# AUTOMATIC VEHICLE IDENTIFICATION

Robert S. Foote

Great strides have been made in the past 10 years in applying electronic technology to improve traffic movements. And the shift from electromechanical to electronic systems of vehicle detection and traffic control is increasing. One of the most important factors in this shift is the development of vehicle detectors that are both more reliable and more accurate than the previous pneumatic tubes and axle treadles.

The next major step in the development of vehicle detectors seems ready for application: the ability to identify electronically not only that a vehicle passed but precisely which vehicle passed. This development will open a new range of applications for traffic control systems and provide traffic engineers, planners, administrators, and researchers with information that would have been inconceivable more than 10 years ago. Several reports (1, 2, 3, 4, 5, 6, 7) describe the development of this new automatic vehicle identification (AVI) technology.

### The AVI Concept

In function, AVI is similar to an electronic license plate. It offers the ability to identify uniquely and automatically a vehicle as it moves at normal highway speed along the road; no action is required on the part of the motorist. AVI involves adding to the underframe of the vehicle a sealed box the size of a small book or placing behind the windshield a small sealed box the size of a cigarette package or placing on the window a reflective sticker. Any of these devices is called a transponder. Encoded in the transponder may be the identity of the vehicle to which it is affixed. AVI also requires a unit on or in the roadside. This unit, called an interrogator, may supply the energy to power the transponder, and it receives the weak signal emitted or reflected by the transponder. The signal can then be printed locally or relayed to a computer for further processing.

The identification technology involved is part of that being developed and applied by the railroad industry, supermarkets, the Postal Service, the military, the maritime industry in identifying containers, and those who operate bus and truck fleets. The technology is all aimed at enabling the unique identification of whatever the transponder is affixed to as it either moves along or is at rest. The technology has so many applications that it will continue to be perfected even if highway applications should lag for several years. The main challenge by engineers and others concerned with improving highway transportation systems is not so much to develop the AVI technology as to apply it in such a way that potential benefits will be realized to the fullest.

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### Classification of AVI Technology

Two broad classification categories are automatic vehicle monitoring (AVM) and automatic vehicle identification (AVI). In AVM, the devices carried on board the vehicle require high-powered 2-way radio systems, which also must be on board the vehicle, to transmit identification to a central point. Equipment by the roadside, however, can be relatively simple. In contrast, in an AVI system the equipment on board the vehicle is relatively simple, but the roadside equipment is relatively complex.

Locating vehicles by automatic vehicle monitoring has taken 2 major forms.

1. The location function has been carried out by trilateration: The radio signal emitted from the vehicle is sensed by 3 or more fixed antennas, and the vehicle is located by standard trigonometric techniques using range bearings. A difficulty that has been encountered with this approach in built-up urban areas is that the radio signals can be reflected from high buildings, causing a multipath transmission and rendering the vehicle location ambiguous.
2. An alternative system uses a signpost technique. In this system, a low-cost, low-power transmitter along the roadside constantly broadcasts its particular number. As the vehicle to be located passes the roadside transmitter, it receives this transmission and stores the signpost number. When the central computer is programmed to locate various vehicles, a radio transmission to each vehicle in turn triggers the device on board the vehicle to retransmit the number of the signpost stored in it. This advises the central computer of the signpost that the vehicle passed most recently.

In contrast, automatic vehicle identification systems do not require high-power 2-way radio equipment, and the equipment carried on board the vehicle can be passive and relatively inexpensive. Roadside equipment is more expensive. Three major types of automatic vehicle identification have been developed during the past 10 years, distinguished according to the frequency spectrum in which information is transferred between the transponder and the interrogator. These 3 systems are (a) the optical system, which uses a sticker on the side of the vehicle; (b) the low-power (microvolts) radio frequency system, in which information is transmitted from the transponder just a few feet to a loop of wire in the roadway; and (c) the microwave system, which transmits information from the transponder in the microwave range.

In addition to the method by which information is transmitted from the transponder to the interrogator, a further subdivision of AVI systems can be developed based on the method of powering the transponder. Power can be derived from the roadside, from the vehicle, or from the transponder itself with a self-contained battery.

**Application Properties**

Choice among these systems will depend on the application. AVM seems best suited where there are relatively few vehicles to be located but many possible locations to be identified. AVI appears preferable where there are a large number of vehicles and relatively few locations.

One problem with the optical system for general highway application is that a line of sight between the interrogator and the transponder is essential. In some applications, such as along a multilane highway, this is difficult if not impossible to obtain. Also in some applications high accuracy (98 percent or better) is essential; the ability of the optical system to perform at this level in typical highway applications has not been demonstrated. Furthermore, there may be aesthetic problems associated with the sticker in some applications, especially where the required information capacity is high.

Field tests have confirmed that the low-power radio frequency system functions at nearly 100 percent accuracy. All elements of the system are electronic and offer long life with low maintenance. But unlike the optical system that is already in use on the railroads, the radio frequency system has yet to be introduced on a broad scale.

The third system, microwave, may offer the potential of lower costs during the long run, but as yet this equipment has not reached the same level of development as the radio frequency systems. Field tests are still needed.

Based on these considerations, the system that now appears most ready for major application in highway traffic where accurate identification of individual vehicles is important is the induction-powered radio frequency AVI system. The self-powered radio frequency system has also demonstrated excellent performance. This technology is able to operate accurately on multilane high-speed facilities and avoids the aesthetic and accuracy problems of the optical system.

As part of the federally supported Urban Corridor Demonstration Program, the Port Authority of New York and New Jersey evaluated AVI performance and potential to improve bus operations. Starting in 1972, the authority invited all potential manufacturers of AVI systems to demonstrate at their expense the performance of their equipment in a field test program that has run for more than a year. Their equipment had to identify, uniquely and automatically, each of as many as 4000 buses moving along the road at normal highway speeds.

The 4 participants were General Electric, WABCO, North American Philips, and Glenayre. Each provided 40 sealed transponders to be bolted to the underframe of the buses. The transponders were installed by Transport of New Jersey on buses traveling the 107 route from Maplewood, New Jersey, to Manhattan. Each bus had several transponders, representing the various manufacturers. These transponders are prototype designs, using transistors and other individual electronic components mounted on circuit cards. The transponders also provide internal antennas to receive energy from the loop in the roadway and to transmit their coded information back to the loop. In full production, the transponders would probably use large-scale integrated circuitry and be more compact.

Although suppliers of optical and microwave systems were also invited to participate in the test, only manufacturers of the radio frequency systems did so.

The test had 2 major phases: operational and accuracy. In the operational test, commencing in the summer of 1972, the Lincoln Tunnel interchange on the New Jersey Turnpike, at the start of the exclusive bus lane, was the western boundary of the test area. Interrogators for WABCO and North American Philips were installed there and connected to a computer at the Lincoln Tunnel Administration Building some 2½ miles away. Experience showed AVI performed well as vehicles moved at very slow speeds over the loops and that AVI data could be relayed over leased telephone lines to a remote computer.

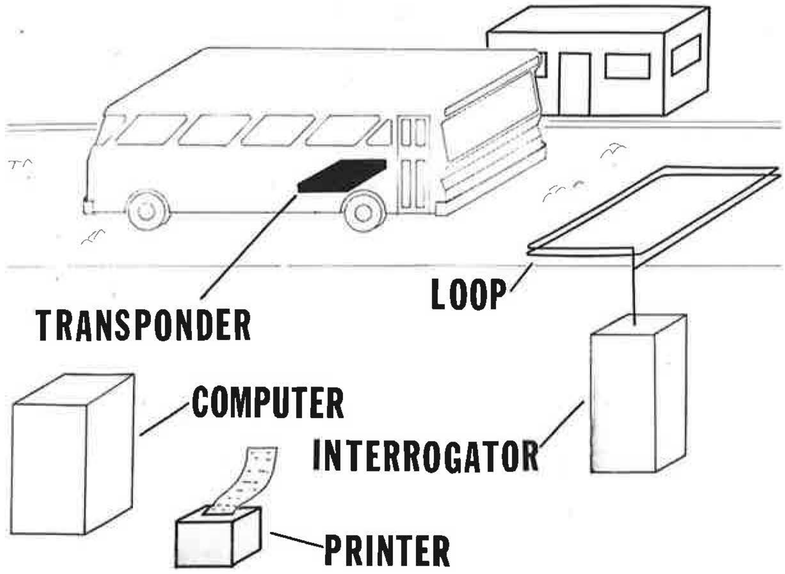
The operational test was to determine the travel times of individual buses between the turnpike and the Port Authority Bus Terminal. Two GE interrogators were installed in February 1972 on the ramps leading to and from the bus terminal. This information was also relayed over leased telephone lines to the computer center at the Lincoln Tunnel Administration Building some 2 miles to the west. The total area covered in the operational test was thus some 4½ miles; the computer was approximately in the center.

As data from the interrogators flowed into the computer, calculations were made to determine the travel time of each bus through the area. With all AVI-equipped buses traveling only between the terminal and the AVI-equipped lanes of the turnpike and with perfect performance of the AVI equipment, a travel time could be calculated for each bus. A bus detected at one interrogator but not at the next one after a reasonable time would indicate a failure in the AVI system. In practice, however, this did not work. Although there were enough complete trips to prove beyond question that AVI was functioning operationally, occasionally buses would not make the assumed trip or would use a different lane at the turnpike other than where the AVI interrogators were located.

Therefore, the second phase of the test was undertaken to establish the accuracy of AVI performance. WABCO and North American Philips interrogators were moved to the bus terminal near the GE interrogators, and the Glenayre system was added. Then in effect each system cross-checked the other; a comparison of the printed record from each made it possible to determine readily when a detection failure occurred. This phase of the test operated from midwinter through spring of 1973.

Apart from running during the worst weather conditions of the year, the test was also rigorous in the sense that the electrical interference in this location was severe. The bus ramps have heating equipment in them and are near major transmitting antennas for commercial radio systems. Moreover, all the interrogators were along less than 100 feet of roadway, and cross-talk among the various AVI systems was possible. But these conditions proved not to be a problem. In addition to tests with these buses, other controlled tests were made to determine the AVI performance at a range of speeds and a range of vertical and lateral transponder placements.

During phase 2, the GE system, which had 2 interrogators, identified 13,814 buses, all but 181 correctly, for an overall performance rate of 98.69 percent. WABCO, which was on line the longest in phase 2, identified 9,199, all but 48 correctly, for a performance rate of 99.48 percent. North American Philips, which used a

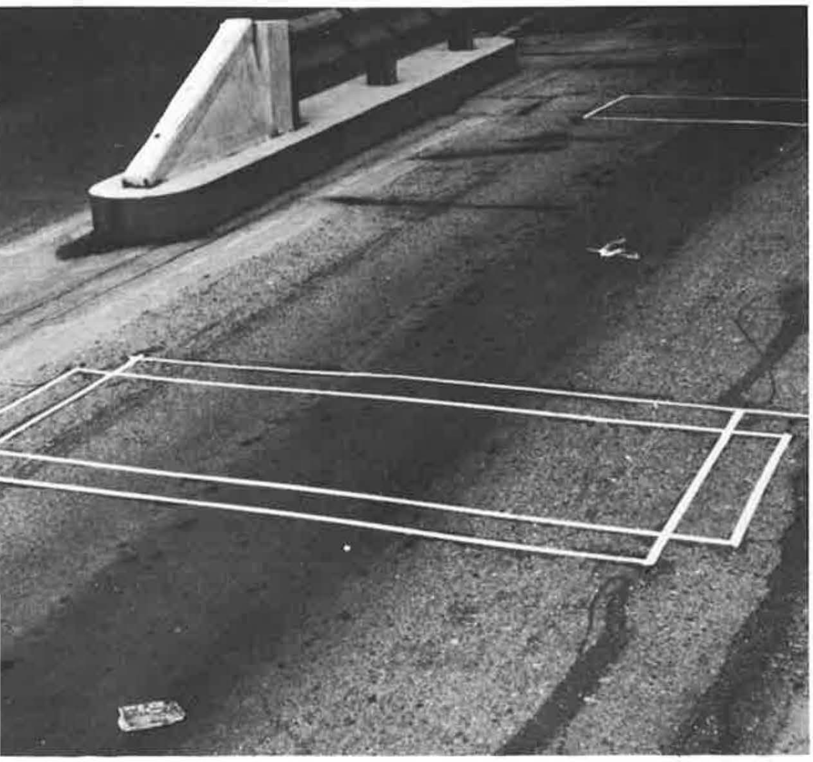



transponder powered by an internal battery rather than inductively from the road loop, identified 5,226, all but 8 correctly, for a performance of 99.85 percent. Glenayre, which was last to come on line, identified 1,416, all but 22 correctly, for a performance of 98.45 percent. These figures are adjusted to exclude a few obviously faulty transponders that were readily observed and removed from the buses.

A report, which has been submitted to the Federal Highway Administration, describes the exact conditions of the test and the performance of each of the various systems, and the potential applications for automatic vehicle identification in bus operation.

To be of greatest use and to avoid a proliferation of noncompatible systems, any transponder should be capable of being read by any interrogator and vice versa. Then as more interrogators are installed, more will be gained from existing transponders—and, again, vice versa. In addition to standard equipment, this will require a standard numbering system and standard coding format. The report discusses these considerations and offers a detailed specification for AVI equipment.

The more this equipment is developed and used, the more feasible it will be to improve bus operations and other highway traffic operations with AVI. Choosing the AVI system that will be most compatible with other needs will help buses more as all AVI applications grow.



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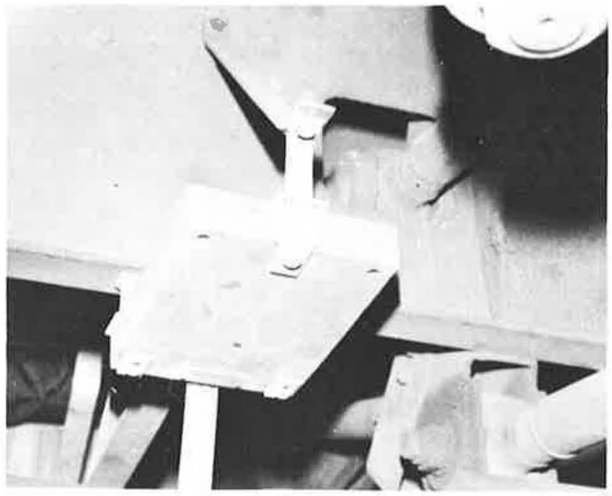

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***1 Loop installation at the Port Authority Bus Terminal is by General Electric, 1 of 4 manufacturers whose equipment was tested by the Port Authority.***

***2 General Electric transponder mounted under bus.***

**Potential Uses of AVI**

One of the most direct uses for automatic vehicle identification is in connection with fleet control, such as maintenance and police vehicles. AVI can assist the managers of these fleets to know where their vehicles are located, to accomplish check-in and check-out functions automatically, and to assist dispatchers in gaining the greatest possible use from the fleets. AVI can also assist in revenue collection and control at municipal parking lots.

Beyond immediate municipal and state and federal uses, automatic vehicle identification offers several possibilities for improving public carrier transportation operations. An area of increasing concern in many cities is urban goods movement. Studies have shown that many trucks in urban areas are greatly underused, carrying only 10 to 15 percent of their freight capacity and unnecessarily duplicating route mileage. Methods to use these trucks more efficiently will benefit the cities as well as the truck operators. The possibility of controlling fleets of trucks through automatic vehicle identification will become more realistic as more interrogators are installed. Another potential benefit is in providing increased protection to trucks against hijacking.

More efficient operation of bus fleets through dispatching and control procedures is another potential benefit of AVI. Buses will continue to play a dominant role in urban public transportation, and a major effort is being undertaken to improve bus service. Experiments such as demand-responsive transportation seek to increase benefits to the public from existing transportation capital investments by means of more effective control systems. A similar possibility exists in the case of taxi fleets. In some cities, taxis are a major source of congestion, and a rationalization of the use of these vehicles can assist both the taxi owners and the public directly through better service and indirectly through less congestion on the streets. Application of AVI for car-pool operations is another interesting possibility.

Municipal, commercial, and private fleet operations offer a significant potential use of AVI in improving urban transportation. But the application of AVI to private automobiles has the greatest significance to traffic engineers. AVI offers a more sensitive, selective, and precise method of controlling traffic than is otherwise available to meet air pollution control standards. Because of the need to limit emissions to maintain air quality and to save fuel and the need to use scarce arterial highway capacity most effectively, it may be necessary to provide access to downtown areas only to qualified vehicles. AVI offers the ability to implement detailed and equitable priority access schemes. Also, AVI can be useful for route guidance and assisting motorists in avoiding arterials where traffic has been subject to breakdowns.

AVI has several potential law enforcement applications. Given the importance of vehicles in criminal activities, systems that can automatically identify particular vehicles as they pass interrogation points may eventually provide an important assist. AVI systems may also provide a certain measure of protection against vehicle theft.

This same ability of AVI to automatically identify vehicles in conjunction with theft cases leads to an application in motor vehicle administration. An allied application is assisting motor vehicle manufacturers to locate vehicles that must be recalled for modification.

One of the most important immediate applications for AVI is in conjunction with parking lot revenue control. Parking in urban centers is an important influence on vehicle use, and AVI systems could provide several benefits through enabling more responsive charging structures.

A similar application is in the case of road-user pricing, which is being advocated by some as a means of limiting highway congestion in urban centers. Because in many of these schemes the charge to be made depends on the time and place of use, automatic vehicle identification systems tied into computers appear to be essential.

The most immediate probable use for automatic vehicle identification is on toll roads. AVI offers the possibility of fully automatic, nonstop toll collection. The results are time and fuel savings, convenience, safety, efficiency and security of funds, and less noise and air pollution.

AVI can also be used in conjunction with traffic data collection. Precise and extensive samples of origin and destination data can be made available to planners and administrators and researchers as by-products of AVI installations.

**A National AVI System?**

Inasmuch as AVI has so many potential applications, it seemed appropriate to explore whether there should be a national standard AVI system. Such a system could serve many needs and prevent a proliferation of noncompatible systems. For any interrogator to read any transponder requires that there be standard equipment, standard message format and coding, and an unambiguous nationwide numbering system.

The FHWA study undertaken by Airborne Instruments Laboratory in response to the 1967 resolution of the International Bridge, Tunnel and Turnpike Association confirmed the desirability of promoting a national standard system, but the opportunity to really explore other possible uses of an AVI system did not arise until IBTTA created it in 1973. Then the results of Port Authority testing of AVI were becoming available and provided an occasion to brief many other potential users concerning the excellent performance of AVI. The message was that AVI technology is ready for field applications demanding high accuracy but the potential benefits to be gained depend on how the system is introduced.

About 40 people representing about a dozen agencies and associations attended a preliminary meeting in Washington in February 1973 (4). The primary output from that meeting was a decision to hold a larger meeting in September 1973. About 180 people, representing virtually all the organizations and interests concerned potentially with AVI, attended the second meeting held September 17, 1973, in Washington, and cosponsored by the Federal Highway Administration with the active cooperation of the American Association of Motor Vehicle Administrators, the American Trucking Associations, the Highway Research Board, and the National Parking Association.

These meetings made it clear that, except for the National Parking Association, the national interest in AVI is too diffuse and contradictory to support a national system at this time. The conference helped to identify diverging viewpoints and to enable everyone to make a more objective assessment of AVI. The main thrust was that toll road agencies should proceed on their own, and that is what is being done.

**Proceeding With AVI**

AVI must be introduced on a voluntary basis to avoid any potential invasion of privacy. If citizens are free to elect whether to equip their vehicles with AVI, then the issue of invasion of privacy should not arise.

In addition, the system should be introduced in such a way that it will be adaptable to other uses in the future so that maximum long-term benefits can be obtained.

The Port Authority and the New Jersey Turnpike Authority invited the 4 manufacturers of AVI systems who participated in the field test to submit proposals for the supply of AVI equipment according to detailed specifications. The proposals were received on November 19, 1973, and for the first time stated the costs of AVI equipment under competitive bidding conditions. The initial quantity is small because the primary purpose is to develop an AVI-based toll system. In the bus tests described earlier, AVI performance was tested as a standalone device. Now AVI hardware will be used in conjunction with other hardware to develop a toll-collection system and to test public reaction. For this the Turnpike Authority will acquire 250 transponders and 6 interrogators and the Port Authority will acquire 100 transponders and 2 interrogators. The Turnpike Authority will make its transponders available to automobiles; those of the Port Authority will be made available to buses. By approaching this as a joint procurement, each agency will be able to read the other's transponders and set a pattern for future joint procurement of larger quantities.

To guard against underbidding and to ensure that proposal costs are representative of larger procurement, the proposers were asked also to quote on 5000 transponders and 18 interrogators with a price firm for 18 months.

In effect each proposer was asked for costs on 4 bases. One alternate concerned the numbering system: use of the vehicle identification number (requiring 97 bits) or use of an 8-decimal digit number (requiring 58 bits). The second alternate concerned providing transponders with fixed information only or, on the other hand, providing additional 5-decimal digits that could be varied from on board the vehicle to give information such as bus route number, passenger load, desired destination, or freight delivery plan.

Of the 4 proposals, 2 were excessive both in cost and delivery. However, the proposals from General Electric and Glenayre were competitive. For 350 transponders, unit costs range between $74 and $260 depending on the alternate and manufacturer. For 5000 transponders the range is $69 to $114. The quantity of 5000 was not enough to justify use of large-scale integrated circuitry. It appears, although this is not quoted, that awards of 100,000 would lower the unit costs by 40 to 50 percent. Thus, on a production basis, a transponder cost of $40 would be possible. For 6 interrogators, unit costs range from $2851 to $7210; for 18 interrogators, the range is $2851 to $5359. These costs are slightly below the middle of the early Port Authority range of estimates.

Still, a transponder cost of $70 could prevent many AVI applications. But a most important element in these quotations is the estimated life of the equipment: Both GE and Glenayre estimate 15 years.

To gain a useful life of 15 years from a transponder will require that it be moved from vehicle to vehicle. The average car life is only 10 years. Based on 3 owners per vehicle during its life, the average duration of vehicle ownership is only 3 or 4 years, or only 20 to 25 percent as long as the transponder life. A transponder that was encoded with a vehicle identification number would be difficult if not impossible to transfer to the new vehicle selected by the system user. This fact alone seems to dictate choice of a serial numbering system, rather than the VIN system, even though the VIN alternate is not much more costly. The cost to a motorist for a transponder could then be spread over the 15-year transponder life. An annual cost of $5 to $10 would be less than many pay now for credit cards.

Use of a serial number will, however, require careful coordination of numbering assignments by toll road agencies. This, plus the need to lease rather than sell transponders to motorists, points strongly to the desirability of setting up a central agency to handle AVI for toll road agencies and eventually other users.

There are other important advantages to the central agency concept. It could act as a single purchasing agent for AVI equipment and obtain large-scale, low unit cost procurement. It could probably supply, install, and service AVI equipment in the most efficient way.

Another key advantage to the central agency concept is the promise of lower cost for account maintenance. Rather than receiving separate toll-road bills, each motorist could receive a consolidated bill and make only 1 monthly payment.

The central agency concept may also simplify the entry into an AVI-based toll system. Any toll road agency need only obtain a few interrogators to start serving transponder-equipped motorists. This ease of getting involved in AVI-based tolls and the consequent more widespread installation of interrogators should, in turn, increase the inducement to motorists to lease AVI transponders. Furthermore, the central agency could also service non-toll-road users easily. The interest of parking operators in obtaining AVI interrogators seems likely to emerge next as the system comes on line.

**References**


1. Prospects for Changes in Toll Collection Systems. International Bridge, Tunnel, and Turnpike Association, 1967.
2. Automatic Vehicle Identification Systems. Airborne Instruments Laboratory, 1968.
3. Toll Collection. International Bridge, Tunnel, and Turnpike Association, 1969.
4. Toward AVI. International Bridge, Tunnel, and Turnpike Association, 1973.
5. Automatic Bus Identification. Port Authority of New York and New Jersey, 1973.
6. Proceedings of Organizing Conference on AVI. International Bridge, Tunnel, and Turnpike Association, 1973.
7. AVI: Challenge and New Direction. Port Authority of New York and New Jersey, 1974.