

# Development of Heavy-Vehicle Electronic License Plate Concept

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## ABSTRACT

Described in this paper is the current progress of the work undertaken by the authors on the development of a heavy-vehicle electronic license plate (HELP) system in the United States. A summary is provided of the results of studies on the technical and economic feasibility of the HELP concept, and its further development before a multistate demonstration project, known as the Crescent Project. The studies have been performed by CRC Corporation under contract to the Arizona Department of Transportation, with funding from the Federal Highway Administration. The HELP system is an integrated heavy-vehicle monitoring system that combines automatic vehicle identification (AVI), weigh-in-motion (WIM), automatic vehicle classification, and data communications and processing. It will permit the collection of transportation planning data, plus general highway system regulation and fleet management. An outline of these applications of the system is included, as well as the AVI and WIM technologies, which would satisfy the needs of the system users. The format and content of the coded information stored in the identification tag attached to vehicles is also discussed. A summary of the cost-benefit analysis and the proposed implementation strategy leading to the demonstration project is also included.

This paper describes the results of studies on the heavy-vehicle electronic license plate (HELP) system concept, performed by CRC Corporation under contract to the Arizona Department of Transportation, with funding from the Federal Highway Administration (FHWA). The HELP system is to be an integrated heavy-vehicle monitoring system that combines automatic vehicle identification (AVI), weigh-in-motion (WIM), automatic vehicle classification (AVC), and data communications and processing.

Included in the paper are details of the initial study into the technical and economic feasibility of developing and implementing a HELP system, and the development and further refinement of the HELP concept in a subsequent study. The aim of the latter study was to build on the work carried out in the feasibility study and Oregon concept demonstration, taking the HELP development program to a stage where several of the system testing and design strands can begin. These activities will include the testing of current AVI systems and the subsequent development of a detailed performance specification for AVI; related work on WIM and AVC performance specifications; the Systems Design Study, dealing with requirements for the data communications and processing systems; and a major demonstration project in several contiguous western states, known as the Crescent Project.

## APPLICATIONS

Throughout the duration of the feasibility study, extensive consultations took place with state and federal agency personnel as well as with representatives of the trucking industry, to establish the po-

tential 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 as follows:

- 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. Particular emphasis is given to the last three areas as these would utilize the system's monitoring and location capability to the greatest extent. Further details of the applications are contained in the feasibility study final report (1).

## Transportation Planning

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 that can be ameliorated by the integration of AVI technology with WIM within the HELP system framework.

## Vehicle Taxation

Vehicle taxation presents a considerable administrative burden to states and truckers alike. Paperwork is extensive and complex, constituting an essen-

tially unproductive activity that 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

The enforcement of size and weight requirements is an essential but costly activity at present, involving delays to trucking firms as well as labor-intensive programs operated by the 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. Size and weight enforcement agencies in the United States would also see substantial benefits as a result of increased productivity of staff through permitting rationalization or redeployment to other essential tasks.

#### Hazardous Materials Monitoring

The mentioning of hazardous materials is a relatively new area that could be satisfied by the HELP system. There is growing concern among state officials and the public that the extent of the movements of this type of commodity are not known. Some operators who haul hazardous materials do not fully comply with all requirements of the regulations, since their main concern is in transporting the goods as efficiently and cheaply as possible.

It would be possible using the AVI technology of the HELP system to provide information about trucks carrying materials of a hazardous nature, thus enabling a data base to be established. The data base containing type of commodity and origin-destination information could subsequently be utilized by transportation planning staff in the execution of their duties. This information would be particularly useful in assessing the type and number of rescue response teams required on different routes to provide an effective coverage of the highway system throughout the state. In addition, it would identify any sections of the highway that are frequently used in the movement of hazardous materials and, where these sections are substandard, design improvements could be made.

#### Truck Fleet Management and Control

The management and control of trucks 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 AVI 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 infrastructure for AVI, which would be rectified by the HELP system.

The role of truck monitoring and location in fleet control is easier to define and the benefits easier to measure than in some areas. Benefits consist of improved fleet utilization, giving a direct increase in productivity for the existing labor force, vehicle fleet, and infrastructure. The proposed heavy-vehicle electronic license plate (HELP) system would make these benefits readily available to truck fleet operators. Fleet control applications can also be expected to extend to the many other

public and privately operated fleets where existing methods of control over fleet movements could be improved, if more accurate and reliable data were available through the use of AVI technology.

#### Crime Detection

The detection of crime through the HELP system could help reduce the current high incidence of theft of cargo in transit, which represents a multibillion dollar drain on the national economy. The problem is one that has been the focus of attention within the industry and by the federal government. Discussions with trucking firms and manufacturers have confirmed the extent of the problem and have highlighted the lack of effective countermeasures.

A recent marketing-distribution plan developed for the Lo-Jack Corporation of Boston, Massachusetts, by Touche Ross & Company (2) assessed the potential market for the company, which has developed and patented a vehicle theft detection system based on 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 to the trucking industry through theft are approximately \$7 billion. The number of automobiles stolen each year in the United States was put at over 1 million, at an estimated cost to society of \$2.9 billion, with automobile insurance losses as a result of theft at approximately \$3 billion 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. For the Arizona study, these application areas were put in a priority order before investigation of the technological options for a HELP system. The main options considered are outlined in the following text.

#### TECHNOLOGY

For each of the system areas covering AVI, WIM, AVC, and data communications and processing, the study team identified technologies that would satisfy the needs of the users. Only AVI and WIM systems are reviewed in this paper.

#### AVI SYSTEMS

The study team considered both ground-based and satellite technologies as possible contenders for use within the HELP system. Satellite systems offer the possibility of continuous monitoring while ground-based systems will only identify vehicles at set locations on the highway system. However, ground-based systems generally offer substantial cost-savings over satellite-based ones.

#### Ground-Based Systems

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 considered in the feasibility study were (a) optical and infrared systems, (b) inductive loop systems, and (c) other ground-based radio frequency and microwave systems.

### Optical and Infrared Systems

Optical systems formed the basis of the earliest vehicle ID technologies. Several systems were developed during the 1960s in the United States and Europe. These were mostly superseded in the vehicle identification field during the 1970s due to several problems that are outlined later in this paper. The fundamental nature of these problems is such that further detailed treatment of optical scanning technology was deemed unnecessary within the feasibility study.

Optical systems require clear visibility, as performance is seriously degraded by snow, rain, ice, fog, and dirt. The systems are sensitive to scanner/label misalignment, focusing problems, and depth-of-field limitations, although 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, and were not considered a serious contender for the HELP system vehicle ID technology.

These approaches were superseded by inductive loop vehicle ID systems, many of which are still in operation, and these techniques are described next.

### 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 receives 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 United States, 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 the HELP context 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 the HELP system.

Passive systems use an electronic tag that 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 retransmits a coded signal of 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.

Semiactive 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 can therefore overcome the problems of the fully active system.

Although semiactive inductive loop vehicle ID systems have not been widely tested, they seem to offer a particular balance of advantages that could make them appropriate for the HELP system design.

### Other Radio Frequency and Microwave Systems

Other ground-based radio frequency and microwave systems have generally adopted roadside or trackside antenna layouts, transmitting and receiving, or both, 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 were therefore excluded from further consideration.

Typically, in a passive microwave application, an 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 radio 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 is 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 problem associated with other radio frequency and microwave passive systems, however, concerns the power levels that must be transmitted to energize the vehicle-mounted tags. In many countries, these may violate limitations on communications systems frequency power outputs.

Semiactive 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, while providing for an electronic license plate design life of several years. Once again, however, the technology is relatively untried, although several prototype systems have been tested.

### Satellite Systems

An area that has, through technological advancement, become feasible as a means of implementing a heavy-vehicle electronic license plate system 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, receiver 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 the minimum HELP system electronic license plate. 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 doubtful whether the HELP cost target of \$100 per electronic tag, inclusive of installation, could ever be approached.

Another satellite system that could be used in the HELP project, however, is being developed by the Geostar Corporation of New Jersey (3). 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 that 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 that 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 suggest that current transceiver costs would be about \$450 per unit. However, it is feasible that a reduced capability system, matched to HELP system needs, could be significantly lower-cost. For this reason, further investigations into the potential of Geostar are envisaged later in the HELP development program.

#### WIM SYSTEMS

Unlike vehicle ID systems, which need to be standardized to permit compatibility between different

states and manufacturers, uniformity of approach to WIM system design is not essential within the HELP context. Each state could choose its own system, or might even decide to use several systems to achieve a range of objectives.

For this reason, the aims of the HELP program are somewhat different in the consideration of WIM systems than they were with vehicle identification. With WIM, the task of the HELP program is to set out the options and evaluate alternatives without necessarily reaching a definitive, unique specification.

Several systems for weighing vehicles in motion are currently obtainable from manufacturers in Europe and the United States. In determining the available WIM technologies, the study team has investigated a wide range of equipment and techniques, including current systems and new approaches that are still at the research and development stage (4).

The main alternatives for permanent weigh-in-motion sites considered in this section are as follows:

- Bending plate systems,
- Shallow weigh-scale systems,
- Deep-pit weigh-scales,
- Bridge systems,
- Piezo systems, and
- Capacitive systems.

#### Bending Plate Systems

This type of system was first developed and patented in West Germany by the Bundesanstalt fuer Strassenweisen (BAST), which can be translated as the Federal Road Research Institute. The system, which is manufactured and distributed by the PAT Corporation, uses a high-strength steel plate only 5/8-in. thick, which can be used for high-speed dynamic weighing when recessed into a shallow pit. Typically, two or three plates are used across a traffic lane, covering both wheel tracks. A lightweight frame supports the plates in a pit of only 2-in. depth, a factor that helps keep installation costs down.

The weigh-plate transducer is supported along its longer sides. Bending of the plate under load, as a vehicle crosses it, is measured by strain gauges located in two slots milled in the underside. For environmental protection, the entire sensor unit is encapsulated in vulcanized synthetic rubber.

The monitoring equipment is located in a large cabinet or hut by the roadside and often includes a microcomputer, which can potentially be interfaced with AVI and data transmission equipment.

The simplicity and precision of this WIM technology must render it a strong contender for incorporation in the HELP system, if problems of cost and supply can be overcome. This system would rank at the head of the established, thoroughly tested approaches, because of its technical excellence and broad-based, successful application.

#### Shallow Weigh Scale Systems

The Radian WIM system is a shallow weigh scale, though much more complex in design than the bending plate. It has been quite widely used within North America, and is capable of giving good results when carefully maintained. The depth of the Radian system is less than 4 in., which, again, would help to keep installation costs down. The roadside equipment is normally located in a mobile motor home, as the system is not usually operated unattended.

At present, this system appears less attractive than the bending plate approach, both in terms of



technical merit and potential for cost reduction. Some savings could certainly be made by the adoption of microprocessor technology in signal processing, but the scale itself would remain complex and relatively expensive. Reliability could also be a problem with large numbers of scales in continuous operation. However, the scale provides an option from the bending plate system, which should be carried forward to the evaluation stage.

#### Deep Pit Weigh Scales

The University of Saskatchewan/IRD Automatic Highway Scale is a deep-pit system, with two rectangular weighing platforms measuring 5 ft and 4 in. by 1 ft and 9 in. resting on a common concrete foundation. One platform is located in each wheel track. Loads applied to a platform produce a vertical movement in a centrally located oil-filled piston, which acts as a load cell. Inductive loops and a roadside monitoring system allow a range of vehicle parameters to be measured. A high statistical accuracy is claimed for an all-in system cost of over \$150,000 per site. The IRD system was selected by the State of Oregon for initial work on interfacing WIM and AVI.

The technology of the IRD system is similar to that of many earlier deep-pit approaches, such as the United Kingdom Transport and Road Research Laboratory's (TRRLs) dynamic weigh bridge, the West German and University of Kentucky's "broken back" designs, the French LCPC dynamic scale and the Streeter-Amet Rollweigh System. However, the high costs of fabrication, installation, and maintenance of these approaches would count against their being used in a nationwide HELP system, and their use can be discounted unless substantial cost reductions become feasible.

In addition to investigations into the performance of current commercially available, proven systems, the study team examined the status of ongoing research into the development of low-cost, permanent, WIM systems and evaluated the potential of these relatively new devices for use in the HELP system. These concepts include the following approaches.

#### Bridge Systems

The Bridge weighing system was first developed at Case Western Reserve University in Ohio. In its current form, reusable strain transducers are clamped to the support beams of a highway underbridge. Tape switches are placed on the road surface for the measurement of vehicle speeds. An optional manual input is also possible for detailed vehicle classification via a portable control box. Data recording is via a minicomputer system and dedicated electronic apparatus mounted in a mobile instrumentation van parked near to the bridge. Individual truck speeds, axle weights, and gross vehicle weights are displayed on a TV monitor or printed in real time. These data are also stored on floppy disc.

#### Piezo Systems

Piezo-electric axle load sensors made from a copper-sheathed coaxial cable have been utilized in France, West Germany, and Britain for some years, and have been the subject of extensive research efforts in several European countries. These sensors offer the potential for an ultra low-cost, permanent axle weighing system if problems concerning the manufacturer's quality control and mounting can be over-

come. The CRC team has been involved in this work for several years, and is also familiar with work carried out by French and Dutch research teams and by the TRRL. The piezo-electric cable sensor is a strong contender as a potential second-generation WIM-AVI system. Research on this technology is planned by Iowa and Minnesota to further develop the present designs for U.S. applications.

#### Capacitive Systems

Capacitive WIM systems are now produced by Electromatic, Golden River, and Streeter Amet, though all three use the same surface-mounted portable capacitive sensor. The Golden River Marksman Axle Weight Classifier was developed in 1982 by the University of Nottingham Transport Research Group (NTRG), on behalf of the Arizona Department of Transportation (5). The GR system utilizes a portable roadside Marksman microprocessor traffic counter-classifier.

The Golden River Weighman is a further development of the Marksman Axle Weight Classifier to a specification developed by the Arizona Department of Transportation. The Weighman counts, weighs, and classifies vehicles by type, as required by the user. Operation is fully automatic and takes place in real time. Separate records can be kept in sets of twelve user-defined weight bands for leading axles, other single axles, tandems, and gross vehicle weights (cross-referenced by 14 vehicle type categories) within time intervals set by the user. Alternatively, data can be grouped into fewer categories with less cross-referencing, or individual vehicle dimensions, weights, speeds, and classes can be stored in memory for subsequent analysis.

Although the capacitive systems are not immediately suitable for use at permanent WIM sites, CRC Corporation has investigated the possibility of adapting the present device as a permanent sensor, under contract to the Golden River Corporation. The results of this work suggested that there was a strong potential for a low-cost, permanent WIM system, after a further period of detailed development, testing, and appraisal. This approach should certainly be considered for second generation HELP system applications.

In conclusion, several alternative WIM systems are available that would be suitable for use at HELP permanent monitoring sites. The main problem with these technologies is the high cost. Portable WIM systems are also available, though less well developed, and could serve the needs of the HELP system as regards mobile units for secondary routes. The study team identified several technologies that have considerable potential for cost reductions to meet HELP system cost targets. Further development, testing, and appraisal is now required to ensure that the aims of the HELP program are met.

#### IDENTIFICATION CODES

Part of the HELP program Concept Development study (6) concerned the development of standards for coding of information onto the trucks' AVI tags. One of the objectives of the study was to make recommendations on the format and content of the coded information. This was undertaken by consideration of the following factors:

- The needs of potential HELP system users,
- The need for international compatibility,
- Technical constraints, and
- Financial constraints.

The approach adopted by the study team was first to determine user information needs and how they may be satisfied. This was undertaken through consultations with representatives of government and industry before consideration of a basic vehicle ID code in relation to each of the potential application areas. In analyzing how user needs may best be satisfied by the coding content, a choice was frequently presented between direct coding of information onto the truck tag and use of a "look-up" table in the system computer data base. In some cases, however, the choice was relatively straightforward, while in others, the decision was dependent on the trade-offs between transponder costs, and the look-up table approach. These cannot be assessed accurately until strategic and detailed design is undertaken during the systems design study. Recommendations were therefore presented as a flexible framework, which will be refined throughout the HELP program to maximize the cost-effectiveness of the code content and format.

The main recommendation in this area is that a two-level AVI system should be utilized. The basic system, which will probably be suitable for the majority of trucks, should have an 11-alphanumeric character, fixed-tag code based on the standard vehicle identification number (VIN) system. Additional characters will be required for security checks. Inclusion of permit status, body type, and commercial-vehicle safety check status can be achieved by the use of look-up tables in state or regional computer data bases.

The second level is an enhanced version of the first and includes an additional 10-character variable code field on the tag, plus security characters. The system will include the capability to write information from the cab or roadside onto the tag. This enhanced level will be utilized for hazardous materials monitoring purposes, and will also be available to truck operators who wish to gain extra benefit from the system through encoding of commodity data, insurance carrier ID, or any other information for their internal management and operational purposes.

Several other coding aspects have been addressed and the following conclusions have been reached:

1. Alphanumeric coding is required to utilize the basic ID-code format chosen;
2. ASCII coding is most appropriate for the HELP system as opposed to any nonstandard form;
3. Several security coding features, which are sufficient to make the system difficult to defraud, should be built into the specified AVI system. An overhead of 100 percent of message characters is recommended to allow for security coding; and
4. Minimum code lengths should be sufficient to encompass the user information needs outlined for each level of system, together with any security features. In the case of the basic system, a 22-ASCII character capability is recommended.

#### ECONOMICS

Preliminary estimates in the feasibility study (1) of the costs and benefits of a HELP system indicated that the magnitude of the annual benefits to truckers and the state could be as much as \$40 million and \$20 million, respectively, set against an initial cost of \$12 million per state, and annual running costs of \$2.5 million. In the subsequent study, the cost-benefit estimates were refined in the light of better data.

High- and low-cost technology options were utilized in assessing the costs of a national HELP system. In addition, improved scaling factors and further consultation with potential system users have led to improved estimates of benefit levels. The conclusion drawn from these figures is that in the highest-cost case, the payback period for a national system would be approximately 7 months, while in the low-cost scenario, a 5-month payback period is envisaged.

The cost-benefit analysis necessarily contains assumptions on deployment density, site distribution, number of trucks fitted and technologies adopted. Current assumptions on these factors will need to be refined as the Crescent Project progresses. Further detailed cost-benefit analysis is included in the scope of National Cooperative Highway Research Program (NCHRP) project 3-34, taking a similar range of deployment variables into account.

#### IMPLEMENTATION

As currently envisaged, the HELP system development program includes laboratory and field testing of alternative AVI systems leading to a preferred AVI specification, a systems design study, development of a WIM-AVC performance specification and the NCHRP National Feasibility Study. Following these program phases, it is considered that a demonstration and evaluation of the complete HELP system is essential. This will allow a realistic evaluation of the system benefits to be undertaken together with an assessment of the system operation including its reliability, durability, and accuracy.

At present, a HELP system demonstration project is planned for the western United States and southwest Canada. This includes Texas, New Mexico, Arizona, California, Oregon, and Washington, and the Canadian province of British Columbia. This corridor, known as "the Crescent," includes several major interstate highways such as I-5, I-10, I-20, and I-40. However, it is not unique in its capability to evaluate the system adequately, and a number of other states have expressed a strong interest in the HELP program since its inception.

A number of alternative implementation scenarios were considered to ensure the Crescent Project is designed to provide the best possible appraisal framework and to assess the capability of other combinations of states to meet the program objectives. The conclusion reached is that the Crescent Project offers distinct advantages in terms of project coordination and its ability to demonstrate and evaluate all the system benefits.

#### CONCLUSIONS

The examination of the Crescent Project implementation strategy completes this paper on the development of a national heavy-vehicle electronic license plate (HELP) system. From the two studies to date, a number of conclusions have been reached and specific recommendations made. In addition, evidence has been provided on the technical and economic feasibility of the national HELP system concept, which suggests substantial returns on the initial investment. The studies performed should provide a platform from which to proceed with the testing and development strands of the HELP program. Given cooperation between the states, and a partnership with industry, a win-win situation can be achieved in bringing benefits of AVI, WIM, and AVC technologies to the motor-carrier industry, the states, and federal agencies.

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## Portable Sensors and Equipment for Traffic Data Collection

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## ABSTRACT

In recent years, the need for traffic data has increased although the resources available to collect them have decreased; consequently, the use of automated traffic data collection procedures and equipment has spread rapidly. These techniques and devices may be used in either a fixed or portable mode. Portable applications require the deployment of sensors that are accurate and rugged as well as portable, easily and quickly installed and removed, and reusable. Presented in this paper are the results of an investigation into available technologies that may be used in portable sensors for vehicle detection. The emphasis of this research was on those technologies that may be used in temporary or short-term traffic data collection. A second objective of this study was to develop performance requirements for portable automated traffic data collection equipment. The research was funded by the Federal Highway Administration under a contract entitled "Automated Speed Data Collection for Temporary Applications."

As the need and demand for traffic data and monitoring have increased over the last few years, the available manpower and financial resources to provide this information have declined in many public agencies. Consequently, the use of automated traffic data collection procedures and equipment has rapidly increased. This technology includes devices that are portable as well as those that are permanently installed. The equipment in all cases includes a sensor that is placed on, in, or near the roadway and provides an indication of vehicle passage and pres-

ence, or both. (Weigh-in-motion devices were not included in this research.) The equipment also includes a detector that interprets a sensor actuation as information and processes or stores it in useful form. The balance of the data collection equipment system consists of computational, data storage, or communication elements. This report deals with portable sensors and equipment used for temporary traffic data collection or monitoring.

Portable applications require the deployment of sensors that are both accurate and durable. Portable sensors fall into two general types--those that are fixed to the surface of the roadway (such as pneu-