Developments in Automatic Vehicle Identification During 1974 and 1975

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Technology for automatically and uniquely identifying vehicles in motion has been under development and testing since the early 1960s and is receiving increasing attention. Systems using this technology make possible nonstop collection of tolls and other road user charges. Other potential applications include traffic control, law enforcement, and fleet management. This report summarizes recent developments of the technology. A coding format has been developed that is suitable for standard use. An intermediate generation of radio frequency equipment did not perform as expected, but a new generation is about to be tested. A system using microwaves is being developed and tested. An optical system is delivering good performance and reduced-rate cash toll collection. Studies of cost elements in a nonstop toll collection system, such as account maintenance, are being conducted. Market research is under way.

By the end of 1973 several reports had been published describing the growth since 1963 of technology for uniquely and automatically identifying vehicles in motion (1, 2, 3, 4, 5, 6, 7). Such a system would make possible fully automatic nonstop collection of tolls and other road user charges such as parking fees and assist traffic operations, vehicle security, law enforcement, vehicle maintenance, fleet management, motor vehicle administration, transportation planning, and other functions.

Since the end of 1973, there have been both progress and setbacks. Some of the major steps forward are as follows:

1. Initial testing by the Port Authority of New York and New Jersey of a new automatic vehicle identification (AVI) system,
2. Development of a new generation of low-power radio frequency AVI equipment,
3. Letting by the U.S. Department of Defense of a second-stage contract for a microwave AVI system,
4. Testing by the New Jersey Turnpike Authority of two additional AVI systems,
5. Testing by the Association of American Railroads of a new generation of AVI equipment, and
6. Use of an optical sticker in conjunction with coin or token collection on Delaware River Port Authority bridges.

On the other hand, AVI equipment tested at the Golden Gate Bridge and the bus terminal of the Port Authority of New York and New Jersey did not meet expectations. This equipment, whose design was later than that tested successfully by the Port Authority under contract for the U.S. Department of Transportation, failed because of breaks in a wire connecting a component to a printed circuit board, which were caused by different coefficients of thermal expansion. This made it impossible for Golden Gate Bridge officials to offer the AVI system to the general public, as had been planned. However, Golden Gate officials are now testing an AVI design developed to meet the Port Authority contract.

In summary, progress has been made. Interest in AVI systems for nonstop toll collection has continued, and the outlook is for field testing and refinement of several forms of AVI for toll collection in the immediate future.

Why should members of the toll road industry be particularly interested in AVI? By automatically and uniquely identifying moving vehicles, AVI, in conjunction with other system components that have already been proved, makes possible fully automatic collection of tolls, i.e., collection without requiring the transfer of currency and therefore without requiring any action on the part of either the motorist or the toll agency. This means toll collection without toll collectors and without toll plazas in its ultimate form. And that provides safety and convenience for patrons and lower costs and higher security for toll agencies. In addition, AVI can provide other benefits for road use and traffic control, vehicle administration, and road planning.

What is AVI? This technology was developed in the last 10 to 15 years and is now being applied in supermarkets, clothing stores, and other retail outlets as well as in military and transportation operations. Typically there are two elements involved: a sticker or other passive device carried on the vehicle or object to be identified and an active element mounted in or near the roadway and capable of reading electronically the identity of the device on the vehicle. Generally the vehicle-

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mounted device is referred to as a transponder; the road device is an interrogator. Depending on the type of system, information may be transferred between the transponder and the interrogator in the visible light spectrum, in the radio frequency spectrum, or in the microwave spectrum. Energy required for the transponder to emit its identity can be supplied by an internal power source such as batteries, by the electrical system of the host vehicle, or by reflectance or inductance from the interrogator power source.

How can this technology be used in a nonstop toll collection system? Because the only transfer at the time of vehicle passage is of electronic information, cash payment can be made either before or after the vehicle uses the toll facility. In either case, an account is maintained for each vehicle (or fleet operator) and is updated after each use and each payment. The amount of bookkeeping this entails is not feasible without computer technology. And, although such accounting is within the scope of today's computers, the cost may still be excessive in some toll applications. A key factor in reducing costs is to use standard transponders and interrogators and possibly a pooled accounting operation. With standardization, the motorist can use his or her transponder at the facilities of many toll and other agencies. And, with standardization, each toll operator can handle a larger proportion of toll collection through AVI. Through standardization, any interrogator can read any transponder, but the message format, coding, and AVI hardware must be standardized.

Who are the principal suppliers of AVI? At this point, only five companies are actively marketing AVI systems, and several others are moving toward the marketing stage with optical and microwave systems.

Where are AVI developments taking place? Both potential suppliers and potential users come from nearly all industrial countries. There has been significant development in France, the Netherlands, Great Britain, Germany, Canada, and Japan as well as the United States. The most significant field testing of radio frequency systems has been at the Golden Gate Bridge in San Francisco and by the Port Authority of New York and New Jersey. During 1972 and 1973 the Port Authority conducted a federally sponsored test (5) that confirmed that radio frequency AVI performs at the 98 percent plus level of accuracy needed for use in a fully automatic AVI-based toll system. Optical systems were tested briefly on the Quebec Autoroutes and by the New Jersey Highway Authority and are now being used in conjunction with a coin system at the Delaware River Port Authority bridges in Philadelphia.

When will AVI be in widespread use? The answer depends on many developments. However, it seems likely that the first fully automatic, nonstop AVI-based toll collection system will be offered to the public in the next 5 years. The Golden Gate Bridge had planned to offer such a system last year, but its introduction was delayed because of poor performance of the hardware. The New Jersey Turnpike may offer such a system on a test basis in the next year. And the Port Authority is working to implement an AVI system for buses in the next year. The rate of public acceptance depends first on the decision by toll agencies to offer such systems, second on the performance of the systems, and third on the actual costs and benefits, and it is increasingly likely that these factors will become well defined in the next 5 years.

PORT AUTHORITY TESTS

The Port Authority has extensively tested radio frequency AVI systems developed by four suppliers in a program supported by the Federal Highway Administration. By 1974, a system had been proposed for further testing. Special attention was given to the coding and message format to ensure that the system could serve as a standard for the toll industry.

The format adopted has an 80-bit transponder that can be coded in two main forms, one containing only fixed numbers (i.e., all bits in the transponder would be coded at time of manufacture and could not be altered subsequently without destroying the transponder) and one providing, in addition to some fixed numbers, five-digit number capacity that could be varied from on board the vehicle. Although the toll road industry is mainly interested in transponders that are coded permanently, some of the variable-unit systems may be particularly valuable for fleet operators. For example, buses could display route number and passenger loading to assist dispatchers to optimize fleet use.

The transponders and interrogators were delivered to the Port Authority in summer 1975. Loops for the interrogators had previously been installed in toll lanes 3 and 5 of the Lincoln Tunnel toll plaza in Weehawken, New Jersey. Also, cable had been run approximately 61 m (200 ft) to a room overlooking the toll plaza where the interrogator circuitry could be located. The functioning of both the interrogator and transponder units has been demonstrated satisfactorily. The Port Authority has tested most transponders to ensure proper operation, and initial units have been delivered to Transport of New Jersey, the bus company participating in the test program.

Information from both the new and old interrogators will be routed to a computer at the Lincoln Tunnel Administration Building. One of the main purposes of the test is to evaluate and demonstrate the feasibility of maintaining AVI accounts on-line.

Although a radio frequency system was chosen for this test, the Port Authority has not committed itself to this technology for the full system. Continuing interest is being maintained in alternate approaches, and additional testing may be scheduled.

NEW JERSEY TURNPIKE STUDIES

Early in 1974, the New Jersey Turnpike Authority decided to cease testing of AVIs, but, because of continuing inflation in the cost of conventional toll collection, the authority is still interested in new forms of automatic toll collection. After rethinking their requirements, turnpike staff solicited proposals for systems that would automatically identify patrons rather than vehicles. The status in September 1975 was summarized in a letter from Harry R. Loewengart, project engineer for the turnpike:

> About one year ago, we formulated a four year toll equipment modernization plan. This plan provides for development (where needed) and implementation of an overall system which includes, among other features, "permanent identification" of commuter vehicles (instead of single use toll tickets), a computer network and prepayment or charging of tolls by about 100 000 patrons. (Cars constitute 85 percent of our traffic.)
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> ... we recently solicited proposals for vehicle identification and detection equipment from 35 firms. From the six responses, we have selected two, ... a microwave system and ... an electro-optical system. A development and demonstration contract has been awarded [for] each; under these contracts both systems will be tested competitively in early 1976, with 100 participants (authority staff).
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> Both systems provide for a transponder or label which can be hand held or attached to the vehicle. ...

In addition to exploring hardware for this system, the turnpike staff is studying the costs of operating such an AVI system and also planning a survey of turnpike patrons to determine their interest in such new approaches to toll collection. The studies are still in progress but

are developing important new data that will be essential in applying AVI technology in the toll road industry.

SYSTEM COST ANALYSIS

The cost of transponders is probably the most visible element in AVI system cost because the ultimate system will deal with millions of vehicles. By far the least expensive transponder is the optical sticker, which costs 10 cents to $8 depending on the required information content, reliability, and longevity. The cost of the radio frequency transponders is about $50, and this is a significant drawback to widespread application at first glance. However, the estimated life of these units, 15 years, along with the greater accuracy, reliability, and information capacity they offer, as compared with optical stickers, may make them competitive in price per use. The cost of microwave transponders has not yet been defined inasmuch as none of these units has yet reached the market stage, but present indications are that their cost would be between that of the optical and radio frequency units.

A preliminary analysis of total system costs was made by Port Authority staff in July 1974. Major capital cost elements include transponders, interrogators, local data recording, and central processing facilities. Tasks include installation and removal of transponders, preparation of monthly statements, and handling of accounts receivable and delinquent accounts. Many choices must be made in defining the exact system. For example, would transponders be purchased or leased by vehicle owners, or would both options be available? If leased, would a deposit be required? What agency would install or remove transponders? Who would pay? What information would be supplied on the periodic statements? Would this vary by class of user? Would all statements be issued monthly, or would variations of this period be desirable? What would be the procedure for issuing statements and receiving payment?

Answers to these questions will be developed in part through a greater understanding of the costs and benefits implicit in the choices and in part through marketing considerations. Much of the work under way to demonstrate a complete AVI-based toll system at the Port Authority is intended to define processing costs. The ball park estimate of total system costs is $10/year/user, of which roughly two-thirds is for the transponder and one-third for mailing and account processing. Other work to define AVI-based toll system costs is being undertaken by the New Jersey Turnpike Authority.

FURTHER AVI EQUIPMENT DEVELOPMENTS

The first routine operation of an AVI system by the public has been implemented by the Delaware River Port Authority, which uses an optical system (19). There are 14 lanes of equipment installed at the Walt Whitman Bridge, 13 lanes at the Ben Franklin Bridge, and 4 lanes at the Commodore Barry Bridge. The optical system is used in conjunction with automatic cash toll collection equipment. Stickers, mounted on the side windows of commuter vehicles, contain four digits: a classification number and three digits for an expiration code representing 30 days from the date of sale. If the date is valid, the patron passes through the lane after depositing a reduced cash toll in the automatic toll collection machine. At the Walt Whitman Bridge, all 14 lanes are equipped with a gate control. Bridge authorities report that they are pleased with the operation of the system.

In November 1974, a microwave AVI system developed under contract for the Army was completed. The microwave system uses a 7.6 by 11.4 by 0.6-cm (3 by 4.5 by 0.25-in) label or transponder affixed to the side of the container (or vehicle). The system is a line-of-sight operation, but, because the information is transmitted in the microwave band rather than the visible light band, the surface of the transponder can be made to appear as part of the vehicle to which it is affixed. As noted above, this system is to be tested by the New Jersey Turnpike Authority.

ROAD PRICING

Road pricing schemes differ from conventional toll road financing in which the primary aim is to recoup road construction and operation costs. Instead, the primary aim is to modify road use to promote public goals such as use of rapid transit. The widespread adoption of such schemes could create a significant market for AVI systems and stimulate the wide introduction of this technology. Thus the development of road pricing is of interest in AVI development as well.

The most significant progress in applying road pricing on a large scale appears to have been made in Singapore. A special charge, equivalent to $1.30, has been imposed on low-occupancy vehicles entering the central area during the morning peak hour. This scheme is being implemented by use of stickers rather than AVI. Peak-hour private car traffic has decreased to 25 percent of its previous level, and bus speeds have increased dramatically. The scheme is generally considered to be a success, and implementation during the evening peak is being considered.

In the United States, studies of road pricing are being made at the federal level, but prospects for implementation appear remote.

RAILROAD DEVELOPMENTS

As the major existing market for automatic identification technology, the railroad industry has been the primary factor in development of equipment suitable for AVI. The multicolored stickers identifying rail cars are ubiquitous, and optical scanners are in widespread use. However, the performance of this system has not met expectations. Identifications were being made only at a level of about 80 percent, even when the problem of dirty labels was attended to.

To evaluate the prospects for improved performance, the Southern Railway staff canvassed developments in identification technology in the United States and other countries and issued a comprehensive report in May 1974 (14). The report states in part:

> Substantial progress is evident in non-optical ACI development. This survey found prototype hardware whose performance exceeds that of the present optical system. All of these non-optical systems operate at wave lengths which penetrate label contaminants which cause the present system to fail.... The tests lead us to conclude that a microwave reflection system can meet crucial AAR specification requirements that are unobtainable by the optical system.... We believe a program could be completed in about 3½ years.

Responding in part to these recommendations, the Association of American Railroads is undertaking a search for a new generation of identification equipment. Progress in that effort will undoubtedly benefit highway applications as well.

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