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## **Transit ITS Proof-of-Concept Tests**

TTI/ITS RCE-01/03

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16. Abstract <p>This report documents a series of proof-of-concept tests conducted to explore the potential of ITS technologies to enhance public transportation services. The projects were undertaken through the cooperative efforts of researchers at the Texas Transportation Institute and staff at the Metropolitan Transit Authority of Harris County (METRO), Brazos Transit, and the Texas A&amp;M University Department of Parking, Traffic, and Transportation Services. The four projects developed and tested were 1) an automatic vehicle location (AVL) system with a rural transit operator, 2) an automatic passenger paging system with the Texas A&amp;M University paratransit service, 3) a next bus information system at the Heights Transit Center in Houston, and 4) a bus notification system at the Eastwood Transit Center on the Gulf Freeway high-occupancy vehicle (HOV) lane in Houston. The results of these proof-of-concept tests show that ITS technologies can be successfully applied in a range of transit applications, benefitting both riders and operators. The projects also identify the technical, institutional, and operational issues that may be encountered with transit ITS applications. The results from the four proof-of-concept tests should be of interest and benefit to transit operators, state and federal agencies, industry groups, researchers, and other individuals interested in advancing the deployment of ITS technologies with public transportation services.</p>					
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## SUMMARY

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Public transportation systems in Texas and throughout the country continue to explore ways to improve the efficient and cost-effective delivery of a wide range of services. Intelligent transportation systems (ITS) and other advanced technologies are being applied by some transit agencies to enhance service operations, to improve customer information, and to better manage the system. The widespread deployment of these technologies with a wide range of transit operators has not yet occurred, however.

The Texas A&M ITS Research Center of Excellence (RCE) sponsored four proof-of-concept tests to help advance the use of ITS with public transit services. These tests focused on applying advanced technologies to address identified transit issues and problems. Researchers monitored and evaluated the test to document the performance of the technologies, to identify potential benefits, and to explore more extensive deployment.

The four tests were conducted through the cooperative efforts of researchers at TTI and staff at Houston METRO, Brazos Transit, and the Texas A&M Department of Parking, Traffic, and Transportation. Private technology vendors also assisted with some projects. The four projects developed and tested were 1) an automatic vehicle location (AVL) system with Brazos Transit, 2) an automatic passenger paging system with the Texas A&M University paratransit system, 3) a next bus information system at the Heights Transit Center in Houston, and 4) a bus notification system at the Easterwood Transit Center on the Gulf Freeway HOV lane in Houston.

An AVL system using a combination of Global Positioning System (GPS) and radio technologies was developed and tested on Brazos Transit buses. Researchers tracked the two equipped buses on rural routes over a four week period. After problems encountered installing the equipment on the buses were addressed, the system operated well during the test. Vehicles were tracked up to 45 miles from the radio antenna site and the accuracy of the system was good.

The same AVL system was used in the second test involving the Texas A&M University paratransit system. This project developed and demonstrated an automatic passenger notification system. Using a combination of commercially available technologies and specially designed software, researchers linked the AVL system and personal pagers to notify paratransit passengers of approaching vehicles. The system was pre-tested for three days and operated over 22 days with eight paratransit passengers. The automated system worked well during the pre-test. Unfortunately, the AVL equipped vehicle was not available for most of the actual test, resulting in preset five minute pages to riders. The test was successful in developing and demonstrating the advanced passenger notification system. In addition, participating passengers responded favorably to preset five minute pages used in the actual test.

Researchers tested the application of a bus notification system using a radio frequency (RF) transmitter, a backlit sign, and a push-button electronic assembly at the Eastwood Transit Center along the Gulf Freeway HOV lane. The system was designed to allow a passenger to push a button

at the Transit Center, which lit a sign over the HOV lane to notify an approaching bus operator that they should enter the Transit Center to pick up the waiting rider. Some technical problems were encountered with the radio signal strength and the sign illumination. Researchers tested the system on 11 trips – four inbound to downtown Houston and seven outbound – over four days. The system worked well and the visibility of the sign provided adequate notification to bus operators once they were alerted to its location. The location and visibility of the sign would need to be improved for more widespread use, however.

The final test involved equipping 16 METRO buses operating on the 24 Montrose Crosstown route with a GPS-based AVL system. The location of the buses was tracked and the real-time information was provided to passengers at the Heights Transit Center. Both the anticipated time of arrival and the anticipated time to arrive were provided on a display unit at the Transit Center. The system functioned well during a one week test and reactions from passengers was very positive.

The results of the four proof-of-concept tests indicate that ITS and other technologies are appropriate in a range of transit applications. The projects also show that these technologies provide benefits to both passengers and transit operators. Additional researchers and testing is needed to further advance transit ITS applications.

## **CHAPTER ONE—INTRODUCTION**

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### **BACKGROUND**

A wide range of intelligent transportation systems (ITS) and advanced technologies are being tested, developed, and deployed to help improve the effectiveness and efficiency of the surface transportation system. Many of these technologies are being applied to enhance the management and operation of the freeway and roadway system. Researchers are also testing and developing advanced technologies with public transportation services. Four projects were undertaken at the Texas A&M ITS Research Center of Excellence exploring the application of advanced technologies to enhance the operation of different types of transit services and to improve customer information. These proof-of-concept tests were conducted through the coordinated efforts of TTI researchers, transit operators, and technology companies.

### **RESEARCH OBJECTIVES**

The four proof-of-concept tests were undertaken to help advance the application of ITS with public transportation services. The projects applied advanced technologies to help address important issues facing transit operators and riders. In each case, researchers matched appropriate ITS technologies to specific problems.

The overall objective of the proof-of-concept tests was to determine the feasibility of advanced technologies to address the identified transit issues. The secondary objectives were to monitor and evaluate the performance of the technologies, to identify potential benefits, and to explore possible system-wide deployment. The specific objectives established for each test are outlined in subsequent chapters.

### **ORGANIZATION OF THIS REPORT**

The remainder of this report is organized into five chapters. The rural transit automatic vehicle location (AVL) system test is presented in Chapter Two. Chapter Three describes the paratransit passenger paging test. The Gulf Freeway high-occupancy vehicle (HOV) lane bus notification test is presented in Chapter Four. The next bus information project at the Heights Transit Center is discussed in Chapter Five. The same format is followed in these chapters. The background and objectives of the test are described first, followed by a summary of the development, implementation, and assessment of the project. Chapter Six summarizes some of the common issues encountered with the projects, identifies possible next steps for deployment of the tested technologies, and describes opportunities for further research.





## **CHAPTER TWO—RURAL TRANSIT AUTOMATIC VEHICLE LOCATION SYSTEM TEST**

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### **BACKGROUND**

Rural transit services are an integral part of the public transportation system in the United States. These services provide a basic level of mobility to residents in rural areas, and are often the only means available for individuals to travel to and from medical appointments, work, school, and other activities. The importance of these services is evident in Texas, which has the largest rural service area of any state in the country.

The 42 rural systems in Texas provide basic mobility for residents in 80 percent of the counties in the state. These services operate in all types of environments. Rural transit operators frequently use gravel or poorly paved roads and serve isolated areas of the state. Ensuring the safe, and at the same time efficient, operation of these services is an ongoing challenge. The use of automatic vehicle location technologies, which monitor the location and the movement of vehicles, offers the potential to enhance operator and passenger safety, to improve the efficiency of these services, and to enhance the responsiveness to riders.

Several factors limit the application of AVL systems with rural transit services. First, the relatively high cost of AVL technologies has been a barrier, since many rural services operate on very limited budgets. Second, most AVL systems require an accurate digital map or geographic information system (GIS), which are limited or not available in some rural areas. Third, most rural transit services operate on a demand-responsive — rather than a fixed-route — basis, cover long distances, and serve large geographical areas, which prohibit ground-based AVL applications. Finally, the implementation and operation of AVL systems require technical expertise that may not always be available at rural transit systems.

The application of AVL systems with rural transit services may become more prevalent in the future, however, as technology costs decrease, GIS maps become more available, and ease of use increases. To help advance the use of AVL systems with rural transit services, researchers conducted a proof-of-concept test in cooperation with Brazos Transit and private sector technology companies.

### **OBJECTIVES OF THE TEST**

The rural transit AVL system proof-of-concept test was conducted to accomplish three objectives. The first objective was to develop a relatively low cost AVL system using available technologies that would be appropriate for use with rural transit services in Texas. The second objective was to test the AVL system with one rural transit operator in the state. The final objective was to monitor and evaluate the various test components including the AVL technology, the problems encountered during the project, and the use of the information available from the AVL system. These objectives were accomplished through the development, implementation, operation,

and evaluation of the proof-of-concept test. Researchers worked with staff from Brazos Transit, other departments at Texas A&M University, and technology suppliers in conducting the test.

## **DEVELOPMENT OF THE TEST**

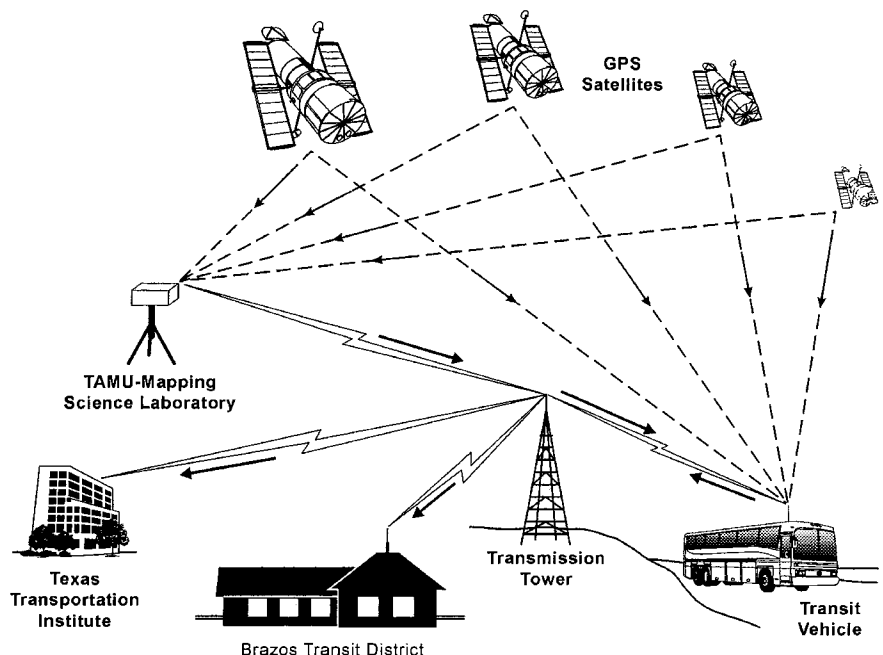
Development of the rural transit AVL system proof-of-concept test involved a number of activities. As outlined in this section, these steps included identifying potential AVL technologies, selecting the most appropriate system, and integrating the selected system components. Potential rural transit operators were also considered. Researchers contacted Brazos Transit, which has its main office in the Bryan/College Station area, and which agreed to participate in the test.

The rural transit AVL test was able to build on an existing project underway at the Texas Agricultural Extension Service Mapping Science Laboratory (MSL) at Texas A&M University. The MSL had developed a relatively simple and inexpensive system for use in a range management project. Referred to as *Cows in Space*, this project used Global Position System (GPS) technology to track the movement of cattle. The system allows ranch managers to view the daily herd activities and to adjust range management accordingly.

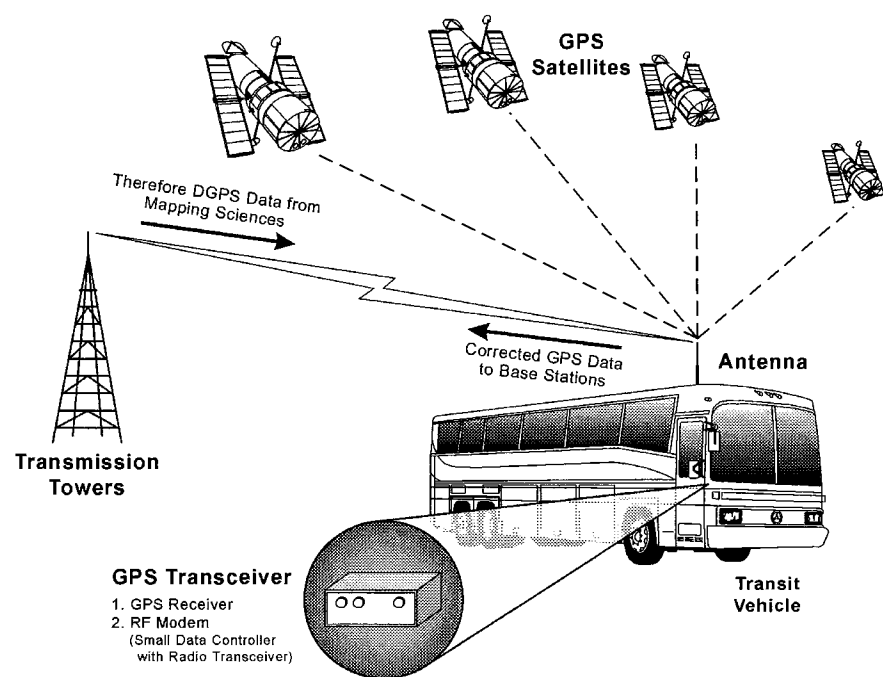
The rural transit AVL system was designed using similar technologies. GPS, combined with an ultra high frequency (UHF) radio communication system, formed the backbone of the approach. The basic elements of the system are highlighted below and illustrated in Figures 1 and 2.

**Global Positioning System.** Researchers selected GPS because it is a universal, relatively low-cost technology. The GPS receivers placed on a vehicle receive location information from the Department of Defense NAVSTAR satellites. The position of these orbiting satellites is continuously transmitted to the receivers. Each receiver listens to several satellites, and the latitude and longitude of the vehicle is determined relative to the position of the satellites. GPS receivers manufactured by Trimble were used in the test. These receivers can operate on any of several strings or methods of assembling GPS information. The National Maritime Electronics Association (NMEA) GPS string was used in the test. It is an open and well-documented standard that provides latitude, longitude, time, and other information about the computed location. GPS receivers were placed on two Brazos Transit buses for the test.

**Differential Global Position System (DGPS).** The project also used information obtained from a differential GPS correction station. DGPS is an earth-based signal sent from a known fixed point. The DGPS information provides a range of correction to each satellite a signal is received from. The GPS receiver on a vehicle processes this information to determine a corrected position. DGPS is used to overcome possible errors in the GPS signal, which may be caused by the intentional downgrading of civilian applications by the military based on national security concerns. Using DGPS greatly enhances the accuracy of GPS vehicle tracking capabilities.



**Figure 1. Rural Transit AVL System Concept**



**Figure 2. Rural Transit AVL System Components**

**Radio Modem.** The test used UHF radio transmission for data communication. The corrected location information from the GPS receiver was sent to a radio modem. The radio modem in turn sent the information on to the digital repeater, which is an information relay station. The GPS transceiver (GPST) used in the project was composed of two boxes: a GPS receiver box and a radio frequency (RF) modem box. The RF modem box included a digital radio transceiver (DRT) and a modem. The interface to the radio modem was a terminal node controller, which assembled the information into packets. These packets are a short fixed length unit of data that can be easily transmitted to another location.

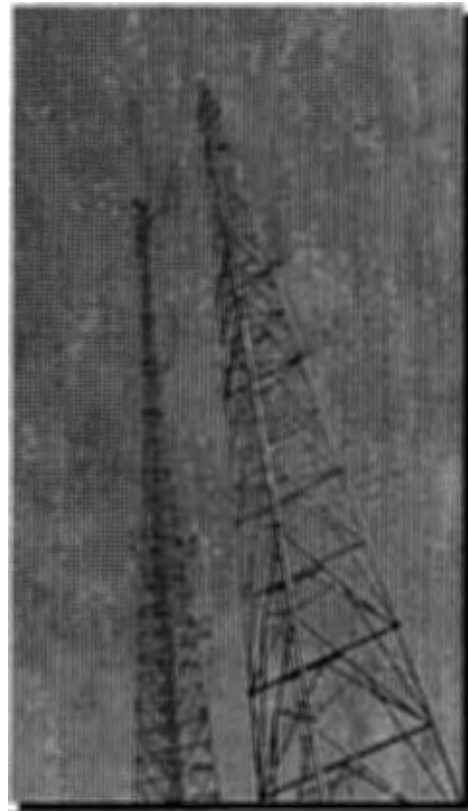
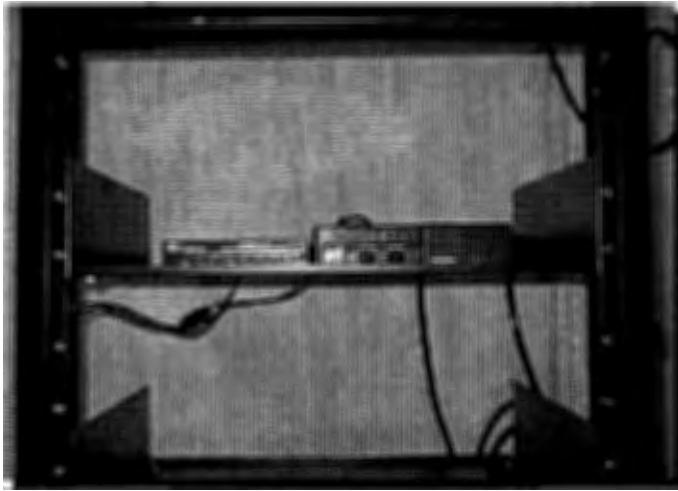
**Digital Repeater.** The digital repeater or information relay station is usually located on an antenna in a convenient location. The higher the antenna, the further the range of the system. Information received from the GPS transceivers is sent to the dispatch monitoring station. The repeater also relays DGPS information and receives signals from the base station which are then sent to the vehicles. The digipeater used in this test was located at a height of approximately 230 feet. Figure 3 illustrates the digipeater located on the City of College Station Radio Tower and the station in the MSL. Figure 4 shows the GPS transceiver and the hand-held palmtop computer located on the buses.

**Monitoring Station.** The monitoring station is another terminal node controller. The monitoring station takes the packet data and decodes it back into GPS information. This GPS data is sent to the software components of the system. In this test a GIS software system was used to display the location of the transit buses. More than one monitoring station may be used, allowing individuals at different locations to access the information. For this test, monitoring stations were located at the MSL and at TTI.

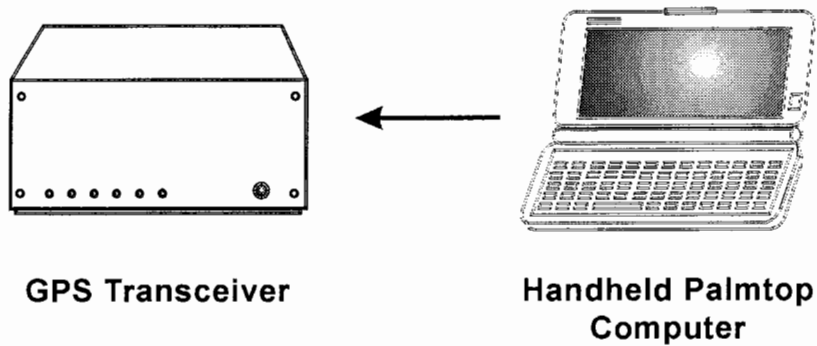
The following sequence of events highlights the operation of the rural transit AVL system:

- The GPS receiver on a vehicle accepts signals from a minimum of four satellites to determine the vehicle's position.
- This information is stored and waits to be processed with differential correction data.
- The differential information is then calculated by the MSL.
- The differential information is sent by a DGPS beacon transmitter to a digipeater on a transmission tower.
- The digipeater then transmits this data forward to a second tower or to all transit vehicles within its range.
- The transit vehicles receive the data through the DRT, and the data is translated by the modem and passed along to the GPS receiver.

- The stored GPS information is then corrected with the differential data, determining the vehicle's location.
- The corrected location data is passed to the modem, translated to a digital data package, and transmitted back to a digipeater located on a transmission tower.
- The digipeater then verifies the data transmission, and either transmits the data to the base station or relays the data to the next transmission tower until it reaches the base station.



**Figure 3. Rural Transit AVL System Communication Technology**



**Figure 4. Rural Transit AVL System On-Board Components**

The processing sequence described above takes place within a matter of seconds, providing real-time information on the location of the vehicle. A software application, produced by Honkus and Associates Inc., integrates digital maps, mapping software, relational database capability, and GPS receiver technologies into one package. Researchers used this software to translate GPS data into a mapping display for both viewing and tracking multiple vehicles. The vehicle tracking can be displayed on a variety of geographically referenced base map sets or incorporated into a GIS desktop mapping package, such as MapInfo or ArcView.

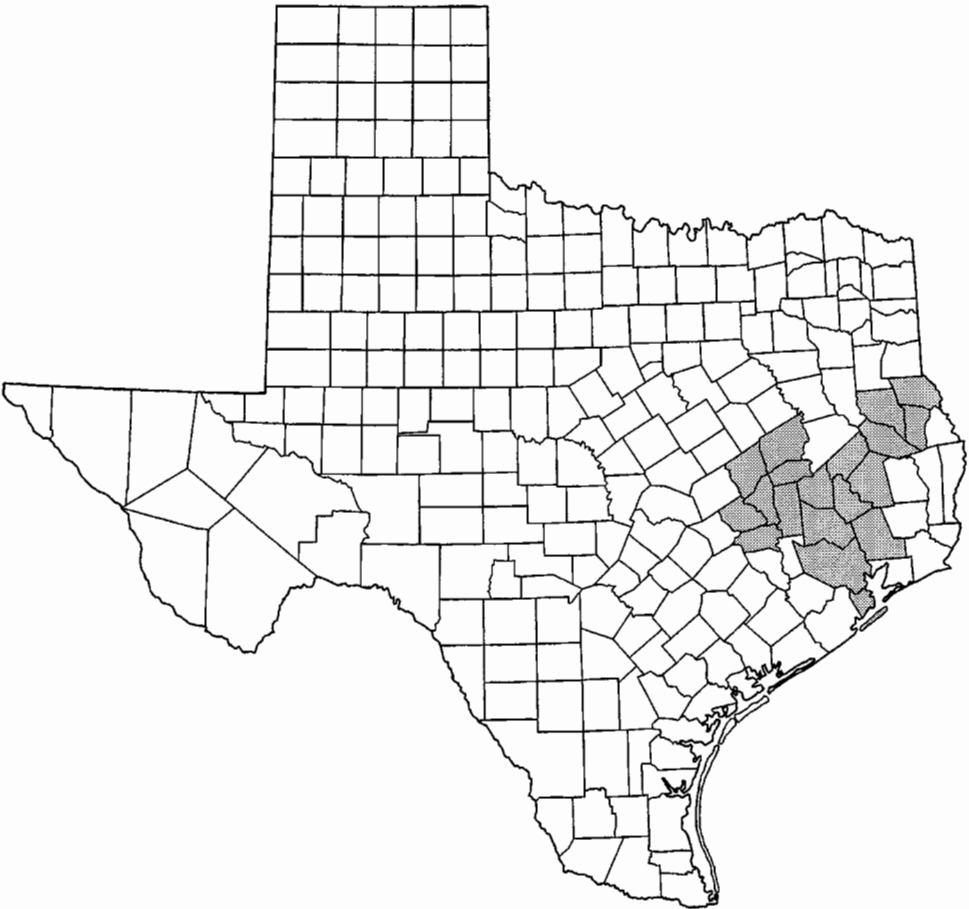
Brazos Transit, which operates service in 14 counties in Central and East Texas, was selected to participate in the test. Brazos Transit’s headquarters are in the Bryan/College Station area, making it easy for researchers to work with operations personnel on the test. Figure 5 highlights the Brazos Transit service area. The test focused on routes in the three counties shown in Figure 6. Brazos Transit was also selected because they have experience with other advanced technologies. For example, Brazos Transit uses an 800 number in combination with the caller-identification feature for service requests. This approach allows the dispatchers to easily match calls with the appropriate services and makes requesting trips more convenient for passengers. Brazos Transit has also equipped its fleet with cellular telephones to provide a communication link between vehicle operators and dispatchers. The cellular telephones allow operators to call for help in the case of an emergency and to ask for directions, and provides dispatchers with the ability to communicate with operators.

**OPERATION OF THE TEST**

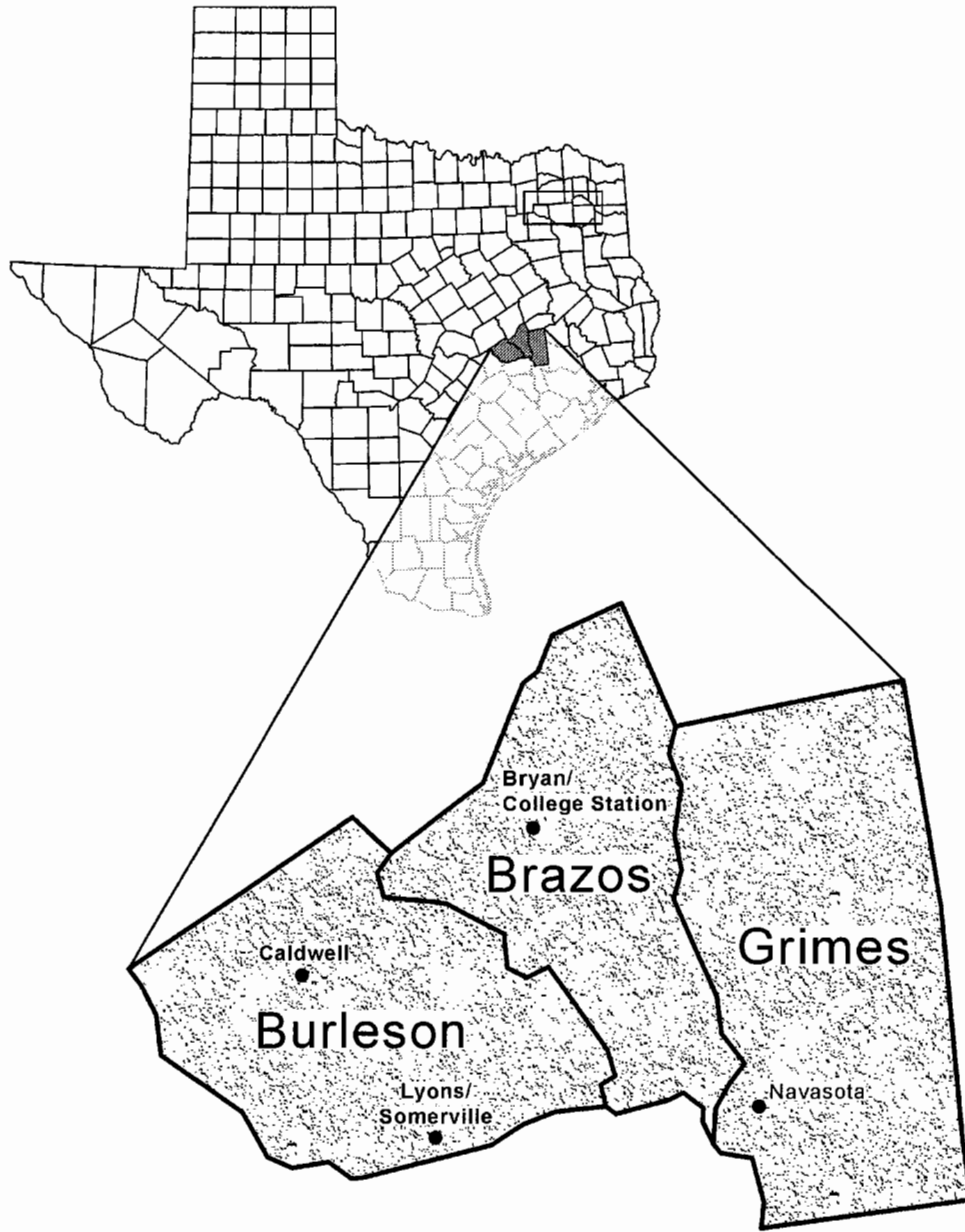
The rural transit AVL system was pre-tested using an automobile equipped with a GPS receiver. The GPS receiver was linked to a laptop computer in the vehicle which had a GIS map that covered the area. The automobile was driven on Brazos Transit routes, and the location of the vehicle was monitored on the laptop computer. This pre-test proved successful with the system tracking the automobile along the routes.

For the full test, two Brazos Transit buses were equipped with the GPS transceivers (GPST) and the radio modems. The communication backbone used was a 25 watt digipeater, allowing a tracking range of approximately 40 miles from the City of College Station's transmission tower. The two buses served the Navasota and Somerville areas highlighted in Figure 6. The project tracked two buses in operating service for a month.

Some problems were encountered with the implementation and operation of the AVL system on the Brazos Transit buses. Both technical and institutional issues caused delays in the development of the test. Preliminary testing of the system identified problems with the equipment installation which caused a battery failure on one of the vehicles. Additional problems were encountered with power surges that caused spikes to the modems. These spikes resulted in the modems losing their settings and disabling the devices. Researchers added a fuse box and redesigned the wiring to address these problems.



**Figure 5. Brazos Transit Service Area**



**Figure 6. Rural Transit AVL System Test Area**



Preliminary monitoring of the vehicles still indicated problems with sporadic and erratic tracking, however. An examination of the AVL units found no malfunctioning problems. A portable computer was installed on one of the buses to track the GPS device and to help identify possible problems with the AVL units. It turned out that some bus operators were turning the units off at various times during the day causing loss of the signal. To address this problem the devices were rewired, the on/off switch was removed, and the units were reinstalled in the buses. The AVL units were upgraded at the same time. New computer chips were added, allowing the units to be accessed remotely to change configuration settings and adjust time slotting.

## **MONITORING AND EVALUATING THE TEST**

Researchers monitored the operation of the AVL units on the two Brazos Transit buses over a four-week period. The vehicles were tracked to determine the distance the signal could be received and the general accuracy of the system. Problems encountered during the test were documented.

The AVL system was tested reporting locational information at 10 second, 30 second, and 60 second intervals. Once the problems noted in the previous section were addressed, the reliability of the AVL system during the four week test period was very high.

Researchers tracked buses up to 45 miles from the antenna site. This distance is beyond the 20 to 30 mile radius originally anticipated. The accuracy of the system was also good. A few software problems were encountered which sometimes distorted the AVL tracking display, however. A default element of the MapInfo GIS program plots all received GIS information on the screen, even when the actual location of the GIS position is outside of the map area in use. In some cases this default element resulted in vehicles displayed in the wrong location on the map.

As noted in the previous section, some bus operators turned off the AVL units on the buses during the initial testing. While these actions did not appear to be intentional attempts to sabotage the system or the test, they do point out the critical need to obtain buy-in and support from operations staff and to place equipment outside the reach of drivers. It was initially anticipated that the GIS mapping software program would be available at Brazos Transit, allowing dispatchers to monitor the location of the buses. This aspect of the test was not implemented, however, due to computer issues at the agency.

## **ASSESSMENT AND FURTHER RESEARCH**

The results of this proof-of-concept test show that a relatively low cost AVL system can be developed and operated with a rural transit service. The cost of the AVL equipment was approximately \$1,000 per unit. Once the infrastructure and software elements are in place, this amount is within the financial reach of many rural operators. Depending on the geographical area to be covered and the number of tower placements needed, the cost of the infrastructure elements is in the \$4,000 to \$5,000 range. The GIS mapping software costs approximately \$1,500.

When the problems described previously were addressed, the AVL system provided accurate tracking of buses up to 40 miles from the tower. Thus, the AVL system proved to be reliable, accurate, and relatively easy to use.

Although a limited test, the results hold promise for further demonstrations and deployment of AVL technologies with rural and small city transit systems in Texas and other parts of the country. At the end of this test, the AVL equipment was transferred to selected Texas A&M University buses and paratransit vehicles for use in other projects. These applications included the paratransit passenger paging test described in Chapter Three and a passenger information demonstration sponsored by the TransLink Research Program. Thus, other research projects directly benefitted from the AVL system developed in this proof-of-concept test.

Additional research is needed to help advance the deployment of AVL systems with rural transit services. Building on the experience gained in this proof-of-concept test, further research should examine using real-time data on vehicle locations to improve trip scheduling and passenger notification and linking AVL and scheduling and dispatching technologies. Given the still limited use of AVL technologies by rural transit operators, there is also an ongoing need to conduct, monitor, and evaluate additional tests and demonstration projects. The following areas for further research would help advance the deployment of AVL systems and related technologies with rural transit operators in the state:

- Conduct, monitor, and evaluate additional demonstrations using AVL systems with rural transit operators. Further projects are needed to build on the limited experience gained in this proof-of-concept test. These demonstrations should focus on further testing the AVL and GIS system components and on the actual use of AVL by transit operators.
- Link AVL technologies with paratransit scheduling software and test them with a rural transit system. An initial review of the potential to link the AVL system with transit routing and scheduling packages was made during the project. It appears that these systems can be integrated, which would further provide benefits to rural and small city transit providers.
- Test the use of real-time vehicle data to enhance transit services. There appear to be numerous opportunities to use the AVL-generated information to enhance services and passenger convenience once the systems have been introduced into the daily operation of rural transit providers. For example, the AVL information could be used to notify a doctor's office of the specific arrival time of a patient. Testing the use of AVL information for these types of service enhancements would be of benefit to passengers and operators.

## **CHAPTER THREE—PARATRANSIT PASSENGER PAGING TEST**

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### **BACKGROUND**

Paratransit systems provide demand-responsive trips, usually to individuals with special needs who are unable to use fixed-route transit services. Unlike fixed-route systems, which operate on regular preset schedules and specific routes, paratransit vehicles are dispatched in response to specific trip requests. Pre-registered individuals call in advance for trip reservations or schedule regular subscription service.

Paratransit services provide challenges to both operators and passengers. A major challenge to transit agencies is estimating the pick-up times for passengers. Travel distances, traffic levels, weather conditions, and passenger loading and unloading times must all be considered in developing paratransit schedules. Most transit agencies provide passengers with scheduled pick-up times, but also give a time window within which the pick-up will occur. This time window, which is usually between five and 15 minutes, is based on historical data or estimates of vehicle travel times between pickup and dropoff points. Smaller systems, such as the Texas A&M University paratransit service tend to use a shorter time window, due to low passenger volumes and limited geographical areas. Systems in large metropolitan areas where there are more chances of vehicles encountering delays are more likely to use longer time windows.

A major challenge to passengers is to be ready for an arriving vehicle, given the potential uncertainty associated with a scheduled pick-up time. Rather than miss a vehicle's arrival, some paratransit passengers may find themselves waiting for a significant time period, which might be upwards of 20 to 30 minutes.

It appears that ITS and other advanced technologies can be used to provide paratransit passengers with real-time advanced notification of approaching vehicles. Such a system would be of benefit to both operators and passengers. The time paratransit passengers spend waiting for a vehicle can be shortened, and the efficiency of the service can be improved if vehicle wait times are reduced. This project developed and demonstrated a passenger paging system with the Texas A&M University paratransit system to test this concept. A more detailed discussion of the research conducted on this project is available in the Masters Thesis, "An Automated Vehicle Arrival Notification System for Paratransit Passengers at Texas A&M University," by Rachel Donovan.

### **OBJECTIVES OF THE TEST**

The paratransit passenger paging test was undertaken to accomplish a number of objectives. The first objective was to develop a passenger notification system by integrating available AVL and paging technologies. The second objective was to test the passenger notification system with the Texas A&M University paratransit system. The third objective was to monitor and evaluate the test. These objectives were accomplished through the development, implementation, operation, and evaluation of a proof-of-concept test with the Texas A&M University paratransit system.

Researchers worked with staff from the Texas A&M University Parking, Traffic, and Transportation Services (PTTS) and technology vendors to accomplish these objectives.

### DEVELOPMENT OF THE TEST

Developing the passenger notification system, which was called the Vehicle Arrival Notification System (VANS), was the first task undertaken in the project. Figure 7 illustrates the various components of VANS. Researchers used a combination of commercially available technologies and specially designed software to create the input, core, and output modules. The input and output modules utilized commercial available technologies to transmit vehicle location and related information to the core input module and to transmit vehicle arrival notification to the passenger or the output module. The core module, created specifically for this project, consisted of software programmed to determine when to notify a passenger of an approaching vehicle based on GPS data and daily trip manifests. The major components of the three modules are described in more detail below.

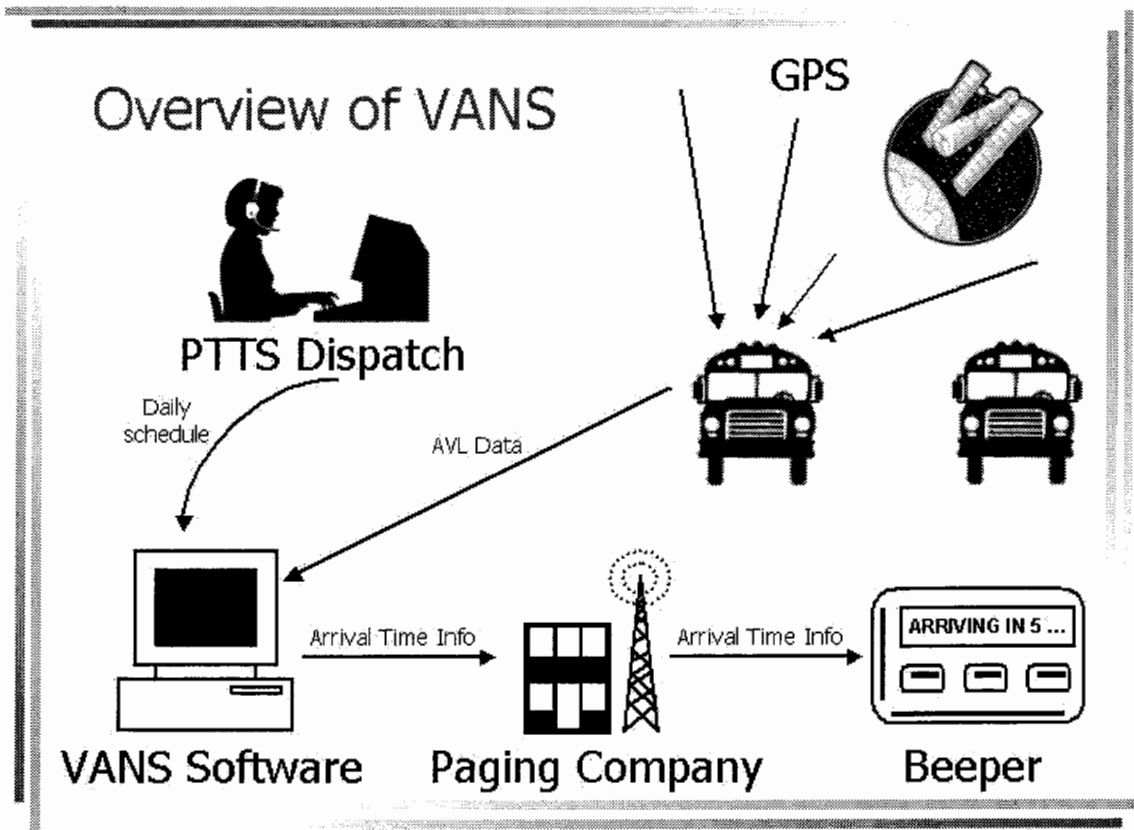


Figure 7. Vehicle Arrival Notification System Components

**Input Module.** The VANS input module contained four sub-modules to receive information on the transportation network, the daily PTTS vehicle schedule, system characteristics, and AVL data. This information is combined to determine when a vehicle-arrival notification should be sent. The key elements of each of these sub-modules are highlighted below.

*Transportation Network Sub-Module.* This sub-module provided the longitude and latitude of all the transportation nodes in the network and the shortest-path travel times from the nodes to the subset of paratransit trip nodes. The nodes or geographic locations of all pick-ups and drop-offs in the PTTS paratransit service, expressed as North American Datum of 1927 (NAD-27) coordinates, were connected by shortest-path algorithms in this module. Researchers used this information to determine the approximate travel times of the paratransit vehicles within the PTTS service area. This travel-time network had been previously developed for the Bryan-College Station area in other research projects. The network was modified by TTI researchers for this test to include only the destinations used by PTTS, in order to reduce the amount of computer time and memory needed to compute travel times.

*Daily Schedule Sub-Module.* In order to send an advanced notification of an individual trip to a specific passenger, the core module needed information on all scheduled trips, including scheduled pick-up times, a passenger identification number, pick-up and drop-off locations, and predicted dwell times. Researchers used this information, along with the travel-time data from the Transportation Network sub-module, to determine which passengers required vehicle arrival notification and the approximate time of day that the VANS should start to locate the vehicle for that purpose. These data were obtained from the daily PTTS schedule, which was available in a Microsoft Excel spreadsheet. A second Microsoft Excel spreadsheet contained information on the paratransit passengers. Using a macro written in Visual Basic for Applications, the data from the two spreadsheets were converted into one text file that formed the input into the core module.

*System Characteristics Sub-Module.* This sub-module contained information on PTTS operations and the characteristics of the notification system. Information on cancellations, gaps in service, late arrivals, no-shows, and other operating characteristics was obtained from PTTS dispatchers and operations personnel. Researchers used this information to further define the conditions under which a vehicle would be tracked by the AVL system and a vehicle arrival notification sent.

*AVL Data Sub-Module.* This sub-module provided close-to-real-time information on the location of a specific paratransit vehicle. Software for reading data from a live GPS feed had been previously developed as part of another research project. This sub-module was capable of reading real-time or saved AVL data.

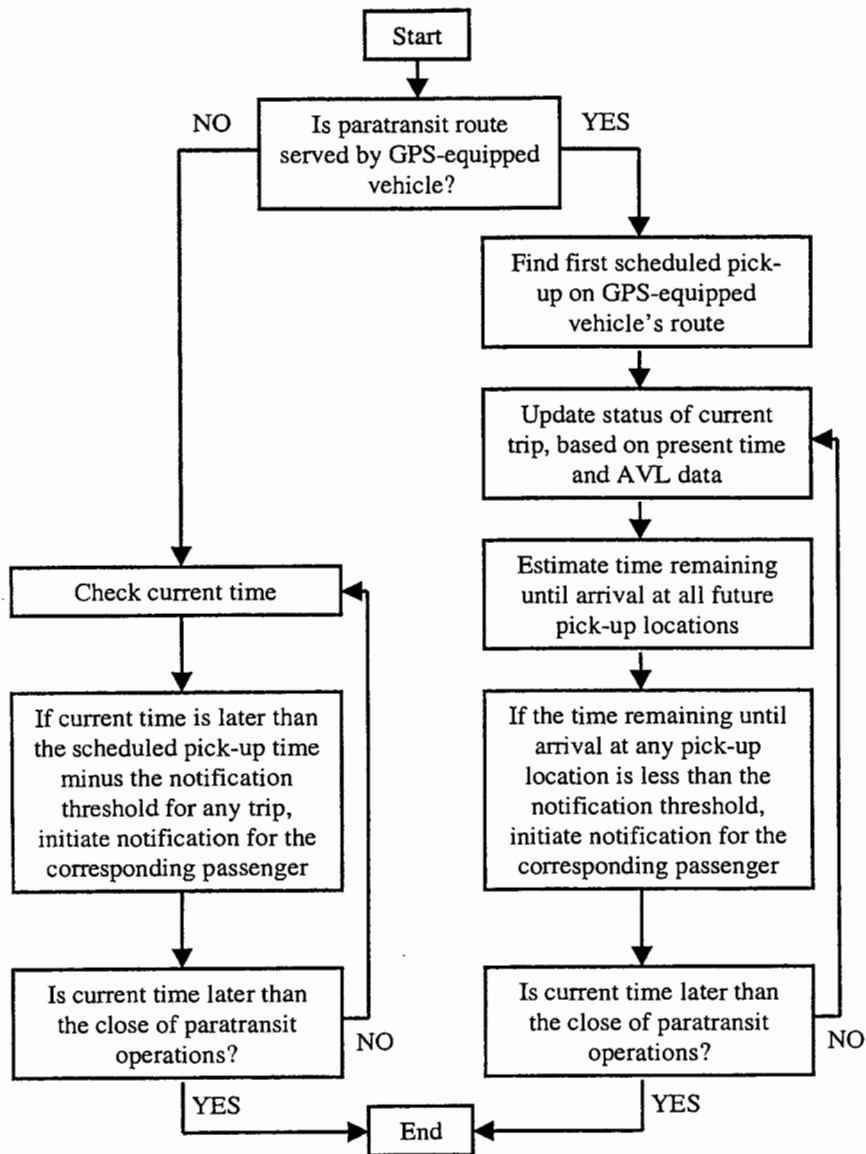
**Core Module.** As illustrated in Figure 8, the core decision-making software module determined when a page should be initiated. The system was developed to operate with and

without AVL equipped vehicles. When used with an AVL system, the core module examined the schedule for the next pick-up location and determined the status of the trip based on the current time and the vehicle's location. The software calculated the arrival time for upcoming scheduled pick-ups. When the estimated arrival time was within the notification threshold, which was set at five minutes for this test, the core module initiated notification to the passenger. Following notification, the module updated the status of the current trip and began to re-calculate the arrival times for upcoming trips.

For vehicles not equipped with an AVL system, the core module based the notification threshold on the scheduled trip times. In this case, the system would automatically send a page to the passenger at a preset time prior to scheduled pick-up. An advanced notification of five minutes was used in this test. In both cases, the core module created a flat text file that triggered the output module to send a vehicle arrival notification message to the passenger.

**Output Module.** The output module communicated the vehicle arrival notification to passengers by sending a message to a hand-held pager. This module used Visual Beeper, a commercially available software. A file was created in the Visual Beeper phonebook for each of the test participants. The file contained an identification number for the individual, the phone number of the beeper, and the access number of the paging company. When Visual Beeper detected a new flat file containing an identification number and message created by the core module, it communicated the page to the paging company, which then transmitted the page to the passenger's beeper. Preliminary testing of the VANS indicated that an average of 53 seconds elapsed between the creation of a flat file by the core module and the reception of the page by the beeper. Researchers factored this delay into the system characteristics sub-routine of the input module to help ensure the correct timing of page notifications. The output module also produced on-screen status messages and log files for trip status and AVL data.

The Texas A&M University Paratransit system is operated by PTTS to compliment the fixed-route bus system. Curb-to-curb service is provided from 7:00 a.m. to 6:15 p.m. for eligible students, faculty, and staff during the Summer Sessions. Trips are generally scheduled every fifteen minutes from 7:00 a.m. until 10:00 a.m. and from 4:00 p.m. to 6:15 p.m. using two vans. Between 10:00 a.m. and 4:00 p.m., trips are scheduled every 30 minutes using one van. Most passengers have subscription orders, as both the student and faculty passengers have regular schedules during a given semester. Trips may be canceled, added, or changed, however, depending on individual needs. Current PTTS policy is to carry only one passenger at a time to help keep travel times to a minimum and to simplify scheduling. PTTS maintains daily manifests on a computer spreadsheet program.



**Figure 8. Vehicle Arrival Notification System Core Module Process**

One of the Texas A&M University paratransit vehicles was equipped with the AVL system developed in the rural transit AVL test described in the previous chapter. This vehicle was to be assigned to one of the two routes operated on weekdays during the test. In addition, the PTTS dispatcher was to e-mail a copy of the daily schedule each morning to a TTI researcher.

PTTS personnel assisted with recruiting the test participants. PTTS sent a letter to the 12 riders using the system during the 1999 second summer session explaining the test and asking them to participate. Follow-up contacts were made by TTI researchers. Eight of the 12 passengers agreed to participate in the test. Participants received free use of a Motorola alphanumeric pager during the test but were not otherwise compensated for their participation. The riders were all between 18 and 55 years of age; four were university students and four were faculty or staff members.

Researchers pre-tested the VANS core module using three days of saved AVL data from a tracked PTTS vehicle. Two simulations were conducted. The first simulation used the beginning-of-the-day PTTS schedule, which was the information that would be available to the VANS during the full test. The second simulation used end-of-day PTTS schedule information, which included any cancellations, additional trips, or other changes made during the service day. The second scenario simulated how the VANS might operate if real-time schedule change information was available. The core module was evaluated on the basis of the pages successfully sent for existing trips, the pages sent for canceled trips, and the accuracy of the predicted vehicle arrival time.

The AVL data were combined with trip information taken from the beginning of the day schedule; cancellations and other trip changes that may have taken place during the service were not reflected. As a result, researchers expected that some pages would be sent for canceled trips and/or at incorrect times. Conversely, trips added during the service day did not appear in the VANS input data, and therefore did not trigger a page. These limitations closely approximate the conditions in effect during the full VANS demonstration, as there was no real-time information link between the VANS system and the PTTS scheduling system.

Forty-eight trips were provided over the three day period. Notification pages were successfully sent for 42 of these trips, or 88 percent, in the early-morning simulation and to all, or 100 percent, of the trips in the end-of-day simulation. The lower rate for the early-morning scenario reflects changes in schedules, cancellations, and no shows throughout the day, which VANS did not obtain notice of. It appears that about 2 percent of the properly initiated pages did not reach the intended beeper during the pre-test. Given the lack of the real-time link between the VANS and the paratransit dispatchers, cancellations or other changes during the day were not available. As a result, pages were sent to most of the 18 canceled trips. Both of these problems could be addressed by linking VANS to the scheduling and dispatching system. The two pages which were initiated but did not arrive at the intended beepers indicate that the use of wireless technology may encounter some unforeseen problems.

Ideally, the notification page should occur five minutes (300 seconds) prior to the PTTS vehicle's arrival at the pick-up point. Prediction error is the difference between this five-minute threshold and the actual time the passenger received the page. A negative prediction error indicates



that the VANS estimated too late an arrival time, and a positive error indicates that the system estimated too early an arrival time. Thirteen pages were sent earlier than the five-minute threshold, with an average prediction error of 178.5 seconds. Ten pages were sent later than the five-minute threshold, with an average prediction error of -156.5 seconds.

Researchers combined the same AVL data with end-of-day schedule information, simulating the conditions that would exist if a real-time link existed between the PTTS scheduling system and VANS. Trip cancellations, late vehicles, and other schedule changes are included in the core module's decision process. Notification pages were successfully sent for all 48 trips, or 100 percent, during the three day period. No pages were sent for the eighteen canceled trips. Fourteen pages were sent earlier than the five-minute threshold, with an average prediction error of 64.5 seconds. Thirteen pages were sent late, with an average prediction error of -110.0 seconds.

## **OPERATION OF THE TEST**

The test of the VANS with the eight passengers using the Texas A&M University paratransit service was conducted on weekdays from July 12 to August 10, 1999. Both the AVL equipment and the paratransit vehicle encountered problems over the course of the test. As a result, the AVL equipped vehicle was not in operation for most of the test. Thus, rather than being able to send a page based on real-time AVL data, the test used the VANS reminder feature that automatically generated a page five minutes before the scheduled pick-up time.

TTI researchers received an e-mail from PTTS each morning during the test with the daily paratransit trip schedule. This file was integrated into the VANS computer software. The VANS software initiated pages to the participating passenger throughout the day. Due to the problems noted previously with the AVL system and the equipped vehicle, pages were sent to the eight participants five minutes before a scheduled pick-up time. No real-time pages were sent during the test. The VANS software automatically recorded the following information for each scheduled trip

- Whether a page was initiated for a trip,
- The time a page was initiated,
- The identification number to which the page was initiated,
- The message to be displayed on the pager,
- Whether the communication with the paging company was successful., and
- The time the page was communicated to the paging company.

PTTS operators routinely radio dispatch personnel when they arrive at a pick-up location, when they depart a pick-up location, and when they arrive at a drop-off location. This information is recorded by the PTTS dispatcher. These records were used in monitoring and evaluating the test

described in the next section. Researchers recorded any problems encountered with the software or other equipment during the test. Participating passengers were asked to maintain daily travel logs and to complete a survey at the end of the test.

## **MONITORING AND EVALUATING THE TEST**

As noted previously, the AVL-equipped PTTS van was not operating during the actual test. As a result, the VANS system automatically sent notification messages five minutes before the scheduled pick-up times to the eight participants. Researchers conducted a number of activities to monitor and evaluate the test of the paging system. Researchers matched the schedule trips with the corresponding log data in the Excel spreadsheet and checked the spreadsheet to determine if a page was initiated, if the pager identification number matched the pager of the scheduled passenger, and if the page was successfully sent to the paging company. The logs kept by participants were reviewed, and the participant surveys were analyzed.

A total of 423 trips were scheduled during the 22 days of the test. The morning scheduled trip page initiation rate during the test was 84 percent. This rate is well below the 100 percent achieved in the simulation. Most of the failures resulted from factors that could have been addressed or were corrected during the course of the test. For example, an error in the algorithm causing it to skip the last passenger trip of the day resulted in no pages sent on 20 trips, or approximately 5 percent. This error was corrected after the test was completed. Four percent, or 16 trips, were not sent a page because the computer in the laboratory was unplugged, and pages were missed on 8 trips, or 2 percent, when the computer locked up. Fifteen missed pages during the first week resulted from information on two new participants arranged improperly in the database. Only three page initiation failures were caused by unknown factors.

Thus, most of the problems with pages not being sent were due to equipment, software, and data entry problems. Researchers corrected many of these problems during the test. The incorporation of the system into the PTTS dispatch operations would also help address these types of issues, resulting in a much higher level of reliability.

Participants kept a log of their paratransit trips during the demonstration. The log included the trip day, origin and destination, the scheduled pick-up time, the actual arrival time of the vehicle, whether a page was received, and the time the page was received. Participants were also requested to complete a questionnaire at the conclusion of the test regarding their experience with the pager system. Questions focused on if the advance notification system made a difference in the time spent waiting for a vehicle to arrive, in their preparation for trips, or in their confidence level. Participants also provided feedback on the reliability and usability of the pager and the overall usefulness of the system. Finally, participants were asked to describe their ideal advance notification system, including the type of equipment and the time and frequency of notification. Four participants submitted completed written evaluations, one returned a partially completed survey, two provided the information through interviews, and one did not respond.

The overall response from participants to the pager notification test was positive. The problems encountered with both the AVL system and the equipped van, which resulted in pages being sent five minutes before the scheduled pick-up time rather than in real-time, may have influenced the perception of the benefits of the system. Five participants rated the ability to receive a page as slightly helpful to neutral. Three passengers noted that the pagers were good reminders that it was time to get ready to leave. Three participants indicated that the notification increased their sense of confidence about the arrival of their ride. Two passengers stated that the notification system was so reliable that they came to depend on it over the course of the test. These two individuals noted that they were late for scheduled pick-ups when they did not receive a page.

Researchers also asked participants about preferred methods for receiving real-time notifications. The pagers used in the test were acceptable to the sighted participants. Sight-impaired passengers indicated they could not read the text messages. These individuals noted a preference for a telephone call or some other non-visual method.

Five participants expressed interest in using an advanced vehicle arrive notification system in the future, if it provided reliable real-time notifications for all trips. Two participants reported no interest in the future use of a notification system in College Station, primarily because they felt the paratransit service was very reliable. These individuals did indicate that this type of system would be a benefit in larger urban areas where travel times are greater and trip reliability is less dependable. Those indicating an interest in future use stressed the importance of system reliability. Only one individual expressed a willingness to pay for a notification service.

## **ASSESSMENT AND FURTHER RESEARCH**

This proof-of-concept test was successful in developing and demonstrating an advanced notification system for paratransit passengers. The Vehicle Arrival Notification System provides a relatively low cost, straight forward, convenient, reliable, and accurate method to provide passengers with personalized advanced notification of an approaching vehicle. Although the problems encountered with the AVL system and the equipped van limited the ability to test real-time notifications, the simulations and the actual test results indicate that VANS is capable of sending advance notification to passengers with high levels of accuracy and dependability.

The results from this test hold promise for the application of advanced passenger notification systems with paratransit services. Given the limited nature of the project, however, more research and demonstration projects are needed to fully test VANS and related technologies. The following activities would build on the experience gained in this project and would help advance the state-of-the-art in applying AVL, paging, and other technologies to providing paratransit passengers with notification of approaching vehicles:

- Integrate VANS into a paratransit service providers scheduling and dispatching system allowing changes in passenger trip scheduled to be automatically reflected in VANS.

- Conduct a series of tests and demonstrations of the integrated VANS with AVL equipped vehicles in different settings. Possible demonstrations could include an expanded test with the Texas A&M University paratransit system, a rural transit operator, and a paratransit system operated by a Metropolitan Transit Authority in Texas.
- Conduct tests using different methods to provide the notification information to passengers. In addition to the pagers used in this project, other possible technologies to test include regular and cellular telephones, computers, and personal information devices.

## CHAPTER FOUR—GULF FREEWAY HOV LANE BUS NOTIFICATION TEST

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### BACKGROUND

Houston METRO operates an extensive system of HOV lanes; park-and-ride lots; transit centers, and park-and-ride, limited express, and local bus services. The park-and-ride bus routes provide frequent premium service from suburban areas to downtown Houston and other major activity centers using the HOV lanes. This service is well received by commuters, indicating that transit can attract riders by providing convenient, comfortable, and frequent bus service.

The park-and-ride bus system has evolved over the years. The route structure initially focused on downtown Houston. As the system has matured, service has been expanded to include other major activity centers such as the Texas Medical Center (TMC), Greenway Plaza, and the Post Oak/Galleria area. To accommodate service to additional destinations, some buses which previously operated non-stop on the HOV lanes now make intermediate stops to serve transit centers and to provide passengers with opportunities to transfer to and from other routes.

The most effective use of this strategy, which is part of METRO's Regional Bus Plan, depends on buses deviating off the HOV lanes and into transit centers only when passengers need to get off or are waiting to be picked up. Deviating at other times – when no passengers are waiting to board the bus or when riders do not wish to get off – results in reduced vehicle operating efficiencies and lower levels of customer satisfaction. Determining that a passenger wishes to be dropped off at a center is not a problem as a rider simply pushes the on-board stop request. Currently the only way of knowing if a rider is waiting to be picked up at a transit center is for a bus to exit the HOV lane and enter the center.

Scheduling service to transit centers and other interim stops is based on current and forecasted passenger demand. Achieving a proper balance is not always easy, however. Riders and potential passengers may perceive a lack of service if too few trips are provided to a center. On the other hand, the scheduling of numerous trips with no riders getting on or off at a center may cause dissatisfaction among passengers on the bus traveling to other destinations.

One area where this problem occurs is at the Eastwood Transit Center on the Gulf Freeway. Currently, some METRO routes, such as the 246 Bay Area Park-and-Ride, detour from the Gulf Freeway HOV lane into the Eastwood Transit Center to pick-up and drop-off passengers. The travel time for buses to exit the HOV lane, enter the transit center, pick-up and/or drop-off passengers, and reenter the HOV lane is approximately three to five minutes, depending on the actual dwell time at the center. A 1997 review of METRO point checks indicated that in the morning no passengers boarded the 246 at the transit center, although eight passengers got off on four of the eight scheduled trips to the center. In the afternoon, 13 passengers boarded at the center on eight of 19 scheduled trips.

METRO staff and TTI researchers examined potential approaches for addressing this issue. It was determined that the situation at the Eastwood Transit Center along the Gulf Freeway HOV lane provided an excellent opportunity to develop and test a bus notification system using advanced technologies. Potential savings of approximately 200 annual bus hours was estimated from reducing the number of unneeded trips into the transit center. The project explored alternative approaches for notifying bus operators of passengers waiting at the transit center. Researchers developed and tested one possible technique at the Eastwood Transit Center.

## **OBJECTIVES OF THE TEST**

The Gulf Freeway HOV lane next bus notification test focused on a number of objectives. The first project objective was to develop a method to notify bus operators on the Houston HOV lanes of passengers waiting at selected transit centers. The second objective was to conduct a test of this technique on the Gulf Freeway HOV lane at the Eastwood Transit Center. Monitoring and evaluating this demonstration represents the final objective. These objectives were accomplished through the development, implementation, operation, and evaluation of a proof-of-concept test. Researchers worked with METRO staff on all phases of the test.

## **DEVELOPMENT OF THE TEST**

The development of the Gulf Freeway HOV lane next bus notification test occurred over a two-year period. Researchers encountered a number of problems and issues during the development process which delayed the project. Technical problems emerged during the test design phase, and coordinating development activities around other projects lengthened the original schedule.

The initial test design focused on an unused traffic signal system located at the top of the T-ramp connecting the Eastwood Transit Center with the Gulf Freeway HOV lane. The signal head is visible to bus operators traveling in both the northbound and the southbound direction on the HOV lane. The anticipated design was to install a pedestrian crossing button at the transit center and connect it to the existing signal controller. A passenger waiting at the center would push the button, activating the signal through the controller, which would in turn be visible to the bus operator traveling on the HOV lane. The operator, seeing the signal would divert into the center. The signal is also visible from the transit center, providing verification to the waiting patron that the system had been activated.

Three issues emerged with this approach during the preliminary design of the test. First, the signals were connected to a TxDOT controller located some distance from the center and were being used for the access gates and at-grade control of the HOV lane entrance and exit. Second, although an empty conduit connected the controller cabinets to the upper part of the T-ramp, the termini were not close to either the TxDOT controller or the signals. Third, consideration was being given to using the signals for their original purpose, making them unavailable for the test.

As a result of these issues, the research team and METRO staff explored alternative approaches using available technologies. The agreed upon design made use of commercially available RF transmitters, backlit signs, and push-button electrical assemblies. These major components are described next and illustrated in Figures 9 through 13.

The Eastwood Transit Center, which is located adjacent to the Gulf Freeway to the south of downtown Houston, is shown in Figure 9. The passenger waiting platform at the Center is illustrated in Figure 10. As shown in Figure 11, a push-button connected to an electrical panel was installed in an existing kiosk in the passenger waiting area of the center. Pushing the button which activated the backlit number sign shown in Figure 12. This sign was mounted on the overhead support at the upper end of the T-ramp. The sign was visible from both travel directions in advance of the point where an operator must make a decision to divert into the center. A light next to the button in the transit center was illuminated, confirming to the passenger that a request had been made for a bus to enter the transit center.

The bus operator used a 390 MHZ RF transmitter to deactivate the sign. The transmitter sent a signal through the RF antenna shown in Figure 13, which operated a receiver mounted within the sign cabinet on the support post. The receiver broke the electrical circuit to turn the sign off. The system was then ready for use by the next passenger waiting at the transit center.

Researchers encountered problems with pre-testing the system components. The RF signal was sometimes weak and erratic. The installation of a new radio antenna helped correct this issue, but problems with signal strength were still encountered during the test. The antenna arrays were also manipulated to address continuing problems with erratic signal strength. Researchers conducted a final test of the system components during the fall of 1999. All of the elements functioned properly, although the overall visibility of the backlit sign remained of concern.

## **OPERATION OF THE TEST**

The actual proof-of-concept test occurred during the week of December 13 through 17, 1999. Two researchers were involved in the test and METRO operators were notified of the project. The first researcher, located at the Eastwood Transit Center, activated the system by pushing the button. The second researcher rode selected buses on the HOV lane. This individual sat directly behind the operator and verified that the sign was illuminated and when the operator was able to see the sign. This individual also recorded the general reaction and comments from the operators.

## **MONITORING AND EVALUATING THE TEST**

Using the technique described above, researchers tested the bus notification system on 11 trips – four inbound to downtown Houston and 7 outbound to the Bay Area Park-and-Ride lot during the week of December 13-17, 1999. Testing took place during both the morning and afternoon peak-periods to monitor the system under different lighting and traffic conditions. Ten of 12 scheduled bus operators were involved in the test runs, with one operator participating in two trips.

The system operated well during the limited test. The sign on the HOV lane was illuminated each time the button was pushed by the researcher at the transit center. The light next to the button on the control panel also came on. The system components worked well, and the visibility of the sign provided adequate notification to bus operators once they were alerted to its location. Discussion with the operators indicated positive reactions to the general concept of the notification system, but some voiced concerns related to the visibility of the sign. Seeing the sign far enough in advance to slow down and exit the HOV lane was especially difficult when the sun was behind the bus. This situation occurred around 7:30 a.m. to 8:00 a.m. and from 4:30 p.m. to 5:30 p.m., time periods with significant numbers of bus trips. Visibility was also somewhat of a problem during darker time periods due to visual clutter of office buildings, lights, and advertising.



**Figure 9. Eastwood Transit Center**

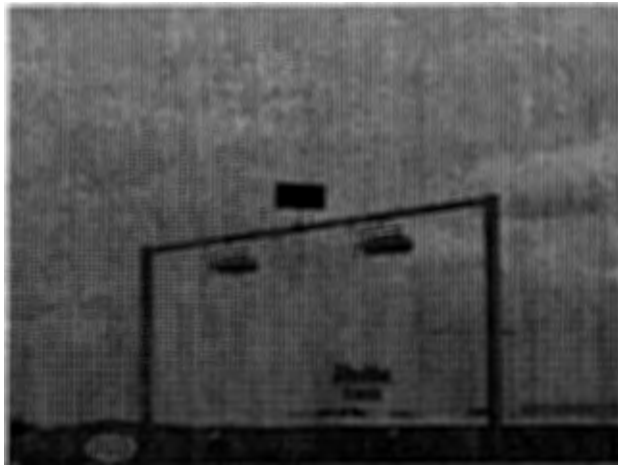


**Figure 10. Eastwood Transit Center Passenger Platform**

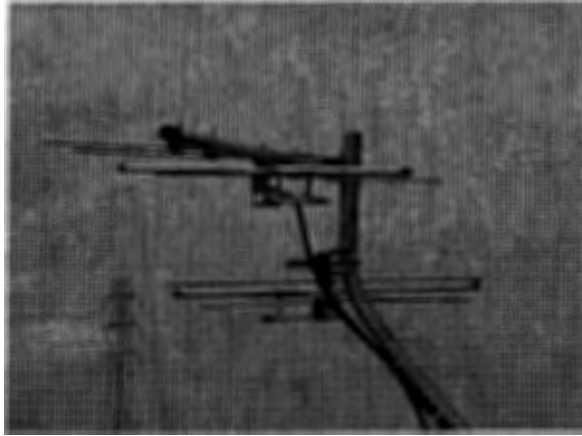




**Figure 11. Bus Notification Button**



**Figure 12. Bus Notification Sign on Gulf Freeway HOV Lane**



**Figure 13. RF Antenna**

## **ASSESSMENT AND FURTHER RESEARCH**

The results of this proof-of-concept test show that a system can be developed to notify operators of buses traveling on the HOV lanes that they should divert into a transit center to pick up waiting passengers. The test indicates that this notification must occur well in advance of the operators' decision point for exiting the lane. The sign used in this test met this criteria under some, but not all, lighting conditions. Thus, while the test supports the viability of the concept, the results indicate that the location and the visibility of the system used in this project may not be appropriate for all types of applications needed for system-wide deployment.

Although the visibility of the sign was of concern to operators, there seemed to be support for the concept. Ideas suggested by the operators to address the problems noted previously included positioning the sign on the HOV lane further in advance of the center exit and sending the notification directly to the vehicle through the bus radio, mobile data terminal (MDT), or some other method.

These approaches could be explored in further research, building on the lessons learned on this proof-of-concept test. The following projects would address the limitations identified in this project:

- Relocate the sign to a position on the HOV lane further in advance of the exit to the transit center. Additional tests could be conducted with different sign locations and increases in the illumination of the sign.

- Develop and test a vehicle-based notification system using the bus radios and MDTs.
- Develop and test a notification system after the METRO AVL system is fully operational.



## **CHAPTER FIVE—NEXT BUS PASSENGER NOTIFICATION TEST**

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### **BACKGROUND**

Transit agencies throughout the country are exploring the use of AVL systems and other advanced technologies to provide real-time information on the status of buses and rail vehicles to individuals at transit stops, park-and-ride lots, transit centers and stations, major activity centers, on vehicles, at home and work, and at other locations. This real-time information may help reduce concerns among existing passengers about the status of their vehicles and may attract new riders to transit. These systems are currently in the early stages of testing and deployment in many areas, especially those focusing on bus rather than rail applications.

Houston METRO is in the process of procuring and deploying an AVL system with its full vehicle fleet. Once this system is operational, real-time information will be available on the location of METRO buses and other vehicles. METRO plans to use this real-time information to enhance internal operations and vehicle deployment. It also plans to disseminate the real-time information to passengers and potential riders at multiple locations through a variety of technologies. This research project was undertaken to test the provision of real-time bus information in advance of the fleet-wide AVL system deployment, which will be occurring over the next few years.

### **OBJECTIVES OF THE TEST**

The next bus passenger notification test focused on accomplishing two major objectives. The first objective was to demonstrate the ability to provide real-time information on the status of buses on one METRO route to riders at a transit center. The second objective was to obtain feedback from passengers and potential riders on preferences relating to the provision and format of the real-time information and the use of the next bus arrival information available during the test. These objectives were accomplished through the development, implementation, operation, and evaluation of a proof-of-concept test.

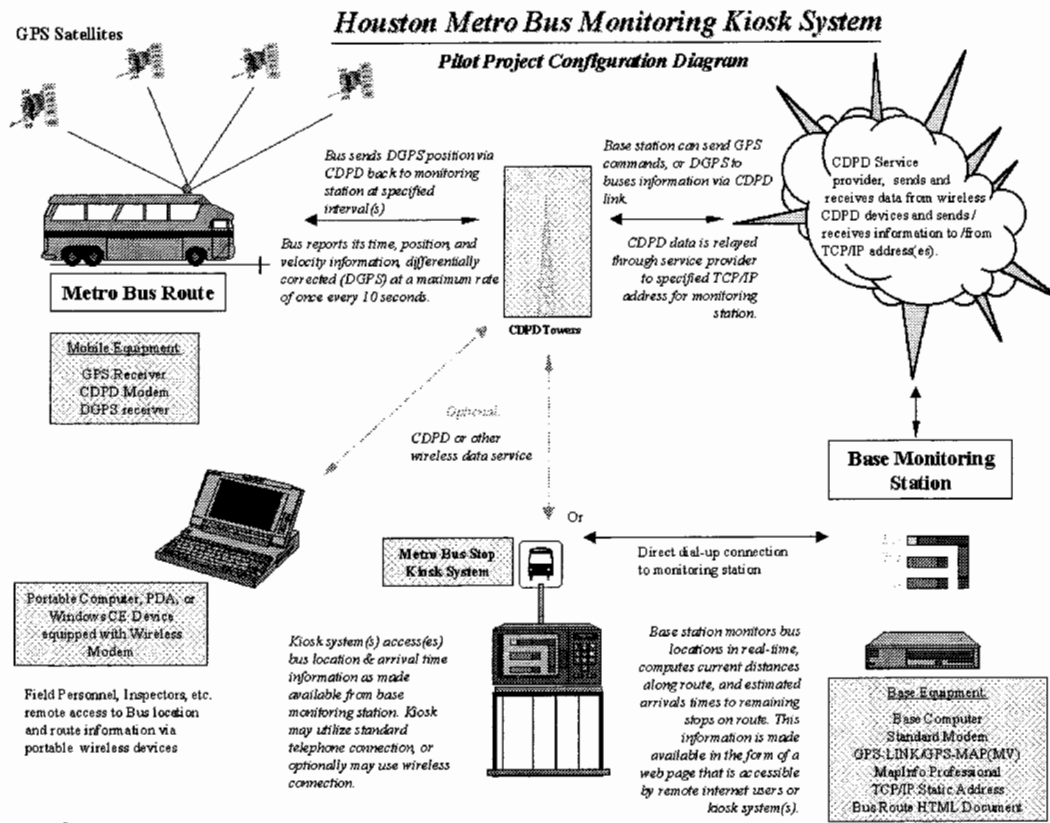
### **DEVELOPMENT OF THE TEST**

Researchers, in coordination with METRO staff, completed a number of activities in developing the next bus passenger notification test. The first task examined potential approaches and technologies for use in advance of METRO's fleet-wide AVL system deployment. The identification of possible approaches was further complicated by the fact that METRO was in the process of replacing its radio system. As a result, transmitting data through the radio system was not a viable option. The selected approach made use of commercially available technology and Cellular Digital Packet Data (CDPD) coverage.

Integrated GPS Technologies (IGT) was selected through a requisition process to provide the necessary hardware and software, as well as data integration capabilities. GPS Link, an IGT software product, which enables various GPS products and communications technologies to exist

within one computerized application, was utilized in the test. GPS Link provides flexibility in the application of AVL systems by reducing the dependence on the proprietary software often associated with specific AVL products.

Figure 14 illustrates the major components of the proof-of-concept test. METRO buses operating on the selected route were equipped with GPS receivers, CDPD modems, and differential corrected broadcast receivers. Data on position, time, and velocity of the bus were sent at a maximum rate of once every 10 seconds by CDPD to the monitoring station. The hardware and software at the base station monitored the location of a bus in real-time, computed current distances along the route, and estimated the arrival time to the next stop or stops. Using a Web page format, this information could be provided to kiosks, laptop computers, or other devices through remote Internet access.



**Figure 14. Major Components of Next Bus Passenger Notification Test**

A total of 16 buses were equipped with the GPS receivers, CDPD modems, and differential correction broadcast receivers. Equipment from different vendors was used as part of the test. Table 1 identifies the products used on each of the 16 buses, along with the general price of the equipment. The three integrated GPS/CDPD devices used were from Sierra Wireless, Anchor Engineering, and Universal Data Communication (UDC). All three brands used Trimble and Ashtech multi-channel GPS receivers capable of outputs of NMEA and Trimble ASCII Interface Protocol (TAIP) formats. The CDPD units use both 0.6 watt Uniden and 3 watt Sierra Wireless devices. The antennas, which were magnetically mounted on the buses, included L-1 low profile patch antennas for the GPS, 0.75 and 0.5 wave (unity and 2.5 db gain) cellular antennas, and combo GPS/CDPD unity gain. Differential corrections were furnished with Differential Corrections Incorporated (DCI), Transmission Control Protocol (TCP), and inverse using Waypoint Consulting DLL.

**Table 1. Equipment Configurations.**

<b>Bus Number</b>	<b>Manufacturer</b>	<b>Equipment</b>	<b>M.S.R.P.</b>	<b>GPS_Ant</b>	<b>Cell_Ant</b>
4260	Sierra Wireless	MP200	\$1,720	L1 Patch	0.5 wave
4261	Anchor Engr.	Anchor	\$1,070	L1 Patch	0.25 wave
4262	Anchor Engr.	Anchor	\$1,070	Combo	Combo
4263	Anchor Engr.	Anchor	\$1,070	L1 Patch	0.5 wave
4264	Sierra Wireless	MP200	\$1,720	L1 Patch	0.25 wave
4265	UDC	MDC-II	\$1,395	Combo	Combo
4266	UDC	MDC-II	\$1,395	L1 Patch	0.625 wave
4267	UDC	MDC-II	\$1,395	Combo	Combo
4268	Sierra Wireless	MP200	\$1,720	L1 Patch	0.25 wave Dome
4269	Sierra Wireless	MP200	\$1,720	L1 Patch	0.25 wave
4270	Anchor Engr.	Anchor	\$1,070	L1 Patch	0.50 wave
4271	Anchor Engr.	Anchor	\$1,070	Combo	Combo
4272	Sierra Wireless	MP200	\$1,720	L1 Patch	0.50 wave
4273	Sierra Wireless	MP200	\$1,720	L1 Patch	0.25 wave Dome
4274	UDC	MDC-II	\$1,395	Combo	Combo
4275	UDC	MDC-II	\$1,395	Combo	Combo

Researchers and METRO staff selected the 34 Montrose Crosstown route for the test because peak-period service is provided using four, 34-foot minibuses. The four vehicles are assigned from a fleet of 16 minibuses located at the Hiram Clark Bus Operating Facility. All 16 minibuses were equipped with the GPS/CDPD devices, as the vehicles are assigned to the 34 Montrose Crosstown and two other routes on a daily basis.

METRO provided the geocoded locations of the bus stops along all three routes and the Heights Transit Center which were entered into the IGT Server's database. Positional information received from a bus was archived into a fleet database by GPS Link. A process was developed to utilize this data and the stored bus stop information to place the vehicle on the appropriate route and to create and update a second database with the average bus running times between stops.

Researchers calculated the average running times by day of the week and hour of the day to account for changing traffic conditions.

An Active Server Page (ASP) was created to generate an automatically updating web page accessible from any device with an Internet connection. By accessing the running time database, the closest vehicle in either direction was determined along with its current time and location, and the average running time to the Heights Transit Center was computed. This information was automatically sent to the web page. The data was updated every minute.

Researchers explored two ways of presenting the next bus arrival information to passengers. The first approach was to show the anticipated arrival time of the next bus, such as 4:15 p.m. The second technique was to show the length of time, such as five minutes, before the next bus would arrive. These two methods are illustrated in Figure 15.

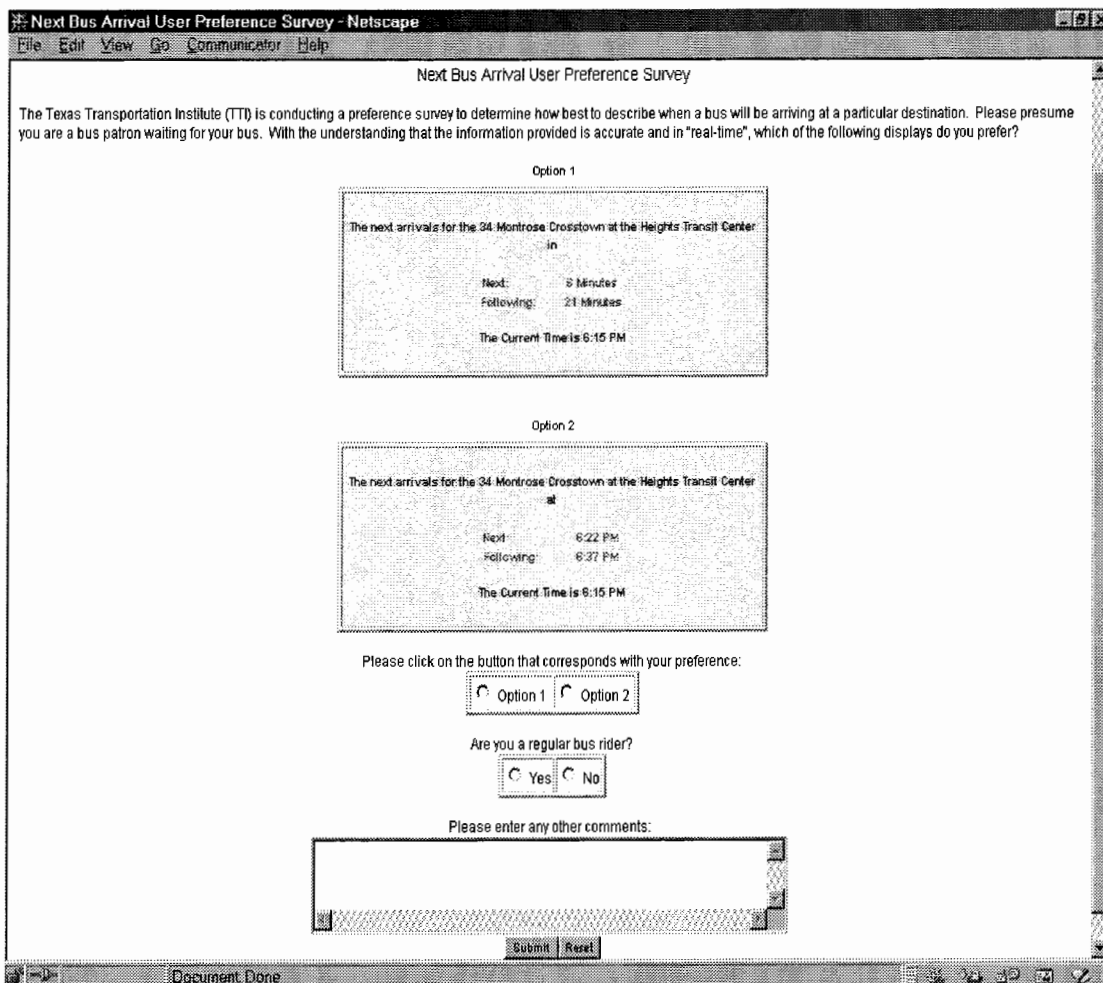


Figure 15. Internet Preference Survey



Researchers conducted an initial survey of riders and non-riders to gain feedback on these two approaches. Examples, similar to the one shown in Figure 4, were used in a survey of bus riders at the Heights Transit Center. A total of 132 passengers completed the survey on one day in October 1999. The survey was also placed on the Internet with a link to METRO's website, and 84 bus riders and 94 non-riders completed the survey.

Of the 310 responses, a slight majority, 63 percent, favored the second option, which provided the time of arrival. Some 34 percent selected the length of time option, and 3 percent did not indicate a preference. Reported preferences were slightly different between riders and non-riders, with non-riders favoring the arrival time option at a slightly higher rate than current passengers. Researchers and METRO staff decided to show both the anticipated arrival time and the length of time based on the survey results.

## **OPERATION OF THE TEST**

Researchers conducted a one week test of the next bus arrival information at the Heights Transit Center at the end of January 2000. Figure 16 shows a bus arriving at the Transit Center and Figure 17 highlights the unit used to display the real-time information. The display device, which was available from a prior METRO project, provided a weatherproof enclosure for housing the desktop computer, CDPD modem, and display screen. As illustrated in Figure 18, information on both the expected arrival time and length of time for the next two buses at the Heights Transit Center was displayed.

The display unit at the Heights Transit Center was activated on Monday, January 24, 2000, and the test continued throughout the week. Researchers monitored the performance of the equipment and the reaction of passengers during the week. Passengers waiting at the Transit Center completed surveys to obtain additional feedback on use of the information system and preferences related to displays and information dissemination techniques.

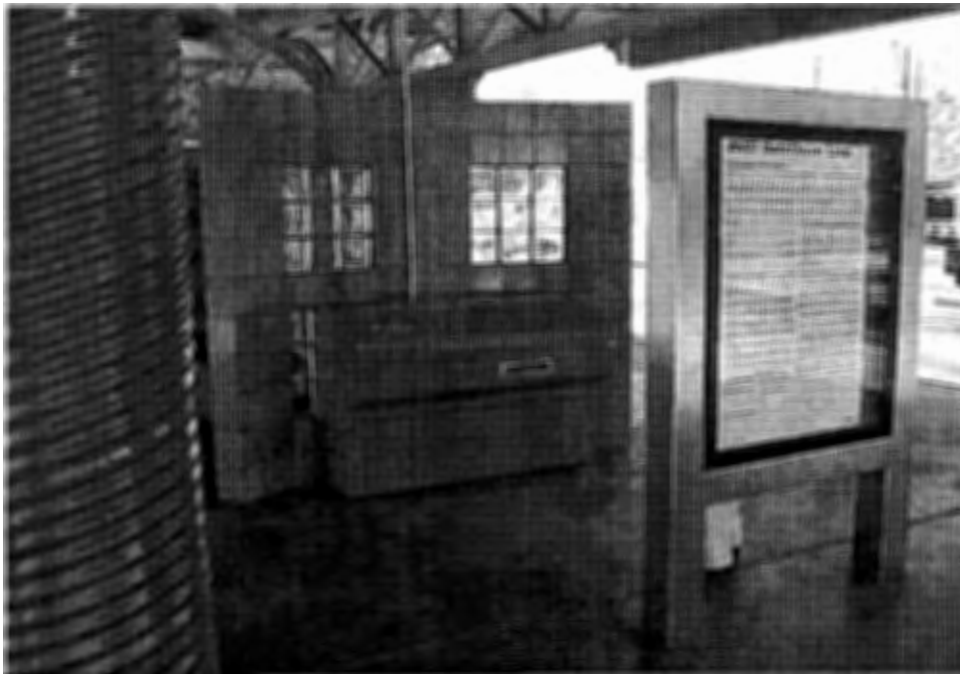
## **MONITORING AND EVALUATING THE TEST**

Researchers conducted three activities as part of the monitoring and evaluation process. First, the performance of the various technologies and the overall system was monitored. Second, researchers observed passenger activity and use of the information kiosk at the Transit Center. Third, passengers waiting at the Heights Transit Center completed a short survey to obtain additional feedback on the next bus arrival information system.

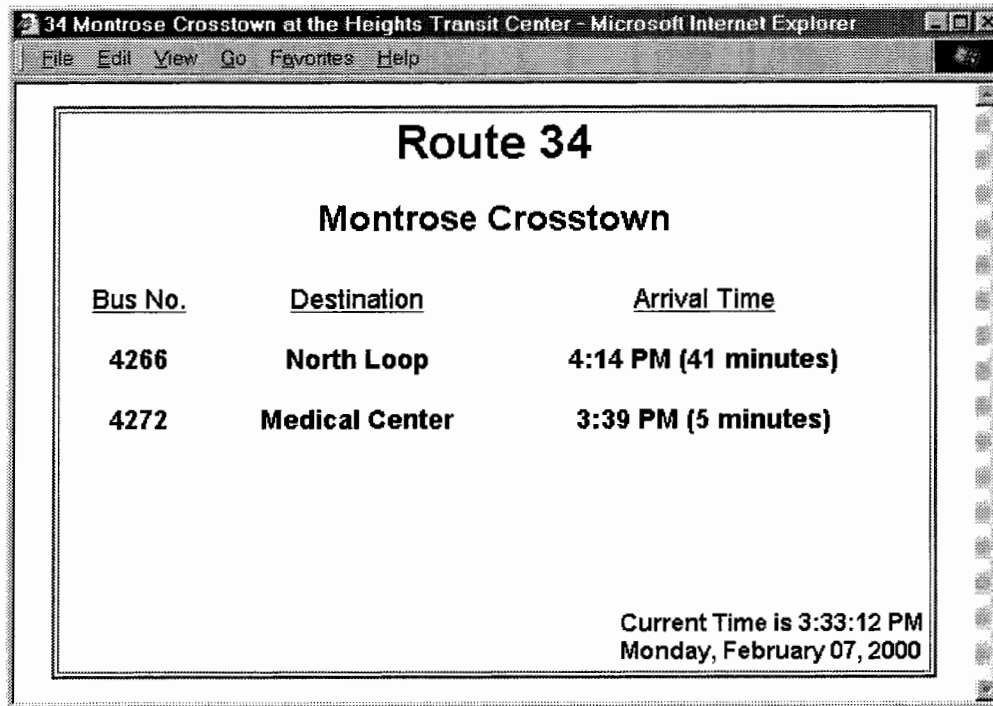
All of the equipment functioned properly during the week long demonstration. The individual components and the system as a whole worked well. The real-time information on the next bus arrivals was updated automatically. Comparisons of the displayed time and the actual arrival time of a bus indicated the information provided was usually accurate within a minute. Observation of passengers waiting at the Transit Center indicated that they did seek out the kiosk and did use the next bus arrival information. The survey results supported these observations.



**Figure 16. Minibus at Heights Transit Center**



**Figure 17. Display Device at Heights Transit Center**



**Figure 18. Next Bus Arrival Display**

A total of 117 individuals completed surveys during the week, which were available in both English and Spanish. Passengers waiting at the Transit Center completed the survey and returned it to TTI staff. As highlighted below, most respondents rated the information system highly. The complete results are provided in the Appendix.

- Most passengers indicated that bus arrival information was of benefit and rated the test system highly. For example, 97 percent agreed that it was helpful to know when the bus would arrive, 93 percent indicated that the display provided the information they needed, 98 percent noted the display was easy to understand, and 95 percent reported that knowing the bus arrival time would increase their comfort level while waiting.
- A majority, 86 percent, of the respondents reported riding the bus on a daily basis. Approximately half indicated they would ride more frequently as a result of having better arrival information, and 44 percent reported they might make other trips.
- A majority of respondents, 80 percent, did not have an automobile available for their trip. Work was the primary trip purpose for 52 percent of the respondents, followed by school, 36 percent. Over half, 68 percent, were transferring from one route to another.

- Slightly more women completed the surveys than men. Respondents were fairly evenly distributed across all age groups.

## **ASSESSMENT AND FURTHER RESEARCH**

The results of this proof-of-concept test show that a relatively low cost next bus arrival information system can be developed and operated using non-proprietary off-the-shelf technologies. The results also indicate that passengers find this type of information of value. Further, based on the survey responses, it appears that real time information on the status of buses enhances rider's comfort levels and may increase bus use among current passengers.

Although only a limited test, these results hold promise for further deployment of real-time transit information systems by METRO and other transit agencies. The experience gained through this proof-of-concept test should be of benefit to METRO in the implementation of the fleet-wide AVL system and the development and deployment of real-time passenger information systems through priority corridor projects and other initiatives.

These efforts would benefit from additional research building on this proof-of-concept test. The following projects would help advance the state-of-the-art in the application of AVL and other related technologies, and the provision of real-time information to passengers and potential riders:

- Develop and test a methodology to use archived AVL data for bus scheduling purposes, including varying schedules by time of day and traffic conditions.
- Expand the use of the real-time information system developed in this test to include other delivery methods, such as the METRO website, changeable message signs, and pagers.
- Expand the real-time information system to other routes and transit centers.
- Test the use of CDPD as an interim approach for managing headways on the downtown trolley bus fleet and for providing next bus arrival information to passengers.

## **CHAPTER SIX—ASSESSMENT**

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### **PROJECT OUTCOMES**

This report summarized four transit ITS proof-of-concept tests sponsored by the Texas A&M ITS Research Center of Excellence. These projects were conducted through the coordinated efforts of researchers at TTI and staff at Houston METRO, Brazos Transit, and Texas A&M University PTTTS. In addition, private sector technology vendors assisted with some of the tests. These projects developed, tested, monitored, and evaluated a rural transit AVL system, a paratransit passenger paging system, a bus operator notification system, and a next bus passenger notification system.

The results of the four proof-of-concept tests show that ITS and other advanced technologies can be applied in a range of transit applications. Further, the projects indicate that these technologies can provide benefits to both transit operators and passengers. Researchers encountered some common institutional, operational, and technical issues during many of the tests. These issues are highlighted in this section and the areas for additional research and testing described in the previous chapters are summarized.

In general, the institutional and operational issues encountered with some of the tests related to obtaining approval from the transit agency to participate in the project, maintaining support and involvement throughout the project, coordinating internal activities, and addressing operator concerns. While none of these problems are insurmountable, they do point out the difficulties that may be encountered with the introduction of advanced technologies and new approaches within transit agencies. Given a need to focus on their key mission of operating reliable transit services, as well as limited financial and staff resources, it is not surprising that it is often difficult for transit operators to participate in tests and demonstration projects. Keeping requests to a minimum, making the process as convenient as possible, and focusing on key issues and elements that will be of greatest benefit all appear to enhance the chances of support and participation from transit agencies.

As could be expected, technical problems were encountered during the course of all four tests. Difficulties emerged in some cases with new applications of existing technologies, while in other cases the problems resulted from attempts to integrate multiple technologies to perform new functions. For the most part, researchers were able to address the technical problems encountered. The experiences reinforced the point that technical issues are likely to emerge with these types of projects, however.

### **AREAS FOR FURTHER RESEARCH**

As noted in the previous chapters, although the four tests indicate that ITS can be successfully applied in a range of transit applications, additional research and testing is needed before the full deployment of many of these applications can occur. The following areas for further research and testing are suggested to help advance the deployment of transit ITS projects.

- Conduct, monitor, and evaluate additional demonstrations using AVL systems with rural transit operators. Further projects are needed to build on the limited experience gained in this proof-of-concept test. These demonstrations should focus on further testing the AVL and GIS system components and on the actual use of AVL by transit operators.
- Link AVL technologies with paratransit scheduling software and test with a rural transit system. Based on the initial review of the potential to link the AVL system with transit routing and scheduling packages made during the project, it appears that these systems can be integrated, further benefitting rural and small city transit providers.
- Test the use of real-time vehicle data to enhance transit services. Numerous opportunities appear to exist to use the AVL-generated information to enhance services and passenger convenience once the systems have been introduced into the daily operation of rural transit providers. For example, the AVL information could be used to notify a doctor's office of the specific arrival time of a patient. Testing the use of AVL information for these types of service enhancements would be of benefit to passengers and operators.
- Integrate VANS into a paratransit service provider scheduling and dispatching system allowing changes in trip schedules to be automatically reflected in VANS.
- Conduct a series of tests and demonstrations of the integrated VANS with AVL equipped vehicles in different settings. Possible demonstrations could include an expanded test with the Texas A&M University paratransit system, a rural transit operator, and paratransit systems in urban areas in Texas.
- Conduct tests using different methods to provide the notification information to passengers. In addition to the pagers used in this project, other possible technologies to test include regular and cellular telephones, computers, and personal information devices.
- Relocate the sign to a position on the HOV lane further in advance of the exit to the transit center. Additional tests could be conducted with different sign locations and increases in the illumination of the sign.
- Develop and test a vehicle-based notification system using the bus radios and MDTs.
- Develop and test a notification system after the METRO AVL system is fully operational.

- Develop and test a methodology to use archived AVL data for bus scheduling purposes, including varying schedules by time of day and traffic conditions.
- Expand the use of the real-time information system developed in this test to include other delivery methods, such as the METRO website, changeable message signs, and pagers.
- Expand the real-time information system to other routes and transit centers.
- Test the use of CDPD as an interim approach for managing headways on the downtown trolley bus fleet and for providing next bus arrival information to passengers.





## APPENDIX – NEXT BUS PASSENGER NOTIFICATION TEST - SURVEY RESULTS

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This survey is being undertaken by the Texas Transportation Institute for Houston METRO. The survey is intended to obtain information about your impression of the display of real-time bus arrival information at the Heights Transit Center. This demonstration is only intended to assess the content and display of the information. The actual device and/or kiosk that will ultimately be used has not been determined. Please take a few minutes to answer the following questions and return this form to the survey taker before boarding your bus.

1. What is the purpose of your trip? **52% Work 36% School 12% Other**
2. What is the nearest street intersection to your home (or your home address)? \_\_\_\_\_
3. What is your final destination on this trip? **26% Downtown 14% Medical Center 3% Galleria Area 57% Other**
4. Why do you choose to ride the bus? (Please check all that apply)  
**19% More convenient than driving 15% Cheaper than driving 80% No car available  
2% Employer pays part of the fare 10% Environmental concerns 4% Other**
5. How did you get to the Transit Center? **6% Dropped off 26% Walked 68% Transferred from another route**
6. Did you participate in a previous survey that described the real-time bus arrival display demonstration at the Heights Transit Center? **27% Yes 71% No 2% No Response**  
If Yes, is the demonstration what you expected? **18% Yes 3% No 79% No Response**
7. Do you think it is helpful to know when your bus will actually arrive? **97% Yes 2% No, the published schedules are sufficient. 1% It doesn't matter to me.**
8. Does the display give you the information you desire? **93% Yes 7% No**
9. Is the display easy for you to understand? **98% Yes 2% No**
10. If you knew when the bus would actually arrive, would you be more comfortable while waiting? **95% Yes 2% No 3% It doesn't matter.**
11. How frequently do you ride the bus? **86% Daily 9% 2-3 times per week 3% Less than once per week 2% No Response**
12. How would your frequency of riding the bus change as a result of knowing when the bus would actually arrive? **50% I would ride more frequently. 13% It would probably not change. 44% I might make other trips that I do not already make.**
13. What route are you going to board from this Transit Center today? **26% 34 Montrose 32% 8 Main 23% 26/27 Outer/Inner Loop 19% 65 Bissonnet/Yale**
14. What is your Sex? **38% Male 52% Female 10% No Response**  
What is your Age **20% 18 or under 20% 18-24 20% 24-35 20% 35-50 19% 50-65 1% Over 65**