information displays, computers, and control systems to improve the quality and usefulness of public transportation services. Effectively integrated and deployed, APTS technologies can enhance safety, transportation mobility, operational efficiency, and environmental protection.

The objective of this paper is to assess which APTS technologies have been successful, which ones have not been successful (and why), where success is unclear, and what can be expected in the future. The following APTS technologies are discussed:

- Automatic vehicle location.
- Operations software.
- Mobile data terminals.
- Silent alarms/covert microphones/surveillance cameras.
- Automatic passenger counters.
- Automated passenger information.
- Vehicle diagnostics.
- Traffic signal priority.
- Electronic fare payment.

Although not a "technology" itself, integration is also discussed, as it is a major factor in the successful implementation of APTS and is usually the most difficult implementation issue.

The technologies discussed herein have all been installed by at least some transit agencies and are in full operation at those sites. Deployment information, except for data on Internet websites, was collected during the fall of 1998 and was published by the John A. Volpe National Transportation Systems Center. In the Volpe Center survey, 525 transit agencies operating fixed-route bus and/or demand-response services were interviewed to determine their level of APTS technology deployment. This database differs from that used in Chapters 2, 3, 4, and 6, which used data from the 78 largest metropolitan areas rather than from individual transit agencies. Consequently, the deployment levels identified here may be different from the deployment levels for the same technology reported in other chapters.

The benefits discussed in this paper are primarily findings from other APTS research and evaluation activities, and consist mainly of claims or statements from deploying agencies. Useful input was also received from attendees at the transit management roundtable session at the Institute of Transportation Engineers (ITE) 2000 International Conference, held in Irvine, California, in April 2000.

Capital cost information, obtained in the Volpe Center study, was not included in the published report. (Collection of cost data was not a major objective for the survey, but agencies did provide some acquisition cost information.) Other cost data for certain APTS hardware and software components can be found in the ITS Joint Program Office (JPO) database compiled by Mitretek Systems from a number of studies and plans.[3] Additionally, the requirement in the Transportation Equity Act for the 21st Century (TEA-21) that all recipients of ITS deployment program funds report cost information should provide much more cost data in the future.

Agencies surveyed in the Volpe Center deployment study were unable to provide any real useful information on the cost of operating APTS technologies. Although operating cost is an important consideration, most agencies deploying transit APTS did not have reduced operating costs as an objective. In fact, many agencies will experience an increase in operating costs stemming from additional dispatching and information technology staffing requirements and equipment maintenance expenditures. Potential operational cost savings will result from deployment of some APTS technologies, however, which can reduce other operational expenses, as illustrated in the discussions of individual technologies. As several transit agencies have stated, a principal reason for installing APTS technologies is to help them provide better service for customers and safer service for customers and vehicle operators. The ability to automate the provision of transit information to potential customers has also been a consideration for some agencies.

APTS TECHNOLOGIES

The following sub-sections describe the various APTS technologies, their benefits, their level of deployment, and their costs (where available).

Automatic Vehicle Location

AVL is a computer-based tracking system. For transit, the actual real-time position of each transit vehicle is calculated and relayed to a control center. The three principal methods of determining vehicle position are as follows: using signals from signposts, dead-reckoning, and using signals from global positioning system (GPS) satellites.

In the signpost system, a series of radio beacons or signposts are placed along the routes. A short-range communication device on the vehicle receives the identification signal transmitted by the signpost. Because location of each signpost is known, vehicle location is determined at the time of passing. The distance traveled since passing a signpost, as measured by the vehicle odometer, is used to estimate the vehicle position along its route at any given time. However, this method is limited because signposts are placed at fixed locations. Thus, changes in routes could require the installation of additional signposts. Additionally, the system is incapable of tracking vehicles that stray off route.

Dead-reckoning is a method of determining vehicle position by measuring distance traveled from a known location (through odometer readings) and direction of travel (through compass headings). Because this method of position determination is less

[3] These data can be accessed through the ITS Benefits and Costs Database at http://www.mitretek.org/its/benecost.nsf.

precise than the others, dead-reckoning is usually supplemented by GPS or a few strategically placed signposts to recalculate position at certain intervals.

GPS technology uses signals transmitted from a network of satellites orbiting the earth and received by a GPS antenna placed on the roof of each vehicle. A GPS receiver, connected to the antenna, calculates position by measuring the antenna's distance (the travel time of radio signals) from at least three satellites. However, there are inaccuracies in the signal due to reflections by the atmosphere or from tall buildings. To correct for these errors, a measured GPS signal offset is used to adjust the calculated position. As a result of this differential correction, many GPS receivers can calculate position to within a few meters. GPS is the method of choice for most new AVL systems.

The two most common methods of transmitting location data to dispatch are through polling and exception reporting by means of wireless communications. Under polling, the computer at dispatch polls each vehicle in turn, asking for its location. Once all the vehicles have been polled, the computer starts again with the first vehicle and repeats the cycle. With exception reporting, each vehicle reports its location to dispatch only at specified intervals or when it is running off schedule beyond selected tolerances. Exception reporting makes more efficient use of available radio channels, which are often scarce commodities. Many agencies use a combination of polling and exception reporting.

AVL is the basic building block for other transit APTS applications that depend on knowing vehicle location. AVL provides the location data needed for operations software, silent alarms, automatic passenger counters, real-time passenger information, in-vehicle signs and annunciators, and traffic signal priority, based on schedule adherence. AVL provides transit agencies with much more and better data than they could previously afford to collect manually. Vehicle location data are used by many transit agency personnel, including dispatchers, vehicle operators, schedulers, planners, maintenance staff, customer information staff, and street supervisors. A major benefit of AVL is the dispatcher's ability to quickly send response personnel to the precise location of an incident or emergency. AVL-equipped buses can also act as probes for monitoring traffic flow on freeways and arterials. Another major benefit reported by transit agencies was improved schedule adherence:

- Milwaukee County Transit System, Milwaukee, Wisconsin, reported an increase of 4.4 percent, from 90 to 94 percent.
- Kansas City Area Transit Authority, Kansas City, Missouri, reported a 12.5 percent increase, from 80 to 90 percent.
- Regional Transportation District, Denver, Colorado, reported an increase of between 12 and 21 percent on various routes.

Despite the benefits AVL systems can provide, they had achieved only moderate deployment status in 1998, with just 61 agencies (12 percent) having fully operational systems.

Although the cost of an AVL antenna and receiver is relatively modest, agencies reporting AVL costs in the Volpe Center study typically included all APTS technologies implemented in conjunction with AVL: software, dispatch center equipment, mobile data terminals, silent alarms, covert microphones, new or upgraded communications, and possibly automatic passenger counters. Reported costs for AVL systems ranged from $1,200 to $23,000 per vehicle, with a median cost of about $8,000. Three groupings of costs were evident. One group of six systems fell between $1,220 and $2,500 per vehicle. Another grouping of seven systems fell within the $6,500-$9,600 cost range. Six systems in the third group ranged in cost from $11,000 to $18,000. Finally, there was a single outlier cost of $23,000 per vehicle. Some systems include AVL for both fixed route and demand-response services. The wide range of costs can be attributed to the differences in the number and functionality of the APTS applications specified, the variation in the number of vehicles to be equipped, and the amount of customized software required. Agency staff costs for system development and training are typically not included in cost calculations.

Operations Software

Operations software is used to develop and display information for a variety of transit decision-making activities. Software is a key element of APTS installations, and a geographic information system (GIS) is a major software component.[4] AVL system software can combine vehicle location data with map data and display them on dispatchers' computer monitors, together with attributes easily customized by each transit agency (e.g., vehicle status, vehicle operator, schedule adherence, and incident information).

Software programs can assist transit agencies in performing a number of functions. Software programs currently support bus dispatchers in making real-time service adjustments (when service begins to deteriorate[5]) and in directing response to vehicle incidents and emergencies. Software programs prioritize calls from vehicle operators for response by the dispatchers and automatically record and print reports of AVL and various other information desired by the agency. Software can provide data to coordinate the intra- or intermodal transfer of passengers from one vehicle to another where services intersect—either through dispatcher involvement or direct vehicle-to-vehicle contact. Software programs can calculate whether traffic signal priority should be requested based on schedule adherence and, in more advanced concepts, on the bus load factor (if real-time information is available from an automatic passenger counter). Programs can assemble and analyze data from different sources to provide assistance to the following:

- To schedulers in adjusting schedules.
- To planners in adding or reducing service.
- To maintenance staff in programming preventive maintenance or identifying vehicles with potential maintenance problems.

[4] GIS is a special type of computerized database management system in which databases are related to one another based on a common set of locational coordinates.

[5] A research initiative undertaken by the John A. Volpe Center and the Massachusetts Institute of Technology will develop software to automate the service adjustment process when the system recognizes that service is deteriorating.

- To customer information staff for answering information requests or providing trip itineraries.
- To street supervisors for monitoring service.
- To administrative staff for generating reports.
- To operations staff to play back vehicle runs for checking operator performance or customer complaints.

Software is also used in the scheduling, dispatching, recordkeeping, and billing for demand-response services. The Winston-Salem Transit Authority, Winston-Salem, North Carolina, reduced operating cost by 8.5 percent per vehicle mile with computer assisted dispatching (CAD) software. Blacksburg Transit's CAD software helped the agency increase passenger-carrying productivity from 0.8 to 2.0 passengers per vehicle hour. Higher-end systems able to receive trip requests by touch-tone phone, schedule trips, and transmit vehicle schedules to operators without manual intervention offer even greater potential for enhanced efficiency.

A total of 170 transit agencies, or 32 percent, have used software to assist certain tasks, helping operations software attain widespread deployment. However, despite potential benefits, few agencies with AVL systems exploit the software's full capabilities. As yet, most agencies are not using software to analyze schedules, plan service changes, coordinate transfers, or provide real-time information to customers. Much greater use could be made of some software applications that offer significant benefits.

The cost of operations software is seldom separated from the overall cost of an AVL system. However, the contract price for the 1,335-vehicle AVL system for the Regional Transportation District in Denver, Colorado, listed operations software at approximately $1.4 million (Weatherford and Castle Rock Consultants 2000). More software cost data are available for demand-response services. The cost of demand-response software reported by close to 50 agencies in the Volpe Center study generally ranged from $15,000 to $120,000, with exceptions being three agencies placing it at less than $10,000 and seven agencies at $300,000 or more. The median value was $50,000. As with AVL cost figures, demand-response software cost rises as the level of sophistication and the number of functions desired increases.

Mobile Data Terminals

A mobile data terminal (MDT) is an in-vehicle device with a small screen to display messages and time, plus a series of buttons to send preset messages to the dispatch center. Where installed, MDTs are the primary communications means between operators and dispatchers. In AVL-equipped vehicles, the MDT-type device is usually augmented by computational capability that calculates vehicle location, compares location and time to the schedule, and determines the vehicle's schedule adherence, which can be displayed on the screen. This combination is commonly called an in-vehicle logic unit. For purposes of this discussion, the term "mobile data terminal" represents both devices.

The ability to send preset messages with the push of a button makes it easy for operators to report certain occurrences to the dispatch center. Examples include mechanical problems, vehicle stuck, fare dispute, lift not working, relief not arrived, etc. The "request to talk" and the "priority request to talk" buttons are the means by which the operators notify the dispatchers that they wish to talk via radio. Dispatchers contact operators either by radio or through messages sent to their MDTs. Voice or MDT messages can be directed to an individual bus, specific groups of buses, or the entire fleet.

Use of MDTs has reduced voice radio traffic by as much as 70 percent for the Ann Arbor Transportation Authority, Michigan, and the Rochester-Genesee Regional Transportation Authority, New York. This voice traffic reduction may reduce the number of voice channels an agency requires. A reduction in voice traffic can be an important result, where available radio frequencies are scarce and highly sought-after by other agencies—the case in many locations.

MDTs are also used to coordinate vehicle-to-vehicle transfers of passengers on intersecting routes. MDTs allow vehicle operators to coordinate the transfers directly, without dispatcher involvement. Connection coordination can be an important customer satisfaction consideration, as missed connections—especially on long headway routes—can discourage future patronage by affected riders.

MDTs are also useful in providing routing instructions and messages to demand-response vehicles. MDTs can provide an electronic manifest of customer pick-ups and drop-offs. Use of MDTs can also facilitate additions or deletions to the vehicle's otherwise predetermined route. MDTs are particularly useful for those agencies dispatching in real time.

The number of transit agencies employing MDTs is unknown, as the Volpe Center study did not track this technology. Virtually every AVL system would be expected to include MDTs; in fact, there would likely be more MDT systems than AVL systems, because MDTs are deployed in demand-response systems that do not have AVL. Therefore, MDTs are presumed to have achieved the moderate deployment level.

Although not specifically covered in the Volpe Center study, one agency quoted a price for MDTs as part of its software procurement. Pierce Transit, Tacoma, Washington, paid $330,000 for MDTs for their 92 demand-response vehicles, or slightly under $3,600 per unit, including software.

Silent Alarm/Covert Microphone/Surveillance Cameras

Silent alarms, covert microphones, and surveillance cameras installed in vehicles enhance the safety and feeling of security of operators and passengers. The silent alarm system consists of a button placed in a concealed location near the driver. When pushed, it activates an alarm in the dispatch office. With most AVL systems, the vehicle from which the alarm was sounded is more frequently tracked than with the normal polling interval, and the dispatcher has the ability to open a secret microphone on the vehicle to try and ascertain the problem. What the dispatcher hears through the microphone is useful in helping to decide the type of assistance to send to the vehicle. The AVL system provides vehicle location so response personnel can proceed to its exact position.

Surveillance cameras have also been placed on some vehicles. These cameras can capture a picture of individuals who cause incidents and may discourage criminal activity. The pictures have also been used to check the validity of personal injury claims made by persons alleging to have been injured on the vehicles. The images may be stored on the vehicle for later download, or relayed to dispatch in near real time.

Measurements of safety or security improvements from AVL system implementations have been scarce. However, Denver's Regional Transportation District reported a 33 percent drop in operator and passenger assaults after AVL, silent alarm, and covert microphone system installation.

The Volpe Center study did not track deployment of silent alarms, covert microphones, and surveillance cameras. Nevertheless, it is presumed that two of the three devices have achieved moderate deployment, as virtually every AVL system includes a silent alarm and most have a covert microphone. Silent alarm systems could even outnumber AVL systems, as they can be installed without an AVL system. In such instances, if the operator is unable to tell the dispatcher his or her position, the dispatcher must use judgment to ascertain the vehicle's location. To date, only a few surveillance camera systems have been installed, cost probably being the limiting factor.

The Volpe Center study did not solicit any cost figures for these technologies.

Automatic Passenger Counters

Automatic passenger counters (APCs) are devices that automatically collect data on passenger boardings and alightings. APCs have three basic components: (1) a method of counting each passenger boarding and disembarking, and a method of distinguishing between the two; (2) a technology able to determine vehicle location when boarding and disembarking occur; and (3) a data management system capable of transmitting the data in real time or storing the data for later transfer and use. Counters are usually treadle mats placed on the steps or infrared beams projected horizontally or vertically at each doorway.

APCs provide much more ridership data than agencies previously collected at a lower cost. Further, a few agencies have stated that APC data are more accurate than those collected manually. Ridership data may be used in several ways, including for National Transit Database reporting, route analysis and planning, adjustments to schedules, and new passenger shelter positioning. These data could also be used to monitor load factors in real time for possible insertion of additional vehicles when circumstances warrant. The Metropolitan Atlanta Rapid Transit Authority, Georgia, reported $1.5 million in operational savings through adjustments to schedules using AVL and APC data.

APCs are not included with all AVL systems. Twenty-four agencies (5 percent) with existing APC systems were recorded in the Volpe Center study. The most likely reason for limited deployment of APCs in the past has been cost. Some older APC installations cost between $5,500 and $6,250 per vehicle (Alameda Contra Costa Transit District, Oakland, California; Central Ohio Transit Authority, Columbus, Ohio; and Bi-State Development Agency, St. Louis, Missouri). As the cost per unit appears to be decreasing, based on recent cost figures ($2,500 at San Joaquin Regional Transit District, Stockton, California; $1,600 at Ventura Intercity Service Transit, Ventura, California; $1,200 at Tri-County Metropolitan Transportation District, Portland, Oregon), APCs should become more prevalent. The decrease in cost for these agencies likely stems from the inclusion of APCs as part of a package of APTS technologies rather than stand-alone systems. It is also possible that the sale of more units and advances in component technology have helped to decrease unit cost.

Automated Passenger Information

There are several types of passenger information and methods of delivery. Information can be provided to customers and potential customers before they begin their trip, while they are en route but not on board a transit vehicle, or after they are on board a transit vehicle. Overall, automated information is widely deployed. However, when separated by the individual types of information, only pre-trip information systems have been widely deployed, while en route and in-vehicle information systems achieved only limited deployment. Probable reasons for lack of greater deployment of en route and in-vehicle information systems are that they are nonessential, extra-cost items, with no solid evidence of their increasing transit ridership.

Pre-trip information can consist of routes, maps, schedules, fares, fare media, and park-and-ride lot locations. Information can include real-time vehicle arrivals and full trip planning itineraries. Devices used to obtain pre-trip information include the telephone, the Internet, pagers, personal digital assistants, and cable television (TV). Depending on their location, kiosks could also provide pre-trip information.

Automated pre-trip information is consistent and more accurate than that relayed by information operators. Accurate information, especially real-time information, reduces the anxiety of transit use and is particularly important for longer headway routes. Real-time vehicle arrival information allows passengers to time their arrival at stops, thereby reducing their wait time and exposure to weather and criminal elements. Not all agencies that could give real-time information to passengers are planning to provide it, for fear the information will not be accurate and passengers will miss their buses.

Automating the information provision process, particularly with voice response units, has reduced the telephone wait time of customers wanting information (from 85 seconds to 27 seconds at New Jersey Transit) and increased the call handling capability and productivity of transit information centers (a 21 percent increase in San Diego County). Fewer customer information staff may be needed, as the Rochester-Genesee Regional Transportation Authority has reported.

Telephone and the Internet are the most generally available and frequently used methods of obtaining pre-trip information for most people. A separate study by the Volpe Center of transit agency websites,[6] which most transit agencies have, reviewed the websites of 613 transit agencies operating bus or demand-response services.

[6] Results of the Volpe Center Internet website search can be found at http://transitweb.volpe.dot.gov.

Ninety-four percent, or 578, provided pre-trip passenger information (i.e., at least route maps or schedule/fare information). Twenty-five, or 4 percent, of sites allow customers to obtain origin-to-destination trip itineraries, although not always on-line.

Access by hand-held devices and TV are used to a much lesser degree, as there is low market penetration of hand-held devices, and the number of locations displaying transit information on TV is quite small.

Eight agencies with strictly automated telephone information provided cost data in the Volpe Center deployment survey. Six quoted acquisition and installation costs between $32,000 and $126,000, the mid-range being between $75,000 and $100,000. The two other agencies quoted costs of $400,000 and $1 million. Three agencies provided cost data for both telephone and Internet information. These cost figures were $23,000, $28,000 and $132,000. The cost to set up an Internet website was quoted as $1,000 and $4,000 by two agencies. No cost data were provided for other pre-trip delivery methods.

En route information such as vehicle arrival times (scheduled or predicted) can be provided by electronic signs, monitors, and kiosks. Signs and monitors are usually placed in passenger shelters or at transfer centers. Kiosks are usually placed at major activity centers served by transit.

The principal benefit of en route devices is the elimination of vehicle arrival uncertainty, which makes the passenger more comfortable using transit and may increase ridership. One liability has been travelers' perception of kiosks as frustratingly slow or frequently out of service.

The Volpe Center study found 21 agencies, or 4 percent, providing en route transit information. Even where en route devices were deployed, typically only a small number were actually installed in any service area because of their cost to purchase, maintain, and operate.

The only en route cost data provided were for kiosks. Three agencies quoted costs of $5,000, $6,250, and $15,000 per kiosk.

In-vehicle information is provided by electronic signs and automated voice announcements (annunciators) of stops and transfer opportunities. Electronic signs are usually placed at one or two high-visibility locations inside the vehicle.

Signs and annunciators relieve the operator of having to announce stops, as required by the Americans with Disabilities Act. These devices provide passengers with better information, as not all operators announce stops, and even those who do may be difficult to hear. Additionally, signs help hearing-impaired passengers and allow operators to drive more safely by concentrating on driving without having to make announcements.

The Volpe Center study found that 14 agencies, or 3 percent, provide in-vehicle transit information. This limited deployment probably stems from signs and annunciators being extra-cost, nonessential items.

No cost data were provided to the Volpe Center on in-vehicle signs and annunciators.

Vehicle Diagnostics

Vehicle diagnostics provide information to the dispatch center and the maintenance department of the transit agency about the condition of certain vehicle components. This information is acquired through sensors connected to the components to be monitored. Items frequently monitored include engine temperature, oil pressure, brakes, and tire pressure. Diagnostic information can be relayed to the dispatch center and/or the maintenance department in real time, which allows a vehicle to be taken out of service immediately if the problem is severe, or stored on the vehicle for later retrieval.

Diagnostic information warns of impending component failures when readings begin to exceed normal operating ranges. Attention to problems identified before failures occur should improve service reliability by reducing the number of vehicle breakdowns and resulting service delays. Early detection can also prevent potentially serious situations or costly repairs or replacements.

Deployment of diagnostic systems is limited (12 agencies, or 2 percent). One possible reason is the lack of quantitative data on savings from advanced failure warning or reductions in on-road breakdowns.

The Volpe Center study did not solicit cost data for vehicle diagnostic systems.

Traffic Signal Priority

Traffic signal priority allows transit vehicles to progress along their routes with less delay at signalized intersections equipped with specialized receivers and controllers. A transit vehicle approaching a signalized intersection transmits a signal to the traffic signal controller. Depending on the traffic signal phase at the time the signal from the vehicle is received, the controller grants an extension of the green phase until the vehicle passes, or until advancement of the next green phase. The signal from the vehicle to the traffic signal controller can be sent manually or automatically if the vehicle is AVL-equipped. Similarly, transit vehicle priority can be employed at signals that meter the flow of traffic at freeway ramp entrances. Another method of transit priority is to provide an exclusive transit lane at the intersection and give that lane an advance green phase so that transit vehicles can start ahead of traffic. No information was uncovered on signal preemption for transit, which would immediately turn the traffic signal to green upon a transit vehicle's approach.

Signal priority produces faster, more reliable transit service and reduced operational cost. Six agencies (Kitsap Transit, Bremerton, Washington; Pierce Transit, Tacoma, Washington; Annapolis Transit, Anne Arundel County, Maryland; Phoenix Transit, Arizona; Metropolitan Atlanta Rapid Transit Authority, Georgia; and Los Angeles County Metropolitan Transportation Authority, California) have reported reduced travel times ranging from 4.2 percent to 19 percent from operation or tests of signal priority. (Other agencies benefiting from signal priority have not reported travel time changes.) If enough running time is saved, reduction in the number of vehicles needed to operate service may even be possible. However, resistance is often encountered from traffic departments of the cities and counties that control local streets, as granting priority for transit may degrade traffic flow. Granting transit vehicles priority would have a greater impact on streets with progressive signal timing. Requesting priority only when transit vehicles are behind schedule by a certain degree or when carrying a sufficient number of riders can mitigate negative impacts. Another mitigating technique, as implemented by Montgomery County, Maryland, is to optimize travel for all individuals—private vehicle occupants and transit riders.

Sixteen transit agencies, or 3 percent, reported having priority for their vehicles at traffic signals. Several test installations, which showed significant benefits for transit operations, were never made permanent after the test period.

The cost of providing transit agencies with priority at traffic signals is normally a shared cost between the agency operating the traffic signal system and the transit agency. Two agencies reported on-board equipment costs: Pace Suburban Bus, Arlington, Illinois ($200-$250 per bus), and Ben Franklin Transit, Richland, Washington ($1,000 per bus). The Chicago Transit Authority cited an installation cost of $125,000 for five signalized intersections.

Electronic Fare Payment

Electronic fare payment (EFP) systems for transit are of two types—those that use magnetic stripe cards and those that use smart cards. Fareboxes that count and display the value of coins or tokens deposited are not considered APTS technology. Magnetic stripe cards require a contact between the card's stripe and a device that validates the card for the trip taken (i.e., a monthly pass) or a read-write device that can deduct the fare from the value stored on the card and restore the remaining balance. A smart card that contains a microprocessor may interface with the reader by direct contact or by radio frequency. A smart card can have both contact and contactless interfaces. Smart cards have greater security, higher reliability, and higher resistance to fraud than magnetic stripe cards, but are more costly. A major convenience of a contactless card is that it need not be removed from a wallet or purse as long as it passes close to the reader.

Both types of cards offer additional convenience for the rider, as there is no need for exact change or frequent standing in line to purchase tokens or tickets. Transit agencies can benefit from the reduction in the labor-intensive manual handling of cash, tickets, or tokens and the reduced chance of fraud or theft, which has saved millions of dollars for New York City Transit, for example. However, payment by cash on transit systems can probably never be totally eliminated.

Increased revenues result from reduced fare evasion, interest on the money between the time a card is purchased and the time it is used up, and, possibly, from increased ridership. Smart card systems provide added benefits of security for lost or stolen cards (if they are registered with the agency), discounts for frequent transit use, greater flexibility in fare products, and reduced paper transfers and equipment maintenance (owing to fewer fare collection equipment moving parts). Smart cards permit collection of more detailed ridership data for use in route planning and travel time studies. They also allow development of seamless regional, multi-agency, multi-application systems, including parking and retail. Contactless cards also result in faster throughput.

Excluding monthly magnetic stripe, pass-only systems, the Volpe Center study found 23 operational magnetic stripe (4 percent) and seven operational smart card (1 percent) fare collection systems. A probable reason for the limited EFP deployment is that replacing an existing fare collection system can be expensive. Capital costs for seven of the agencies providing EFP cost data ranged from $8,500 to $10,200 per vehicle. The other five agencies paid between $2,500 and $6,000 per vehicle. The median cost was slightly over $8,500 per vehicle. Some systems incorporate both magnetic stripe and smart cards.

Integration

The difficulty of getting systems to work together continues to be a major obstacle to successful APTS installation. The more APTS elements an agency implements, the more difficult the integration task becomes. The integration problem has been the cause of many delays, while recent transit APTS systems have been implemented more rapidly. Both the equipment and software have become more "off the shelf." Nevertheless, these improvements do not guarantee that implementations will proceed smoothly, on budget, or on schedule.

A principal integration problem involves software. For early systems, the software had to be newly developed—an arduous task. As experience is gained with more systems, the basic software has become more standardized and transferable. Nevertheless, because transit agencies do not all want the same features or capabilities, a certain degree of customization is necessary at each location. The less customization specified by a transit agency, the easier and quicker the installation will be. Also, developing input data for the software can be a considerable undertaking.

Although integration of APTS with other ITS services and modes has been limited to date, some notable examples of multimodal integration do exist. Houston TranStar's transportation management center (TMC) is staffed by City of Houston, Harris County, Houston Metro, and state personnel who cooperate on all aspects of transportation management. The New York City Metropolitan Transit Authority is implementing an AVL, which will provide real-time vehicle location and arrival information to TRANSCOM℠ (Transportation Operations Coordinating Committee), where it will be widely available through the iTravel information network. The Metropolitan Atlanta Rapid Transit Authority receives live pictures of traffic conditions from the TMC's video cameras over a fiber optic cable and can choose which cameras to view, as well as point the cameras in the desired direction. In other locations, integration mainly takes the form of highway and transit agencies sharing traffic and incident information via telephone.

CONCLUSIONS

Using deployment criteria described in the Introduction, data from the Volpe Center reports place APTS technologies at the following levels, as depicted in Table 5-2:

Table 5.2. Deployment Levels for APTS Technologies

APTS Technologies	Deployment Level		
	Widespread	Moderate	Limited
Automatic Passenger Counters			✣
Automatic Vehicle Location		✣	
Electronic Fare Payment			✣
En Route Passenger Information			✣
In-Vehicle Passenger Information			✣
Mobile Data Terminals*		✣	
Operations Software	✣		
Pre-Trip Passenger Information	✣		
Silent Alarms/Covert Microphones*		✣	
Surveillance Cameras*			✣
Traffic Signal Priority			✣
Vehicle Diagnostics			✣

* Quantitative deployment tracking data not available. Deployment level determined by expert judgment.

Only operations software and pre-trip automated passenger information have reached the widespread deployment level. Given the number of agencies in the process of implementing or programming AVL systems (100 additional agencies), this technology will reach widespread deployment in a few years. Because mobile data terminals, silent alarms, and covert microphones are typically deployed with AVL systems, these technologies are also expected to reach widespread deployment status. Automated passenger counters (40 additional agencies), traffic signal priority for transit (40 additional agencies), and electronic fare payment (68 additional agencies) should attain moderate deployment status. Increases in deployment of vehicle diagnostic systems (31 additional agencies), surveillance camera, and en route and in-vehicle passenger information systems will likely not be sufficient to move these technologies out of the limited deployment category.

All APTS technologies appear to work and to provide benefits to the implementing agencies, as well as directly or indirectly to their customers. Agencies implementing APTS have expressly determined that the benefits outweigh the costs. A comparison of data from the two Volpe Center deployment studies shows that individual APTS technology deployments increased by a minimum of 44 percent and a maximum of 160 percent over the three-year interval.

While this paper did not cover rail or ferryboat operations, technologies such as AVL operations software, surveillance cameras, automated passenger information, vehicle diagnostics, traffic signal priority, and electronic fare payment would apply equally as well to heavy and/or light rail systems, and, in some instances, to ferryboats.

From the customer perspective, APTS deployments can lead to measurable improvements in transit service and ease of use. However, whether these improvements appreciably change public perception and resistance to using transit is yet to be seen. There are many reasons why people do not ride transit, such as incompatible land-use patterns, free or inexpensive parking, lack of comfort and privacy, affordability of driving, and unsuitability for trip-chaining and carrying packages, which cannot be overcome by APTS applications.

From the transit agency perspective, APTS technologies offer a wide array of benefits. Some of the benefits have been measured, while many more have been realized but not measured. Nevertheless, many agencies still are not considering APTS technologies. For some agencies, certain APTS technologies may not be appropriate because of the small size of their operations or the type of services they provide. Other agencies may not be considering APTS technologies because of cost, lack of awareness of benefits, resistance to change, or absence of personnel knowledgeable about APTS. Also, APTS technologies have the reputation of being difficult to implement, although recent installations have been quicker and less troublesome. For the most part, technologies are proprietary from vendor to vendor and can be difficult to operate and maintain for transit agency personnel with little advanced technology experience. Many agencies are still uncertain as to how APTS can be used to fundamentally change transit operations and services for the better.

To overcome these deployment obstacles, agencies need to be more informed about the relative benefits and costs of APTS technologies, which requires that continued evaluations be conducted to quantify and publicize these benefits and costs. It is imperative that transit agencies be made aware of what works and how to implement these technologies. As such, education and training of transit agency personnel on APTS technologies is critically important. The APTS Mobile Showcase, a 48-foot expandable trailer that traverses the country functioning as a research laboratory, standards testing facility, and briefing room on wheels, is a step in this direction.

THE FUTURE

It is anticipated that:

- APTS deployments will continue to increase and AVL, silent alarm, covert microphone, and automated passenger information technologies will likely reach widespread deployment levels.

- Implementation periods will be shorter as more experience is gained and the software becomes more standardized.
- More APTS technologies will be included in installations as more benefit and cost data from applications of these technologies are documented and publicized.
- Removal of selective availability (a degradation of signals from the orbiting global positioning satellites), announced in May 2000, has increased the accuracy of vehicle location GPS to the extent that the need for differential correction of the GPS location calculations may no longer be necessary.
- New software will be developed that will result in AVL data being used to a much greater extent in making on-street service corrections (in some cases automating this process), adjusting schedules, planning route changes, and providing customer information.
- Transit operations will increasingly be integrated with TMCs for sharing information on traffic conditions and incidents and, to a lesser extent, for providing traffic signal priority for transit vehicles.
- The cost of APTS implementations will continue to be a major impediment, although not the only impediment, to greater deployment.

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