TRANSMIT: An Advanced Traffic Management System

By K.R. Marshall, PB Farradyne Inc. and Tom Batz, TRANSCOM

TRANSCOM's System for Managing Incidents and Traffic, known as TRANSMIT, was initiated to establish the feasibility of using Automatic Vehicle Identification (AVI) equipment for traffic management and surveillance applications. AVI technology systems are typically installed at toll booths where they classify oncoming vehicles, then identify and debit them by reading data stored on a vehicle-mounted transponder through wireless communication with a roadside antenna. In the New York City Metropolitan Area, this application of electronic toll collection is called E-ZPass[sm]. A seven agency group (called the Interagency Group) representing toll authorities in New York, New Jersey, and Pennsylvania was formed for the purpose of promoting this one-transponder system which can be used on toll roads, bridges, and tunnels in the three states. E-ZPass will eliminate the need for motorists to exchange cash, tokens, or tickets at a toll booth. Instead, tolls are paid electronically as a vehicle passes nonstop through the toll booth. When fully implemented by 1999, E-ZPass will be available at all participating toll facilities in the tri-state region. The use of this technology for toll collection is already growing rapidly. The New York State Thruway Authority reports that approximately 40 percent of all their toll transactions are made using E-ZPass transponders. At the Tappan Zee Bridge Toll Plaza where the TRANSMIT system is currently operating, 75 percent of the a.m. peak period transactions are made through E-ZPass.[1] On the New York State Thruway west of the Tappan Zee Bridge, vehicles equipped with E-ZPass transponders have recently been detected at a rate of 3,500 per hour by TRANSMIT. While on the Garden State Parkway, over 250 per hour have been detected, even though AVI technology has not yet been incorporated into the toll plazas.

The TRANSMIT system is based on the same technology. This technology offers the potential for using vehicles equipped with transponders to serve as *vehicle probes* within the traffic stream of the area for which surveillance is being established. It requires the installation of readers with the capability of identifying the vehicles equipped with transponders, at periodic intervals, along the roadway.

The cornerstone of Advanced Traffic Management System (ATMS) technology is its ability to provide reliable surveillance of roadway traffic conditions. These surveillance requirements are being met by the use of vehicle detectors that included inductive loop, radar, and sonic detectors, all of which are used to identify the presence of a vehicle in a very limited detection zone[2]. These detectors then derive the vehicle speed either by the time required to traverse two closely spaced detectors (detector separations of four feet are typical), or in the case of the radar detectors by measuring

1 Interview with Richard Newhouse, New York State Thruway Authority, November 27, 1995.

2 Historically, there has been very little detector surveillance on roadways in the New York City Metropolitan Area.

the Doppler shift of the received signal. These detectors all suffer from a common problem: they are only capable of measuring vehicle speed at a point on the roadway.

When monitoring traffic and advising motorists of alternate routes, travel time over a given section of roadway is a more meaningful control variable than point speed. Until recently, travel time could not be directly measured, but had to be derived from a series of point detectors. Within the past five years, a series of new technologies generically identified as vehicle probe technology has made it possible to directly and accurately measure travel time. The AVI technology can be classified as one of these probe technologies. Two others include vehicle positioning and cellular telephones.

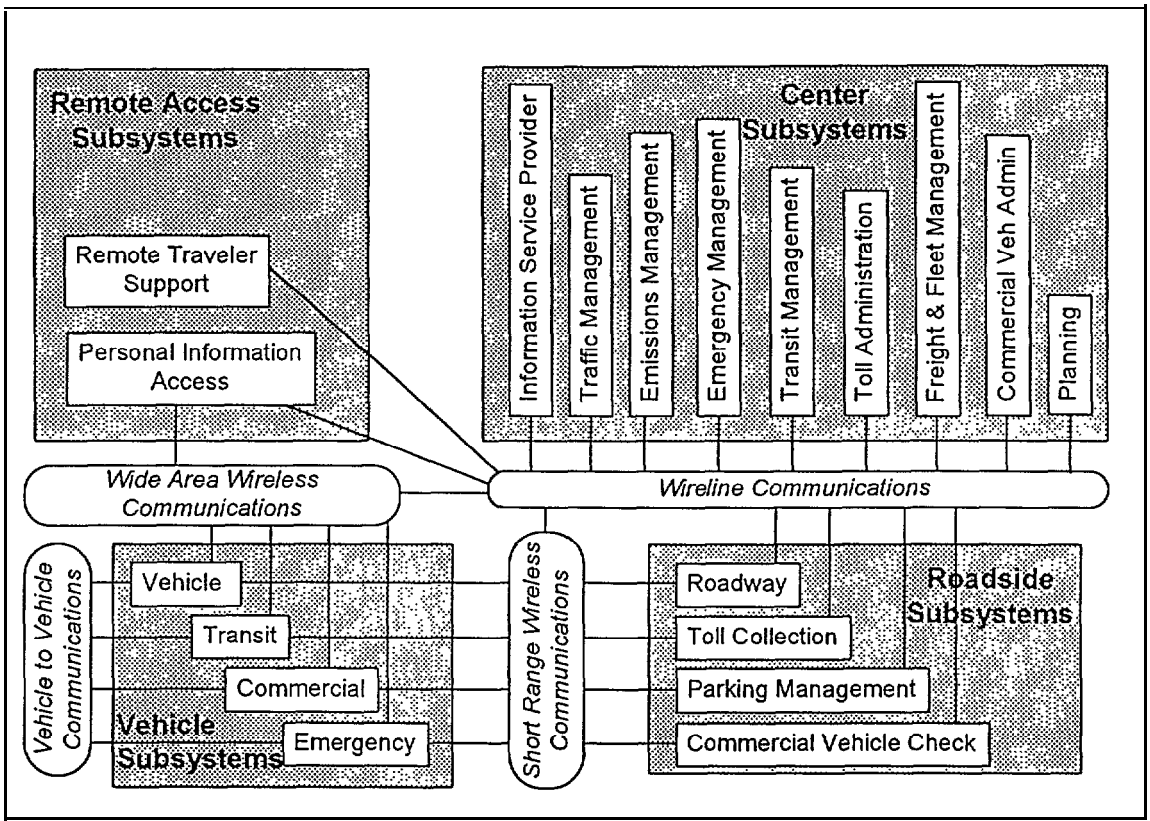
- Vehicle Positioning - This technology requires the instrumentation of the vehicle using either a Global Positioning Satellite (GPS) receiver or another on-board instrumentation that will allow the vehicle to determine its own location. The vehicle then transmits this location to a central location which tracks the vehicle location to derive travel times. This technology suffers from the problem that a large number of vehicles must be equipped with expensive electronics in order to obtain meaningful measurements of travel time on a large number of roadways.
- Cellular Telephone - An operational test is currently underway in which vehicles are located by geolocating their position when the cellular telephones inside the vehicles are in use. This technology requires the installation of highly directional receivers throughout the coverage area in order to triangulate on the cellular telephone transmissions. This system is less expensive to implement than a system such as TRANSMIT, but it suffers from significantly lower accuracy. In addition, the future capability of the system will be somewhat restricted by its need to differentiate between large numbers of portable, hand held cellular phones used by pedestrians and those that are being used by motorists.

Today, the TRANSMIT, AVI-based technology appears to offer the greatest promise in regions which use Automatic Vehicle Identification because of its increased accuracy, as well as the presence of numerous probe vehicles, In the future, this technology will have more widespread applications to all types of facilities. In addition, the enhanced two-way communications capabilities of this technology offer the capability for both probe-based surveillance and communications with the motorist.

AVI and the National ITS Architecture

AVI systems such as TRANSMIT are a key ingredient in the National Intelligent Transportation Systems (ITS) Architecture which has been under development since 1993. According to the National ITS Architecture Development Program, Phase 2 Deliverables, Evolutionary Deployment Strategy[3], the transportation layer consists of 18 interconnected subsystems, as presented in Figure 1. This diagram spans the transportation and communication layers of the architecture by depicting both the transportation layer elements and the major communications interconnects required to support the user services.

3 National ITS Architecture Development Program, Phase 2 Deliverable, Evolutionary Deployment Strategy, October 1995.



igure 1: ITS Architecture Subsystems and Communications

Toll Administration and Toll Collection Subsystems

AVI systems are represented by both the Toll Administration and Toll Collection Subsystems. The Toll Administration Subsystem is part of the Center Subsystem and provides general payment administration capabilities to support electronic assessment of tolls and other transportation usage fees.

The Toll Collection Subsystem is part of the Roadside Subsystems which provide the direct interface to vehicles traveling on the roadway network. The TRANSMIT system is a Toll Collection Subsystem. Each of these subsystems include functions that must be distributed to the roadside to support direct surveillance, information provision, and control plan execution. All roadside subsystems interface to one or more of the center subsystems which govern overall operation of the roadside subsystems. The roadside subsystems also generally include direct user interfaces to drivers and other travelers on the roadway network as well as short range interfaces to the Vehicle Subsystems.

The TRANSMIT System

In 1994, the TRANSMIT system was implemented as a Federal Highway Administration (FHWA) sponsored operational test on 18 miles of roadway which includes the New York State Thruway and the Garden State Parkway (see Figure 2). This system, as conceptually depicted in Figure 3, includes AVI transponder readers installed overhead at approximately 1½ mile intervals in both directions of the roadway. The

readers receive the identification numbers of transponder-equipped vehicles and record the number and the times of arrival of the vehicles. The transponder numbers are transmitted with the arrival times to a central site at TRANSCOM headquarters in Jersey City, NJ where they are encrypted. The data is then processed in the TRANSCOM Operations information Center (OIC) to derive travel time and to detect incidents. The processed information is sent to similar workstations located at the Tarrytown, NY Office of the New York State Thruway Authority (NYSTA), and to the New Jersey Highway Authority (NJHA) headquarters in Woodbridge, NJ.

To date, the TRANSMIT system has proved to be an accurate source of travel time data. This data has been used for traffic management, monitoring, planning, and incident detection. Both the NYSTA and the NJHA have realized additional benefits of the system. The success of this technology is demonstrated by the plans of the participating agencies to expand TRANSMIT both geographically and technologically.

Traffic Management Uses of the TRANSMIT System

The TRANSMIT system was originally developed as a tool to monitor and manage traffic using travel time data. Since November 1994, this system has been in operation and use by TRANSCOM, NYSTA, and NJHA. During this period, these agencies have used the system for a variety of traffic management applications which have resulted in increased safety and mobility for the public. At the same time, a number of future uses for the system have been identified which will be possible as the system is expanded and enhanced. The current and future uses of TRANSMIT are identified below.

Current Uses

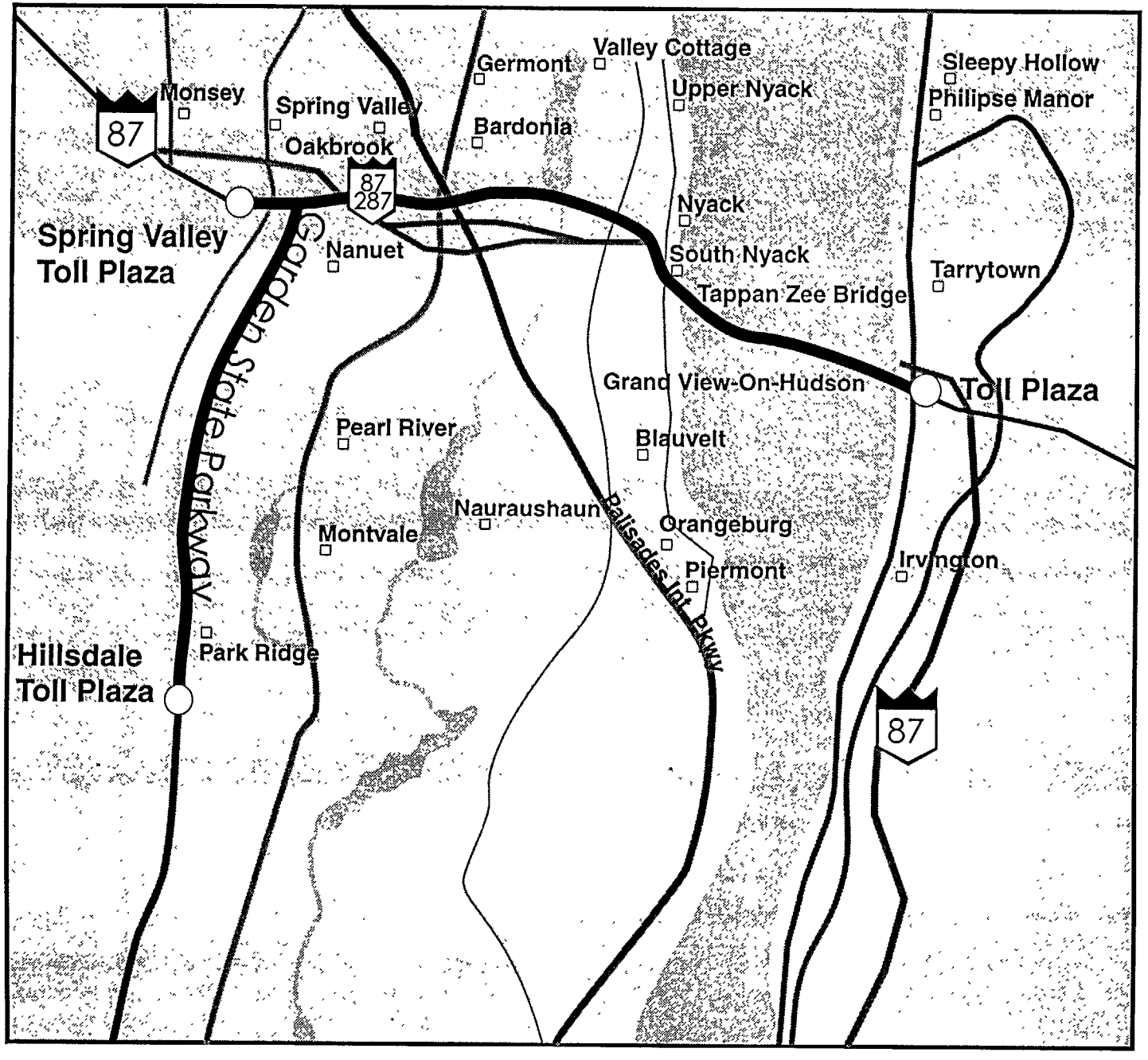
Engineers and operators at both NYSTA and NJHA have successfully applied TRANSMIT as a tool to improve their respective traffic management operations. These people have discovered that TRANSMIT provides a wealth of data which is extremely useful to alert motorists and initiate measures to help them manage traffic. A summary of these uses is given below:

- Traffic incidents have been automatically identified from the TRANSMIT incident detection algorithm. This feature has reinforced the goal of this system of increasing the safety and mobility of the instrumented roadways. The algorithm determines the probability of an incident when transponder-equipped vehicles detected at an upstream reader site are not detected at the downstream site within the expected arrival time. The later a vehicle becomes, the higher the probability there is an incident. Before TRANSMIT, incidents were detected manually.

- Data is now available on vehicle *speeds* within each roadway segment by time *of day.* This information is being used to document the varying levels of congestion within the roadway network. Bottleneck locations within the roadway network are more easily identified. From this, countermeasures have been developed to address these capacity deficient locations.

Figure 2. TRANSMIT Project Boundaries

TRANSMIT *Project Boundaries*



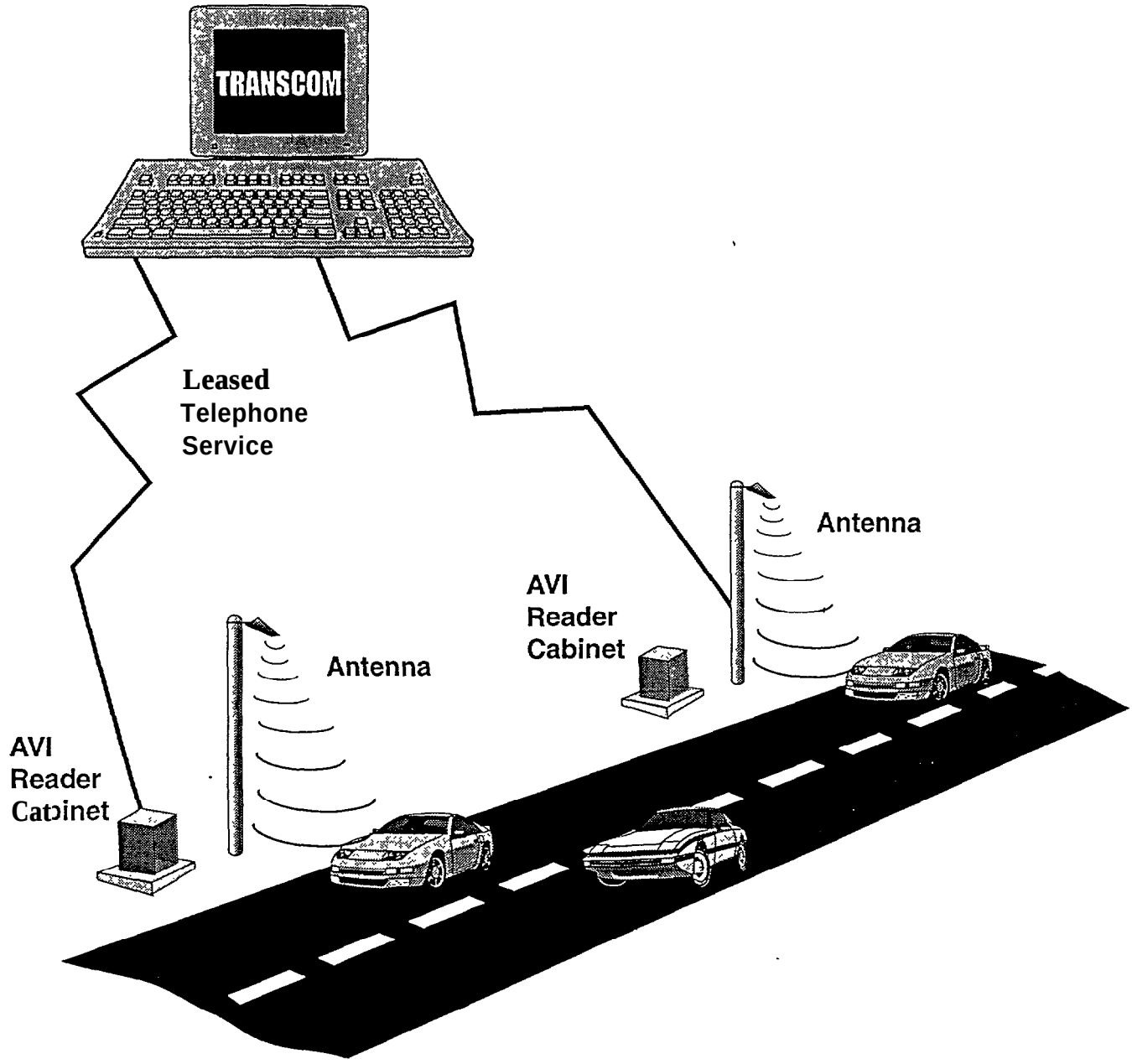


Figure 3. TRANSMIT System Concept

- Another use of the transponder data is to *determine the level of staffing* required to staff toll booths by time of day and type of day. Historical usage trends have been developed in advance to manage staffing. In certain instances, the real-time data produced by the system can be used to address sudden, unanticipated surges in level of activity at a toll plaza.

- TRANSMIT provides a historical database which can be used to respond to *citizen complaints and legislative inquiries.* Since data is stored by time of day, references to the traffic conditions at a specific section of roadway at a certain time of day can be researched and verified.

- A wealth of objective data is now available to these agencies which has helped them to *better understand how their systems operate* on both a daily and hourly basis. Before TRANSMIT was installed, these agencies had to rely on subjective information provided by the State Police, the public, and agency traffic personnel. They had knowledge of their operations at the toll plazas, but they did not have good information about traffic operations between the toll plazas which may include 10 miles of roadway or more.

Future Uses

Public agencies responsible for implementation of AVI systems are recognizing a broader range of capabilities offered by this equipment. With proper encoding, transponders can be used for traffic surveillance (such as is done with the TRANSMIT system), vehicle location for dispatch and tracking applications, vehicle classification to differentiate between buses, trucks, and passenger cars, parking access and control, and, most important, to improve the efficiency of their toll collection systems. These systems may be used in the future for congestion management, by charging fees to enter congested roadways such as those to the central business districts of major cities.

Effective traffic management also requires good communication with the motorist, as well as a high level of confidence on the part of the motorist in the accuracy and reliability of the information being received. TRANSMIT is ideally suited to the New York/New Jersey/Connecticut Metropolitan Area with high levels of traffic congestion and a large number of alternate routes. By instrumenting these alternative routes, the level of congestion and the amount of available capacity on these routes can be determined before traffic is diverted from the primary facility. Some of the ways that the NYSTA and NJHA plan to use TRANSMIT are identified below:

- As the historical data is established for specific types of incidents, TRANSMIT could be useful in developing strategic and/or tactical countermeasures. These may involve engineering, education, and/or enforcement efforts to *reduce the occurrence or duration of incidents* in a very targeted way.

- The data generated by TRANSMIT could be used by agencies to assess *the impact; effectiveness, and performance* of implemented traffic management strategies. Since the data encompasses the entire system, operations personnel can potentially use the TRANSMIT data to assess the

effectiveness of control strategies, such as ramp metering, traveler information broadcasts, etc., on system and driver performance.

- TRANSMIT can be used to monitor congestion on an alternative diversion route so it will not exceed the congestion on the primary route. Through its ability to obtain travel time data from reading the encrypted identification numbers of diverted vehicles, the operating agencies will be able to *measure the impact of their diversion messages* on traffic flow. This capability is unique in the traffic management systems field. By doing this, agencies can adjust the duration and impact of their messages in order to balance traffic throughout the network. This capability represents true traffic management.

- The TRANSMIT AVI system could be used for *transit fleet management* An installation of such a system has been proposed for the Route 3/I-495/Lincoln Tunnel corridor in New Jersey and New York. As proposed, the system would determine the location of each bus in the corridor and estimate travel times to the Port Authority Bus Terminal in Manhattan. The data would then be routed to the bus terminal staff who would use this information to make informed decisions to insure that all service operates on its assigned schedule. The plan also calls for the system to provide incident detection capabilities.

- The Northeast Corridor of the United States is one of the heaviest traveled commercial vehicle corridors and, therefore, commercial vehicle safety is a critical concern. TRANSMIT could be used to facilitate the movement of freight and goods in a more efficient manner. AVI technology can be used in conjunction with weigh-in-motion stations which permit trucks to be weighed without stopping. It could also be used for automated clearance and "one stop shopping" which will streamline paperwork for commercial vehicles.

- The *automated interaction of the TRANSMIT system* with variable message signs *(VMS)* and highway advisory radio *(HAR)* equipment, or with future radio data systems (RDS), could reduce the labor required for motorist information system operation. This enhancement to the TRANSMIT system would consist of the development of an interface with these field devices. Roadway travel time information could be automatically broadcast or displayed for recurring traffic conditions. If an incident is detected and verified, predetermined messages could be automatically placed on the appropriate VMS and HAR. These automated features could be implemented using a phased approach, in which operators could monitor the system operation to ensure that the correct messages are being selected and displayed. However, in the long term, fully automated operation is anticipated.

- Both NYSTA and NJHA plan to track vehicles within their systems to develop travel patterns. By tracing the *origins and destinations* of the encrypted transponder IDs, the agencies will be able to understand where vehicles equipped with AVI transponders enter and exit their facilities, as well as the average trip length. Since the transponder IDs are encrypted, the privacy of the motorists is maintained. Currently, agencies are only able to trace vehicles from one toll plaza to another. If a vehicle does not show up at a downstream toll plaza, the toll

agencies have no knowledge of where the vehicle exited their system. The O/D data developed from TRANSMIT will allow the agencies to determine the level of facility access activity occurring on both an historical and real-time basis.

- Both agencies plan to use TRANSMIT to estimate *traffic volumes* on individual roadway segments. Although traffic volume is not a direct measurement from TRANSMIT, it can be estimated by knowing the percentage of transponder-equipped vehicles at the nearest toll plaza and applying this percentage to upstream and downstream roadway sections. As is the case with vehicle speeds, this information can be used to identify problem locations for which capacity improvements or other countermeasures can be developed.

- AVI equipment manufacturers are currently developing *third generation transponders* which will have the capability of both transmitting the vehicle information to a roadside reader, and receiving information from these readers which can be, in turn, presented to motorists inside their vehicles. The E-ZPass system is being developed to use this technology. Two-way systems will enable the infrastructure equipment to inform the motorist, who subscribe to receive this information, of current roadway conditions and to communicate dispatch and routing information to motorists. This information could be presented in the form of audio or visual messages from an in-vehicle device linked to the transponder via an RS-232 port. The audio form would make use of a voice enunciator. The visual form could be an alphanumeric text stream or map and come from a personal data assistant (PDA). The PDA could be a laptop, a palmtop or other small portable computer. For instance, since TRANSMIT calculates travel time and speed along instrumented facilities, the system could provide travel time information to the motorist inside the vehicle. Through the availability of in-vehicle motorists information devices linked to the transponder, the system could provide motorists with the benefits of meaningful and accurate probe-based information.

  Also, since the system is capable of targeting motorists for specific information, motorists could receive unique messages. One example of this is the communication of messages directly to commercial vehicle operators, For instance, for roadway locations having steep grades (i.e., greater than four percent), messages could be transmitted which would direct a truck to the right lane or a message sign could be activated which would accomplish the same. Also, the system could be used to communicate height clearance restrictions. Warnings could be transmitted or signs could be activated which would notify a truck operator of an approaching low clearance situation. Another example of targeting TRANSMIT messages to a specific set of the driving population is the elderly drivers. Static sign messages which are typically difficult for these drivers to read could be broadcast to them inside their vehicles.

TRANSMIT Expansion

As described earlier, the TRANSMIT system presently covers 18 miles of the New York State Thruway and the Garden State Parkway. On the heels of the success of this initial system, TRANSCOM has selected expansion sites for the second phase of

TRANSMIT. Of the $1.2 million available for construction of TRANSMIT II, 25 percent of the funds will be allocated to the northern corridor for the determination of travel times. As Figure 4 depicts, this new installation will extend east from the Tappan Zee Bridge along the Cross Westchester Expressway; parallel to the Cross Westchester Expressway along the Cross County Parkway; and along three sections of roadway connecting the Cross Westchester Expressway and the Cross County Parkway (the Hutchison River Parkway, Sprain Brook Parkway, and New England Thruway (I-95)).

The remaining 75 percent of the funds will be allocated to the southern corridor for the determination of travel times and detection of incidents. Installation in the southern corridor will be as follows (see Figure 4): on the Staten Island Expressway from the Verrazano Narrows Bridge, across the Goethals Bridge, to the New Jersey Turnpike; along the West Shore Expressway from the Staten Island Expressway to the Outerbridge Crossing; and in New Jersey, from the Outerbridge Crossing along Route 440 to the New Jersey Turnpike.

The planned expansion in both the northern and southern corridors is expected to be completed by 1997.

Summary

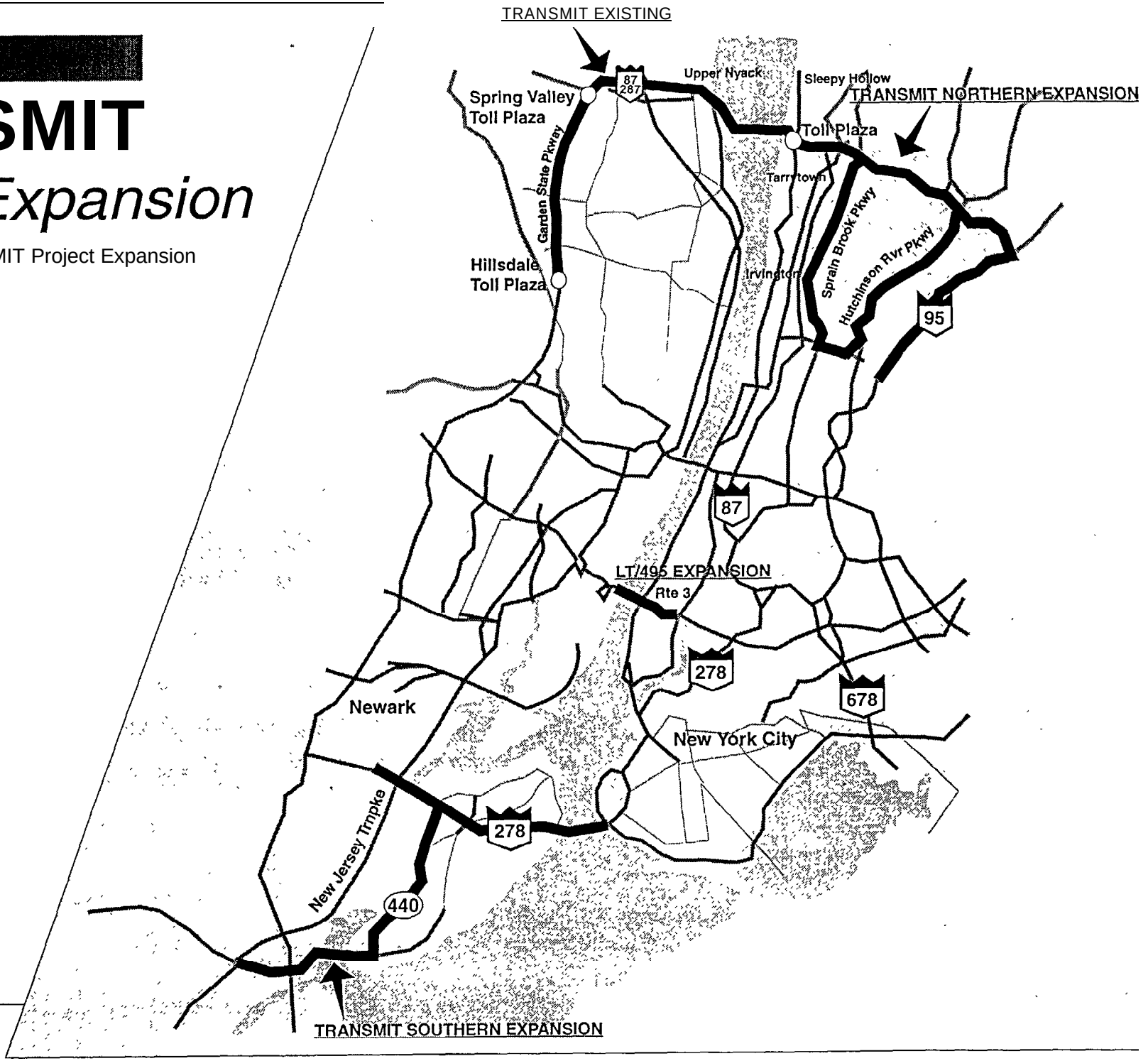
The TRANSMIT System is a unique application of AVI technology for traffic management purposes. Not only does it provide engineers with travel time (and speed) data for the main line sections of their facilities, but it is also used to detect traffic incidents. Through geographical expansion and technology enhancements, the TRANSMIT system will continue to provide engineers and planners with additional capabilities, such as the ability to measure O/D patterns, estimate traffic volumes, provide in-vehicle motorist information, and manage transit fleets,

Effective traffic management results from a combination of good motorist communication and the establishment of a high level of confidence on the part of the motorist in the accuracy and reliability of the information being received. TRANSMIT is ideally suited for regions experiencing high levels of traffic congestion, having a significant number of vehicles equipped with AVI transponders, and having a large number of alternate routes as is the case in the New York/New Jersey/Connecticut Metropolitan Area.

TRANSMIT

Project Expansion

Figure 4. TRANSMIT Project Expansion



Acknowledgments

The following individuals are acknowledged for their contributions to the development of this paper.

TRANSCOM
Tom Batz
Peter Dwyer

New York State Thruway Authority
Richard Newhouse
John Baniak
Don Hubicki

Federal Highway Administration
Jonathan McDade

New Jersey Highway Authority
Jude Depko
David Ernest