# AUTOMATIC VEHICLE IDENTIFICATION FOR TRANSPORTATION MONITORING AND CONTROL

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Automatic Vehicle Identification (AVI) appears to be an idea whose time has come. Over the past twenty years, AVI technology has offered the potential to provide accurate and timely information on the movement of individual vehicles on our transportation systems, though relatively few schemes have been put into practice. During the next five, AVI seems set to take off through a multitude of public and private sector applications.

Automatic Vehicle Identification is the term used for techniques which uniquely identify vehicles as they pass specific points in the roadway, without requiring any action by the driver or by an observer. The original approach of a vehicle-mounted transponder and a roadside reader has been under study since the early 1960s. Recent significant advances in vehicle detection and data processing techniques have made the application of this concept both technically and economically practicable.

The ability to uniquely identify vehicles offers potential benefits in many fields including fleet management and control, revenue collection, traffic operations, transportation planning, safety and law enforcement. When utilized in conjunction with vehicle weighing systems, specific advantages for weight-distance taxation, tax assessment by vehicle category, size and weight limit enforcement and oversize/overweight vehicle routing requirements become apparent.

The feasibility and potential of AVI systems in highway and traffic engineering has been studied in the USA and Europe since the 1960's and several small scale demonstration projects have been implemented to aid passenger transport services. More recently there has been a revival of interest in AVI with the announcement in 1983 of the Hong Kong road pricing scheme, which aims to charge directly for the use of road space in congested downtown areas.

In North America, the growing impact of freight transportation on highway maintenance expenditures has led to an increasing interest in the application of AVI to truck fleet management. The Heavy Vehicle Electronic License Plate (HELP) scheme is a proposal for an integrated truck traffic monitoring system. It combines automatic vehicle identification (AVI), weigh-in-motion (WIM), and automatic vehicle classification (AVC) technologies with a computerized data communications network, illustrated in Figure 1.

This paper comprises an overview of AVI developments, world-wide. It examines potential applications of AVI technology and its use in conjunction with other state-of-the-art techniques for vehicle weighing and classification. The advantages and problems associated with the

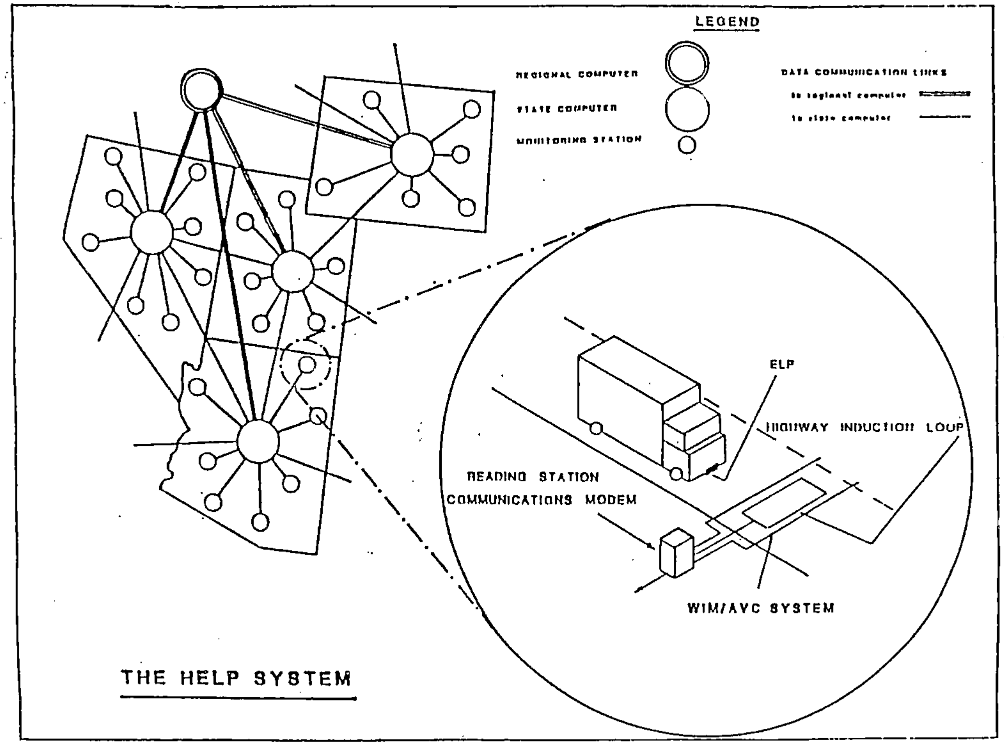
LEGEND
REGIONAL COMPUTER
STATE COMPUTER
MONITORING STATION
DATA COMMUNICATION LINKS
ELP
HIGHWAY INDUCTION LOOP
READING STATION
COMMUNICATIONS MODEM
WIM/AVC SYSTEM
THE HELP SYSTEM

Figure 1

implementation of large scale AVI systems for the monitoring of private and public vehicle fleets are discussed. The paper reviews the main technological options for AVI, and examines the major highway-based applications of AVI technology in Hong Kong, Europe and North America. Finally, it concludes with a look ahead to the future of AVI systems.

## POTENTIAL APPLICATIONS

Automatic vehicle identification systems could have applications throughout the field of highway transportation (1). Specific applications will be found in such areas as planning, design and operation of highway systems, surveillance, communications and control. These include:

1. toll collection - charging vehicle operators at specific points for the use of toll highways and bridges;

2. road pricing - charging motorists for the use of congested road space;

3. fleet management - monitoring and optimization of the utilization of a particular vehicle fleet;

4. urban traffic control - the use of AVI data for on-line computer optimization of signal timings and for special priorities at signals;

5. transportation data collection - the collection of data for subsequent use in transportation planning, traffic engineering and highway design.

Developments in data transmission, processing and communications techniques have increased the viability and reliability of automatic vehicle identification equipment and several city-wide or area-wide systems for the monitoring of public transit fleets are now in operation. Techniques for the collection of data on traffic volumes, speeds, vehicle weights and types have now become a practical proposition as has the reliable transfer of data from remote sites. The combination of these techniques with automatic vehicle identification could improve the potential and viability of AVI in a number of applications, including the following.

### Heavy Vehicle Monitoring

AVI techniques would appear to offer substantial benefits in the monitoring, control and operation of the heavy vehicle population. In recent years, there has been a trend toward the use of heavier and larger commercial vehicles which has resulted in an accelerated deterioration of the major highway systems. Legislation to curtail the use of excessively laden vehicles exists but is costly and difficult to enforce. Concern over the effectiveness of current taxation structures in ensuring that commercial vehicles contribute a proportionate payment for road track costs has also been shown. In the U.K., the influx of larger and heavily laden vehicles from Europe has reinforced the need for increased vehicle weighing and monitoring activities. In the U.S.A., both federal and state governments have shown concern for the problem and have begun to investigate schemes for the automatic monitoring of truck size and weights involving the use of AVI techniques.

Automatic vehicle identification, coupled with state-of-the art techniques for weighing vehicles in motion, could provide a method by which truck data collection efforts may be rationalized and coordinated. The technique could improve productivity while reducing long term data collection costs. In addition, an AVI system could offer advantages to the operators of commercial vehicle fleets by providing a means by which fleet managers could monitor the location of vehicles and therefore utilize the resouces at their disposal more efficiently.

Finally, AVI technology could be used in the enforcement of size and weight limits. Using a combination of automatic identification, weigh-in-motion, and vehicle classification, enforcement agencies could identify a truck and determine its size and weight and whether it was covered by a special permit exemption.

## Revenue Collection

AVI used in revenue collection applications could speed operations at toll booths, car park entrances, and other facilities where a vehicle has to come to a stop to present payment. The system could be operated in either a prepaid or credit mode. In either case, the patron would receive periodic statements of usage and account facilities. Such a system would offer the patron convenience of payment, nonstop passage through the facility, and printed records of usage. An AVI-based revenue collection system could offer the operator very significant labor savings and better information on vehicular movements through the facility.

In revenue collection systems where the operation is hindered by lack of capacity at the collection point, the much greater throughput afforded by an AVI system could substantially improve operations. A further extension of this concept is the introduction of toll charges on congested facilities, using AVI for electronic road pricing. The concept of road pricing, whereby users of congested highways would pay for the use of the road on a differential basis, has been widely examined and is currently being demonstrated in Hong Kong.

Another form of revenue collection to which AVI could certainly contribute is weight-distance taxation. Certain states in the U.S.A. already implement this form of heavy vehicle taxation whereby a particular vehicle is charged on the basis of the distance travelled and the registered load (calculated as ton-miles). While the system offers benefits in terms of proportional contribution to cost responsibility, the operation of the system is relatively expensive requiring regular monitoring activities.

An AVI system for the administration of a weight-distance tax would have several advantages over the present tax collection process. State governments could use a common data base for standardized truck taxation, enabling a uniform and continuous tax program to be achieved. The use of AVI technology could lead to considerable reductions in the cost of operating the revenue collection process and in addition lead to equally significant reductions in evasion. Furthermore, an AVI system offers the potential for a more equitable vehicle tax structure. Taxes could be based on a combination of vehicle parameters such as gross weight, axle weights, vehicle configuration, location, time, functional class of highway, etc., so as to reflect the broader impacts of transportation users on the community as a whole.

## Traffic Operations and Transportation Planning

AVI offers potential for improved traffic operations, particularly where priority access systems are planned or utilized. By providing the ability to uniquely and accurately identify vehicles by type, the effectiveness of priority access systems could be greatly increased. Surveillance and control systems could also benefit as AVI information coupled with data on vehicle speeds, lengths and types would permit more precise definition of traffic composition and flows.

The prediction of the number of interzonal trips, and their distribution by time of day, route, and mode is inherent in the transportation planning process. These predictions are based upon large quantities of origin-destination data, the collection of which is an expensive and time-consuming process. It is unlikely that an AVI system would be installed specifically to benefit the transportation planning process, but if the installation of AVI systems for other applications became a reality, AVI readers at specific locations could produce automatic and accurate origin-destination data in a form that can be used efficiently by transportation planners.

## Law Enforcement

Motor vehicles are used directly or indirectly in a wide variety of criminal activities. These range from the theft of private automobiles and the hijacking of trucks to the use of vehicles in perpetrating the crime itself or fleeing from the scene of the crime. The present methods of locating these vehicles are, in large part, cumbersome and ineffective, although recent developments in automatic video scanning of conventional license plates has shown promising results.

In one application an electronic video scanning system was located at the toll plaza to the Dartford tunnel, near London, England. As a vehicle stopped to pay the toll, its number plate was electronically read and compared with an online data base of license plate numbers of wanted vehicles. Detection of a wanted vehicle resulted in a message being relayed to a local police control center. The development of this equipment is continuing with the adaptation of the system to read the license plates of vehicles as they move at full highway speeds.

The use of license plate scanning techniques for automatic vehicle identification avoids the need to equip vehicles with a special transponder unit. However, electronic identification tags that could not be altered or replaced, and with a very low reading error rate, would have distinct advantages over conventional license plates for law enforcement activities.

Automatic vehicle identification coupled with speed monitoring techniques could have application in speed limit enforcement activities. Systems that automatically photograph a speeding vehicle's license plate are already commercially available. An AVI-based speed trap could operate unmanned, the identification of violators being automatically recorded and stored to enable subsequent warnings to be given or prosecution to be made.

Another law enforcement application is in the trucking industry where hijacking of vehicles is a serious problem. The location of trucks equipped with AVI transponders would be determined automatically as they moved along known routes. Knowledge that the truck had not reached a specific point within a predetermined time interval could indicate a potential problem.

A recent marketing distribution plan developed for the Lo-Jack Corporation of Boston, Massachusetts by Touche Ross & Co assessed the potential market for the company, which has developed and patented a vehicle theft detection system based upon state-of-the-art technology. In defining the nature of the motor vehicle theft problem, the report uses as evidence costs borne by society and the trucking industry. It was estimated that annual losses through theft to the trucking industry approximate to $7 billion. The number of automobiles stolen each year in the United States was put at over one million, at an estimated cost to society of $2.9 billion, with automobile insurance losses due to theft approximately $3 billion annually. It was also noted that stolen cars and trucks are responsible for causing over 5,000 disabling injuries and fatalities annually. If increased deterrence through use of a freight traffic monitoring system could lead to even a small percentage reduction in these figures, the benefits to society would be substantial.

## POTENTIAL PROBLEMS

The above discussion has highlighted some of the potential applications and benefits associated with the use of automatic vehicle identification systems. In many areas these benefits appear to be substantial and indeed have led to the implementation of AVI for railroad and public transit applications. Larger, more general applications have, however, yet to be implemented, for both practical and political reasons.

With the recent advances in vehicle sensing, data processing and information transfer techniques, the technical problems of large scale AVI systems have been considerably diminished. Current AVI applications have indicated the reliability of transponder/reader technology. The techniques for the remote control of distributed data collection stations and the retrieval of data using telemetry techniques are well established and in use in many parts of the world.

The practical implementation of a large scale AVI system remains, however, far from easy. In many AVI applications maximum benefits are obtained from the system when a large vehicle fleet is equipped with transponders. The problem arises in determining just how to achieve this situation. Should all vehicles currently on the highway be fitted with transponders or should only new vehicles be equipped? The former approach requires a large capital outlay while the latter would mean that it would be many years before the majority of the vehicle population carried transponders. A third approach would be to implement local area systems which could be combined over a period of time. In this case the problem of maintaining compatibility between equipment arises.

In addition to installing the transponders, the problem of ensuring reliable operation has to be considered. A system for the regular checking of transponders would be required for the whole vehicle population. In revenue collection applications, an accidentally or deliberately malfunctioning transponder could cause serious problems. The prevention of fraud has been a major consideration in the development of the Hong Kong road pricing scheme. Special transponders, using security coding and scrambling techniques have been designed to help eliminate this problem. In speed enforcement applications, the speed monitoring and vehicle identification systems would have to be proved to be accurate and reliable enough to be considered admissible evidence in court.

Perhaps the most important problem to be overcome in the implementation of an AVI system is the political aspect of monitoring individual vehicle movements. Applications to date have commonly involved the monitoring of public transit vehicles where the information obtained has been used only to improve the efficiency of operations, the public in many cases being unaware of the monitoring activity. Current studies into the development of heavy vehicle tracking systems involve the individual identification of privately owned vehicles which may be acceptable where the application can be seen to have direct advantages for the trucking industry and its operators.

The advantages to the general public of individual monitoring of private cars are likely to be less distinct or direct. The technology could be seen as an intrusion of individual privacy and strong opposition to its implementation can be anticipated. AVI systems could be considered as a step closer to the Orwellian 1984, despite the fact that for many years every vehicle has been uniquely identifiable from its license plate. The electronic reading of these plates as against human observation could certainly provide more scope for an unacceptable intrusion of privacy. The identification of vehicles by electronic coded tags that are out of sight and unalterable by the owner may therefore be best postponed into the indefinite future.

## AVI TECHNOLOGIES

The main technologies for automatic vehicle identification can be divided into ground-based and satellite-based systems (2). Satellite systems offer the possibility of continuous monitoring while ground-based systems will only identify vehicles at fixed locations on the highway system. However, ground-based systems currently offer substantial cost-savings over satellite-based ones.

Ground-based systems for the automatic monitoring of vehicles typically consist of three functional elements: the vehicle-mounted electronic license plate or tag; the roadside reader unit, with its associated antennae; and a system for the transmission, analysis and storage of data. The broad technological options comprise:

optical and infrared systems;
inductive loop systems; and
other ground-based r.f. and microwave systems.

## Optical and Infrared Systems

Optical systems formed the basis of the earliest vehicle ID technologies. Several systems were developed during the 1960's in the USA and Europe. These were mostly superseded in the vehicle identification field during the 1970s due to several problems which are outlined below.

Optical systems require clear visibility, performance being seriously degraded by snow, rain, ice, fog or dirt. They are sensitive to scanner/label misalignment, focusing problems and depth of field limitations, though improvements in performance have been achieved in recent years. Infrared systems were tried during the 1970s as a substitute for the earlier optical approaches, but these never gained widespread application. They share most of the problems of the optical systems, being similarly sensitive to environmental conditions.

## Inductive Loop Systems

Inductive loop vehicle ID systems use conventional traffic detection and counting loops in the highway pavement to detect signals from tags mounted on the underside of vehicles. Inductive loop systems operate in the kHz frequencies, typically 70 to 150 kHz. These approaches can be divided into active, semi-active and passive systems, according to the source of power used by the vehicle-mounted tag.

Active systems use an electronic tag which takes its power supply from the vehicle on which it is mounted. These systems may transmit the identification code continuously, or may be triggered by a signal from the inductive loop in the pavement. As the power supply for transmission of the vehicle ID code is not significantly limited, they may be picked up over a wide range of lateral positions on the highway, given an appropriate design of inductive loop array.

Inductive loop vehicle identification systems based on active electronic tags have been successfully applied to bus and streetcar ID applications, in the USA, Europe and Australia. In these applications, power from the vehicle is readily available and incentives to cheat the system are normally absent. Of great importance in many cases, however, is the problem of system security. Any externally-powered electronic license plate must be vulnerable to external switching or disablement. Even where deliberate fraud is excluded, the power feed cable and its connections are likely to be the weakest link in the system. This source of unreliability is unlikely to be acceptable within a revenue collection or enforcement system.

Passive systems use an electronic tag which is energized by power transmitted from the inductive loop in the pavement. Typically, a pure sinusoidal unmodulated carrier is emitted by the road loop, and picked up by a similar loop or ferrite rod antenna on the vehicle. The mechanism of energy transfer is via electromagnetic induction, analogous to that between the primary and secondary windings of an air-core transformer. The electronic tag then re-transmits a coded signal of very much lower power, which is detected by a second loop or by another antenna in the pavement. Passive tags are sealed units with no external power supply. When outside the field of the powering inductive loop, these tags are totally inactive.

Passive systems are generally less vulnerable than active units to outside interference or damage, whether accidental or deliberate. With appropriate security coding, a high resistance to fraud can be built into these systems.

Semi-active systems have been developed most recently, and use an internal battery to provide power to transmit the vehicle ID code when triggered by an inductive loop. These totally sealed units require no external power supply, and therefore overcome the problems of the fully active system.

Although semi-active inductive loop vehicle ID systems are relatively untried and have not been widely tested, they seem to offer a particular balance of advantages which could make them most appropriate for system designs.

## Other r.f. & Microwave Systems

Other ground-based radio frequency and microwave systems have generally adopted roadside or trackside antenna layouts, transmiting and/or receiving on a wide range of frequencies in the kHz, MHz and GHz ranges. Like inductive loop systems, these technologies can be divided into active, semi-active and passive approaches. Active systems suffer from the same problems as their inductive loop counterparts and are therefore likely to be excluded from many applications.

Typically, in a passive microwave application, the encapsulated tag is attached to the side of a vehicle or container. The tag contains a small internal receiving antenna, an internal transmitter, and solid-state electronic circuitry. The roadside reader unit illuminates the tag with a fixed RF frequency, some of which the transponder absorbs, converts and transmits back to the reader unit, in a form containing the ID code. Conversion may be to a harmonic frequency or simply by polarization and modulation of the radiated signal.

Results of tests on microwave systems suggest that their performance can be sensitive to reader/tag alignment, focusing, temperature and vibration. The reader requires line-of-sight contact with the tag, though not necessarily an optically clean path. In multi-lane situations, however, occlusion of the beam by vehicles in adjacent lanes constitutes a serious problem.

The most serious concern associated with other r.f. and microwave passive systems, however, concerns the power levels which must be transmitted in order to energize the vehicle-mounted tags. In many countries these may violate limitations on communication systems frequency power outputs, or even user safety standards.

Semi-active systems may again offer a satisfactory compromise, using a sealed unit transponder with an internal lithium battery. These should allow radiated power levels to be greatly reduced, whilst providing for an electronic license plate design life of several years. Once again, however, the technology is relatively untried, though several prototype systems have been tested.

## Satellite Systems

An area which has become feasible as a means of implementing a heavy vehicle electronic license plate system through technological advancement is the use of satellites for position fixing.

Satellite location systems operate by precise timing of signals transmitted from a ground station, through two or three satellites, to a receiver. By looking at the difference in the time of arrival of signals routed by each satellite, the distance of the receiver from each satellite can be calculated. This leads to a position fix in three dimensions through trilateration.

By the end of 1987 the Navstar/Global Positioning System (GPS) will be fully operational. The Navstar/GPS system will give highly accurate, all weather continuous navigation fixes to users anywhere in the world that will permit users to obtain position, velocity and time.

At the time of implementation of Navstar/GPS, manufacturers have suggested that their receiver would be about the size of a car radio. Receivers are quite sophisticated, with complex timing and computation functions required, and costs are currently much higher than could be accepted for a typical AVI system. Once the position of a vehicle has been found, it is still necessary to transmit its location to a central point for data analysis, perhaps by cellular radio. However, the complex nature of the required total equipment package makes it very doubtful acceptable cost targets could ever be approached.

Another satellite system which could be used in AVI schemes, however, is being developed by the Geostar Corporation of New Jersey. Geostar will provide accurate information on position, and two way data transmission by satellite, for users with a small, battery-operated transceiver, like a single channel CB radio. Geostar will use three geostationary satellites for coverage of the United States and a ground station which will carry out all computations and positioning. Each position measurement is processed by the ground station computers with the identification of the user's receiver given by a unique individual code.

In the first-generation Geostar system (coverage of the continental United States) there will be three satellites in orbit above the equator at fixed longitudes, over the Atlantic, over the central United States, and over the Pacific. The ground station, which can be at any convenient secure location, sends a radio signal up to one of the satellites many times per second. The satellite relays the signal in a broad beam covering the United States. When the transceiver, which can be on a vehicle, boat, aircraft or building, receives the signal it responds with a binary sequence or 'fingerprint' of pulses which uniquely identify that transceiver. Additional digital data or a message may be added to the same signal.

The communications pulse code is received at each of the three satellites and relayed by them to the ground station over tight beams, arriving as three identical pulse sequences at three different times. The computer at the ground station identifies the fingerprint, measures the three times and from that timing information computes the longitude, latitude and time of response of the communication.

Discussions with electronics manufacturers have shown that current transceiver costs would be about $450 per unit. However, it is feasible that a reduced capability system matched to an AVI system needs could be substantially cheaper. For this reason, further investigations into the potential of Geostar would be worthwhile before major commitments are made to ground-based AVI technologies.

## CURRENT DEVELOPMENTS

Several countries are currently investigating applications of AVI technology. The Hong Kong Government has just completed a pilot stage evaluation of an Electronic Road Pricing scheme, based on AVI. In North America, toll authorities have studied the possibility of using AVI as part of non-stop toll collection systems. A group of western states and provinces is currently implementing a heavy vehicle electronic license plate (HELP) system which will utilize AVI for truck monitoring. Finally, the European Economic Community has recently commissioned a study of the feasibility of developing a European monitoring system for vehicles transporting hazardous goods and wastes.

### ERP in Hong Kong

In March 1983 the Hong Kong Government announced its intention to pursue the demonstration of Electronic Road Pricing (ERP).

In the six years up to 1982, car registrations in Hong Kong had soared from 113,600 to 219,000, with traffic congestion reaching alarming proportions. The Government reacted to this by doubling the registration tax and tripling the annual licensing fee. These measures helped to limit congestion to the then-existing levels. However, in the busiest areas, not much improvement was made, as it was only the lesser used vehicles and those in rural districts which were taken off the road. These vehicles had contributed little to the problem in the first place.

As a result, the Hong Kong Government decided to investigate a system which would inhibit the use of vehicles at the times and places where roads are most congested. This system uses AVI technology for Electronic Road Pricing (ERP). Road pricing is considered to be the most efficient and equitable method of restraining traffic under the circumstances prevailing in Hong Kong.

The theoretical objective of road pricing systems is widely agreed. That is, no vehicle should come on to the roads if the benefit from it doing so is less than the costs the vehicle imposes on others in the community. If this is achieved, then supply and demand are balanced in the most cost-effective way. 'Costs' and 'benefits' are, of course, defined in the broadest possible way to include environmental pollution, accidents and so on, as well as fuel and journey time differences.

When there are these congested conditions, road pricing imposes a small charge designed to make a small percentage of road users think again about making a particular trip in a particular way to a particular place at a particular time. Those motorists whose trip making in congested conditions is least valuable in terms of benefit to the community, will be deterred by the charge and make alternative arrangements. Other motorists will benefit from the reduction in congestion and significant increase in overall journey speeds which for many will outweigh the road pricing charges. Perhaps most importantly, all road-based public transport users will feel the results directly and their journeys will be improved.

A pilot stage ERP project was carried out in Hong Kong during 1983-85 (3). The pilot stage system was installed to demonstrate the case for a full Territory-wide system. The formal objectives of the pilot stage were that:-

a. the case for the transport planning benefits from a proposed design should be proved in detail;

b. the technology should be robustly tested;

c. the administrative means to implement and run the system should be demonstrated; and

d. the implications of introducing ERP should be fully understood.

The major components of the ERP system are:

1. the electronic number plate (ENP), or tag, fitted to each vehicle;

2. the toll site which comprises an inductive loop array in the road, and outstation (microprocessor-based intelligent unit) and toll charge signs;

3. the data transmission system, enabling data to be passed from the outstations to a central control point and vice versa;

4. the control center, which contains the processors for communicating with the outstation, collecting and verifying data and managing the system operations; and

5. the CCTV enforcement system, which records and transmits photographs of vehicles about which there is query.

A full system would operate as follows. Each motor vehicle in the Territory except (initially) motorcycles would be fitted with an AVI tag. At each toll site there would be an inductive loop arrray. The unique identity of a vehicle's tag would be decoded by the roadside computer and passed via dedicated telephone lines to the control center. The roadside computer also controls a sign displaying the current charge for crossing the site.

At the control center, data are checked for consistency and validated information is passed to the accounting computer. Once a month a statement, like a credit card account, is sent to each owner prior to eventual requests for payment.

During the trial period, the system operated successfully and demonstrated that a full system could persuade a proportion of car users in busy times and places to change the time of their journeys or to use public transport. However, full scale implementation raised significant political objections, which at present seem set to delay full implementation indefinitely.

Although the Hong Kong system may not be used for road pricing, there are several other potential benefit areas. One of these is the use of AVI technology to automate bridge and tunnel toll collections in the Territory.

Fleet management and location services might also be provided for commercial and government vehicles, or public transport operators. The system could provide a substantial input to traffic data collection, replacing much of the annual Traffic Census and giving significant improvements in coverage and content. Finally, the roadside equipment could be linked to traffic signal controllers, enabling emergency vehicles to be identified and given priority.

Whether or not the final decision is taken to go to a full system in Hong Kong, the pilot stage has demonstrated that Electronic Road Pricing is both technically and economically feasible, and is potentially of net benefit to the community as a whole. Interest in ERP systems has been shown by many countries and the concept may spread now that the technology has been demonstrated.

## Toll Collection

The potential application of AVI for toll collection was reported to the 1967 Workshop of the International Bridge, Tunnel and Turnpike Association (IBTTA), at whose recommendation the Federal Highway Administration (FHWA) funded a study of the feasibility of a national automatic vehicle identification system. The study provides a comprehensive review of the field at that time, and concluded that several promising benefits could be derived from the implementation of a national AVI system.

Major recommendations of the study were: (1) there should be a national standard AVI system; (2) the standard system for highway use should adopt the low frequency induction technique; (3) there should be a full-scale test and demonstration of the system; and (4) a single numbering system should be adopted nationally to avoid ambiguity in vehicle identification.

In 1973 the FHWA and IBTTA jointly sponsored a conference on automatic vehicle identification, following a preliminary briefing earlier in the year. The conference led to the conclusion that the national interest in AVI was too diffuse and contradictory to provide support for a national system. It was recommended that the development of AVI for individual applications should continue, and that an awareness of contemporary techniques should be maintained to increase the potential for a national standard.

Tests on AVI systems continued when the Port Authority of New York and New Jersey received Urban Corridor Demonstration Program funds from the FHWA to support tests of AVI systems for buses. The aims of the tests were: (1) to evaluate the performance of the bus identification systems; (2) to consider the benefits of AVI in bus operations; (3) to develop code and numbering methods for an AVI system; and (4) to prepare specifications for an AVI system based on the test results.

Four manufacturers supplied AVI systems using low power r.f. techniques, which were evaluated on the basis of accuracy and reliability. For the tests, each manufacturer supplied equipment for monitoring buses in a closed loop system, and for transmitting data over telephone lines to a computer. The four systems included both active and passive tags, ie., they were powered either from loops placed in the road, or were battery supported.

The final report by the Port Authority concludes that the systems were capable of performing with approximately 98% accuracy and that installation of an AVI system was feasible. It was noted, however, that a national standard on equipment design and coding structures was desirable to maintain future compatibility.

In 1973/4 Golden Gate Bridge staff conducted tests on a radio frequency AVI system designed for the identification of buses. Special attention was given to the coding and a message format to ensure the system could serve as a standard for the tolling industry. The system allowed two types of tag, one with a permanently fixed code and the other with a facility for a varying source of the code from on board the vehicle. The system had restricted use on some passenger cars, but was not extended to the general public.

A small-scale optical AVI system for toll collection was implemented at this time in Philadelphia, PA, by the Delaware River Port Authority. This system covered 31 traffic lanes over 3 bridges around the port. Stickers mounted on the side windows of commuter vehicles indicated that a vehicle was eligible for a reduced toll, which was deposited into automatic collection equipment at the toll booth. The system did not uniquely identify vehicles, but determined eligibility for the reduced toll. In 1976 the New Jersey Turnpike Authority (NJTP) tested microwave AVI equipment, using smaller and lighter tag components than those of the earlier approaches. The equipment was tested as both a vehicle-mounted and a hand-held system. The mounted system used a passive encapsulated tag which contained a small internal receiving antenna, an internal transmitting antenna and a small solid state electronics unit.

The reader unit worked in the range of 4 to 20 feet and illuminated the tag with fixed frequency RF energy. The receiving antenna of the tag absorbed some of the energy and converted a portion of it to a second harmonic frequency which was transmitted back to the reader. The rest of the absorbed energy powered the electronic circuits. The control logic of the tag modulated the transmission to the reader with the desired identification number.

The Port Authority of New York and New Jersey also expanded tests of microwave systems in the late 70's. Strict control was kept on the levels of microwave radiation, for public safety reasons. The vehicle tags were about credit card size, but about 1/2" thick. The four systems tested were an infrared system from the Kilo Corporation of Detroit, and microwave systems from Swedens Microwave Institute Foundation (M.I.F.), the Siemens Corporation of West Germany, and Toshiba of Japan (4).

Kilo's infrared system was battery operated, incorporating an infrared tag which received energy from the reader and used a light emitting diode to transmit the tag number back to the roadside. The MIF reader was a simple box unit which was fixed under the canopy of the Lincoln Tunnel. The unit was about book size and self contained, the tags being battery charged. Siemens supplied two units for testing, again based on microwave technology. The Toshiba system used a reader which had a transmitting antenna mounted horizontally. The antenna was larger than those of the other manufacturers, but this system had the advantage of a passive tag of a swept frequency type which resonated at characteristic frequencies to transmit coded information.

Toll authorities continue to play an active role in AVI development, with tests continuing at the Port Authority of New York and New Jersey, and at the Coronado Bridge, California, at the present time.

## The HELP System

The Heavy Vehicle Electronic License Plate (HELP) System is currently being developed by a group of western US states and Canadian provinces. This is an integrated truck traffic information system for North America combining automatic vehicle identification (AVI), weigh in motion (WIM), automatic vehicle classification (AVC), and a data processing and communications system. The aim is to implement a nationwide system capable of automatically collecting truck weight and classification data, as well as tracking individual vehicles.

This section describes the results of a study of the technical and economic feasibility of developing and implementing a national heavy vehicle electronic license plate (HELP) system. The feasibility study was carried out by Castle Rock Consultants (CRC) under contract to the Arizona Department of Transportation, with funding from the US Federal Highway Administration.

Throughout the duration of the feasibility study, extensive consultations took place with state and federal agency personnel, and also with representatives of the trucking industry to establish the potential applications of a comprehensive monitoring and data collection system. Six main application areas of the HELP system were established, with some overlap in specific areas. The six applications are:

transportation planning;
vehicle taxation;
size, weight and speed enforcement;
hazardous materials monitoring;
truck fleet management; and
crime detection.

Taking each of these areas in turn, the potential benefits of the system were identified, as outlined below.

Transportation planning relies on the collection of extensive truck data used in pavement design, highway cost allocation, pavement research, and highway maintenance management systems. Traditional methods of truck data collection have considerable disbenefits which may be ameliorated by the introduction of automatic vehicle identification (AVI) technology within the HELP system framework.

Vehicle taxation presents a considerable administrative burden to US states and truckers alike. Paperwork is extensive and complex, constituting an essentially unproductive activity which is however necessary for the assessment and audit of tax liabilities. Here the HELP system offers enormous potential for simplification and rationalization of existing procedures, offering substantial savings to both trucking firms and states alike.

Size and weight enforcement is an essential but costly activity at present, involving delays to trucking firms as well as labor intensive programs operated by the US states. By automating most of the enforcement program, the HELP system could benefit the trucking industry through time savings at weigh stations and ports of entry. US size and weight enforcement agencies would also see substantial benefits due to increased productivity of staff, permitting rationalization or redeployment to other essential tasks.

Hazardous materials monitoring is very limited at present, because of the difficulties of tracking dangerous cargoes on different routes. Public safety considerations require that rescue response activities should be coordinated and planned in accordance with both general needs and specific loads being moved within the state. The HELP system could permit effective monitoring of hazardous cargoes for the first time, avoiding the high cost and increased paperwork of a conventional monitoring system which might otherwise be demanded in this area.

Truck fleet management and control may prove to be the single most important area of application for the HELP system. Fleet management information is essential for efficient utilization of the resources available to trucking firms. Most past applications of automatic vehicle identification technology have involved this basic objective, which has normally been sufficient justification in itself for a major systems investment. Widespread highway applications have been held back by the absence of an appropriate roadside infrastructure for AVI, which would be rectified by the HELP system. The potential benefits to trucking firms from this application are very substantial.

Crime detection through the HELP system could help reduce a multibillion dollar drain on the national economy, resulting from the theft of cargo while in transit on the highways. Annual losses through theft within the trucking industry approximate to $7 billion each year. Even a small percentage reduction in the volume of truck theft could effectively pay for the HELP system within a short period of time.

A development program has been drawn up for the national implementation of the HELP system which incorporated hardware testing of the HELP technologies and the design of a system which will integrate the technologies into a "total system". This is to be followed by a full scale demonstration of the HELP system involving a 'Crescent' of states in the USA and the province of British Columbia, before a final evaluation report is submitted to Congress. (See Fig 2).

The HELP development program builds upon the initial studies which showed that the HELP system was both technically and economically feasible (5). The magnitude of the annual benefits being estimated as substantially greater than the initial system cost. The system operating costs would also be significant, though apparently small in relation to the potential benefits. Although subject to considerable uncertainty, the preliminary figures suggest that a fully operational system could pay for itself within as little as six months.

Given cooperation between states, and a partnership with industry it seems as if a win-win situation can be achieved in bringing the benefits of new technology to the motor carrier industry in North America.

## European Developments

Recent events in several countries have focused public attention on dangers associated with the manufacture, transportation and storage of hazardous substances. Freight vehicle bans proposed for London and elsewhere are symptomatic of a general public disquiet on the heavy truck problem, in which hazardous materials transportation is perhaps the single most emotive issue. Economically and socially, however, such blanket bans may be neither practicable nor desirable. More selective means are required to deal with this problem and monitor the effectiveness of traffic controls.

Studies show that more than 50 percent of all goods transported throughout the world are potentially hazardous, to a degree. Hazardous materials are associated particularly with the petro-chemical, chemical, nuclear and defence industries. However, many other industries depend on raw materials whose transportation presents a risk to highway users and residents of adjacent properties. These risks are most acute in urban networks, but also extend throughout the interurban system and all functional classes of highway.

In general, the safety record of hazardous cargo transport firms is good, with a relatively small number of incidents per year resulting in serious injury or death. This may largely be due to the current control systems operated throughout the world. Agreements such as those concerning transport of hazardous materials across international borders in Europe by road (ADR) and rail (RID) have certainly helped to restrict the frequency and severity of effect of incidents involving hazardous materials.

However, there is no room for complacency within the hazardous cargo industry. Incidents such as the 1978 Spanish camp site disaster, in which more than 200 people were killed when a liquefied petroleum gas tanker exploded, illustrate the need for continuing development of safeguards and standards.

The advent of modern microprocessor technology provides an ideal opportunity to improve the monitoring and control of hazardous material movements and therefore provide a further reduction in the element of risk inevitably associated with this type of cargo.

A number of systems have already been developed which make use of computer database approaches, such as the Harwell Information System currently operated in the United Kingdom. This stores data on a wide range of properties and parameters associated with hazardous substances, such as hazard classification, action in fire and first aid requirements. These data can be retrieved by emergency response services or planners requiring detailed information on how to handle a particular substance.

AVI technology could have a substantial impact on the monitoring and control of hazardous materials transportation. The AVI technology that is ultimately adopted may be either ground-based or satellite-based. Alternative systems are currently the subject of a European Economic Community (EEC) study.

The study aims to produce proposals on:

1 the vehicle mounted identification unit (the tag) in which

information about the vehicle and its load can be stored in a tamperproof manner.

2 A receiving and transmission system compatible with the vehicle mounted unit.

3 A central data storage system with feed-back to local authorities, police or fire-brigade.

Specifications for the system hardware will be developed and cost estimates for hardware to be used in a pilot project will be produced as an output from the study.

## CONCLUSION

This paper has highlighted the fact that AVI seems set to take off through a multitude of public and private sector applications. Several potential application areas have been reviewed and available technological options have been examined. Case studies of current AVI applications are cited. It is probable that with the installation of AVI systems increasing worldwide, momentum will continue to grow and applications will flourish. One problem that may arise from this is that diverse and incompatible technologies may be implemented, either within individual countries or internationally. It is apparent that a high degree of cooperation is necessary to achieve international compatibility in order that the full potential benefits of AVI can be achieved.

## REFERENCES


1 Salter D., (1984), "The Potential of Automatic Vehicle Identification", International Conference on Road Traffic Data Collection, London, December.

2 Castle Rock Consultants, (1985), "Heavy Vehicle Electronic License Plate - Feasibility Study Report", Arizona Department of Transportation.

3 Catling I and Turner J.D., (1984), "Automatic Data Collection in Hong Kong", International Conference on Road Traffic Data Collection, London, December.

4 Foote R.S., (1984), "Prospects for Non-Stop Toll Collection using AVI", Transportation Research Board, Washington, January.

5 CRC Corporation, (1985), "Heavy Vehicle Electronic License Plate System Concept Development Study Report," Arizona Department of Transportation.