COLLECTION PROBLEMS AND THE PROMISE OF AUTOMATIC VEHICLE IDENTIFICATION

Robert S. Foote, The Port Authority of New York and New Jersey

Because traditional toll collection cannot be used as a congestion pricing method on federally aided roads, another equitable method needs to be found. Three types of automatic vehicle identification presently available—optical systems, radio frequency systems, and microwave systems—are discussed. Field test results of radio frequency equipment are given for a study done by the Port Authority of New York and New Jersey in 1971. The accuracy of the technology tested shows that it will be possible to charge people for road use in close proportion to their actual use. An automatic vehicle identification system can achieve greater fairness in allocating road use charges than other means existing today.

•ORIGINALLY I had felt that the problems in implementing a congestion pricing scheme would be like those in conventional toll collection. But in doing some homework for this session, I discovered a paper by Coit that caused a change in the approach I had been planning to follow. This paper states (1, p. 9):

> Clearly, congestion tolling in the traditional conception, with the use of collection booths to charge the users on the spot, is not to be allowed on federally-aided roads. However, use of the more sophisticated AVI systems or the simple self-cancelling ticket (à la Sumner Myers), sold in books at a time and place separate from the passageway, would seem to place the congestion pricing experiment safely on the "tax side" of the line, rather than the "toll side."

So the specific problems of traditional toll collection are not pertinent here, because traditional toll collection cannot be used for congestion pricing.

PRICING SCHEMES

Transferring funds from a driver to a collection agency separate from the passageway requires establishment of proof that payment has been made, and destruction of that proof when it is no longer valid. There are two places this proof can be held—by the collection agency or by the driver. For example, if the pricing scheme requires that all vehicle drivers entering the central business district (CBD) between 8 a.m. and 9 a.m. on weekdays pay the city $10 per month, the payment record for a particular vehicle could be carried on a sticker and be checked on a sampling basis. Or it could be carried in a computer maintained by the city that would be accessed on line in real time on a sampling basis by an observer reading license plates.

This form of congestion pricing would be simple from the collection standpoint, especially if a time-dependent sticker were used. Time dependency might be achieved by an expiration date, color code, or automatic sharp change in color after some interval "à la Sumner Myers" (2). Automatic vehicle identification (AVI) installation for this type of collection would be a case of technological overkill and would be uneconomic too.

But such a simple pricing scheme may be unsatisfactory for redistributing traffic, which the proponents of congestion pricing want to accomplish. The goal is to achieve more efficient use of roads by inducing motorists who have only a marginal need for congested highways to travel instead on noncongested routes or at off-peak times. The marginal user then should be defined by the particular congestion existing at the time and by the route he or she would travel. Otherwise either too few or too many people will be diverted to other routes. This could be a serious problem because of the variability in day-to-day and route-to-route traffic conditions. For example, congestion at 7:59 a.m. and 9:01 a.m. could be major.

So if the congestion pricing scheme requires charging the marginal motorist on the route he or she uses and the time he or she uses it, then the sticker system will not be fair because the monthly sticker cost per trip to a motorist traveling to the CBD 4 times a month would be 5 times more than the cost per trip to a regular commuter. That is, the deterrent effect would be weakest for the motorist contributing the most to congestion. A sticker good for only 1 trip would avoid this, but the costs to monitor the stickers would be too high. And if the charge were made proportional to the length of the trip or how late in the peak period it was made or the type of vehicle it was made in, then the number of stickers and monitors would be too high. Here, AVI may be the answer.

AVI PROPERTIES

Automatic vehicle identification is a type of electronic license plate, with a transponder (a small device carried on a vehicle) and an interrogator (an electronic element in or near the roadway). A complete AVI system may also be tied into a computer, have a local printer, and have additional peripheral elements downstream. But the key components are the transponder and the interrogator.

There are 3 forms of AVI techniques that are now available: One sends information in the visible light spectrum by optical technology, another sends information by low-power radio frequency, and the third by microwave energy. An AVI transponder can be powered by a vehicle source, by a part of the transponder, or by roadside circuitry.

The results desired indicate which AVI form would be most suitable. Some of the key elements to be considered are accuracy, amount of information capable of being transmitted, transponder appearance, counterfeiting difficulty, service life of the transponder, and cost.

If accuracy is required, then optical systems may not be suitable. Optical systems have the most field experience—they have been adopted by the Association of American Railroads as standard for identifying railroad freight cars and more than 80 percent of railroad freight cars are equipped with multicolored stickers. However, the accuracy of these transponders, as reported by the Association of American Railroads, is from 70 to 80 percent. The main problem is keeping the labels clean. Collection accuracy must be in the 99 percent range because the cost of handling inaccurate collection information is very high. The microwave systems are not nearly so dependent on the cleanliness of the transponders as the optical systems are, so the microwave approach should offer higher accuracies. But there has not been enough field experience to permit a true judgment of their accuracy. The low-power radio frequency (rf) systems have been tested, and they have demonstrated accuracies from 98 to 99 percent. By more precise coding and other data protection techniques, accuracies of 99.9 percent appear attainable.

Although accuracy is a key element in deciding among various forms of AVI, the amount of information capable of being transmitted by the transponders is also important. The amount of information that can be transmitted from optical stickers on the side of a vehicle is small compared to what can be transmitted with rf and microwave transponders. Optical systems now in use, with stickers 18 in. (457 mm) long, transmit 6 to 8 decimal digits. Systems with rf transponders suitable for a national collection system can transmit 14 decimal digits. Microwave systems have comparable capacity. Both rf and microwave capacity values may be increased without significantly altering the size of the transponder.

Transponder appearance is a problem that depends on how widely used the system will be and whether the equipping of vehicles with transponders will be voluntary. It seems that automobile owners would object to placing 18-in. (457-mm) multicolored stickers on the side of their vehicles far more than they would object to adding a small box underneath their vehicles.

Another inportant factor is the need to protect against counterfeiting. It is easy to counterfeit the optical sticker but not rf or microwave devices.

The service life of the transponder is another point for consideration. An optical sticker has a limited life, and, if the sticker will be renewed at short intervals, this could be advantageous. In the case of the railroad application, however, the identification is for the life of the freight car and label maintenance is a problem. The rf transponder is expected to have a service life of 15 years. These devices use solid-state components and are sealed.

Cost is another major consideration. The attractiveness of the optical system depends primarily on the low cost of the transponder. The installed cost of the multicolored sticker on a railroad car is about $8. The cost (uninstalled) of a rf transponder in production quantities is expected to be $35 to $40. The cost of a microwave transponder would probably be less than rf transponders, but because the technology is still being developed there is no firm information yet.

The costs of interrogators, a significant part of a total system, are reversed. An optical interrogator is considerably more expensive than a rf interrogator, which costs from $4,000 to $7,000.

STATUS OF AVI

Several years of experience with optical transponders on railroad cars in the United States have produced results that are not encouraging—the labels or stickers cannot be kept clean enough to achieve an accuracy of better than 70 to 80 percent. The optical system is also being used widely on containers and on a pilot basis for toll collection at the Baltimore Harbor Tunnel and Philadelphia's Walt Whitman and Ben Franklin bridges. When the stickers are sensed the driver can deposit a reduced rate of toll. But these are systems with limited information capability.

The U.S. Department of Defense is funding the development of a microwave system that will be adapted for identifying containers, freight, and packages. Until this system is field tested, though, we will not know much about it. Microwave systems have been demonstrated as laboratory components but not for unattended field use. Although accomplishing identification using microwave technology is technically feasible, performance questions like the effect of ambient electrical noise can only be resolved through extensive field testing.

The distance required between the interrogator and the transponder may be a potential difficulty in using microwave techniques for identifying highway vehicles. Locating the transponder under the vehicle would subject it to the least amount of interference, but the consequent close distance between the interrogator and transponder would require more precise positioning of vehicles over the interrogator head than is feasible in many highway applications.

FIELD TEST PERFORMANCE

Radio frequency equipment has been rigorously tested. The Port Authority of New York and New Jersey, in the fall of 1971, invited potential manufacturers of AVI devices to demonstrate their equipment by supplying 40 transponders to be mounted on 40 buses and be tested for several months in rigidly controlled field conditions. Although discussions were held with suppliers of all types of AVI systems, only the suppliers of low-power rf systems participated in the field test. Entering the test, which required that the manufacturer provide 40 transponders and an interrogator without cost to the project, represented a commitment on the part of the manufacturer of many thousands of dollars. Thus, only the most serious prospective suppliers took the test. Agreements were concluded with GE, WABCO, North American Philips, and Glenayre Electronics. All but North American Philips were powered inductively from the roadway; the Philips systems used a 3- to 5-year battery in the transponder.

The transponders were mounted on commuter buses that operate between Maplewood, New Jersey, and the Port Authority bus terminal in midtown Manhattan. Interrogator locations were about 4½ miles apart at New Jersey Turnpike interchange 16 leading to the Lincoln Tunnel and the Port Authority bus terminal. The interrogators were connected over leased telephone lines to a computer in the Lincoln Tunnel administration building halfway along the route.

The test was conducted in 2 phases. In the first phase the stress was on the ability to measure travel times for individual buses passing through the road network. In the second phase interrogators for all of the 4 systems being tested were located on the Port Authority bus terminal ramps, and data from each were used to cross-check the others.

Because buses using the suburban level enter the terminal by only 1 lane and leave by only 1 lane, accuracy can be checked by 1 interrogator in the inbound lane and another in the outbound lane. This was done for GE, which provided 2 interrogators. But any errors arising from the failure of the system to detect buses at both the entrance and the exit would pass unnoticed in this system. However, when interrogators from the other 3 manufacturers were placed alongside the inbound GE interrogator, the chance of all failing to detect an inbound bus was remote.

The 4 transponders were mounted on a rig in front of 1 of the test vehicles to determine the accuracy of each system at varying height, lateral placement, and speeds. The maximum speed possible in this restricted location was 30 mph (48 km/hour).

Although the transponders used in this test differ from each other, typical dimensions would be 1½ by 5 by 9 in. (38.10 by 127.00 by 228.60 mm). When the transponder is mounted underneath the vehicle, brackets must separate by 4 in. (101.60 mm) the transponder and the nearest metal on the vehicle because, if the transponder is too close to vehicle metal, its weak signal can be diverted. Based on more than 2 years of experience with buses, no difficulty has been encountered because of the transponder being struck, but mounting similar devices on small cars may be a problem. Most standard-sized cars, though, offer suitable locations for AVI transponders. In large-scale production, large-scale integration (LSI) circuits will undoubtedly be used. Although the primary reason for using LSI components is to reduce transponder costs, they will also make the transponder more compact and make mounting easier.

The interrogator loop cut into the pavement is similar to that required for an induction-loop vehicle interrogator, except that for the GE system 2 overlapping loops are needed—one to start power and the other to receive transponder signals. Typical dimensions are 2 ft (0.6096 m) in the direction of travel by 8 ft (2.4384 m) across the lane. The test on the bus ramp was especially rigorous because of the large amount of reinforcing steel and heating tubes in the ramp and the radio frequency noise from nearby commercial radio stations. These factors proved not to be a problem, however.

The interrogators for the various systems differed considerably in the amount of circuitry provided. But in a typical final installation the interrogator would be enclosed in a box measuring 2 by 2 by 3 ft (0.6096 by 0.6096 by 0.9144 m). With LSI circuitry, the size could be reduced greatly.

The 4 systems were performance tested on the bus terminal ramp for 3 months and were checked against each other. The GE system had the most transactions (because there were 2 interrogators). Out of a total of 13,814 bus passages, all but 181 were measured correctly; the accuracy of the GE system was 98.69 percent. The WABCO system was on line for the longest time for this test, with its 1 loop sensing a total of 9,199 transactions, all but 48 of them correctly, for an accuracy rate of 99.48 percent. The highest accuracy was attained by the North American Philips system. Once initial tuning was completed, which delayed the placement of this system on line, the Philips interrogator sensed 5,226 vehicles, all but 8 of them correctly, for a performance rate of 99.85 percent. The smallest amount of experience was gained with the Glenayre system. During the test Glenayre sensed 1,416 passages, missing only 22—a performance rate of 98.45 percent.

APPLICATION PLANS

What applications are being planned now, based on this experience? The Golden Gate Bridge, Highway and Transportation District has been testing the GE equipment for several years using its own vehicles. Performance of the system has now reached the level where the district has developed plans to make equipment available to the public in the near future.

The Port Authority of New York and New Jersey is now purchasing GE transponders and interrogators to develop an AVI-based toll collection system for nonstop movement of buses. When the toll system is demonstrated, funds will be sought from the Urban Mass Transportation Administration to equip most of the buses using the Port Authority bus terminal with transponders. Because rf systems can display variable as well as fixed data, this installation being planned by the Port Authority of New York and New Jersey could relay such information as the route number of a bus and the number of passengers it is carrying. This information would contribute to the efficiency of bus-fleet management. One purpose of the next Port Authority test is to evaluate such potential benefits.

The New Jersey Turnpike Authority, in conjunction with the Port Authority, is considering the purchase of 250 transponders and 6 interrogators to evaluate AVI on automobiles commuting between interchanges 14 and 16 in the New York metropolitan region. The turnpike test will be particularly valuable in determining the public interest in AVI.

So the development of AVI is proceeding step by step on a limited scale. There are still many important elements to be evaluated, now that the basic performance of the AVI technology itself has been confirmed. Although there are few technical questions about the feasibility of processing nonstop toll collection (or road user pricing) data on line in real time, the best equipment use and configuration and the costs for maintaining accounts for AVI customers need to be defined.

CONCLUSION

It will be possible to charge people for road use in close proportion to their actual use. Automatic vehicle identification technology offers the possibility of greater fairness in allocating road use charges than can be obtained with other means existing today. For example, although a gasoline tax is relatively simple to administer, it is not equitable. Those who must use the poorest quality roads, with many interruptions along their route because of intersections and traffic signals, consume more gas per mile. They pay more for using poor roads than do motorists using costly limited-access facilities. If gas tax revenues decrease because of the scarcity and high cost of gasoline supply and because of the introduction of new forms of energy, AVI can fill an important need in maintaining equitable taxation for road use. However, in simplifying road use pricing, AVI may not be the deterrent that some economists look to for reallocating traffic.

It should be stressed that, in conducting AVI research, the Port Authority of New York and New Jersey is not advocating deterrent pricing. The purpose of highway traffic operations is to serve as efficiently as possible the transportation needs of the people consistent with environmental and other constraints. The availability of employment and, more generally, the quality of life in an urban area depends in part on the availability of efficient and economical transportation. Automatic vehicle identification hopefully can contribute to improving the quality of transportation. But the rate at which AVI is accepted will depend entirely on the judgment of the people. Acceptance of AVI on a broad scale will undoubtedly take much time, but essential work is being done.

REFERENCES

1. Coit, R. J. Tolls or Use Taxes? An Inquiry Into the Prohibition Against Tolling on Federally-Aided Roads. The Urban Institute, Washington, D.C., WP 1212-6, July 1973.
2. Myers, S. Collection Problems and the Promise of Self-Canceling Tickets. Paper in this Record.
3. Automatic Vehicle Identification Systems. Airborne Instruments Laboratory; National Tech. Info. Service, Springfield, Va., PB 185 387.
4. Prospects for Changes in Toll Collection Systems. International Bridge, Tunnel and Turnpike Assn., 1967.
5. Toll Collection: 1969. International Bridge, Tunnel and Turnpike Assn.
6. Foote, R. S. Toward AVI. International Bridge, Tunnel and Turnpike Assn.
7. Tunnels and Bridges Research Staff. Automatic Bus Identification. Port Authority of New York and New Jersey.

8. Automatic Vehicle Identification. International Bridge, Tunnel and Turnpike Assn., Proc. Conf., Sept. 17, 1973.
9. Foote, R. S. Automatic Vehicle Identification: Challenge and New Direction. Port Authority of New York and New Jersey, TBR 3-73, Nov. 28, 1973.
10. Foote, R. S. Automatic Vehicle Identification. Port Authority of New York and New Jersey, TBR 2-74, 1974.