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16. Abstract

This report documents the development of an Automatic Vehicle Identification (AVI) system for monitoring traffic conditions on urban freeways. The AVI system is being implemented in Houston in a stage construction program. Phase 1 covers 60 miles of urban roadways on three radial freeways. The report outlines the system design and the hardware and software requirements for measuring travel times and average speeds and processing and distributing the results in real time (with one minute of detection).

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DESIGN AND IMPLEMENTATION OF AUTOMATIC VEHICLE IDENTIFICATION TECHNOLOGIES FOR TRAFFIC MONITORING IN HOUSTON, TEXAS

ANNUAL RESEARCH REPORT

by

Dennis G. Smalley
Research Associate
Texas Transportation Institute

Dan R. Hickman
Research Associate
Texas Transportation Institute

and

William R. McCasland, P.E.
Research Engineer
Texas Transportation Institute

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Research Study Title: Development and Implementation of an Automatic Vehicle Identification (AVI) System for the IH-10 (Katy), IH-45 (North), US 290 (Northwest) Freeways and High Occupancy Vehicle (HOV) Lanes — Phase 1

Sponsored by the
Texas Department of Transportation

November 1995

TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas 77843-3135

IMPLEMENTATION STATEMENT

This project identifies a number of valuable institutional, operational, and logistical lessons related to developing a real time travel information program. The use of the Automatic Vehicle Identification (AVI) technology for gathering, processing, and analyzing data was found to be an effective and timely procedure.

The time required to install an AVI system to monitor long sections of freeway was much less than the conventional traffic surveillance systems. With sufficient numbers of vehicles equipped with electronic tags, accurate travel time information could be updated each minute during peak travel times and three to five minutes during off peak travel times. The travel time results from the AVI system are easily disseminated to the public through various information systems and to the operating agencies over computer networks.

The project results present a fully implemented traffic information system that can be duplicated in other cities.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation. It is not intended for construction, bidding, or permit purposes. The engineer in charge of this project was William R. McCasland, P.E. #21746.

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SUMMARY

GOAL

The goal of the project was to develop a traffic monitoring system that could be installed in a short time period over a large network of freeways at a reasonable cost. The purpose was to provide timely information on the traffic conditions on the freeway, toll road, and High Occupancy Vehicle Lane (HOVL) system and make this information available to the traveling public from the Houston Interim Traffic Management Center by way of radio reports (traffic service companies) and roadside changeable message signs. Motorists could then select a route or mode of travel that would reduce their travel time.

OBJECTIVE

Specific objectives of the project were to:

- provide an electronic traffic monitoring system that utilizes an automatic vehicle identification (AVI) system using radio frequency identification (RFID) technology;
- select a system compatible with other Houston area transportation agencies operating or developing similar transportation monitoring technologies;
- require that all necessary electronic field equipment be installed above the traffic to minimize the inconvenience to the traveling public; and
- require that the AVI system meet operational requirements for vehicle tag read accuracy and field data transmission during a test phase.

CONCLUSIONS

The selection of Amtech System Corporation to provide the electronic technology for the project proved successful in achieving the requirements set forth by the TxDOT/TTI study staff during installation and testing phases of the project.

Compatibility with the Harris County Toll Road Authority (HCTRA) automated toll collection program and other statewide Amtech installations provided access to over 50,000 vehicles with transponder tags. The more transponders that are available in the traffic stream, the more frequently the data base is updated.

Benefits of the AVI system are difficult to measure directly because its purpose is to provide information to the public by which travelers can make decisions as to the route and timing of their trips. The AVI system has demonstrated that it can be a good source of information in identifying operational problems on the freeway, toll road, and HOVL system.

INTRODUCTION

Passage of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) provided a new direction for transportation system development and operation in the United States. With completion of the Interstate Highway System, the focus of national transportation policy shifted to multimodal approaches which use existing and upgraded facilities efficiently. One of the new programs included in ISTEA to address this new direction is the Intelligent Vehicle-Highway System (IVHS) [now known as the Intelligent Transportation System (ITS)]. This program provides research and implementation funding for application of advanced technologies to the operation of transportation systems. The essence of ITS is to make improvements in mobility, highway safety, and productivity by improved transportation systems that apply advanced traffic control concepts, electronic technologies, and computer science. Thus, the new direction moves away from expansion of roadway systems by construction of new highways and toward improvements in operation of existing facilities and transportation services.

The ITS legislation challenges major urban areas to develop new approaches to minimizing peak period traffic congestion. One approach affects shifts in traffic demand in either space (route diversion), time (adjustments in time of departure), or travel mode (shifts to bus or carpool), with the traveler's decision based on real time travel information. For trip pre-planning or in-progress trip changes to be meaningful, accurate and timely information on travel times, speeds, and roadway conditions must be available in easy-to-use formats.

In 1992, the Houston District of the Texas Department of Transportation (TxDOT) introduced the "Real Time Information Program" (RTIF) and contracted with Texas Transportation Institute (TTI) to develop necessary hardware and software systems. The program encompasses five phases. Phase 1, 2, and 3 (Figure 1) provide coverage of the central freeway system in the Harris County area. Phase 4 provides special applications of AVI for monitoring incident detection, HOV bus operations, and shuttle bus operations. Phase

Figure 1. AUTOMATIC VEHICLE IDENTIFICATION (AVI) SYSTEM ANTENNA/READER STATION LOCATION AND PHASE CONSTRUCTION

5, which is not yet approved for implementation, expands the system on the Sam Houston Toll Way and provides initial installation on Beltway 8. Phases 1 and 2 are operational at the time of this report, November 1995, and the reader sites are identified in Figure 1.

PROGRAM NEED AND PURPOSE

The purpose of the program is to measure the travel time and average speed conditions of the freeway, toll road, and HOVL roadways and to relay this information back to the public in a timely manner by way of radio reports, roadside message signs, and other communication techniques. This information enables an individual to select an alternate route or different mode of travel, if the traveler can determine that the usual route is experiencing delay. Anticipated results reduce delay for the diverted traffic as well as congestion on the primary route. A TxDOT demonstration project conducted by TTI in 1991 (1) using cellular phones to provide traffic data proved the viability of developing real time information systems.

PROGRAM TECHNOLOGY

The RTIF program utilizes an Automated Vehicle Identification (AVI) system as one of the technologies for monitoring traffic conditions. AVI antennas and readers mounted on existing roadway structures monitor the passage of the vehicles equipped with transponder tags. A transponder tag, which is powered by a small battery, reflects encoded radio signals transmitted from the antennas/readers. The reflected signals are modified by the identification code of the tag so that the tags information can be read by the antenna/reader system.

The antennas/readers are installed along the freeway, toll road, and HOVL system at approximately five kilometer intervals. As a vehicle with a transponder tag attached to the windshield passes the antenna/reader stations, the antenna/reader activates (reads) the encoded message on the transponder tag. The message transmits over telephone lines to a computer in the Interim Traffic Management Center. The message identifies the transponder number, location of the reader, and time of day. As a vehicle passes successive AVI reader locations along a route, software determines accurate travel times and average speeds. System design

requires field information be transmitted to the computer within one minute. This "real time" information is then processed and formatted in tables and maps (Appendix A) and is made available to the general public and any appropriate transportation agencies.

TRAFFIC PROBES

A critical element in the development of the AVI project was the recruitment of 4,200 citizen volunteers to serve as traffic probes as they travel along the freeway, toll road, and HOVL system. By agreeing to place a transponder tag on the windshield of their vehicles, the volunteers provided the traffic data necessary for continuous updates of traffic conditions. The Phase 1 contract (I-45N, I-10W, US 290) provided for 1,000 tags and the Phase 2 contract (I-610, US 59, Hardy Toll Road, I-45S) provided for 3,200 tags.

Recruitment of citizen volunteers required more time and effort than first anticipated. The misconception that the tag is an electronic locating or tracing device contributed to participant reluctance. Concerns that the AVI system would be used by law enforcement agencies for controlling vehicle speeds on the freeways also contributed to participant reluctance. Recruitment efforts included contacting large employers, seeking publicity through the news media, and advertising on roadside message signs.

FUNDING

Funding for the five phases of the program involves both state and federal funds. Phase 1 used funds from the State Public Transportation Program. The use of these funds were justified because the freeways in Phase 1 included the HOVLs located in the center of the freeway mainlanes. The AVI system provides direct comparison of travel conditions on the two types of roadways. The availability of these funds accelerated the implementation of Phase 1. These funds were authorized by TxDOT Commission Minutes Number 91350, dated February 26, 1991.

SYSTEM DESIGN

GENERAL GUIDELINES

Project staff planned to develop a traffic monitoring system that could be quickly and easily implemented on the freeway, toll road, and HOVL system with minimum inconvenience to the motoring public.

Companies throughout the United States that provide Automatic Vehicle Identification (AVI) electronic detection systems were contacted. Researchers invited representatives to make presentations and provide material explaining their technology. TxDOT/TTI study staff established and presented the following installation and operational requirements to interested companies.

1. Antennas are to be installed above the traffic. An above ground AVI system will utilize existing sign and roadway structures. Installation of in-pavement detection sensors is considered cost prohibitive because of the freeway lane closure requirements and resulting traffic congestion.
2. The system design must be capable of 95% accuracy. That is, 95% of vehicles equipped with transponders will be identified by the AVI system when operating at maximum freeway conditions of high volume and high speeds.
3. The system must be responsive. The system must have the capability to transmit field data to a traffic management center within one minute after the transponder has been read.

Because electronic monitoring of transportation is a relatively new science in this country, the TxDOT selection team felt that a company with longevity and a successful track record was a crucial element in the selection process. State law permits the selection of an equipment supplier (vendor) as sole provider on this type of project upon approval of the Department of Information Research Office in Austin. The contract to install the equipment must be awarded on the basis of competitive bidding.

After review and evaluation of the companies that presented their qualifications, the team selected the Amtech Systems Corporation technology for this project.

Amtech was selected because of its experience in implementation of similar systems in Texas, Oklahoma, and Louisiana with good reports from these locations. Critical to the selection was the use of Amtech technology by the Harris County Toll Road Authority (HCTRA) for their toll tag program and the planned use of Amtech technology by the City of Houston Aviation Department for traffic management at the two city airports. This compatibility of technologies has provided thousands of additional probe vehicles traveling the freeway mainlanes and HOVLs. As of September 1, 1995, over 40,000 toll tags had been issued by HCTRA.

Amtech's Automatic Vehicle Identification (AVI) system uses radio frequency identification (RFID) technology. The system consists of vehicle transponder tags, antennas, RF modules, and software. Transponder tags are small, battery powered, electronic devices that reflect and modify received continuous radio wave signals. Antennas broadcast and receive radio frequency signals generated by RF modules. Readers receive the signal from the antennas and RF modules, and transmit the data to a host computer. Telephone lines were selected to transmit the data to the Interim Transportation Management Center. The use of telephone communications provided flexibility of coverage on any freeway and allowed quick implementation of the program. To date, the use of telephone communication has proven to be reliable.

The acceptance of Amtech as provider of the technology hardware was contingent upon its system meeting the outlined requirements in the testing phase of the contract. Amtech was responsible for providing the necessary computer software and field equipment to meet these requirements.

SYSTEM IMPLEMENTATION

PRE-BID CONFERENCE

A pre-bid conference, attended by both vendors (product suppliers) and construction contractors (installers), was conducted on Phase 1 by the Houston District of TxDOT on February 2, 1993. The conference gave prospective bidders an opportunity to review the project plans and specifications.

CONTRACT AWARD

Following the recommendation of the General Services Commission to TxDOT, a contract award was made to the team of Amtech Systems Corporation and Florida Traffic Control Devices Company in the amount of $1,894,160 on March 29, 1993. This was the only bid received and required the approval of the General Services Commission.

INSTALLATION OF SYSTEMS

The project required a close working relationship between the contractor and the TxDOT/TTI staff. Continuous preliminary testing of computer software programs and field equipment during installation was necessary to meet the functional requirements of the contract.

Installation of Phase 1 of the AVI system began in June 1993 and was completed in October 1993, although many adjustments were made after this date. The installation proceeded in stages starting with I-45 North Freeway, then US-290 Northwest Freeway, and finally I-10 Katy Freeway.

Team members experienced several software and equipment problems during and after installation of the system. The main delay in beginning operation of the system resulted from delayed completion of the central software which collects data from each of the field reader

stations. This software, called the "Transaction Collecting, Storing, and Forwarding System" (TCSF) was being developed by Amtech. As an interim solution, the I-45 North Freeway was operated using Amtech's Tag Information Management System (TIMS) software executing on a 80486 micro computer until the new TCSF software was completed. The TIMS software was not designed to handle the large number of tag reads produced by the AVI system, so only data from the I-45 North Freeway portion was collected in an attempt to reduce the number of readings. Near the beginning of operation, time clocks in the field reader station computers did not stay synchronized, making the collected data invalid. Technicians corrected this problem by programming the central AVI computer to set the field reader station time clocks each time the reader station computers called in.

The TCSF software package became operational the week of October 25, 1993. This allowed collection of data from the US-290 Northwest Freeway and the I-10 Katy Freeway as well as the I-45 North Freeway. The Houston AVI system was the first installation of the TCSF software program by Amtech. As a result, many system problems had to be corrected during the installation of the software. Several of these problems and their solutions are listed below.

- **Problem:** The TCSF system would fail whenever certain types of tags, used mainly by freight truck lines, were processed by the system.
  Solution: Amtech modified their software program to correct this problem after the system became operational.
- **Problem:** The TCSF software failed at what seemed to be random intervals.
  Solution: Amtech created a software program which automatically restarted the TCSF software if it failed. Eventual refinement of the TCSF software by Amtech solved the system failure problem.
- **Problem:** The TCSF software data processing would periodically fall behind schedule.
  Solution: This happened during the morning peak period and is believed to be a symptom of a problem with the daily archival of data that takes place each

morning at 1:00 a.m. This problem was corrected in the revised version of the software program.

- **Problem:** Other problems were encountered with the field equipment and caused communications to be lost to field reader station computers. Communications were lost to an average of 0.8 sites per day from 11/1/93 until 2/22/94. Some of these problems were due to circumstances beyond the control of Amtech such as power loss and telephone service loss, but the majority were unexplained failures. Usually, if the telephone modem at the field reader station was reset, communications would continue normally.

  Solution: Some of the problems were determined to be with the Radio Frequency (RF) modems used at most sites to communicate data from the reader station to a site off the roadway where telephone service was more accessible. These devices sometimes seem to fail during bad weather. After the modem was reset, communications would continue normally. The solution to this problem came unexpectedly, when the field reader station computers were programmed on 2/22/94 to call in every 30 minutes to verify operation. This reprogramming seemed to fix many of the communication problems. From 2/23/94 until 5/22/94, communications losses dropped to an average 0.3 sites per day and most of these were due to factors outside the control of Amtech.

DISTRIBUTION OF TRANSPONDER TAGS

Researchers sought to enlist volunteers to serve as traffic probes through:

- corresponding with large employers;
- seeking news media coverage; and
- displaying changeable message signs and trailer message signs along the freeways.

Company Response

Only three company representatives contacted the project office to say that they would distribute information about the program to their employees. It could not be determined if the other companies had made the information available to their employees.

In a followup effort, researchers contacted 90 additional companies located throughout the Houston area. A revised letter (Appendix D) was directed to the company Employee Trip Coordinator (ETC). To meet the Environmental Protection Agency's air quality guidelines from Harris County companies of 100 or more employees are required to designate a company ETC to develop various strategies (carpool, transit use, etc.) for their company employees designed to reduce single occupancy vehicle commuter trips. The total potential citizen contacts through these 90 companies was approximately 180,000. Again the results were disappointing. Sixteen company ETC's contacted the project office to say that they were making the information available to employees. Other companies may make the information available to their employees without contacting the project office.

Of the 4,000 volunteers participating In Phase 1 and 2 of the AVI program to date, 1,200 were recruited through private company contact.

News Media Efforts

In an effort to distribute tags in bulk, the main emphasis on recruiting volunteers was initially placed on contacting large employers, first in the Central Business District (CBD) and later, citywide. The ten major employers in the CBD were contacted by letter (Appendix B). A flyer describing the program was included (Appendix C) in the mail-out. Contacting these ten companies had the potential of reaching nearly 100,000 citizens.

Researchers sent this letter to the four major television stations in the Houston area, believing that inviting their employees to participate would prompt the television stations to provide publicity about the program. However, it was not until the Interim Traffic

Management Center became operational that the stations did stories about the Center, which included the Real Time Information Program.

Message Signs

The most successful method of recruiting volunteers was the use of TxDOT's changeable message signs and trailer message signs. Changeable message signs are electronic signs strategically located along the freeway system. These signs are permanent installations and the messages are encoded from the Interim Traffic Management Center. Trailer message signs are portable signs that can be placed at specific locations. The message on these signs are placed by hand. The message on both types of signs stated that freeway travel volunteers were needed and identified the TTI office telephone number.

This method was time consuming because of the many phone calls to be processed, but it allowed for a more detailed explanation of the program and provided an opportunity for the individual to ask questions. A total of 2,200 volunteers were recruited in this manner.

Miscellaneous Recruitment

Various recruiting methods obtained the remaining volunteers. TTI personnel advertised the program in their booth at the last two annual Houston Auto Shows. TTI sponsored a booth and presented the program at the 1993 Transportation Appreciation Day.

As the program progressed, the TTI office began receiving calls from people who heard of the program by word of mouth. TTI also placed a notice on Internet's World Wide Web (Appendix E). People with personal computers can access this notice and the traffic map and can e-mail the TTI office to volunteer. A total of 123 people volunteered through the Internet to be probes. To date, volunteers recruited under these various methods numbers 600.

Recruitment Incentives

The primary recruiting inducement to participate in the program is the appeal to the individual to perform a public service. The only direct incentive was the use of the TxDOT tag as a toll tag. The Harris County Toll Road Authority (HCTRA) agreed to waive its $15 deposit and $1 per month service charge for TxDOT tags used as toll tags. TTI estimates that several hundred volunteers are using the TxDOT tags as toll tags. However, the TxDOT AVI traffic monitoring program is now discouraging this practice because:

- it is apparent in many cases that the individual is requesting the TxDOT tag primarily as a toll tag; and
- the traffic monitoring program is getting an adequate number of reads, from both TxDOT tags and HCTRA toll tags, on the freeway mainlanes in the corridors (Phase 1) where the toll roads are located.

For Phases 3 and 4, the AVI traffic monitoring program will identify the exact freeways where travel volunteers are needed and will limit tag distribution to those locations. This incentive will remain available to the volunteers, but only if a person specifically asks about it and his or her primary route is on a needed freeway location. TTI has stayed in contact with HCTRA regarding this incentive and the Toll Tag Department Manager has stated that HCTRA has not had any problems with the program and will continue to honor the incentive unless directed otherwise.

Citizen Response/Attitude

In the personal contacts that staff has had with individuals, the ones who refused to participate gave consistent reasons: they did not want an electronic device on their vehicles that could be used to locate or trace their locations. There is a segment of society that feel that "Big Brother" (government) is infringing too much in their personal lives. Even with assurances that the AVI tag could only be activated and read by the antenna/reader stations along the designated roadway system, many people would not participate because they were

concerned that their vehicles could be located or traced anywhere in Harris County. Others, while apprehensive at first, did agree to participate after an explanation of the program.

To offset this reluctance, staff informed skeptical individuals that they did not have to give their addresses or even their names. They could come to the office to pick up a tag. This forthright approach seemed to convince individuals that the program simply measured the operating condition of the freeway system. Thus far, all persons who have agreed to participate have also given their name to the program.

Another question asked by prospective volunteers was, "Will I receive a traffic ticket in the mail?" Volunteers were assured that no traffic citations would be issued based on speeds measured by the AVI system. Given this explanation, no one has refused to participate because of this concern.

Tags are distributed by mail, and an accompanying packet includes an instruction sheet (Appendix F) and tag position template (Appendix G). Participants are advised that the program will last from three to five years, but volunteers may quit at any time for any reason. Upon request, the individual is provided a self-addressed, stamped envelope to return the tag. To date, only 23 tags have been returned. Reasons given by these individuals for leaving the program were that they were leaving town or no longer traveled the freeway system. These tags were reissued to new volunteers.

Participants reported eight tags lost or stolen. Four were lost when the participants forgot to remove the tags when purchasing a new car. Two tags were reported stolen from the vehicles. Two tags were destroyed by the participants' dogs (Rottweiler and German Shepherd). The tags apparently resembled their favorite chew toy and the dogs grabbed the tags from the kitchen table/bar prior to the tags being placed on the vehicles. Two individuals returned their tags because they did not like the looks of the tag from outside their cars.

To date, the volunteers seem to be following instructions regarding placement of the tags on the inside of the windshield. No one has called claiming the tag broke their windshield wipers as has happened with HCTRA toll tags.

In one incident, a woman claimed that when she passed by one of the reader stations, and the tag was read, it caused a crack in her windshield. She brought her vehicle to the project office for inspection. It was apparent that the crack was caused by a small pebble that hit the windshield in the area of the tag. The woman was adamant that the tag had caused the crack and demanded that the project buy her a new car because she thought a new windshield would not fit properly. She was advised to contact the Houston District of TxDOT, by letter, with this request. This incident was reported to the Houston District of TxDOT by memorandum dated September 27, 1994, and no further action has been taken.

There has been only one serious complaint involving the ability of the TxDOT antennas/readers to read Harris County Toll Road Authority (HCTRA) toll tags on the freeway mainlanes. Several people with toll tags called expressing the concern that readings were being done without their permission. An explanation of the program and their contribution to it satisfied most of the callers. On March 10, 1995, a woman called and was indignant that her toll tag was being read without her permission and wanted it stopped. She was told that her tag number could be masked out so that it could not be read in the TxDOT program. This was confirmed by a Amtech representative. She replied that she wanted to think about it. Two days later she called and gave permission for her toll tag to be read in the program.

Probe/Tag Read Distribution

All Automatic Vehicle Identification (AVI) tags or toll tags that utilize the Amtech technology can be read in the Real Time Information Program. Agencies and private companies represented in the program are as follows:

- HCTR—Harris County Toll Road Authority;
- HJBT—J.B. Hunt Trucking Company;

- MTRO—TxDOT tags on METRO buses;
- OTA—Oklahoma Turnpike Authority;
- OTHR—All other tags (approximately 20 sources); and
- TXDT—TxDOT tags excluding METRO buses.

The following tables identify the number of probes and reads for the week of August 7, 1995, for AVI Phases 1 and 2. Table 1 identifies the total number of probes by freeway and agency/company for the week. Depending on trip length and direction, an individual probe can be identified on more than one freeway. Table 2 identifies the total number of tag reads by freeway and agency/company for the week. These reads reflect the number of reader stations that an individual probe passes on a trip. Table 3 identifies the total number of individual probes by agency/company for the week.

The total number of probes from all sources for the week of August 7th was 37,293 which equals 1,048,253 total reads. This total is consistent with the weekly totals for the last few months, and may be low because of summer vacations. Project staff are pleased with this number of reads and feel that it provides a more than adequate measurement of the operating conditions on the freeway and toll road mainlanes during peak hours and an adequate measurement during off-peak hours. The goal of one tag read per minute is being attained on the high volume freeways during peak hours of operation. The tag read frequency for the peak hours of operation on the HOVL is 2-3 minutes during peak hours of operation.

To improve read time, efforts are being made to increase traffic probe participation on the HOVLs. However, because of the relatively low volume and low congestion on the HOVLs, the read time of 2-3 minutes provides an acceptable measure of traffic conditions. At present, there are 700 traffic probes for all the HOVLs. This includes 400 METRO buses that operate on the lanes. The HOVLs are restricted to two and three plus vehicle occupancy. To get a daily read, all members of the carpool must have a tag. Again, some members will participate and others will not.

TABLE 1. NUMBER OF PROBES BY FREEWAY FOR WEEK: 08/07/95 TO 08/11/95									
PHASE	FREEWAY		TAG TYPE						TOTAL
			HCTR	HJBT	MTRO	OTA.	OTHR	TXDT	
AVI PHASE 1	I-10 Katy	Frequency	14333	186	175	976	486	881	17037
		Percent	13.29%	0.17%	0.16%	0.91%	0.45%	0.82%	15.80%
		Row Pct	84.13%	1.09%	1.03%	5.73%	2.85%	5.17%	
		Col Pct	15.83%	15.36%	21.90%	15.55%	15.77%	14.84%	
	US-290 NW	Frequency	10522	117	88	406	219	649	12001
		Percent	9.76%	0.11%	0.08%	0.38%	0.20%	0.60%	11.13%
		Row Pct	87.68%	0.97%	0.73%	3.38%	1.82%	5.41%	
		Col Pct	11.62%	9.66%	11.01%	6.47%	7.11%	10.93%	
	I-45 North	Frequency	12207	244	114	1473	401	745	15184
		Percent	11.32%	0.23%	0.11%	1.37%	0.37%	0.69%	14.08%
		Row Pct	80.39%	1.61%	0.75%	9.70%	2.64%	4.91%	
		Col Pct	13.49%	20.15%	14.27%	23.47%	13.01%	12.55%	
AVI PHASE 2	US-59 Eastex	Frequency	4206	126	51	694	340	262	5679
		Percent	3.90%	0.12%	0.05%	0.64%	0.32%	0.24%	5.27%
		Row Pct	74.06%	2.22%	0.90%	12.22%	5.99%	4.61%	
		Col Pct	4.65%	10.40%	6.38%	11.06%	11.03%	4.41%	
	Hardy Toll	Frequency	9309	7	0	126	62	236	9740
		Percent	8.63%	0.01%	0.00%	0.12%	0.06%	0.22%	9.03%
		Row Pct	95.57%	0.07%	0.00%	1.29%	0.64%	2.42%	
		Col Pct	10.28%	0.58%	0.00%	2.01%	2.01%	3.97%	
	I-45 Gulf	Frequency	5558	34	72	366	217	612	6859
		Percent	5.15%	0.03%	0.07%	0.34%	0.20%	0.57%	6.36%
		Row Pct	81.03%	0.50%	1.05%	5.34%	3.16%	8.92%	
		Col Pct	6.14%	2.81%	9.01%	5.83%	7.04%	10.31%	
	Loop 610	Frequency	18782	400	172	1698	996	1428	23476
		Percent	17.42%	0.37%	0.16%	1.57%	0.92%	1.32%	21.77%
		Row Pct	80.01%	1.70%	0.73%	7.23%	4.24%	6.08%	
		Col Pct	20.75%	33.03%	21.53%	27.05%	32.32%	24.05%	
	US-59 SW	Frequency	12426	85	127	437	346	990	14411
		Percent	11.52%	0.08%	0.12%	0.41%	0.32%	0.92%	13.36%
		Row Pct	86.23%	0.59%	0.88%	3.03%	2.40%	6.87%	
		Col Pct	13.73%	7.02%	15.89%	6.96%	11.23%	16.67%	
	Beltway 8	Frequency	3177	12	0	101	15	135	3440
		Percent	2.95%	0.01%	0.00%	0.09%	0.01%	0.13%	3.19%
		Row Pct	92.35%	0.35%	0.00%	2.94%	0.44%	3.92%	
		Col Pct	3.51%	0.99%	0.00%	1.61%	0.49%	2.27%	

Tag Types:

HCTR—Harris County Roll Road Authority
HJBT—J.B. Hunt Trucking Company
MTRO—TxDOT tags on METRO buses
OTA—Oklahoma Turnpike Authority
OTHR—All other tags
TXDT—TxDOT tags excluding METRO buses

TABLE 2. NUMBER OF READS BY FREEWAY FOR WEEK: 08/07/95 TO 08/11/95									
PHASE	FREEWAY		TAG TYPE						TOTAL
			HCTR	HJBT	MTRO	OTA.	OTHR	TXDT	
AVI PHASE 1	I-10 Katy	Frequency	117903	1172	5447	5353	1507	8511	139893
		Percent	11.25%	0.11%	0.52%	0.51%	0.14%	0.81%	13.35%
		Row Pct	84.28%	0.84%	3.89%	3.83%	1.08%	6.08%	
		Col Pct	13.11%	15.88%	22.74%	15.75%	15.41%	11.48%	
	US-290 NW	Frequency	107761	655	2194	2029	593	10437	123669
		Percent	10.28%	0.06%	0.21%	0.19%	0.06%	1.00%	11.80%
		Row Pct	87.14%	0.53%	1.77%	1.64%	0.48%	8.44%	
		Col Pct	11.99%	8.87%	9.16%	5.97%	6.06%	14.07%	
	I-45 North	Frequency	115763	1805	5599	9368	1522	10748	144805
		Percent	11.04%	0.17%	0.53%	0.89%	0.15%	1.03%	13.81%
		Row Pct	79.94%	1.25%	3.87%	6.47%	1.05%	7.42%	
		Col Pct	12.88%	24.45%	23.38%	27.57%	15.56%	14.49%	
AVI PHASE 2	US-59 Eastex	Frequency	29038	548	1706	3113	832	2789	38026
		Percent	2.77%	0.05%	0.16%	0.30%	0.08%	0.27%	3.63%
		Row Pct	76.36%	1.44%	4.49%	8.19%	2.19%	7.33%	
		Col Pct	3.23%	7.42%	7.12%	9.16%	8.51%	3.76%	
	Hardy Toll	Frequency	166784	36	0	728	151	2550	170249
		Percent	15.91%	0.00%	0.00%	0.07%	0.01%	0.24%	16.24%
		Row Pct	97.96%	0.02%	0.00%	0.43%	0.09%	1.50%	
		Col Pct	18.55%	0.49%	0.00%	2.14%	1.54%	3.44%	
	I-45 Gulf	Frequency	37626	92	2562	1369	570	6259	48478
		Percent	3.59%	0.01%	0.24%	0.13%	0.05%	0.60%	4.62%
		Row Pct	77.61%	0.19%	5.28%	2.82%	1.18%	12.91%	
		Col Pct	4.19%	1.25%	10.70%	4.03%	5.83%	8.44%	
	Loop 610	Frequency	212124	2567	1777	9507	3325	20864	250164
		Percent	20.24%	0.24%	0.17%	0.91%	0.32%	1.99%	23.86%
		Row Pct	84.79%	1.03%	0.71%	3.80%	1.33%	8.34%	
		Col Pct	23.60%	34.77%	7.42%	27.98%	33.99%	28.14%	
	US-59 SW	Frequency	103316	482	4664	2388	1266	11697	123813
		Percent	9.86%	0.05%	0.44%	0.23%	0.12%	1.12%	11.81%
		Row Pct	83.45%	0.39%	3.77%	1.93%	1.02%	9.45%	
		Col Pct	11.49%	6.53%	19.47%	7.03%	12.94%	15.77%	
	Beltway 8	Frequency	8695	25	0	122	16	298	9156
		Percent	0.83%	0.00%	0.00%	0.01%	0.00%	0.03%	0.87%
		Row Pct	94.97%	0.27%	0.00%	1.33%	0.17%	3.25%	
		Col Pct	0.97%	0.34%	0.00%	0.36%	0.16%	0.40%	
	Total		899010	7382	23949	33977	9782	74153	1048253
			85.76%	0.70%	2.28%	3.24%	0.93%	7.07%	100.00%

Tag Types:

HCTR—Harris County Roll Road Authority
HJBT—J.B. Hunt Trucking Company
MTRO—TxDOT tags on METRO buses
OTA—Oklahoma Turnpike Authority
OTHR—All other tags
TXDT—TxDOT tags excluding METRO buses

TABLE 3. NUMBER OF PROBES ON ALL FREEWAYS FOR WEEK: 08/07/95 TO 08/11/95 (AVI PHASE 1 AND AVI PHASE 2)							
FREEWAY	TAG TYPE						TOTAL
	HCTR	HJBT	MTRO	OTA.	OTHR	TXDT	
Frequency	30250	466	310	2623	1597	2047	37293
Percent	81.1%	1.2%	0.8%	7.0%	4.3%	5.5%	100.0%

The total number of TxDOT tags (METRO plus TxDOT) shown in Table 3 is 2,357. The number of TxDOT tags distributed at that time was 3,975. The difference of over 1,600 tags is disappointing. Again, it may be a seasonal problem. However, project staff will begin contacting those volunteers whose tags have not been read in some time to determine their status in the program. A problem in this regard may be the tag battery. To date, Amtech has replaced two tags because of bad batteries. These tags were discovered because they were being used as toll tags and the individuals were contacted by HCTRA. Contacting volunteers to determine their participation in the program may reveal additional battery problems.

Summary of Tag Distribution

Finding the 4,000 volunteers to participate in the program has been a challenge. The reluctance of the average citizen to place a tag on their vehicles' windshield was surprising. The attitude that the tag is a locating or surveillance device has been difficult to overcome. It is interesting to note that those individuals that have access to the traffic map by computer are quick to volunteer for the program. These individuals can access and see what they would be contributing to as volunteers.

Perhaps when the TranStar Center is operational and the general public becomes more familiar and better informed about transportation management programs, the public's attitude about participating in these programs will improve.

SYSTEM TESTING

The AVI system was tested in two different phases: a 30-day acceptance test and a 90-day final acceptance test. The 90-day test included the 30-day test. Each freeway included in the AVI system was tested on an individual basis. During the testing phases, the AVI system was required to read 95% of the tags that passed through detection zones on the freeway. Criteria allowed TxDOT to suspend or restart the tests under conditions such as total failure of a site a certain number of times.

TTI was responsible for evaluating whether the AVI system met the 95% requirement. Daily reports showed statistics used to evaluate the system. Three main methods were used in evaluating the accuracy of the AVI system. The following gives an explanation of each method.

COMPARATIVE READS FROM ADJACENT CHECKPOINTS

The first method used tag reads from surrounding checkpoints to verify whether the system correctly read the tag at a reader station. Under normal conditions, as a vehicle travels through the system, it is detected by field reader locations along its travel route. If there is no detection recorded at a point along the probable route, the vehicle may have gotten off the freeway and not actually passed the detection station, or the vehicle may have passed the detection station but not been detected. Programs were created to analyze the AVI data and determine missing detection points classified as system errors. Although some of these errors may have been vehicles that actually exited the freeway, bypassed the detection station, and then re-entered the freeway to pass the next checkpoint, it was assumed that this type of maneuver would involve a very small percentage of the total vehicles detected.

CONTROLLED COMPARISONS WITH TEST VEHICLES

The above method works well for interior reader stations where there were reader stations both upstream and downstream of the reader station. However, endpoints of the

freeway cannot be checked using this method, since they will not have adjacent checkpoints on either the upstream or downstream sides of the reader station. A second method was developed to check the endpoint reader stations. TxDOT and TTI employees traveling these freeways were asked to record the time, date, and reader station ID as they passed these reader stations. Comparison to the tag read data collected by the AVI system determined if the system had correctly detected the tags.

MONITORING READS FROM ADJACENT ROADWAYS (CROSS READS)

A third method was developed to test for errors caused by antennas reading tags in adjacent roadways. This problem occurred at several locations where antennas which were responsible for detecting vehicles traveling on freeway lanes detected vehicles actually traveling on the HOV lane, and when antennas responsible for detecting vehicles traveling on the HOV lane detected vehicles actually traveling on a freeway lane. This "cross read" causes three potential problems. First, if a vehicle is incorrectly detected at two adjacent reader stations, an incorrect travel time is reported. For instance, if a vehicle was detected at HOV reader station A and HOV reader station B but was actually travelling on the inside freeway lane, the freeway travel time would be reported as the HOV lane travel time. Second, when vehicles are detected by the wrong antenna, data may be lost for that vehicle. Third, if the AVI system is ever to be used as an automatic vehicle location system, this situation would report invalid vehicle locations.

Programs were created to test for occurrences of these "cross reads" by identifying invalid sequences of tag reads. For example, an invalid sequence could include a vehicle reportedly traveling on the HOV lane at one checkpoint, but being reported on the freeway at the next checkpoint when there was no exit from the HOV between detector stations. This indicates that either the HOV detector indicated a vehicle on the freeway at the first checkpoint or the freeway detector detected an HOV vehicle at the second checkpoint. These programs were used to determine reader stations which had these problems.

To solve the "cross read" problems, first the RF power to the antennas was lowered (attenuated) so the RF field would not reach into the other lane. Many times, though, this would cause the antenna to miss many tags in the lane(s) it was intended to read. If attenuation was not successful, the antenna would be physically re-aligned to point away from the unwanted lane. At several locations, the situation was a tradeoff between high "cross reads"/high accuracy and low "cross reads"/low accuracy. A balance of "errors" was determined depending on the potential impact of the "cross reads" on data validity and the potential impact of a lowered number of data points due to less tags being detected.

The error reports showing these analysis were provided to Amtech on a daily basis prior to and during the test periods so that Amtech could identify locations needing maintenance or adjustments.

Communications problems, software development delays, and cross read problems during the 30-day tests resulted in several weeks of delay, extending the 30-day test period. Official testing start and stop dates for AVI Phase 2 are shown in Table 4.

TABLE 4. OFFICIAL TESTING START AND STOP DATES FOR AVI PHASE 2

PERIOD	I-45	US-290	I-10
30-day test begin	12/01/93	12/31/93	12/13/93
30-day test end	02/28/94	03/14/94	03/21/94
(90-day test begin)			
90-day test end	04/30/94	05/12/94	05/20/94

SYSTEM OPERATION

COMPUTER AND SOFTWARE SYSTEMS

The AVI System uses various software elements to automatically gather tag data, compare tag data at successive reader locations to measure the progress of the probes along the roadways, and display the resulting data representing current travel conditions. Most software used in the system was developed specifically for use in this system, although it could be configured to work in similar AVI systems. TTI and Amtech developed separate software elements for TxDOT. Although the development tasks were segmented by function, it was critical that Amtech and TTI work together to implement the software systems. The following sections describe these development efforts.

Amtech Software Development

Amtech was responsible for providing a system to bring each tag read record from the field reader stations to a centralized point and transfer the data to the TxDOT computer system. Communication between the central office and the field reader stations is performed via data modem connections over the public telephone system. At each reader station, a computer, called an Automatic Data Processor (ADP), is used to recognize each tag read, add a time and date stamp to the tag read record, and communicate the tag read to the central site. Amtech used its existing Tag Information Management System (TIMS) software within the ADPs with minor changes. TIMS is the same software used in many of Amtech's automatic toll collection facilities.

In Amtech's toll collection applications, either VAX or PC computers are usually used at the central site to receive incoming tag information. Because of the large load that would be put on the central AVI computer, neither of these systems were found to be suitable in terms of cost and performance. A Sun SPARCstation computer, executing Solaris operating system, was chosen for its price/performance advantage. This was a new computer platform for Amtech, requiring development of new software specific to the Sun computer. This

software was developed by Amtech and is called the "Transaction Collecting, Storing, and Forwarding System (TCSF)." The TCSF software is responsible for processing and storing each tag read record as it is received from the field reader station computers. Tag information is stored within the Sun computer within a local database as well as on shared disk drive storage. This storage of information on the shared disk enables data access by the AVIcalc program described in the next section. The TCSF software also monitors connections to the field reader station computers and issues status messages if communications are lost or error messages are received from a field computer.

The Sun AVI computer includes a multi-port adapter that allows connection of up to 32 modems to receive incoming calls from the ADPs. Eighteen modems were connected to the AVI computer to service 32 ADPs.

TTI Software Development

While Amtech was responsible for bringing all tag read records to a central point, TTI was responsible for taking those records from Amtech's software and processing them to create useful travel time and speed information which traffic management personnel could use. TTI's software development efforts were split into two distinct software programs, the AVIcalc program and the AVIview program. TTI developed these programs using Borland C/C++ programming environment.

AVIcalc is responsible for receiving tag read data from the AVI Sun Computer (described above), processing the data to produce vehicle travel times, identifying and discarding any "bad" or "invalid" data, and forwarding this information to the AVIview programs. The AVIcalc program executes on a single IBM compatible 386DX computer connected to a Novell Netware 3.11 network. AVIcalc receives information from the AVI Sun computer through a shared file which is accessed through the Novell file server. This was made possible by connecting the AVI Sun computer to the Novell Netware server using a special software package called Netware NFS Gateway, which allows computers connected to the Novell file server to access files on the AVI Sun computer.

The AVIview program(s) takes the travel time information provided by the AVIcalc program, calculates average travel speeds, and presents the information to the user in various forms. There are two forms available at this time: tabular format that presents travel times, speeds and a historical plot of data by section; and color coded maps that present average speeds by section for quick identification of conditions.

DISTRIBUTION OF INFORMATION

Travel time and speed information collected by the AVI system is provided, in real time, to personnel of TxDOT, the Metropolitan Transit Authority (METRO) and two traffic reporting companies within the Interim Greater Houston Traffic Management Center (ITMC). Personnel within the Houston TranStar center have access to the AVI data through the AVIview program on their desktop PCs which are connected to the Novell Network. Also included in the Center is a computer with a high resolution 37" computer monitor which allows quick viewing of the AVI map overview screen. The AVI data is used within the ITMC to monitor freeway conditions in order to detect incidents and to gather information needed to inform commuters of congested areas and alternate routes. Two traffic reporting companies have personnel located within the Center. These companies provide traffic reports on many local area radio and television stations. The AVI data can also be viewed in real time by select TTI personnel for operational monitoring of the AVI system.

In December of 1994, TTI developed a system which provides the AVI-map to the public through the World Wide Web portion of the Internet, the international network of computers. The map is updated once every minute so that people with Internet access can view the map at work or at home to better plan their commute. This allows other transportation agencies around the world to learn about Houston's AVI system. TTI's Internet server at address *http://herman.tamu.edu/traffic.html* is used to serve out the AVI map. This site has been one of the most popular internet sites in the Houston Area. A front page article on the traffic map was published in the Houston Chronicle on March 10, 1995, and has been featured in numerous local television news reports. As of August 1995, the Internet traffic

map was being accessed between 1,300 and 1,500 times per day and the number of accesses is steadily growing as more people begin to use the internet.

It is planned that the AVI data will be more widely distributed in the future to allow area transportation agencies, businesses, and citizens to use the information. It is planned that the various traffic reporting companies will be allowed remote access to the information through the AVIview program, enabling them to inform the public through the media. A remote connection already exists at a Harris County building in downtown Houston. A kiosk-type computer was set up with the AVI map in the lobby of that building so commuters could check traffic conditions before leaving work. Remote connections of this type are planned at the TxDOT district office, City of Houston offices, and Metropolitan Transit Authority offices. Research is looking into providing the AVI map to the public through a municipal cable television channel during peak travel times.

The AVI data will be provided to the Smart Commuter system as well. The Smart Commuter project, an ITS operational test, will provide current traffic and transit information to a select group of citizens. The travel patterns of these individuals will be studied to evaluate the usefulness of this type of data in affecting their travel patterns.

The tag read information collected by the AVI system is archived on a daily basis. All AVI data will be stored for use in research studies as historical data. For example, the data has been used by TTI on a research project titled "Quantifying Energy, Air Quality, and Travel Time Reliability Benefits of High Occupancy Vehicle Facilities Using IVHS Technologies."

OPERATION AND MAINTENANCE

The AVI system requires a limited amount of daily system operation. Some areas, though, need regular attention. TTI personnel are responsible for monitoring the AVI system for malfunctions of field and computer equipment detected at the Central Site. Amtech maintenance personnel also monitor these malfunction reports and are responsible for

correcting the problems. If field equipment malfunctions are not corrected, the Amtech Response Center is contacted for an explanation. Amtech is required to correct any problem within 24 hours. Most malfunctions have dealt with communications, although there have been instances of equipment damage due to rain and vehicle accidents. TTI is responsible for the management and archival of all data collected by the AVI system. An automated program backs up the AVI data to magnetic tape storage on a daily basis.

Amtech Systems Corporation provides maintenance of the system under contract with TxDOT.

CLOSURE

SUMMARY

The AVI traffic monitoring project involved some new approaches for contracting TxDOT projects. TxDOT approved the designation of Amtech as the sole provider of the equipment with the provision that the installation, which was more than 50 percent of the total cost, would be awarded by competitive bidding. Designing the communication system presented some challenges: the Southwestern Bell Telephone system was organized such that small areas were represented by area engineers. Since the AVI system covered many miles of freeway, the field contacts for the telephone service involved a large number of telephone representatives.

The design used existing roadway structures as platforms for AVI antennas and, where possible, to support equipment cabinets. These roadway structures varied in composition from concrete and steel roadway bridges to high sign structures of different lengths. The brackets for the antennas had to provide for flexible movement in order to position the antennas for maximum reception.

The communications from the roadway structure equipment cabinet to the telephone service drop was provided by wireless modems, at most locations, to reduce the cost of placing conduit under the freeway service roads and running the copper conductors for long distances.

The solicitation of the general public to serve as probes required more time and effort than first anticipated. The issuance of transponders was essential to providing adequate coverage of all roadways at the critical traffic times during heavy commute hours. The agency's staff contacted commuters through employers, civic groups, and other community meetings. The program was advertised through the media and roadside signs. Part of the reluctance to take part in the project is the fear that AVI monitoring can be used for enforcement. Project staff continually describe how this information cannot and will not be used for that purpose.

BENEFITS

Benefits of the AVI system are difficult to measure directly because the purpose is to provide information to the public on which they can make decisions as to the trip route or the time travellers start their trips. The AVI system demonstrates that it can be a good source of information of the location of problems such as stalled vehicles and accidents that cause slow speeds. Early detection of these events can save hundreds of hours of travel time for each incident.

Another benefit is the availability of true travel time information for planning and design functions. This information is historically collected one or two times per year by driving each section of roadway three or four times each peak period. The AVI system provides continuous travel time information for all peak periods, for every day of the year.

Cost constraints have limited implementation of previous methods of traffic management systems to small sections of the freeway system. This would delay implementation on some freeways from 10 to 15 years. The AVI system design enables a traffic management system to be implemented on the entire freeway/toll road/HOVL system in a short period of time (two to three years) at a relatively low cost (approximately $30,000 per centerline mile).

FUTURE PLANS

At the present time, AVI Phases 1 and 2 are operational and Phases 3 and 4 are approved and will be installed in 1996. AVI Phase 5 is scheduled for implementation by 1998. Depending on the success of the incident detection application in Phase 4, other monitoring stations may be added to decrease the spacing between readers.

Other applications of AVI are scheduled to be tested under the Priority Corridors Program. The main application is to use a "smarter" transponder that provides read/write capabilities and two-way communications from the roadside to the motorists. The first

application will be with large trucks traveling through freeway to freeway interchanges that have reduced speed limits. The AVI system will be used to activate a warning device in the driver's compartment if the truck's speed is too high. Other applications will be investigated to provide general traffic conditions for persons that have the AVI transponders on their vehicle.

Finally, greater emphasis will be placed on the dissemination of the AVI information to the general public in forms that can be received anywhere and that can be easily understood.

REFERENCES

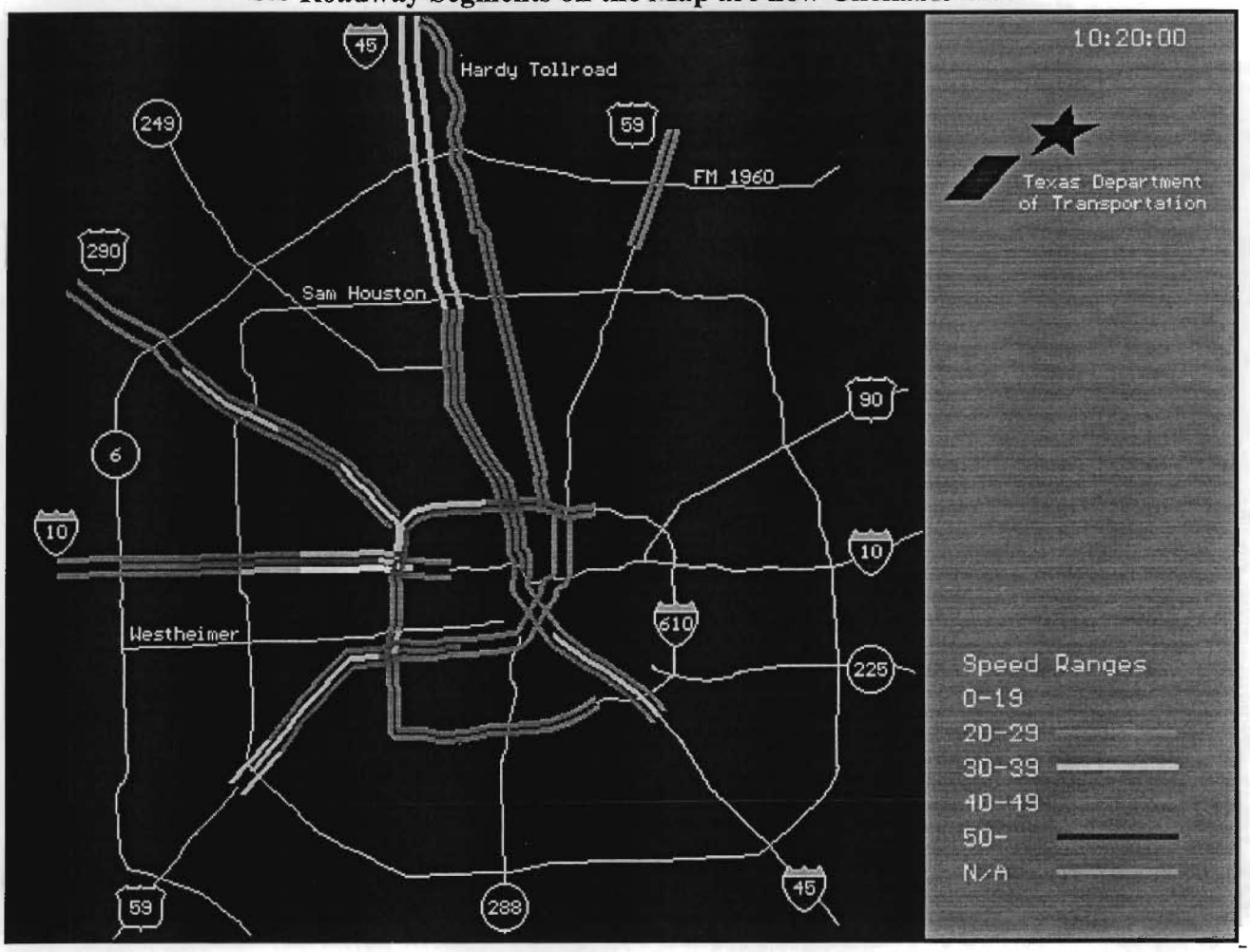
1. Smalley, Dennis G. and William R. McCasland, *A Public/Private Sector Partnership to Provide Traffic Information by Cellular Telephone Reports*, Research Report 1941-1, September 1993.

APPENDIX A

HOUSTON REAL-TIME TRAFFIC MAP AND AVI SYSTEM OPERATOR CONSOLE DATA FOR PHASES 1 AND 2

Houston Real-Time Traffic Map

NEW Roadway Segments on the Map are now Clickable NEW



Brought To You By **Houston TranStar**

Data Source Description | Description of the Map

To update the image map, you must RELOAD

The time stamp in the upper right hand corner of the image is in Central Standard Time. It should correspond to your time within a minute or so. If it doesn't, you need to update the image map.

Most browsers have a RELOAD button or menu option. Some browsers, such as NCSA Mosaic for UNIX, require the use of the RELOAD IMAGES menu option.

Back to Home Page

Comments can be e-mailed to www@ttisys.tamu.edu

AVI System Operator Console 10:23:46

	Last-Data Time	Distance (miles)	Travel Time	Speed (mph)	1 2 3 4 5 6 7
I-10 Katy Freeway EB					
Barker Cypress - Eldridge	10:23	3.95	3:34	66	
Eldridge - Sam Houston Tlwy	10:20	3.65	3:37	60	
Sam Houston Tlwy - Blalock	10:20	2.25	6:23	21	
Blalock - I-610	10:16	4.05	8:03	30	
I-610 - T.C. Jester	10:21	2.45	2:26	60	
TOTAL :		16.35	24:03	40	
I-10 Katy HOV EB					1 2 3 4 5 6 7
SH 6 - Sam Houston Tlwy	10:21	4.40	4:14	62	
Sam Houston Tlwy - Bunker Hill	:	1.55	:	.	
Bunker Hill - Silber	:	4.10	:	.	
Silber - HOV Endpoint	:	1.40	:	.	
TOTAL :		11.45			
I-10 Katy Freeway WB					1 2 3 4 5 6 7
T.C. Jester - N. Post Oak	10:23	2.40	2:34	56	
N. Post Oak - Blalock	10:22	3.65	7:23	29	
Blalock - Sam Houston Tlwy	10:22	2.90	2:56	59	
Sam Houston Tlwy - Eldridge	10:22	2.90	2:49	61	
Eldridge - Barker Cypress	10:23	4.50	3:49	70	
TOTAL :		16.35	19:31	50	

AVI System Operator Console 10:38:36

	Last-Data Time	Distance (miles)	Travel Time	Speed (mph)	1 2 3 4 5 6 7
US-290 Northwest Freeway EB					
Barker Cypress - F.M. 1960	10:37	4.05	3:22	72	
F.M. 1960 - Sam Houston Tlwy	10:35	5.10	5:07	59	
Sam Houston Tlwy - Fairbanks	10:37	1.55	1:25	65	
Fairbanks - Pinemont	10:37	2.90	2:34	67	
Pinemont - 34th Street	10:35	2.45	2:26	60	
34th Street - Dacoma	10:38	1.10	1:06	60	
TOTAL :		17.15	16:00	64	
US-290 Northwest HOV EB					1 2 3 4 5 6 7
West Rd. - Sam Houston Tlwy	:	2.95	:	.	
Sam Houston Tlwy - Fairbanks	:	1.55	:	.	
Fairbanks - Pinemont	:	2.85	:	.	
Pinemont - 34th Street	:	2.45	:	.	
34th Street - Dacoma	:	1.00	:	.	
Dacoma - Old Katy Road	:	1.55	:	.	
TOTAL :		12.35			
US-290 Northwest Freeway WB					1 2 3 4 5 6 7
Dacoma - 34th Street	10:35	1.10	0:57	69	
34th Street - Pinemont	10:35	2.45	2:21	62	
Pinemont - Fairbanks	10:37	2.90	2:38	66	
Fairbanks - Sam Houston Tlwy	10:37	1.55	1:17	72	
Sam Houston Tlwy - F.M. 1960	10:33	4.25	4:05	62	
F.M. 1960 - Barker Cypress	10:36	4.90	4:21	67	
TOTAL :		17.15	15:39	65	

AVI System Operator Console 10:38:36

	Last-Data Time	Distance (miles)	Travel Time	Speed (mph)	1 2 3 4 5 6 7
I-45 North Freeway SB					
Hardy Toll Road - Holzwarth	:	3.70	:	.	
Holzwarth - Richey	:	3.80	:	.	
Richey - Aldine Bender	:	4.85	:	.	
Aldine Bender - Shepherd	10:38	3.60	3:20	64	_____
Shepherd - Crosstimbers	10:37	4.30	4:01	64	_____
Crosstimbers - I-10	10:36	2.90	2:50	61	_____
TOTAL :		23.15			
I-45 North HOV SB					1 2 3 4 5 6 7
Aldine Bender - Shepherd	10:17	3.60	3:21	64	_____
Shepherd - Crosstimbers	10:35	4.30	4:04	63	_____
Crosstimbers - I-10	10:19	3.75	3:55	57	_____
TOTAL :		11.65	11:20	61	_____
I-45 North Freeway NB					1 2 3 4 5 6 7
I-10 - Crosstimbers	10:36	2.90	2:58	58	_____
Crosstimbers - Shepherd	10:36	4.30	4:15	60	_____
Shepherd - Aldine Bender	10:38	3.60	3:31	61	_____
Aldine Bender - Richey	:	4.85	:	.	
Richey - Holzwarth	:	3.80	:	.	
Holzwarth - Hardy Toll Road	:	3.70	:	.	
TOTAL :		23.15			

AVI System Operator Console 10:38:36

	Last-Data Time	Distance (miles)	Travel Time	Speed (mph)	1 2 3 4 5 6 7
US-59 Southwest Freeway SB					
I-610 North - Fannin	10:32	6.25	5:55	63	
Fannin - Hazard	10:37	1.75	2:01	52	
Hazard - Newcastle	10:37	2.50	2:25	62	
Newcastle - I-610 West	10:38	1.35	1:20	60	
I-610 West - Hillcroft	10:38	1.60	1:48	53	
Hillcroft - Bissonnet	10:38	5.10	5:23	56	
Bissonnet - Wilcrest	:	1.20	:	.	
TOTAL :		19.75			
US-59 Southwest HOV NB					1 2 3 4 5 6 7
Bissonnet - I-610 West	:	6.70	:	.	
I-610 West - Newcastle	:	1.35	:	.	
Newcastle - Hazard	:	2.50	:	.	
TOTAL :		10.55			
US-59 Southwest Freeway NB					1 2 3 4 5 6 7
Wilcrest - Bissonnet	:	1.20	:	.	
Bissonnet - I-610 West	10:39	6.70	6:24	62	
I-610 West - Newcastle	10:38	1.35	1:16	63	
Newcastle - Hazard	10:38	2.50	2:18	65	
Hazard - Fannin	10:37	1.75	1:51	56	
Fannin - I-610 North	10:32	6.25	5:42	65	
TOTAL :		19.75			

AVI System Operator Console 10:41:02

		Last-Data Time	Distance (miles)	Travel Time	Speed (mph)	1 2 3 4 5 6 7
I-45 Gulf Freeway	SB					
I-10 - Scott Street		10:37	4.20	4:18	58	
Scott Street - Wayside		10:39	2.55	2:16	67	
Wayside - Woodridge		10:40	1.60	1:27	66	
Woodridge - Broadway		10:38	1.30	1:11	65	
TOTAL :			9.65	9:12	62	
I-45 Gulf HOV	NB					1 2 3 4 5 6 7
Broadway - Woodridge		10:40	1.30	1:21	57	
Woodridge - Wayside		10:32	1.60	1:26	66	
Wayside - Scott Street		:	2.55	:	.	
TOTAL :			5.45			
I-45 Gulf Freeway	NB					1 2 3 4 5 6 7
Broadway - Woodridge		10:39	1.30	1:18	59	
Woodridge - Wayside		10:40	1.60	1:30	64	
Wayside - Scott Street		10:38	2.55	2:09	71	
Scott Street - I-10		10:39	4.20	4:22	57	
TOTAL :			9.65	9:19	62	

AVI System Operator Console 10:41:44

	Last-Data Time	Distance (miles)	Travel Time	Speed (mph)	1 2 3 4 5 6 7
I-610 * Freeway CW					
South Wayside - Scott Street	10:39	3.30	3:14	61	
Scott Street - SH 288	10:40	1.35	1:28	55	
SH 288 - Stella Link	10:39	1.85	1:47	62	
Stella Link - Evergreen	10:39	3.20	2:55	65	
Evergreen - US-59 Southwest	10:40	2.40	2:46	52	
US-59 Southwest - Westheimer	10:25	0.90	0:55	58	
Westheimer - Woodway	10:26	1.80	1:37	66	
Woodway - I-10 Katy Freeway	10:41	1.65	1:33	63	
I-10 Katy Freeway - Ella	10:40	2.30	2:11	63	
Ella - Airline	10:40	2.90	2:57	58	
Airline - Irvington	10:40	1.20	1:13	59	
Irvington - US-59 Eastex	10:39	1.50	1:23	65	
US-59 Eastex - Lockwood	10:41	1.25	1:09	65	
TOTAL :		25.60	25:08	61	
I-610 * Freeway CCW					1 2 3 4 5 6 7
Lockwood - US-59 Eastex	10:39	1.70	1:46	57	
US-59 Eastex - Irvington	10:41	1.50	1:14	72	
Irvington - N Main	10:40	1.50	1:27	62	
N Main - US 290 exit	:	3.00	:	.	
US 290 exit - I-10 Katy Freeway	:	2.20	:	.	
I-10 Katy Freeway - Post Oak	10:40	2.00	1:52	64	
Post Oak - Westheimer	10:24	1.30	1:21	57	
Westheimer - Fournace	10:26	1.30	1:22	57	
Fournace - S Post Oak	10:41	2.55	2:34	59	
S Post Oak - Stella Link	10:40	2.65	2:18	69	
Stella Link - SH 288	10:38	1.86	1:42	65	
SH 288 - Scott Street	10:39	1.05	0:59	64	
Scott Street - South Wayside	10:39	3.65	3:37	60	
TOTAL :		26.26			

AVI System Operator Console 10:42:19

		Last-Data Time	Distance (miles)	Travel Time	Speed (mph)	1 2 3 4 5 6 7
US-59 Eastex 1 Freeway	SB					
McClellan - FM 1960		10:40	2.20	2:18	57	
FM 1960 - Rankin		10:39	2.90	3:03	57	
TOTAL :			5.10	5:21	57	
US-59 Eastex 1 Freeway	NB					1 2 3 4 5 6 7
Rankin - FM 1960		10:39	2.90	2:37	66	
FM 1960 - McClellan		10:41	2.20	1:49	72	
TOTAL :			5.10	4:26	69	

AVI System Operator Console 11:30:13

	Last-Data Time	Distance (miles)	Travel Time	Speed (mph)	1 2 3 4 5 6 7
Hardy Tollroad Freeway SB					
I-45 - Cypresswood	11:26	3.20	2:50	67	
Cypresswood - FM 1960	11:29	2.80	2:55	57	
FM 1960 - Greens	11:28	5.80	5:24	64	
Greens - Aldine-Bender	11:29	1.55	1:14	75	
Aldine-Bender - Little York	11:28	4.20	3:54	64	
Little York - I-610	11:29	3.60	3:04	70	
TOTAL :		21.15	19:21	65	
Hardy Tollroad Freeway NB					1 2 3 4 5 6 7
I-610 - Little York	11:29	3.60	2:51	75	
Little York - Aldine-Bender	11:29	4.20	4:15	59	
Aldine-Bender - Greens	11:29	1.55	1:15	74	
Greens - FM 1960	11:25	5.80	4:49	72	
FM 1960 - Cypresswood	11:28	2.80	2:36	64	
Cypresswood - I-45	11:28	3.20	2:58	64	
TOTAL :		21.15	18:44	67	

APPENDIX B

LETTER TO MAJOR EMPLOYERS INVITING EMPLOYEES TO BE TRAFFIC PROBE VOLUNTEERS

June 30, 1993

FIELD(1)
FIELD(2)
FIELD(3)
FIELD(4)

Dear Sir:

As we move through the 1990s and into the 21st century, the road, street, and freeway systems in the greater Houston area will be strained to meet the projected growth in travel demands while meeting the air quality requirements. To meet this challenge, transportation agencies are studying and developing ways to better manage our roadway system to more effectively maintain traffic flow.

Two programs that show promise in this regard are the development of Intelligent Vehicle Highway Systems and Traffic Management Systems. The essence of these programs is to make significant improvements in mobility, highway safety, and productivity by building transportation systems that apply advanced electronic technologies, computers, and computer software. To obtain the maximum benefits from these type of systems, the private sector and private citizens must become more involved.

The Texas Department of Transportation (TxDOT) recently authorized a project identified as a "Real Time Information Program." This is in keeping with their efforts to maximize the operating efficiency of the existing freeway system. The attached flyer describes the program in detail. The Texas Transportation Institute will conduct the program for TxDOT and success will depend on our ability to recruit volunteers from the private sector.

The first step of the project will install the necessary field equipment (antennas/readers) on I-45 (N), U.S. 290, and I-10 (W). Subsequent contracts will expand the program to the remaining freeway system. The ultimate goal is to have several thousand volunteers (probes) participating in the program.

As a major employer in Houston, you have the opportunity to involve your employees in the program. Additional flyers can be made available for your company bulletin boards. Sign-up sheets (copy attached) and sample tags can be provided for your various departments. The tags will be mailed to the employee's home from our office. A member of your staff may contact me at 686-2971 to discuss the program in more detail.

We hope that we can count on your cooperation as we all strive to improve mobility and air quality in the Greater Houston area.

Sincerely,

Dennis G. Smalley
Research Associate

APPENDIX C

FLYER DESCRIBING PROGRAM AND INVITING CITIZEN VOLUNTEERS

FREEWAY TRAVEL VOLUNTEERS NEEDED!!

HELP SOLVE HOUSTON'S TRAFFIC PROBLEMS

The Texas Department of Transportation (TxDOT) is seeking volunteers to participate in a "Real Time Information Program" on Houston freeways. If you drive to and from work on one of the freeways or HOV lanes, TxDOT needs your help.

The program will use an Automatic Vehicle Identification (AVI) system. The AVI system involves placing a small transponder (tag) on the inside of your vehicle's windshield. The tag is the approximate size of a credit card and is about 1/4" thick. The tag, provided to you at no cost, is read by an antenna/reader as your vehicle passes predetermined stations along your route. This data is transmitted to a computer used to determine traffic conditions on that freeway. These operating conditions of the freeways and HOV lanes are then made available to the general public through message signs and radio traffic reports.

The purpose of the program is to provide "real time" information on traffic conditions to the motoring public so that they can make "informed" decisions on the selection of routes, the times for making the trip, and the mode of the trip.

- Your vehicle cannot be located or tracked by the Central Control office. The tag is activated only when you pass under or near an antenna/reader located on a freeway.
- The tag will not be used for speed control by any law enforcement agency. The program is designed to determine traffic conditions on the freeways only.
- You cannot drive the tollroads free using the tag. You may use this tag to set up an account with the Harris County Toll Road Authority by calling 875-1400.

The Texas Transportation Institute (TTI) will be conducting the program for TxDOT. If you are interested in participating, please contact Dennis Smalley or Dick McCasland at the TTI office (713/686-2971).

This is an opportunity for you to help solve the traffic problems on our freeways in the greater Houston area.

APPENDIX D

LETTER TO COMPANY EMPLOYEE TRIP COORDINATOR SOLICITING TRAFFIC PROBE VOLUNTEERS

May 31, 1994

FIELD(1)
FIELD(2)
FIELD(3)
FIELD(4)

Dear **FIELD(5)**:

Transportation agencies, along with private companies, recognize the impact of forthcoming air quality requirements. The road, street, and freeway systems in the Greater Houston Area will strain to meet the projected growth in travel demands while achieving these requirements. To meet this challenge, transportation agencies are studying and developing ways to better manage our roadway system and more effectively maintain traffic flow. In this regard, the Texas Department of Transportation (TxDOT) is implementing a traffic management program identified as a "Real Time Information Program." Our office will conduct the program for TxDOT.

To be successful, these types of programs require that the private sector and private citizens become more involved. The Real Time Information Program will require the participation of several thousand citizen volunteers.

As your company's Employee Trip Coordinator (ETC), you are busy developing a program that satisfies the air quality requirements for private companies and we are hesitant to impose on your time. However, we are working toward the same goal and would like to ask your help in making information about our program available to your fellow employees.

I have enclosed a transponder tag for display to employees. You may keep this tag for your use or assign it to another employee. I have enclosed a flyer that describes the program in detail. Additional flyers and sign-up sheets can be made available for your company bulletin boards. We are available to present the program to the employees. The program is scheduled to last from three to five years and may be an ongoing program. A participant may stop at any time for any reason. We only ask to make arrangements to return the tag.

We hope that we can count on your cooperation as we strive to improve mobility and air quality in the Greater Houston Area. If you have any questions, please contact me at 686-2971.

Sincerely,

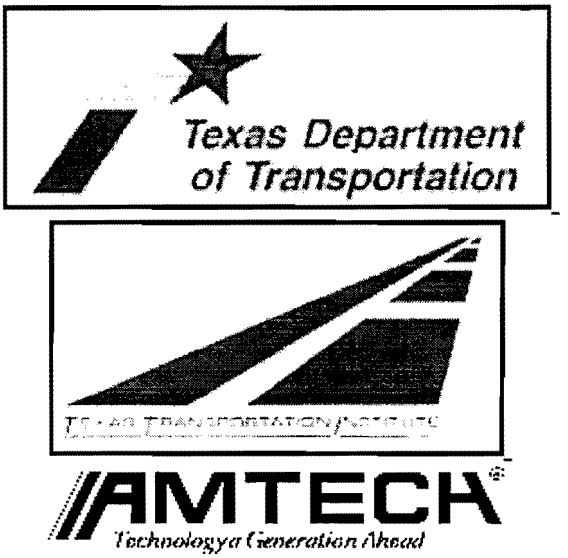
Dennis G. Smalley
Research Associate

APPENDIX E

NOTICE PLACED ON INTERNET'S WORLD WIDE WEB INVITING TRAFFIC PROBE VOLUNTEERS

Houston's Traffic Monitoring System

System Design and Development by :



The traffic monitoring system is used to collect real-time information showing current travel conditions on major Houston area freeways. This information is provided to personnel within the Houston TranStar Center for use in detecting congestion due to accidents and stalled vehicles in order to more quickly respond to traffic problems. For trip planning purposes, this travel information is also being provided to the public through this Internet World Wide Web server, through media reports and through roadside electronic message signs.

How the System Works

The system uses vehicles equipped with transponder tags as vehicle "probes". Transponder tag "readers" are placed at 1 to 5 mile intervals along freeways and HOV lanes. Each "reader" senses probe vehicles as they pass a reader station and transmits the data to a central computer. This information is used to calculate travel times of these probe vehicles between reader stations. From this travel time data, average speeds can be calculated for the roadway sections. This is the information shown on the Map display.

You Can Become a Volunteer Probe for the Houston Area.

Back to Traffic Map | Back to Home Page

Comments can be e-mailed to www@ttisys.tamu.edu

ITMC Last update: 10/13/95. 1:00p.m. CDT., U.S.A.

This page is Netscape 1.1 friendly.
ITMC, Texas Transportation Institute, Texas A&M University System
TransLink Homepage: *http://herman.tamu.edu*

Houston Area Travel Volunteers Needed

We are now accepting travel volunteers for the following freeways :

- ☐ Any HOV Lane
- ☐ I-45 Gulf Freeway
- ☐ I-610 South Loop
- ☐ I-610 East Loop
- ☐ I-10 East Freeway
- ☐ S.H. 288

To collect travel data on major Houston freeways and HOV lanes, the Texas Department of Transporation is seeking volunteers to serve as traffic probes as they make their commute trip to and from their work place or as they travel about the freeway system during the day.

The volunteers are provided a small transponder tag about the size of a credit card only 3\8" thick. The tag sticks to the inside of the windshield behind the rear view mirror. As the volunteers are making their trip on the freeway system they will pass reader stations that have been positioned along the freeway system at 1 to 5 mile intervals. As they pass the stations the reader reads the tag. The readers record the information from the tags and the progress of the vehicle is computed in minutes of travel and converted to average speeds between reader stations. These average speeds are used to measure the level of service of operation on the freeway system. These speeds are not used in law enforcement and no traffic tickets are issued from this program. The technology used in this program is the same used by the Harris County Toll Road Authority, EZ Tag Program. If you have an EZ Tag, you don't need ours. We can read the EZ tag. Our tag does NOT permit you to drive the toll roads free.

Participation in the program is a public service by the individual. You may quit at any time for whatever reason. We simply ask that you contact this office to arrange to return the tag.

Travel Volunteer Online Signup Form

Or Contact :

Dennis Smalley
(713) 686-2971
Texas Transportation Institute
Through e-mail : d-smalley@tamu.edu

To sign up, all we need is your name, address and phone number so a tag can be mailed to you.

Back to System Description | Back to Home Page

Comments can be e-mailed to www@ttisys.tamu.edu

ITMC Last update: 10/13/95. 1:00p.m. CDT., U.S.A.

This page is Netscape 1.1 friendly.
ITMC, Texas Transportation Institute, Texas A&M University System
TransLink Homepage: *http://herman.tamu.edu*

Travel Volunteer Signup Form

Name

Email

Telephone

Normal Freeway

Postal Address:

Comments:

Back to Travel Volunteers Page | Back to Home Page

Comments can be e-mailed to www@ttisys.tamu.edu

The following items are for mail information only and cannot be changed.

To: Subject: Errors-To:

ITMC Last update: 10/13/95. 1:00p.m. CDT., U.S.A.

This page is Netscape 1.1 friendly.
ITMC, Texas Transportation Institute, Texas A&M University System
TransLink Homepage: *http://herman.tamu.edu*

Description of Traffic Report Map

The map display shows current average speeds in both directions as well as on the HOV lane using up to three color coded lines. If three lines are present for a roadway, the middle line represents the HOV lane. The two outer lines represent the freeway lanes in each direction. Speeds are in Miles per hour. Freeway links are marked as Not Available (gray line) if no information has been collected for 30 minutes.

Back to Traffic Map | Back to Home Page

Comments can be e-mailed to www@ttisys.tamu.edu

APPENDIX F

AVI PARTICIPANT'S INSTRUCTION SHEET

AVI PARTICIPANT

Thank you for volunteering to participate in the AVI program. Your transponder tag is enclosed along with a mounting template. The tag must be mounted on the inside of the windshield, preferably in the center behind the rear view mirror. This location provides for the tag to be read by the antenna/reader from either the left or right side of the travel lane. On most vehicles, this location should place the tag out of the driver's line of sight. If this is not the case with your vehicle, you may position the tag at a location on the windshield that is more acceptable to you. It is important that the tag not interfere with your ability to operate your vehicle safely.

The tag affixes to the windshield by removing the two adhesive strips. The velcro attachment allows for the tag to be removed and replaced due to malfunction. If you change vehicles, this office will provide new adhesive strips.

We would like to take this opportunity to clear up some possible misconceptions about the transponder tag.

- Your vehicle cannot be located or tracked by the Central Control office. The tag is activated only when you pass under or by an antenna/reader located on a freeway.

- The tag will not be used for speed control by any law enforcement agency. The program is designed to determine traffic conditions on the freeways only.

- You cannot drive the toll roads free using this tag. You may use this tag to set up an account with the Harris County Toll Road Authority by calling 875-1400.

If you are unable to continue in the program, contact our office and arrangements will be made to return the tag.

If you have further questions, please contact our office at 686-2971.

APPENDIX G

WINDSHIELD TAG POSITION TEMPLATE


PLACE REAR-VIEW MIRROR ARM INSIDE THIS CIRCLE
OR
PLACE TEMPLATE AT TOP, CENTER EDGE OF WINDSHIELD
TAG
TEMPLATE
PLACE TAG INSIDE THIS OPENING
UP
MOUNT ON THE INSIDE OF YOUR WINDSHIELD