A Summary of Vehicle Detection and Surveillance Technologies used in Intelligent Transportation Systems

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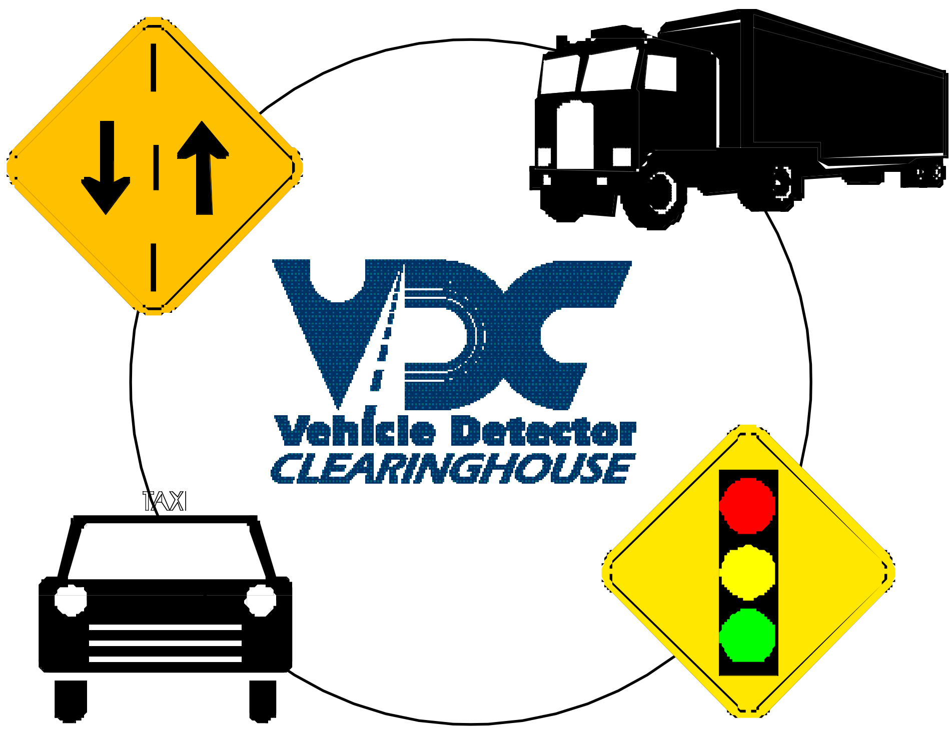
Transportation Systems Joint Program Office



Produced by

The Vehicle Detector Clearinghouse

A multi-state, pooled-fund project managed by the
Southwest Technology Development Institute (SWTDI) at
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Transportation FHWA

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SUMMARY OF VEHICLE DETECTION AND SURVEILLANCE TECHNOLOGIES USED IN INTELLIGENT TRANSPORTATION SYSTEMS

SUBMITTED TO:

Federal Highway Administration s (FHWA) Intelligent Transportation Systems Joint Program Office

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November 30, 2000

(Latest version of this handbook can be found at http://www.nmsu.edu/~traffic/)

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This document does not constitute a standard, specification, or regulation.

The United States Government or the Vehicle Detector Clearinghouse does not endorse products or manufacturers. Vendor and manufacturer s names appear herein only because they are considered essential to the purpose of this document.

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Chapter 1 - Introduction

The surface transportation system of the United States is comprised of approximately 3.7 million miles of roads and 503 public transit systems, which accommodate 4 trillion passenger miles and 3 trillion ton miles of freight per year (Apogee/Hagler Bailly, 1998). Demands on the system are growing rapidly with an estimated travel demand increase of 30% over the next ten years (Proper & Cheslow, 1997). In order to prevent congestion at current levels from getting worse, the U.S. would have to increase the capacity of the transportation system by the same 30%. One option is to increase the capacity by increasing the number of lane miles, which translates to about 4,427 lane miles of new miles of roadway every year. At the present time, roads are being built at about two-thirds this rate.

A second option is to develop alternatives that increase capacity by improving the efficiency of the existing transportation system. This option focuses on building fewer lane-miles, while investing in Intelligent Transportation Systems (ITS) infrastructure. In 1991, the Intermodal Surface Transportation Efficiency Act resulted in the formation of the Federal Intelligent Transportation Systems (ITS) program to address ways to deal with the increase in travel demand on the nation s transportation systems using the second option.

The goals of ITS include the following:

- Enhance public safety;
- Reduce congestion;
- Improved access to travel and transit information;
- Generate cost savings to motor carriers, transit operators, toll authorities, and government agencies; and
- Reduce detrimental environmental impacts.

ITS include sensor, communication, and traffic control technologies. These technologies are assisting states, cities, and towns nationwide meet the increasing demands on the surface transportation system. Vehicle detection and surveillance technologies are an integral part of ITS, since they gather all or part of the data that is used in ITS. It is estimated that an investment in ITS will allow for fewer miles of road to be built, thus reducing the cost of mitigating recurring congestion by approximately 35 percent nationwide (Apogee/Hagler Bailly, 1998).

New vehicle detection and surveillance technologies are constantly being developed and existing technologies improved, to provide speed monitoring, traffic counting, presence detection, headway measurement, vehicle classification, and weigh-in-motion data. This summary document was developed to assist in the selection of vehicle detection and surveillance technologies that support traffic management and traveler information services. The information will also be useful to personnel involved in traffic data collection for planning, policy, and research purposes. Included are descriptions of common types of vehicle detection and surveillance technologies in terms of theory of operation, installation methods, advantages and disadvantages, and summary information about performance in clear and inclement weather and relative cost. Following each technology description is vendor-provided information about specific sensor models, their functions and applications, users, and installation and maintenance costs. A 3-ring binder format was selected to allow the contents to be easily updated.

The *Summary of Vehicle Detection and Surveillance Technologies Used in Intelligent Transportation Systems* will be updated periodically as long as the Vehicle Detector Clearinghouse remains in operation. The latest version of this summary document is available in electronic format at the following URL: http://www.nmsu.edu/~traffic .

Chapter 2 - Methods and Approach

To accomplish the objectives outlined in Chapter 1 of this document, a multi-task approach was taken using a team of experts from Southwest Technology Development Institute (SWTDI), the Vehicle Detector Clearinghouse (VDC), and Dr. Lawrence A. Klein a private consultant in the traffic management and sensor technology areas. The following sections discuss briefly the tasks carried out to complete the objectives of the project.

Collection of Product Information

Product information for vehicle detection and surveillance technologies used in ITS was obtained from the vendors and manufacturers of the equipment. To facilitate this effort, a database of vendors and manufacturers addresses and contact information was developed in electronic format using the Excel¤ worksheet software package. The information for the database was gathered from the following sources:

- Existing VDC product database;
- List supplied by FHWA;
- List supplied by private consultant;
- Internet based searches using specific key words;
- Intelligent Transportation Society of America s Tenth Annual Meeting and Exposition Official Exhibitor Directory; and
- Traffic Technology International, April/May 2000 issue.

Once the database of vendor and manufacturer information was compiled, vendors and manufacturers were contacted to obtain specific information on their products. The vendors and manufacturers were sent a vendor survey and a cover letter explaining the purpose of the survey. The vendors and manufacturers that were selected were contacted by regular mail, facsimile, and

Email. The database included a status column that provided updated information, such as whether the vendor survey response was received from the corresponding vendor/manufacturer or whether it was returned unopened. If the survey packet was returned unopened, the address was checked and corrected if necessary and a second packet was sent.

The vendor/manufacturer database, a copy of a blank survey and a copy of the form cover letter are included in Appendix A of this document. At the time this edition was prepared, a total of 86 additional vendor survey packets had been sent, thus more responses were expected. The survey responses included product name, a general description of the equipment, sensor technology and configuration, installation time and requirements, product capabilities/functions, recommended applications, list of users, etceteras.

VDC project consultants reviewed the vendor s and manufacturer s survey responses for errors. When necessary, VDC project consultants contacted the vendors and manufacturers to obtain clarification on some of the vendor survey responses.

Collection of User Information

User information was obtained from compiled responses to the *State Equipment Questionnaire* and the *Survey of Degree of Satisfaction of State DOT Personnel with Vehicle Detection Equipment* for the ongoing VDC project. Although the user data collected was specific to the make and model of certain types of equipment, generalizations were made based on equipment types so as not to unfairly criticize vendors and manufacturers. The generalizations made were then included in this summary document in the equipment description sections.

Compilation of Information

Once a response to the vendor and manufacturer survey was received, it was compiled in electronic format and added to *The Summary of Vehicle Detection and Surveillance Technologies*

Used in Intelligent Transportation Systems document. In order to avoid misinterpretation of vendor and manufacturer information, the vendor survey information was entered directly onto a blank survey form identical to the one the vendor or manufacturer had filled out. The vendor and manufacturer survey responses were organized according to the type of sensor technology utilized (e.g. loops, road tubes, video, etc.).

In addition to the vendor and manufacturer two-page survey responses, a detailed technology description was added and organized according to the type of sensor technology. The detailed description included principles of operation, typical uses, relative costs for some, advantages and disadvantages, etceteras. Also, in Chapter 3, a comparison of several technologies based on cost, applications, etc. was presented.

Finally, the information contained in this summary document was compiled and organized into a three-ring binder format to allow for quick removal and addition of outdated and updated information, respectively with the most current version of the document available in electronic format at the following URL: **http://www.nmsu.edu/~traffic/** . Furthermore, in the hard copy version of the document the vendor and manufacturer survey responses do not have page numbers, thus when these are taken out or added to the binder, the table of contents will remain undisturbed. The authors felt that the information contained in this summary document would be useful to a wide audience with varied practical and technical backgrounds.

Chapter 3 — Overview of Vehicle Detection and Surveillance Technologies

Vehicle detection and surveillance technologies may be described as containing three components, the transducer, a signal processing device, and a data processing device. The transducer detects the passage or presence of a vehicle or its axles. The signal-processing device typically converts the transducer output into an electrical signal. The data-processing device usually consists of computer hardware and firmware that converts the electrical signal into traffic parameters. Typical traffic parameters include vehicle presence, count, speed, class, gap, headway, occupancy, weight and link travel time. The data processing device may be a part of the sensor, as with devices that produce serial output data, or may be controllers external to the sensor as utilized with sensors that have optically-isolated semiconductor or relay outputs.

The following chapters describe the operating principles, sensor measurement accuracy, costs, advantages, and disadvantages of technologies that find application in intrusive and non-intrusive sensors. Each section also contains equipment-specific data supplied by the manufacturers or vendors of representative sensors.

Intrusive sensors

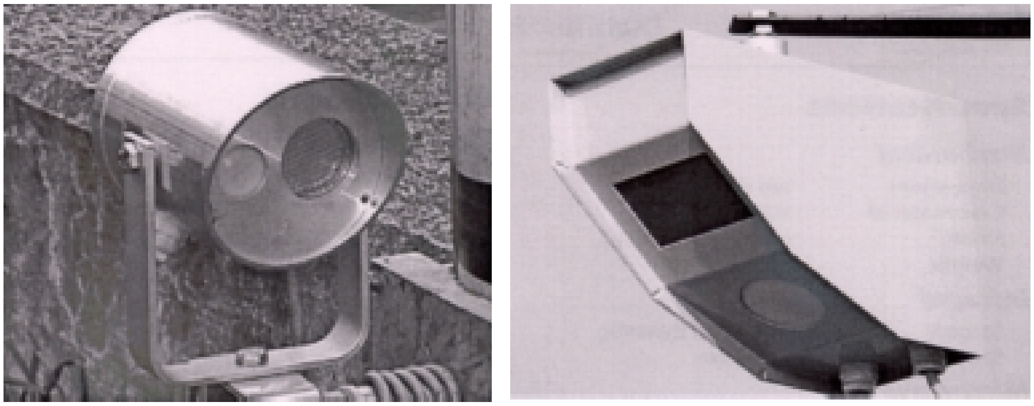
Intrusive sensors include inductive loops, magnetometers, microloop probes, pneumatic road tubes, piezoelectric cables and other weigh-in-motion sensors. These devices are installed directly on the pavement surface, in saw-cuts or holes in the road surface, by tunneling under the surface, or by anchoring directly to the pavement surface as is the case with pneumatic road tubes. The operation of most of these sensors is well understood as they generally represent applications of mature technologies to traffic surveillance. The drawbacks to their use include disruption of traffic for installation and repair and failures associated with installations in poor road surfaces and use of substandard installation procedures. Resurfacing of roadways and utility repair can also create the need to reinstall these types of sensors.

Non-intrusive Sensors

The quest for an alternative reliable and cost-effective vehicle detection and tracking system, which can be installed and maintained with safety and minimal disruption of traffic and can provide traffic data at least as accurate as the inductive loop detector, has been underway for some time. Recent evaluations have shown that modern aboveground sensors produce data that meet the requirements of many current freeway and surface street applications. Aboveground sensors can be mounted above the lane of traffic they are monitoring or on the side of a roadway where they can view multiple lanes of traffic at angles perpendicular to or at an oblique angle to the flow direction. The technologies currently used in aboveground sensors are video image processing, microwave radar, laser radar, passive infrared, ultrasonic, passive acoustic array, and combinations of sensor technologies such as passive infrared and microwave Doppler or passive infrared and ultrasonic. Like the subsurface sensors, the aboveground sensors measure vehicle count, presence, and passage. However, many also provide vehicle speed, vehicle classification, and multiple-lane, multiple-detection zone coverage.

Applications of Sensor Combinations

Figure 1 displays sensors that combine passive infrared presence detection with ultrasound or Doppler radar. The passive infrared-ultrasonic combination provides enhanced accuracy for presence and queue detection, vehicle counting, and height and distance discrimination. The passive infrared-Doppler radar sensor is designed for presence and queue detection, vehicle counting, speed measurement, and length classification.



ASIM DT 272 Infrared-ultrasonic sensor ASIM DT 281 Infrared-Doppler radar sensor

Figure 1. Infrared combination sensors. (Photographs courtesy of ASIM Technologies, Uznach, Switzerland).

The dual-passive infrared Doppler radar sensor relies on the radar to measure high to medium speeds and the passive infrared to measure vehicle count and presence. At medium speeds, the multiple detection zone passive infrared automatically calibrates its speed measurements against the radar s. This calibration permits the infrared to measure slow vehicle speeds and detect stopped vehicles.

Relative Cost of Sensors

A satisfactory cost comparison between various sensor technologies can only be made when the specific application is known. For example, a relatively inexpensive ultrasonic, microwave, or passive infrared sensor may seem to be the low-cost choice at first glance for instrumenting a surface street intersection if inductive loop detectors are not desired. But when the number of sensors needed is taken into account along with the limited amount of directly measured data that may be available (e.g., speed is not measured directly by a single zone infrared sensor), a more expensive sensor such as a video image processor (VIP) may be the better choice. Consequently, if it requires twelve to sixteen conventional inductive loop detectors (or ultrasonic, microwave, or infrared, etc. sensors) to fully instrument an intersection, the cost becomes comparable to that of a VIP. Furthermore, the additional traffic data and visual information made available by the VIP may more than offset any remaining cost difference. In this example, the VIP is assumed to meet the other requirements of the application, such as the desired 100 percent detection of vehicles at the intersection. Similar arguments can be made for freeway applications using multiple sensors and requiring information not always available from the less expensive sensors.

Microwave presence radar mounted in a side-looking configuration may perform other applications, such as simple monitoring of multilane freeway traffic flow or surface street vehicle presence and speed. In this case, the microwave sensors replace a greater number of loops that otherwise need be installed in the travel lanes. Furthermore, the microwave sensor potentially provides direct measurement of speed at a greater accuracy than provided by the loops.

Other factors that affect the cost and selection of sensors are the maturation of the designs and manufacturing processes for sensors that use the newer technologies, reduced prices through quantity buys, and availability of mounting locations and communications links at the application site. In some urban areas, the cost of trenching in the street and restoration for lead-in cable or cable to connect to a controller cabinet is very high, e.g., $50 per foot (0.3 m) or more. Trenching, thus becomes a significant part of the installation cost. In these cases, non-intrusive sensors that utilize an RF, microwave, or spread spectrum radio links may be the low-cost alternative to gather and transmit sensor data to the controller.

Sensor Technology Comparison

Table 1 compares the strengths and weaknesses of the sensor technologies that will be discussed in the following chapters of this document with respect to installation, parameters measured, performance in inclement weather and variable lighting conditions, and suitability for wireless operation.

Table 1.
Strengths and weaknesses of aboveground and subsurface sensor technologies (Klein, 2001)

Technology	Strengths	Weaknesses
Inductive Loop	• Flexible design to satisfy large variety of applications. • Mature, well understood technology. • Provides basic traffic parameters • (e.g., volume, presence, occupancy, • speed, headway, and gap). • High frequency excitation models provide classification data.	• Installation requires pavement cut. • Decreases pavement life. • Installation and maintenance require lane closure. • Wire loops subject to stresses of traffic and temperature. • Multiple detectors usually required to instrument a location.
Magnetometer (Two-axis fluxgate magnetometer)	• Less susceptible than loops to stresses of traffic. • Some models transmit data over wireless RF link.	• Installation requires pavement cut. • Decreases pavement life. • Installation and maintenance require lane closure. • Some models have small detection zones.
Magnetic (Induction or search coil magnetometer)	• Can be used where loops are not feasible (e.g., bridge decks). • Some models installed under roadway without need for pavement cuts. • Less susceptible than loops to stresses of traffic.	• Installation requires pavement cut or tunneling under roadway. • Cannot detect stopped vehicles.
Microwave Radar	• Generally insensitive to inclement weather. • Direct measurement of speed. • Multiple lane operation available.	• Antenna beamwidth and transmitted waveform must be suitable for the application. • Doppler sensors cannot detect stopped vehicles.
Infrared	• Active sensor transmits multiple beams for accurate measurement of vehicle position, speed, and class. • Multizone passive sensors measure speed. • Multiple lane operation available.	• Operation of active sensor may be affected by fog when visibility is less than »20 ft or blowing snow is present. • Passive sensor may have reduced sensitivity to vehicles in its field of view in rain and fog.
Ultrasonic	• Multiple lane operation available.	• Some environmental conditions such as temperature change and extreme air turbulence can affect performance. Temperature compensation is built into some models. • Large pulse repetition periods may degrade occupancy measurement on freeways with vehicles traveling at moderate to high speeds.

Table 1.
Strengths and weaknesses of aboveground and subsurface sensor technologies (continued)

Acoustic	• Passive detection. • Insensitive to precipitation. • Multiple lane operation available.	• Cold temperatures have been reported as affecting data accuracy. • Specific models are not recommended with slow moving vehicles in stop and go traffic.
Video Image Processor	• Monitors multiple lanes and multiple zones/lane. • Easy to add and modify detection zones. • Rich array of data available. • Provides wide-area detection when information gathered at one camera location can be linked to another.	• Inclement weather, shadows, vehicle projection into adjacent lanes, occlusion, day-to-night transition, vehicle/road contrast, and water, salt grime, icicles, and cobwebs on camera lens can affect performance. • Requires 50- to 60-ft camera mounting height (in a side-mounting configura-tion) for optimum presence detection and speed measurement. • Some models susceptible to camera motion caused by strong winds. • Generally cost-effective only if many detection zones are required within the field of view of the camera.

Most overhead sensors are compact and not roadway invasive, making installation and maintenance relatively easy. Some installation and maintenance applications may require the closing of the roadway to normal traffic to ensure the safety of the installer and motorist. All the sensors discussed operate under day and night conditions.

Table 2 lists the types of data typically available from each sensor technology, coverage area, communication bandwidth requirements, and purchase costs. Several technologies are capable of supporting multiple lane, multiple detection zone applications with one or a limited number of units. These devices may be cost effective when larger numbers of detection zones are needed to implement the traffic management strategy.

Table 2.
Traffic sensor output data, bandwidth, and cost (Klein, 2001)

Technology	Output Data: Count	Presence	Speed	Occu-pancy	Classifi-cation	Multiple Lane, Multiple Detection Zone Data	Communi-cation Bandwidth	Sensor Purchase Cost[1] (each in 1999 $)
Inductive loop	X	X	X[2]	X	X[3]		Low to moderate	Low[9] ($500 to $800)
Magnetometer (Two-axis fluxgate)	X	X	X[2]	X			Low	Moderate[9] ($1,100 to $6,300)
Magnetic (Induction or search coil)	X		X[2]	X			Low	Low to moderate[9] ($385 to $2,000)
Microwave radar	X	X[4]	X	X[4]	X[4]	X[4]	Moderate	Low to moderate ($700 to $3,300)
Infrared	X	X	X[5]	X	X[6]	X[6]	Low to moderate	Low to high (Passive: $700 to $1,200; Active: $6,500 to 14,000)
Ultrasonic	X	X		X			Low	Low to moderate (Pulse model: $600 to $1,900)
Acoustic array	X	X	X	X		X[7]	Low to moderate	Moderate ($3,100 to 8,100)
Video image processor	X	X	X	X	X	X	Low to high[8]	Moderate to high ($5,000 to $26,000)

1. Installation, maintenance, and repair costs must also be included to arrive at the true cost of a sensor solution as discussed in the text.
2. Speed can be measured by using two sensors a known distance apart or by knowing or assuming the length of the detection zone and the vehicle.
3. With specialized electronics unit containing embedded firmware that classifies vehicles.
4. From microwave radar sensors that transmit the proper waveform and have appropriate signal processing.
5. With multi-detection zone passive or active mode infrared sensors.
6. With active mode infrared sensor.
7. Models with appropriate beam forming and signal processing.
8. Depends on whether higher-bandwidth raw data, lower-bandwidth processed data, or video imagery is transmitted to the traffic management center.
9. Includes underground sensor and local receiver electronics. Receiver options are available for multiple sensor, multiple lane coverage.

The communication bandwidth is low to moderate if only data and control commands are transmitted between the sensor, controller, and traffic management center. The bandwidth is larger if real-time video imagery is transmitted at 30 frame/s. The requirement for large bandwidth communications media such as T1 telephone lines, which support transmission rates of 1.544×10^6 bits/s or baud at a bandwidth of 125 MHz, and fiber can be reduced if compressed imagery (e.g., transmission rates of 256,000 bit/s at a bandwidth of 20.5 MHz) is suited for the application. The required transmission rate increases when large numbers of sensors, roadside information devices such as changeable message signs and highway advisory radio, signal timing plans, and traveler information databases are used to implement traffic management strategies.

The range of purchase costs that are shown for a particular sensor technology reflects cost differences among specific sensor models and capabilities. If multiple lanes are to be monitored and a sensor is capable of only single lane operation, then the sensor cost must be multiplied by the number of monitored lanes. Direct purchase cost is not the only cost associated with a sensor. Installation, maintenance, and repair should also be factored into the sensor selection decision. Installation costs include fully burdened costs for technicians to prepare the road surface or subsurface to install the sensor and mounting structure (if one is required), close traffic lanes where required, and verify proper functioning of the device after installation is complete. Maintenance and repair estimates may be obtained from manufacturers and from other agencies and localities that have deployed similar sensors. The technologies listed in Table 2 are mature with respect to traffic management applications, although some may not provide the data required for a specific application. Some technologies, such as video image processing, continue to evolve by adding capabilities that measure additional traffic parameters, track vehicles, or link data from one camera to those from another.

Summary

The operation and applications of the following vehicle detection and surveillance technologies are discussed in the following chapters:

- Pneumatic road tube;
- Inductive loop;
- Piezoelectric cable;
- Magnetic sensor;
- Bending Plate Weigh-in-Motion (WIM);
- Piezoelectric WIM;
- Load Cell WIM;
- Capacitance Mat WIM;
- Video image processor;
- Microwave radar;
- Laser radar;
- Passive infrared;
- Ultrasonic; and
- Passive acoustic array.

Inductive loop detectors continue to be widely used to monitor traffic flow and control signals because of their relatively low cost, maturity, aesthetics, and policy issues. Some of the overhead technologies, such as video image processing and multizone microwave and infrared sensors, can replace several inductive loops. In these applications, the higher cost of the aboveground technologies can offset the costs associated with installing and maintaining multiple inductive loops. The mounting location is critical to the selection and proper operation of a traffic sensor. Experience by state DOTs has indicated that suitable mounting locations must be available with the proper elevation and proximity to the roadway in order for above-the-road sensors to function properly. Sensors selected for a first time application should be field tested under actual operating conditions that include variations in traffic flow rates, day and night lighting, and inclement weather.

Chapter 4 — Intrusive Technologies

Intrusive technologies are those requiring the installation of the sensor directly onto or into the road surface. The pneumatic road tube, inductive loop, piezoelectric cable, and magnetic sensors are discussed in the following sections in this chapter. Also discussed are the piezoelectric, bending plate, load cell, and capacitance mat weigh-in-motion (WIM) systems.

Pneumatic Road Tube

Principles of Operation

Pneumatic road tube sensors send a burst of air pressure along a rubber tube when a vehicle s tires pass over the tube. The pulse of air pressure closes an air switch, producing an electrical signal that is transmitted to a counter or analysis software. The pneumatic road tube sensor is portable, using lead-acid, gel, or other rechargeable batteries as a power source.

Applications and Uses

The road tube is installed perpendicular to the traffic flow direction and is commonly used for short-term traffic counting, vehicle classification by axle count and spacing, planning, and research studies. Some models gather data to calculate vehicle gaps, intersection stop delay, stop sign delay, saturation flow rate, spot speed as a function of vehicle class, and travel time when the counter is utilized in conjunction with a vehicle transmission sensor (JAMAR Technologies).

Advantages

Advantages of road tube sensors are quick installation for permanent and temporary recording of data and low power usage. Road tube sensors are usually low cost and simple to maintain. Also, the sensor manufacturers to assist with data analysis often supply software packages.

Disadvantages

Disadvantages include inaccurate axle counting when truck and bus volumes are high, temperature sensitivity of the air switch, and cut tubes resulting from vandalism and wear produced by truck tires.

Installation Configuration

Figure 2 shows some of the road tube configurations utilized on single and multilane highways to count and classify vehicles. Figure 3 displays the front panel of the TimeMark Delta IIIb counter to indicate the ease with which collected data are matched to the tube layout.

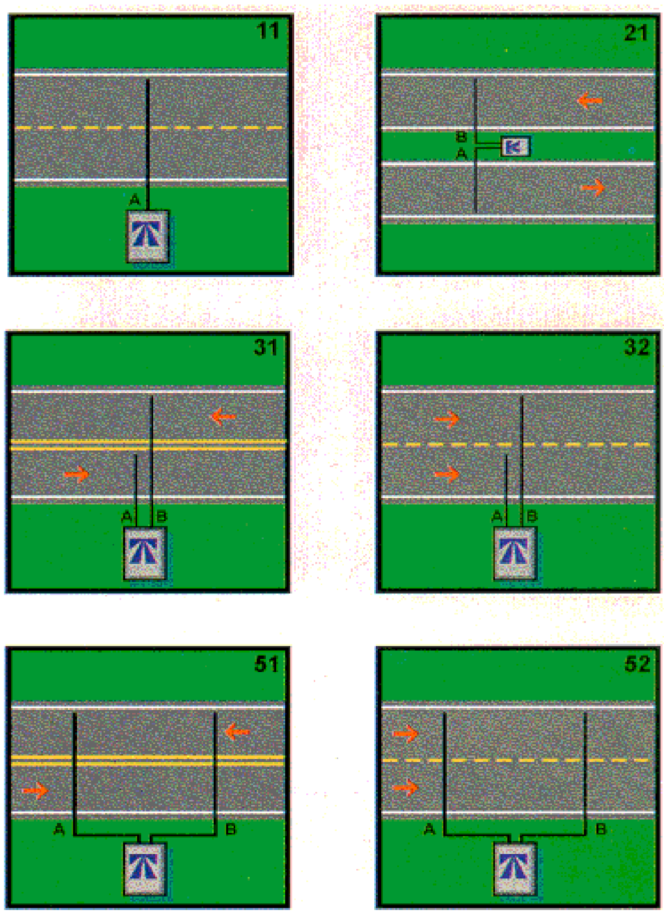


Figure 2. Road tube configurations for single and multilane highways. (Photograph courtesy of Time Mark, Inc., Salem OR).

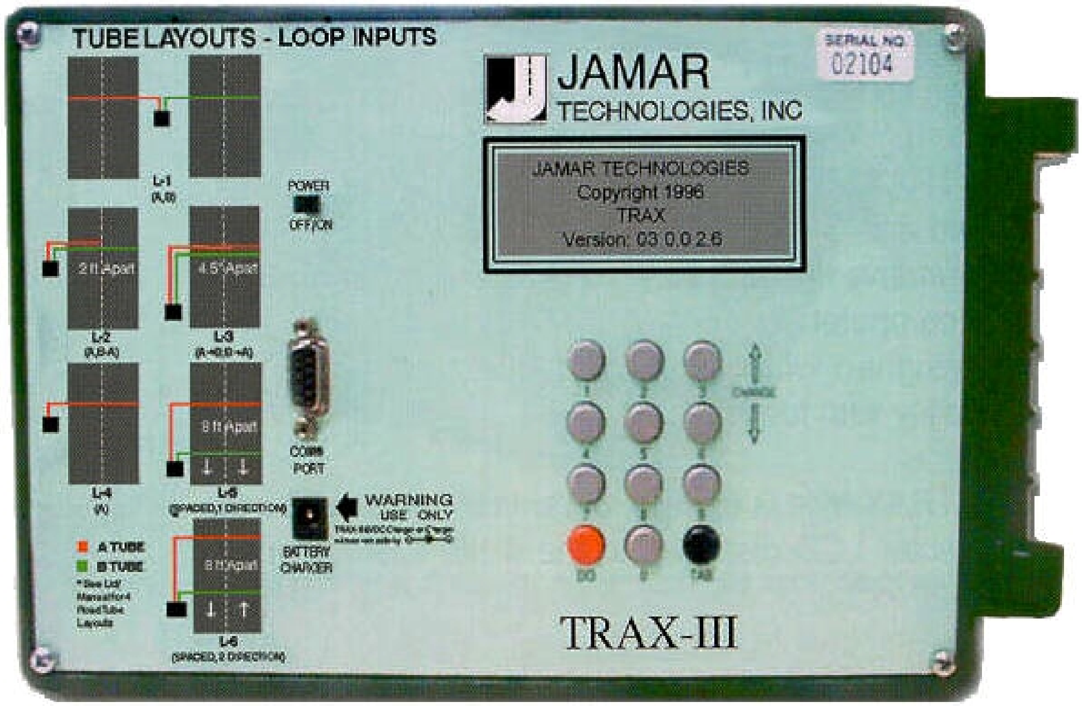


Figure 3. Front panel display of TimeMark Delta IIIB counter. (Photograph courtesy of Time Mark, Inc., Salem OR).

MANUFACTURER AND VENDOR INFORMATION

Effective Date: March 22, 2000

Manufacturer name: International Road Dynamics Inc. (IRD)	Sales representative name(s): Rod Klashinsky
Address: 702 43rd St. East, Saskatoon SK, S7K 3T9 CANADA	Address:
Phone number: 306-653-6600	Phone number:
Fax number: 306-242-5599	Fax number:
e-mail address: info@ird.ca	e-mail address: rod.klashinsky@ird.ca
URL address: www.irdinc.com	URL address:

PRODUCT NAME/MODEL NUMBER: Model TCC540 Traffic counter Classifier

FIRMWARE VERSION/CHIP NO.: V2.6

SOFTWARE VERSION NO.: V4.73

GENERAL DESCRIPTION OF EQUIPMENT: Portable or permanent battery operated multi-lane time interval recording counter & classifier that collects traffic data

SENSOR TECHNOLOGY AND CONFIGURATION: Uses road Tube, Inductive Loops, Piezoelectric sensors, IRD Dynax™ Sensor. Most common configuration is Loop-Piezo-Loop configuration

SENSOR INSTALLATION: Portable (On road) Permanent (In road)

INSTALLATION TIME (Per Lane): Approximately 4-5 hours in a permanent Loop-Piezo-Loop configureation. Approximately 15-20 minutes in a portable application.

INSTALLATION REQUIREMENTS: See attached Installation sheet.

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: 8 lanes classifying, 16 lanes counting.

PRODUCT CAPABILITIES/FUNCTIONS: Collects vehicle traffic data, including vehicle classification, speed, volume, headway and gap.

RECOMMENDED APPLICATIONS: Traffic Planning, Traffic Profile, Safety, and Audit.

POWER REQUIREMENTS (watts/amps): AC Power for 6 volt, 12 amp rechargeable battery.

POWER OPTIONS: Dual battery units, Solar package.

CLASSIFICATION ALGORITHMS: See attached specifications.

TELEMETRY: RS232 port with baud rates from 300-19,2000.

COMPUTER REQUIREMENTS: MSDOS.

DATA OUTPUT: IBM PC, Modem, Take-Away-Memory (TAM)

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM: Trafman™ Software

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane): Permanent One lane — Approx. US $ 5,000, 4 lanes Approx. US $ 9,000.

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/New Jersey		
Canada/Saskatchewan		
Canada/Manitoba		
Canada/Ontario		
Canada/Quebec		
Canada/Nova Scotia		
Canada/New Brunswick		
Canada/Newfoundland.		
Brazil		
Uruguay		
Venezuela		
Columbia		
India.		

MANUFACTURER AND VENDOR INFORMATION

Effective Date: March 22, 2000

Manufacturer name: International Road Dynamics

Address: 702 43rd Street East, Saskatoon SK, S7K 3T9 CANADA

Phone number: 306-653-6600
Fax number: 306-242-5599
e-mail address: info@ird.ca
URL address: www.irdinc.com

Sales representative name(s): Rod Klashinsky

Address:

Phone number:
Fax number:
e-mail address: rod.klashinsky@ird.ca
URL address:

PRODUCT NAME/MODEL NUMBER: Model AS4XX Dynax¤Treadle Systems

FIRMWARE VERSION/CHIP NO.: Not applicable

SOFTWARE VERSION NO.: NA

GENERAL DESCRIPTION OF EQUIPMENT: Speed independent axle sensing systems.

SENSOR TECHNOLOGY AND CONFIGURATION: Pressure sensitive activation. Set in frame, using 1,2,3 or four sensors

SENSOR INSTALLATION: Frame and Treadle system are permanent, sensor installation or replacement, less than 20 minutes.

INSTALLATION TIME (Per Lane): 4-5 hours for Frame and Treadle systems; 20 minutes for sensors.

INSTALLATION REQUIREMENTS: Contact IRD for information.

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: One treadle per lane (from stop and go traffic to 100 miles per hour).

PRODUCT CAPABILITIES/FUNCTIONS: Classification of vehicles by number of axles detected.

RECOMMENDED APPLICATIONS: Toll plaza

POWER REQUIREMENTS (watts/amps): 12 volts DC (+/-5%)

POWER OPTIONS: With voltage regulator between 15 VDC to 28 VDC

CLASSIFICATION ALGORITHMS: NA (axle sensor output activation only)

TELEMETRY: NA

COMPUTER REQUIREMENTS:

DATA OUTPUT: B-420-4-A Dynax¤ Interface Circuit Board outputs sensor activation only.

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM: Customers own data base

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane): Installation & equipment costs for 1 sensor 8 ft. systems US $ 6,500. For 4 sensors 10 foot system — US$ 8,500.00

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State

USA/California
USA/Colorado
USA/Delaware
USA/Florida
USA/Maine
USA/Michigan
USA/New York
USA/New Jersey
USA/Oklahoma
USA/Texas
USA/Virginia
Canada/Nova Scotia
Canada/New Brunswick
Brazil
Columbia
Uruguay
India.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: March 1, 2000

Manufacturer name: Traffic Monitoring Technologies	Sales representative name(s): Donald Dixon
Address: 6510 Chantilly Drive, 1st Floor Sykesville, Maryland 21784-8100	Address: 6510 Chantilly Drive, 1st Floor Sykesville, Maryland 21784-8100
Phone number: (410) 549-8779	Phone number: (410) 549-8779
Fax number: (410) 549-5113	Fax number: (410) 549-5113
e-mail address: tmt@erols.com	e-mail address: tmt@erols.com
URL address: trafficmonitoring.com	URL address: trafficmonitoring.com

PRODUCT NAME/MODEL NUMBER: The Blocker

FIRMWARE VERSION/CHIP NO.:

SOFTWARE VERSION NO.:

GENERAL DESCRIPTION OF EQUIPMENT: A cover and protector for low-profile or mini road tube and the lead-in cable for electronic sensors. It incorporates a tough and durable polymer that is flexible enough to contour the road yet strong enough to prevent vehicles from compressing it. Used to get multi-lane volume/speed/class counts and WIM data from interior lanes.

SENSOR TECHNOLOGY AND CONFIGURATION:

SENSOR INSTALLATION: The Blocker is placed over the road tube leading cable and taped to the road to prevent movement.

INSTALLATION TIME (Per Lane): 2-5 minutes

INSTALLATION REQUIREMENTS: Road tape, dry conditions

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: The Blocker comes in 6 feet lengths, can be placed end-to-end to cover unlimited number of lanes.

PRODUCT CAPABILITIES/FUNCTIONS: Prevents vehicles from predicting in road tube and protects lead-in cables of electronic sensors so counts and WIM data can be collected from interior lanes.

RECOMMENDED APPLICATIONS: Where multiple lanes of data are needed and the road tube or sensor must cross lanes with vehicular traffic. Also used to block out turn lanes for intersection studies.

POWER REQUIREMENTS (watts/amps): None

POWER OPTIONS: None

CLASSIFICATION ALGORITHMS: N/A

TELEMETRY: N/A

COMPUTER REQUIREMENTS: N/A

DATA OUTPUT: N/A

DATA OUTPUT FORMATS: N/A

SUPPORTING DATA BASE MANAGEMENT SYSTEM: N/A

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane): $138 per lane, the Blocker is portable and can be used again and again over several applications

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/PETCORP (Maryland)	John Reed	(410) 381-1995
USA/STS (Florida)	Mark Knowles	(800) 786-3374
USA/The Traffic Group	Anthony Zuckert	(410) 931-6600
USA/Traffic Data Services	Ryan	(800) 837-2562

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 2/22/2000

Manufacturer name: TimeMark Inc.

Address: P.O. Box 12947 Address: Salem, OR 97309-0947

Phone number: (503) 363-2012
Fax number: (503) 363-1716
e-mail address: sales@timemarkinc.com
URL address:

Sales representative name(s): Mike Bonser, Kerry Penn, Tim Miner

Address:

Phone number:
Fax number:
e-mail address:
URL address:

PRODUCT NAME/MODEL NUMBER: Delta 111B & Delta 111L

FIRMWARE VERSION/CHIP NO.: 1.02

SOFTWARE VERSION NO.: 3.2.7

GENERAL DESCRIPTION OF EQUIPMENT: 4 tube counter, classifier

SENSOR TECHNOLOGY AND CONFIGURATION: Road tube

SENSOR INSTALLATION: Road tube hardware

INSTALLATION TIME (Per Lane): 5 min.

INSTALLATION REQUIREMENTS:

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Four

PRODUCT CAPABILITIES/FUNCTIONS: Bi-directional volume, speed, axle classification, gap — all with one setting of counter under 5,000 ADT — volume counts on 4 lanes of traffic simultaneously

RECOMMENDED APPLICATIONS: 2 lane — same way or bi-directional 5,000 A.D.T. and above. 4 lane roadways for volume

POWER REQUIREMENTS (watts/amps):

POWER OPTIONS: 60 day rechargable gel cell battery

CLASSIFICATION ALGORITHMS:

TELEMETRY: If needed

COMPUTER REQUIREMENTS: 486 or better — Win 95, 98, NT

DATA OUTPUT:

DATA OUTPUT FORMATS: Comma delimited, strecter, TAS plus, GK and others as needed

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane): $1,950.00

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number

CONTACT TIMEMARK INC. FOR CURRENT LIST OF REFERENCES.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 2/22/2000

Manufacturer name: TimeMark Inc.

Address: P.O. Box 12947
Salem, OR 97309-0947

Phone number: (503) 363-2012
Fax number: (503) 363-1716
e-mail address: sales@timemarkinc.com
URL address:

Sales representative name(s): Mike Bonser, Kerry Penn, Tim Miner

Address: same

Phone number:
Fax number:
e-mail address:
URL address:

PRODUCT NAME/MODEL NUMBER: Gamma

FIRMWARE VERSION/CHIP NO.: 1.02

SOFTWARE VERSION NO.: 3.2.7

GENERAL DESCRIPTION OF EQUIPMENT: Two tube counter/classifier

SENSOR TECHNOLOGY AND CONFIGURATION: Road tube

SENSOR INSTALLATION: Road tube hardware

INSTALLATION TIME (Per Lane): 5 minutes

INSTALLATION REQUIREMENTS:

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Two

PRODUCT CAPABILITIES/FUNCTIONS: Bi - Directional volume, speed, axle classification, gap — all with one setting of counter under 5,000 ADT

RECOMMENDED APPLICATIONS: 2 lane — same way or bi-directional roadways

POWER REQUIREMENTS (watts/amps):

POWER OPTIONS: 90 day rechargeable gel cell battery

CLASSIFICATION ALGORITHMS:

TELEMETRY:

COMPUTER REQUIREMENTS: 486 or better — Win 95, 98, NT

DATA OUTPUT:

DATA OUTPUT FORMATS: Comma delimited, strecter, TAS plus, GK and others as needed

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane): $1,650.00

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number

CONTACT TIMEMARK INC. FOR CURRENT LIST OF REFERENCES.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 2/22/2000

Manufacturer name: TimeMark Inc.	Sales representative name(s): Mike Bonser, Kerry Penn, Tim Miner
Address: P.O. Box 12947 Salem, OR 97309-0947	Address: same
Phone number: (503) 363-2012	Phone number:
Fax number: (503) 363-1716	Fax number:
e-mail address: sales@timemarkinc.com	e-mail address:
URL address:	URL address:

PRODUCT NAME/MODEL NUMBER: Beta

FIRMWARE VERSION/CHIP NO.: 1.02

SOFTWARE VERSION NO.: 3.2.7

GENERAL DESCRIPTION OF EQUIPMENT: Traffic counter volume only road tube

SENSOR TECHNOLOGY AND CONFIGURATION: Road tube

SENSOR INSTALLATION: Road tube hardware

INSTALLATION TIME (Per Lane): 5 minutes

INSTALLATION REQUIREMENTS:

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Two

PRODUCT CAPABILITIES/FUNCTIONS: Bi - Directional volume count

RECOMMENDED APPLICATIONS: Roadway

POWER REQUIREMENTS (watts/amps):

POWER OPTIONS: Rechargeable GSL cell battery

CLASSIFICATION ALGORITHMS:

TELEMETRY: If needed

COMPUTER REQUIREMENTS:

DATA OUTPUT:

DATA OUTPUT FORMATS: Comma delimited, strecter, TAS plus, GK and others as needed

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane): $1,550.00

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number

CONTACT TIMEMARK INC. FOR CURRENT LIST OF REFERENCES.

Inductive Loop Detectors

The inductive loop detector (ILD) is the most common sensor used in traffic management applications. Its size and shape vary, including the 5-ft by 5-ft or 6-ft by 6-ft square loops, 6-ft diameter round loops, and rectangular configurations having a 6-ft width and variable length (Gordon, et. al., 1996). Figure 4 shows the principal components of an inductive loop detector: one or more turns of insulated wire buried in a shallow saw-cut in the roadway, a lead-in cable that runs from a roadside pull box to the controller cabinet, and an electronics unit located in the controller cabinet.

Principles of Operation

The wire loop is excited with signals whose frequencies range from 10 KHz to 50 KHz and functions as an inductive element in conjunction with the electronics unit. When a vehicle stops on or passes over the loop, the inductance of the loop is decreased. The decreased inductance increases the oscillation frequency and causes the electronics unit to send a pulse to the controller, indicating the presence or passage of a vehicle.

Applications and Uses

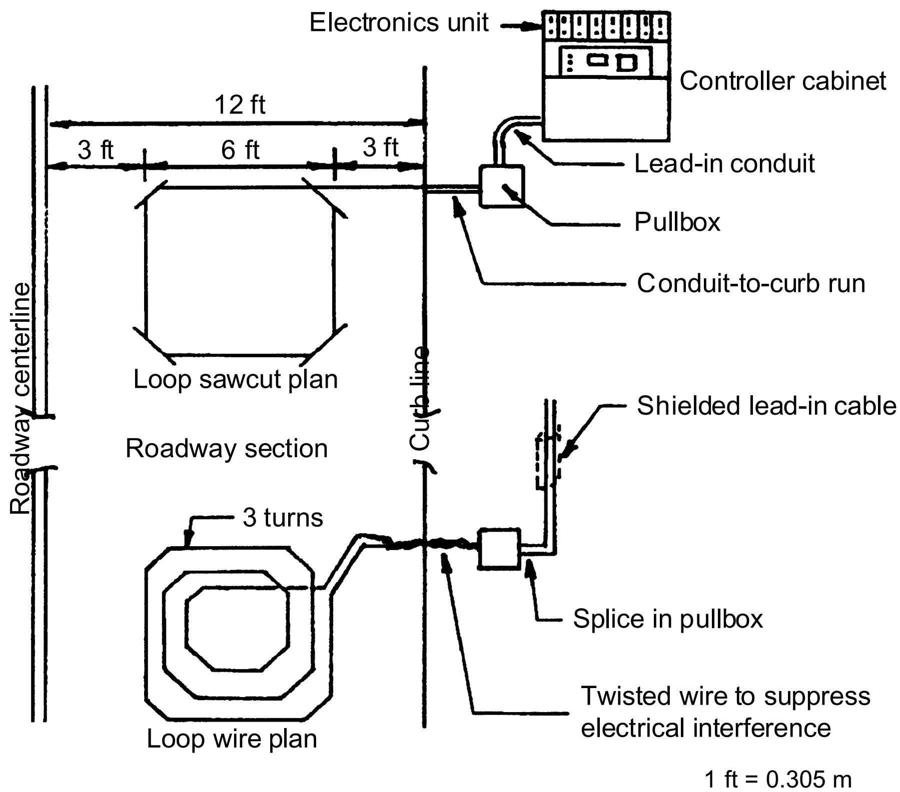
The data supplied by conventional inductive loop detectors are vehicle passage, presence, count, and occupancy. Although loops cannot directly measure speed, speed can be determined using a two-loop speed trap or a single loop detector and an algorithm whose inputs are loop length, average vehicle length, time over the detector, and number of vehicles counted. Vehicle classification is supported by newer versions of the inductive loop containing electronics units that excite the wire loop at the higher frequencies that identify specific metal portions on the vehicle.

Advantages

The operation of inductive loop sensors is well understood and their application for providing basic traffic parameters (volume, presence, occupancy, speed, headway, and gap) represents a mature technology. As was the case with the pneumatic road tube, the equipment cost of inductive loop sensors is low when compared to non-intrusive sensor technologies. Another advantage of inductive loop sensors is their ability to satisfy a large variety of applications due to their flexible design.

Disadvantages

The drawbacks to the use of inductive loop sensors include disruption of traffic for installation and repair and failures associated with installations in poor road surfaces and use of substandard installation procedures. In many instances multiple detectors are usually required to instrument a location. In addition, resurfacing of roadways and utility repair can also create the need to reinstall these types of sensors. Also, wire loops are subject to stresses of traffic and temperature.



(*Source*: Gordon, R.L., R.A. Reiss, H. Haenel, E.R. Case, R.L. French, A. Mohaddes, and R. Wolcott, *Traffic Control Systems Handbook*, FHWA-SA-95-032, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C., Feb. 1996.)

Figure 4. Principal components of an inductive loop detector.

MANUFACTURER AND VENDOR INFORMATION

Effective Date:____________________

Manufacturer name: Never Fail Loop Systems.	Sales representative name(s): Roland Smits
Address: 285 N. Hancock, Portland, OR 97227	Address: same
Phone number: (503) 288-8871	Phone number
Fax number: (503) 288-0274	Fax number:
e-mail address: info@neverfail.com	e-mail address: roland@neverfails.com
URL address: www.neverfail.com	URL address:

PRODUCT NAME/MODEL NUMBER: Never-Fail

FIRMWARE VERSION/CHIP NO.: N/A

SOFTWARE VERSION NO.: N/A

GENERAL DESCRIPTION OF EQUIPMENT: Preformed Traffic Detection Loops

SENSOR TECHNOLOGY AND CONFIGURATION: Inductive Loops

SENSOR INSTALLATION: In-ground

INSTALLATION TIME (Per Lane): New pavement aps 10 minutes, existing pavement approximately 1 hour

INSTALLATION REQUIREMENTS:

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: No maximum

PRODUCT CAPABILITIES/FUNCTIONS: Traffic control, preemption, volume count, speed count, intersection control, traffic jam detection

RECOMMENDED APPLICATIONS: Intersections, freeways

POWER REQUIREMENTS (watts/amps): N/A

POWER OPTIONS: N/A

CLASSIFICATION ALGORITHMS: N/A

TELEMETRY: N/A

COMPUTER REQUIREMENTS: N/A

DATA OUTPUT:

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number

CONTACT NEVERFAIL LOOP SYSTEMS FOR CURRENT LIST OF REFERENCES.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 3/1/00

Manufacturer name: Peek Traffic Inc.	Sales representative name(s): Bill Ippolito & Rob Gaines
Address: 1500 N. Washington Blvd. Sarasota, FL 34236	Address:
Phone number: (941) 951-0221	Phone number: (301) 733-2125
Fax number: (941) 365-0837	Fax number: (301) 745-3558
e-mail address: rgaines@peektrafficinc.com	e-mail address: bippolito@peektrafficinc.com
URL address:	URL address:

PRODUCT NAME/MODEL NUMBER: IDRIS/ADR 6000/Prism

FIRMWARE VERSION/CHIP NO.:

SOFTWARE VERSION NO.:

GENERAL DESCRIPTION OF EQUIPMENT: Smart loop system. Roadside mounted rack. Loop based classifier.

SENSOR TECHNOLOGY AND CONFIGURATION: Loops, dependent on application

SENSOR INSTALLATION:

INSTALLATION TIME (Per Lane): 4 hours

INSTALLATION REQUIREMENTS:

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Eight

PRODUCT CAPABILITIES/FUNCTIONS: Classification, axle count, vehicle count, lane designation, enforcement trigger

RECOMMENDED APPLICATIONS: Manual toll lanes, express toll lanes, DOT classification in congestion

POWER REQUIREMENTS (watts/amps): Less than .1 amp

POWER OPTIONS: Currently A/C

CLASSIFICATION ALGORITHMS: IDRIS; vehicle by vehicle for toll booths

TELEMETRY: Yes

COMPUTER REQUIREMENTS: Data analysis done in outstation

DATA OUTPUT: Based on application

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number

CONTACT PEEK TRAFFIC FOR CURRENT LIST OF REFERENCES.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 6/1/00

Manufacturer name: Peek Traffic Inc.

Address: 1500 N. Washington Blvd.
Sarasota, FL 34236

Phone number: (941) 366-8770
Fax number: (941) 365-0837
e-mail address: rgaines@peektrafficinc.com
URL address:

Sales representative name(s):
Rob Gaines
Debbie Rupp

Address: same

Phone number:
Fax number:
e-mail address:
URL address:

PRODUCT NAME/MODEL NUMBER: 224 GP7 (New Product!)

FIRMWARE VERSION/CHIP NO.:

SOFTWARE VERSION NO.:

GENERAL DESCRIPTION OF EQUIPMENT: 2 channel inductive loop detector. For TS-1 and TS-2

SENSOR TECHNOLOGY AND CONFIGURATION: Monitors the change of inductance and frequency

SENSOR INSTALLATION: Plug in module, plugs into card rack

INSTALLATION TIME (Per Lane): Minimal

INSTALLATION REQUIREMENTS: Must be connected to in-ground inductive loop

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Two

PRODUCT CAPABILITIES/FUNCTIONS: Monitors loop coil for inductive changes. Outputs on passage of vehicle over buried loop of wire.

RECOMMENDED APPLICATIONS: Intersection and freeway control. Used in traffic signal systems.

POWER REQUIREMENTS (watts/amps): 10 to 30 VDC

POWER OPTIONS:

CLASSIFICATION ALGORITHMS:

TELEMETRY:

COMPUTER REQUIREMENTS:

DATA OUTPUT:

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number

CONTACT PEEK TRAFFIC FOR CURRENT LIST OF REFERENCES.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 6/1/00

Manufacturer name: Peek Traffic Inc.	Sales representative name(s): Rob Gaines, Debbie Rupp
Address: 1500 N. Washington Blvd. Sarasota, FL 34236	Address: same
Phone number: (941) 366-8770	Phone number:
Fax number: (941) 365-0837	Fax number:
e-mail address: rgaines@peektrafficinc.com	e-mail address:
URL address:	URL address:

PRODUCT NAME/MODEL NUMBER: 224T GP7 (New Product!)

FIRMWARE VERSION/CHIP NO.:

SOFTWARE VERSION NO.:

GENERAL DESCRIPTION OF EQUIPMENT: 4 channel inductive loop detector. With extend and delay timers. For TS-1 and TS-2

SENSOR TECHNOLOGY AND CONFIGURATION: Monitors the change of inductance and frequency

SENSOR INSTALLATION: Plug in module, plugs into card rack

INSTALLATION TIME (Per Lane): Minimal

INSTALLATION REQUIREMENTS: Must be connected to in ground inductive loop

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Four

PRODUCT CAPABILITIES/FUNCTIONS: Monitors loop coil for inductive changes. Outputs on passage of vehicle over buried loop of wire.

RECOMMENDED APPLICATIONS: Intersection and freeway control. Used in traffic signal systems.

POWER REQUIREMENTS (watts/amps): 10 — 30 VDC

POWER OPTIONS:

CLASSIFICATION ALGORITHMS:

TELEMETRY:

COMPUTER REQUIREMENTS:

DATA OUTPUT:

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number

CONTACT PEEK TRAFFIC FOR CURRENT LIST OF REFERENCES.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 6/1/00

Manufacturer name: Peek Traffic Inc.	Sales representative name(s): Rob Gaines, Debbie Rupp
Address: 1500 N. Washington Blvd. Sarasota, FL 34236	Address: same
Phone number: (941) 366-8770	Phone number
Fax number: (941) 365-0837	Fax number:
e-mail address: rgaines@peektrafficinc.com	e-mail address:
URL address:	URL address:

PRODUCT NAME/MODEL NUMBER: 222TGP7

FIRMWARE VERSION/CHIP NO.:

SOFTWARE VERSION NO.:

GENERAL DESCRIPTION OF EQUIPMENT: Two channel inductive loop detector. With extend and delay timers. For TS-1 and TS-2

SENSOR TECHNOLOGY AND CONFIGURATION: Monitors the change of inductance and frequency

SENSOR INSTALLATION: Plug in module, plugs into card rack

INSTALLATION TIME (Per Lane): Minimal

INSTALLATION REQUIREMENTS: Must be connected to in ground inductive loop

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Two

PRODUCT CAPABILITIES/FUNCTIONS: Monitors loop coil for inductive changes. Outputs on passage of vehicle over buried loop of wire.

RECOMMENDED APPLICATIONS: Intersection and freeway control. Used in traffic signal systems.

POWER REQUIREMENTS (watts/amps): 10 — 30 VDC

POWER OPTIONS:

CLASSIFICATION ALGORITHMS:

TELEMETRY:

COMPUTER REQUIREMENTS:

DATA OUTPUT:

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number

CONTACT PEEK TRAFFIC FOR CURRENT LIST OF REFERENCES.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 6/1/00

Manufacturer name: Peek Traffic Inc.

Address: 1500 N. Washington Blvd.
Sarasota, FL 34236

Phone number: (941) 366-8770
Fax number: (941) 365-0837
e-mail address: rgaines@peektrafficinc.com
URL address:

Sales representative name(s):
Rob Gaines
Debbie Rupp

Address: same

Phone number:
Fax number:
e-mail address:
URL address:

PRODUCT NAME/MODEL NUMBER: 222 GP7

FIRMWARE VERSION/CHIP NO.:

SOFTWARE VERSION NO.:

GENERAL DESCRIPTION OF EQUIPMENT: 2 channel inductive loop detector. For TS-1 and TS-2

SENSOR TECHNOLOGY AND CONFIGURATION: Monitors the change of inductance and frequency

SENSOR INSTALLATION: Plug in module, plugs into card rack

INSTALLATION TIME (Per Lane): Minimal

INSTALLATION REQUIREMENTS: Must be connected to in ground inductive loop

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Two

PRODUCT CAPABILITIES/FUNCTIONS: Monitors loop coil for inductive changes. Outputs on passage of vehicle over buried loop of wire.

RECOMMENDED APPLICATIONS: Intersection and freeway control. Used in traffic signal systems.

POWER REQUIREMENTS (watts/amps): 10 — 30 VDC

POWER OPTIONS:

CLASSIFICATION ALGORITHMS:

TELEMETRY:

COMPUTER REQUIREMENTS:

DATA OUTPUT:

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number

CONTACT PEEK TRAFFIC FOR CURRENT LIST OF REFERENCES.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 2/28/00

Manufacturer name: Peek Traffic Inc.	Sales representative name(s): Rob Gaines, Debbie Rupp
Address: 1500 N. Washington Blvd. Sarasota, FL 34236	Address: same
Phone number: (941) 366-8770	Phone number
Fax number: (941) 365-0837	Fax number:
e-mail address: rgaines@peektrafficinc.com	e-mail address:
URL address:	URL address:

PRODUCT NAME/MODEL NUMBER: 224 GP5

FIRMWARE VERSION/CHIP NO.:

SOFTWARE VERSION NO.:

GENERAL DESCRIPTION OF EQUIPMENT: 4 channel inductive loop detector.

SENSOR TECHNOLOGY AND CONFIGURATION: Monitors the change of inductance and frequency

SENSOR INSTALLATION: Plug in module, plugs into card rack

INSTALLATION TIME (Per Lane): Minimal

INSTALLATION REQUIREMENTS: Must be connected to in ground inductive loop

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Four

PRODUCT CAPABILITIES/FUNCTIONS: Monitors loop coil for inductive changes. Outputs on passage of vehicle over buried loop of wire.

RECOMMENDED APPLICATIONS: Intersection and freeway control. Used in traffic signal systems.

POWER REQUIREMENTS (watts/amps): 10.8 to 28.8 VDC 80mA maximum

POWER OPTIONS:

CLASSIFICATION ALGORITHMS:

TELEMETRY:

COMPUTER REQUIREMENTS:

DATA OUTPUT:

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/California	Bob McMillan	(916) 654-4385
USA/New York	Mike Naumiec	(518) 783-7746

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 2/28/00

Manufacturer name: Peek Traffic Inc.	Sales representative name(s): Rob Gaines, Debbie Rupp
Address: 1500 N. Washington Blvd. Sarasota, FL 34236	Address: same
Phone number: (941) 366-8770	Phone number:
Fax number: (941) 365-0837	Fax number:
e-mail address: rgaines@peektrafficinc.com	e-mail address:
URL address:	URL address:

PRODUCT NAME/MODEL NUMBER: 222GP6

FIRMWARE VERSION/CHIP NO.:

SOFTWARE VERSION NO.:

GENERAL DESCRIPTION OF EQUIPMENT: 2 channel inductive loop detector.

SENSOR TECHNOLOGY AND CONFIGURATION: Monitors the change of inductance and frequency

SENSOR INSTALLATION: Plug in module, plugs into card rack

INSTALLATION TIME (Per Lane): Minimal

INSTALLATION REQUIREMENTS: Must be connected to in ground inductive loop

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Two

PRODUCT CAPABILITIES/FUNCTIONS: Monitors loop coil for inductive changes. Outputs on passage of vehicle over buried loop of wire.

RECOMMENDED APPLICATIONS: Both intersection and freeway control with 170 & 2070 controllers. Used in traffic signal systems.

POWER REQUIREMENTS (watts/amps): 10.8 to 28.8 VDC 80mA maximum

POWER OPTIONS:

CLASSIFICATION ALGORITHMS:

TELEMETRY:

COMPUTER REQUIREMENTS:

DATA OUTPUT:

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/California	Bob McMillan	(916) 654-4385
USA/New York	Mike Naumiec	(518) 783-7746

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 8/1/00

Manufacturer name: Peek Traffic Inc.

Address: 1500 N. Washington Blvd.
Sarasota, FL 34236

Phone number: (941) 366-8770
Fax number: (941) 365-0837
e-mail address: rgaines@peektrafficinc.com
URL address:

Sales representative name(s):
Rob Gaines
Debbie Rupp

Address: same

Phone number:
Fax number:
e-mail address:
URL address:

PRODUCT NAME/MODEL NUMBER: 537B.MS GP7

FIRMWARE VERSION/CHIP NO.:

SOFTWARE VERSION NO.:

GENERAL DESCRIPTION OF EQUIPMENT: 4 channel inductive loop detector with loop diagnostics

SENSOR TECHNOLOGY AND CONFIGURATION: Monitors the change of inductance and frequency

SENSOR INSTALLATION: Shelf mount

INSTALLATION TIME (Per Lane): Minimal

INSTALLATION REQUIREMENTS: Must be connected to in ground inductive loop

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Two

PRODUCT CAPABILITIES/FUNCTIONS: Monitors loop coil for inductive changes. Outputs on passage of vehicle over buried loop of wire.

RECOMMENDED APPLICATIONS: Intersection and freeway control. Used in traffic signal systems.

POWER REQUIREMENTS (watts/amps): 110 VAC

POWER OPTIONS:

CLASSIFICATION ALGORITHMS:

TELEMETRY:

COMPUTER REQUIREMENTS:

DATA OUTPUT:

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/Florida		
USA/Illinois		
USA/Wisconsin		
Canada/Ontario		

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 8/1/00

Manufacturer name: Peek Traffic Inc.	Sales representative name(s): Rob Gaines, Debbie Rupp
Address: 1500 N. Washington Blvd. Sarasota, FL 34236	Address: same
Phone number: (941) 366-8770	Phone number:
Fax number: (941) 365-0837	Fax number:
e-mail address: rgaines@peektrafficinc.com	e-mail address:
URL address:	URL address:

PRODUCT NAME/MODEL NUMBER: 537T/MS GP7

FIRMWARE VERSION/CHIP NO.:

SOFTWARE VERSION NO.:

GENERAL DESCRIPTION OF EQUIPMENT: 4 channel inductive loop detector. With extend and delay timers.

SENSOR TECHNOLOGY AND CONFIGURATION: Monitors the change of inductance and frequency

SENSOR INSTALLATION: Shelf mount

INSTALLATION TIME (Per Lane): Minimal

INSTALLATION REQUIREMENTS: Must be connected to in ground inductive loop

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: 2

PRODUCT CAPABILITIES/FUNCTIONS: Monitors loop coil for inductive changes. Outputs on passage of vehicle over buried loop of wire.

RECOMMENDED APPLICATIONS: Intersection and freeway control

POWER REQUIREMENTS (watts/amps): 110VAC

POWER OPTIONS:

CLASSIFICATION ALGORITHMS:

TELEMETRY:

COMPUTER REQUIREMENTS:

DATA OUTPUT:

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number

CONTACT PEEK TRAFFIC FOR CURRENT LIST OF REFERENCES.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 8/1/00

Manufacturer name: Peek Traffic Inc.

Address: 1500 N. Washington Blvd.
Sarasota, FL 34236

Phone number: (941) 366-8770
Fax number: (941) 365-0837
e-mail address: rgaines@peektrafficinc.com
URL address:

Sales representative name(s):
Rob Gaines
Debbie Rupp

Address: same

Phone number:
Fax number:
e-mail address:
URL address:

PRODUCT NAME/MODEL NUMBER: 536B/MS GP7

FIRMWARE VERSION/CHIP NO.:

SOFTWARE VERSION NO.:

GENERAL DESCRIPTION OF EQUIPMENT: 2 channel inductive loop detector.

SENSOR TECHNOLOGY AND CONFIGURATION: Monitors the change of inductance and frequency

SENSOR INSTALLATION: Shelf mount

INSTALLATION TIME (Per Lane): Minimal

INSTALLATION REQUIREMENTS: Must be connected to in ground inductive loop

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: 2

PRODUCT CAPABILITIES/FUNCTIONS: Monitors loop coil for inductive changes. Outputs on passage of vehicle over buried loop of wire.

RECOMMENDED APPLICATIONS: Intersection and freeway control. Used in traffic signal systems.

POWER REQUIREMENTS (watts/amps): 110 VAC

POWER OPTIONS:

CLASSIFICATION ALGORITHMS:

TELEMETRY:

COMPUTER REQUIREMENTS:

DATA OUTPUT:

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number

CONTACT PEEK TRAFFIC FOR CURRENT LIST OF REFERENCES.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 8/1/00

Manufacturer name: Peek Traffic Inc.

Address: 1500 N. Washington Blvd.
Sarasota, FL 34236

Phone number: (941) 366-8770
Fax number: (941) 365-0837
e-mail address: rgaines@peektrafficinc.com
URL address:

Sales representative name(s):
Rob Gaines
Debbie Rupp

Address: same

Phone number:
Fax number:
e-mail address:
URL address:

PRODUCT NAME/MODEL NUMBER: 535B/MS GP7

FIRMWARE VERSION/CHIP NO.:

SOFTWARE VERSION NO.:

GENERAL DESCRIPTION OF EQUIPMENT:
1 channel inductive loop detector.

SENSOR TECHNOLOGY AND CONFIGURATION: Monitors the change of inductance and frequency

SENSOR INSTALLATION: Shelf mount

INSTALLATION TIME (Per Lane): Minimal

INSTALLATION REQUIREMENTS: Must be connected to in ground inductive loop

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: One

PRODUCT CAPABILITIES/FUNCTIONS: Monitors loop coil for inductive changes. Outputs on passage of vehicle over buried loop of wire.

RECOMMENDED APPLICATIONS: Intersection and freeway control. Used in traffic signal systems.

POWER REQUIREMENTS (watts/amps): 110 VAC

POWER OPTIONS:

CLASSIFICATION ALGORITHMS:

TELEMETRY:

COMPUTER REQUIREMENTS:

DATA OUTPUT:

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number

CONTACT PEEK TRAFFIC FOR CURRENT LIST OF REFERENCES.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 8/1/00

Manufacturer name: Peek Traffic Inc.

Address: 1500 N. Washington Blvd.
Sarasota, FL 34236

Phone number: (941) 366-8770
Fax number: (941) 365-0837
e-mail address: rgaines@peektrafficinc.com
URL address:

Sales representative name(s):
Rob Gaines
Debbie Rupp

Address: same

Phone number:
Fax number:
e-mail address:
URL address:

PRODUCT NAME/MODEL NUMBER: 535T/MS GP7

FIRMWARE VERSION/CHIP NO.:

SOFTWARE VERSION NO.:

GENERAL DESCRIPTION OF EQUIPMENT: Single channel inductive loop detector with extend and delay timing.

SENSOR TECHNOLOGY AND CONFIGURATION: Monitors the change of inductance and frequency

SENSOR INSTALLATION: Shelf mount

INSTALLATION TIME (Per Lane): Minimal

INSTALLATION REQUIREMENTS: Must be connected to in ground inductive loop

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: One

PRODUCT CAPABILITIES/FUNCTIONS: Monitors loop coil for inductive changes. Outputs on passage of vehicle over buried loop of wire.

RECOMMENDED APPLICATIONS: Intersection and freeway control

POWER REQUIREMENTS (watts/amps): 110 VAC

POWER OPTIONS:

CLASSIFICATION ALGORITHMS:

TELEMETRY:

COMPUTER REQUIREMENTS:

DATA OUTPUT:

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number

CONTACT PEEK TRAFFIC FOR CURRENT LIST OF REFERENCES.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 2/29/00

Manufacturer name: Truvelo Manufacturers (Pty) Ltd.

Address: P.O. Box 14183
Lyttelton 0140
South Africa

Phone number: 011-27-11-314-1405

Fax number: 011-27-11-314-1409

e-mail address: rudi@truvelo.co.za

URL address: www.truvelo.co.za

Sales representative name(s): James E. Kelly
AVIAR inc

Address: P.O. Box 162184
Austin, TX 78716

Phone number: (512) 295-5285

Fax number: (512) 295-2603

e-mail address: aviar@aviarinc.com

URL address: www.aviarinc.com

PRODUCT NAME/MODEL NUMBER: Vehicle Classifier/Data Logger (TCL-300)

FIRMWARE VERSION/CHIP NO.: N/A

SOFTWARE VERSION NO.: N/A

GENERAL DESCRIPTION OF EQUIPMENT: Electronic unit to store data (TCL-300) and inductive loop for data gathering

SENSOR TECHNOLOGY AND CONFIGURATION: 2 inductive loops/lane up to 4 lanes

SENSOR INSTALLATION: Temporary installation on surface of pavement or permanent installation in pavement surface

INSTALLATION TIME (Per Lane): Temp: 15 min
Perm: 2 hr/lane

INSTALLATION REQUIREMENTS: N/A

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: 4 lanes

PRODUCT CAPABILITIES/FUNCTIONS: Vehicle number, date, time, direction, vehicle class, length, headway, data of 20,000 individual vehicles.

RECOMMENDED APPLICATIONS: Vehicle classification, vehicle following distances, queuing and lane occupancy.

POWER REQUIREMENTS (watts/amps): 6 volt internal battery (rechargeable from 12 volt battery, commercial power, or solar energy)

POWER OPTIONS: See above

CLASSIFICATION ALGORITHMS: Vehicle pattern recognition s in light, medium, heavy or light, rigid trucks and buses, trucks and trailers, tractor and semitrailer, multitrailer heavy vehicles

TELEMETRY: RS232 serial port and modem

COMPUTER REQUIREMENTS: Compatible PC

DATA OUTPUT: See Product Capabilities

DATA OUTPUT FORMATS: N/A

SUPPORTING DATA BASE MANAGEMENT SYSTEM: N/A

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

	Temporary		Permanent	
	1 lane	4 lane	1 lane	4 lane
Equipment	$4,000	$4,000	$4,700	$4.700
Installation costs	$500	$1.500	$1,000	$2,500

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	**Contact name**	**Telephone number**
USA/Michigan	Jim Kramer	(517) 322-1736

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 2/24/00

Manufacturer name: 3M Intelligent Transportation Systems	Sales representative name(s): D. Henderson/Sales Mgr.
Address: 3M Center, Bldg 225-4N-14 St. Paul, MN 55144-1000	Address: 3M ITS same
Phone number: (800) 328-7098	Phone number:
Fax number:	Fax number:
e-mail address:	e-mail address:
URL address: www.mmm.com/ITS	URL address:

PRODUCT NAME/MODEL NUMBER: Canoga Vehicle Detection System C800 Series Digital Loop Detector

FIRMWARE VERSION/CHIP NO.: Various

SOFTWARE VERSION NO.: Various

GENERAL DESCRIPTION OF EQUIPMENT: Two and four channel digital loop detectors with delay and extension timing, vehicle counting, speed measurement

SENSOR TECHNOLOGY AND CONFIGURATION: Wire-loop and 3M Canoga Microloops and non-invasive microloop

SENSOR INSTALLATION: In road surface for wire loops and microloops beneath road for non-invasive microloops

INSTALLATION TIME (Per Lane): Various

INSTALLATION REQUIREMENTS: Directional boring for non-invasive microloops

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Unlimited

PRODUCT CAPABILITIES/FUNCTIONS: Various

RECOMMENDED APPLICATIONS: All presence and passage applications

POWER REQUIREMENTS (watts/amps): 24 VDC < 30 watts

POWER OPTIONS: None

CLASSIFICATION ALGORITHMS: Length and speed

TELEMETRY: RS 232 and RS 485 port available

COMPUTER REQUIREMENTS: OS req: windows 95/98 or NT 4.0

DATA OUTPUT: N/A

DATA OUTPUT FORMATS: N/A

SUPPORTING DATA BASE MANAGEMENT SYSTEM: N/A

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane): Various

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number

CONTACT 3M FOR CURRENT LIST OF REFERENCES.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: Fall 2000

Manufacturer name: Computer Expertise Corporation	Sales representative name(s): Gerald Gerlach
Address: P. O. Box 1899 Windham, ME 04062	Address: Same
Phone number: (207) 892-0740	Phone number:
Fax number: (207) 892-0740	Fax number:
e-mail address: cecorp@computerexpertise.com	e-mail address:
URL address: computerexpertise.com	URL address:

PRODUCT NAME/MODEL NUMBER: CE2002

FIRMWARE VERSION/CHIP NO.: 2.3

SOFTWARE VERSION NO.:

GENERAL DESCRIPTION OF EQUIPMENT: Controller board that counts axles, and classifies vehicles. Uses light bars, treadles, loops and infrared detectors as inputs.

SENSOR TECHNOLOGY AND CONFIGURATION: Pair of light bars, treadle(s), loop(s)

SENSOR INSTALLATION: By others

INSTALLATION TIME (Per Lane): One day

INSTALLATION REQUIREMENTS: By others

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: One

PRODUCT CAPABILITIES/FUNCTIONS: Controller counts axles, with optional sensors; detects trailer hitch, axles, height and separation

RECOMMENDED APPLICATIONS: Toll lanes requiring classification

POWER REQUIREMENTS (watts/amps): 2 amps
POWER OPTIONS: 120

CLASSIFICATION ALGORITHMS: Axles + height + trailer hitch = class

TELEMETRY: None

COMPUTER REQUIREMENTS: Controller interfaces either serial or DO

DATA OUTPUT: Serial messages

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM: By others

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane): Controller requires A/C plus serial connection to lane and sensor hookups

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/Maine	Neil Libby	(207) 871-7771

Piezoelectric Sensors

A piezoelectric is a specially processed material capable of converting kinetic energy to electrical energy. Some polymer materials exhibit these properties to a high degree and it is these types of materials that are ideal to use in the construction of piezoelectric sensors.

Construction of the piezoelectric sensor is coaxial with a metal, braided core element, followed by the piezoelectric material and a metal outer layer. During the manufacturing process, subjecting it to an intense electrical field radially polarizes piezoelectric material. This electrical field is applied in a corona field on the non-jacketed cable. The polarization field changes the amorphous polymer into a semi-crystalline form, while retaining many of the flexible properties of the original polymer (Halvorsen, 1999).

Principles of Operation

Piezoelectric materials generate a voltage when subjected to mechanical impact or vibration. Electrical charges of opposite polarity appear at the parallel faces and induce a voltage. The measured voltage is proportional to the force or weight of the vehicle. The magnitude of the piezoelectric effect depends upon the direction of the force in relation to the axes of the crystal. Since the piezoelectric effect is dynamic, i.e., charge is generated only when the forces are changing, the initial charge will decay if the force remains constant (Castle Rock Consultants, 1988)

Another type of piezoelectric sensor is Vibracoax cable, manufactured by Thermocoax. It utilizes a mineral-based powder as the piezoelectric material that forms the dielectric between the copper wire at the center of the coaxial cable and the solid copper tube that serves as the outer conductor. During manufacture, the temperature of the cable is increased to 400^{o}C and a voltage is applied between the inner and outer conductors to polarize the powder by orienting the electrical charges on the molecules of powder. The voltage is maintained as the cable is cooled, thus stabilizing the polarized field. The cable can be supplied expoxied into an aluminum channel to ensure that it is installed without kinks as shown in Figure 5.

Applications and Uses

Piezoelectric sensors are utilized to classify vehicles by axle count and spacing and to measure vehicle weight and speed (the latter when multiple sensors are deployed). They are frequently used as part of weigh-in-motion systems. Class I piezoelectric sensors detect and weigh axles, while Class II sensors only detect the axle. There is typically a price advantage of buying Class II sensors for non-WIM applications, although the total installed cost is only fractionally more than that of a Class II sensor, for sensors of the same length (Halvorsen, 1999).

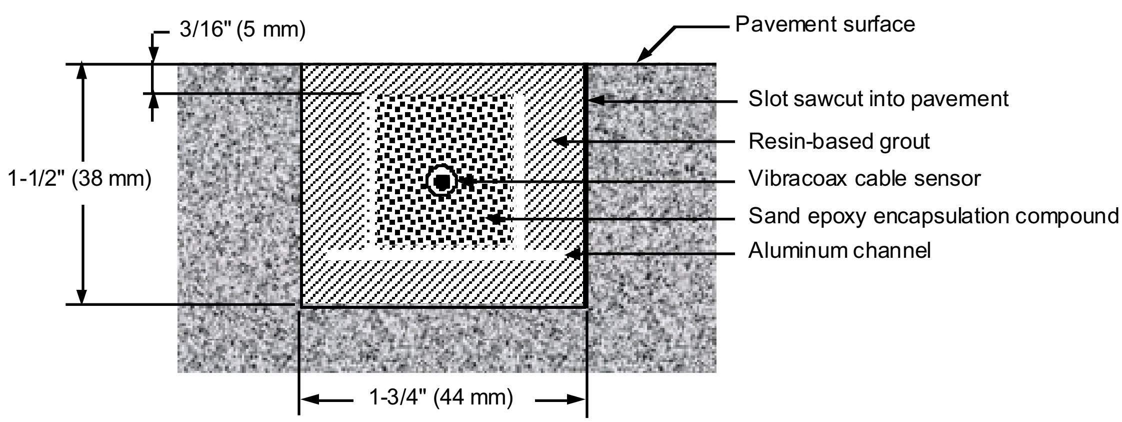


Figure 5. Vibracoax piezoelectric sensor mounted in aluminum channel as installed in a roadbed. (Drawing courtesy of IRD, Inc., Saskatoon, SK).

Vibracoax is recommended for weigh-in-motion, vehicle classification by axle count and spacing, gross vehicle and load measurement, speed measurement, and counting applications. Foam rubber is placed along the vertical sides of the sawcut when Vibracoax cable is utilized in weigh-in-motion systems manufactured by ECM, Inc. This technique enhances the vertical pressure measurement and reduces side stresses. This configuration is particularly useful for installations in concrete slabs that may contain cracks that would otherwise transfer horizontal forces to the cable sensor. The sawcut and cable are sealed with fillers that match the mechanical properties of the road surface to produce a slightly domed surface.

Other examples of piezoelectric sensors include the Roadtrax BL and the BLC sensors. The Roadtrax piezoelectric sensor is manufactured with and without an aluminum channel for permanent or temporary installation in the roadbed (Roadtrax, 1995-1996). It supports Class I and Class II operations.

The BL (Brass Linguini^{TM}) model is installed directly into the roadbed in a slot 0.75-in (19-mm) wide by 0.75-in (19-mm) deep (typical). Polyurethane, epoxy, and acrylic grouts are available for sealing the slot.

When the BLC aluminum channel model is installed, as depicted in Figure 6, the same epoxy is used inside the channel to encapsulate the sensor and for installation in the road. This eliminates or greatly reduces temperature coefficient effects.

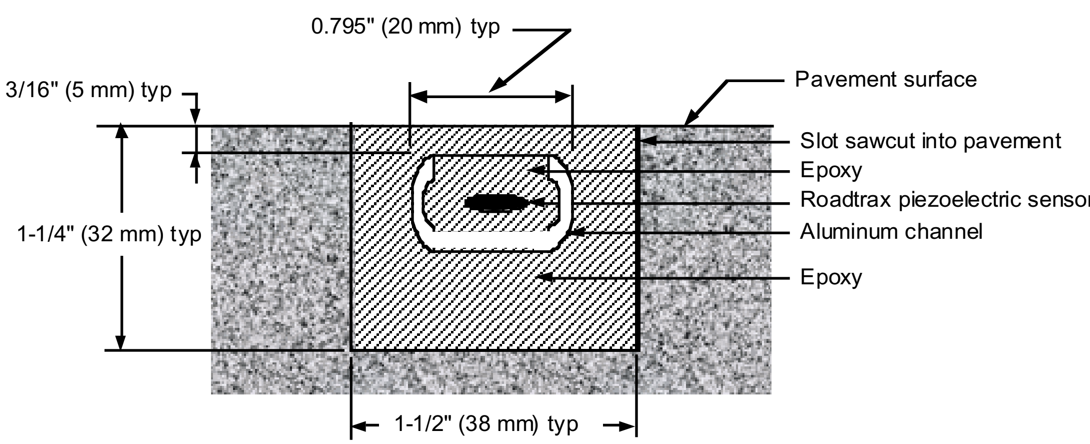


Figure 6. Roadtrax piezoelectric BLC sensor mounted in aluminum channel as installed in a roadbed (Roadtrax, 1995-1996).

Bonding Materials

A study by Fowler (Fowler, 1996) of current state practices for bonding piezoelectric sensors to pavement revealed that the bond between the piezoelectric sensor and the pavement was lost where rutting occurred. Several laboratory tests performed on the bonding material were found more relevant than others in predicting field performance of bonding agents. The most beneficial tests are listed in Table 3. Although all of these characteristics were critical, some were more indicative of desired material behavior as indicated by their rank.

Table 3.
Recommended tests for determining bonding ability of agents used with piezoelectric sensors

Recommended Test	Required Result	Importance Rank[a]
Compressive strength (ASTM C 116-90)	Approx. 7 MPa	1
Storage modulus (G) component of the complex shear modulus (AASHTO TP5)	14 to 70 Mpa at 25°C, decreases with increasing temperature	2
Gel time (ASTM C881)	5 to 15 min	3
Shrinkage (DuPont method)	1.0% expansion to 0.5% shrinkage	1
Vicat set time (ASTM C 191-192)	Approx. 30 min	3
Viscosity (optional) ASTM D 2393)	20 to 40 Pa-s	1
Flexural bond strength (ASTM C 78-84)	Approx. 700 kPa to asphalt, Approx. 2100 kPA to concrete, at least 50% of failures in paving material and away from the bond	2
Filed trial (ease of use)	Acceptance by installation crew	3

[a]3 most important, 1 least important.

Advantages

Piezoelectric sensors offer the unique advantage of being able to gather information on the tire passing over the sensor, rather than on the passing of a vehicle. Piezoelectric sensors detect the passing of the tire over the sensor, thus creating an analogue signal that is proportional to the pressure exerted on the sensor. This unique ability of piezoelectric sensors allows them to differentiate individual vehicles with extreme precision. In addition, on an installed cost basis, they are only marginally more expensive than an inductive loop, but provide significantly more information in the form of improved speed information, the ability to determine the classification of the vehicle, and the capability to determine and monitor the weights of vehicles for WIM systems.

Disadvantages

The drawbacks to the use of piezoelectric sensors are similar to those of inductive loop sensors in that they include disruption of traffic for installation and repair and failures associated with installations in poor road surfaces and use of substandard installation procedures. In many instances multiple detectors are usually required to instrument a location. In addition, resurfacing of roadways and utility repair can also create the need to reinstall these types of sensors. Also, piezoelectric sensors have been known to be sensitive to pavement temperature and vehicle speed.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 29 March 2000

Manufacturer name: Diamond Traffic.	Sales representative name(s): Guy Gibson Sr., Vice President
Address: P.O. Box 1455, Oakridge, OR 97463	Address: P.O. Box 1455, Oakridge, OR 97463
Phone number: (541) 782-3903	Phone number:
Fax number: (541) 782-2053	Fax number:
e-mail address: Diamondtrf@aol.com	e-mail address: Diamondtrf@aol.com
URL address: www.diamondtraffic.com	URL address:

PRODUCT NAME/MODEL NUMBER: Phoenix Vehicle Classifier

FIRMWARE VERSION/CHIP NO.: 2.39

SOFTWARE VERSION NO.: Trafman 469

GENERAL DESCRIPTION OF EQUIPMENT: Time interval vehicle classifier and counter utilizing loops, piezo, road tube, fiber optic, and radar

SENSOR TECHNOLOGY AND CONFIGURATION: Loops, piezo, road tube, fiber optic, radar

SENSOR INSTALLATION:

INSTALLATION TIME (Per Lane): Sensors cut into pavement can require 6-10 hours

INSTALLATION REQUIREMENTS:.

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: 16 using loops for count or 8 using loops and piezo for classification

PRODUCT CAPABILITIES/FUNCTIONS: Count, classify, vehicles, incident detection and notification.

RECOMMENDED APPLICATIONS: 2 lane to multilane freeways for count and classification

POWER REQUIREMENTS (watts/amps): Range form 50 milliamps to 100 milliamps

POWER OPTIONS: 110 VAC, battery, or solar

CLASSIFICATION ALGORITHMS: FHWA 13, European

TELEMETRY: 300 to 19200. Optional 14.4K low power drew modem

COMPUTER REQUIREMENTS:

DATA OUTPUT: 28 print formats, spreadsheets

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM: Mix of windows and DOS software, NT compatible

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):
One lane $1100 to $1500
Four lanes $1400 to $2000

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/Idaho	Brian Hagen	(208) 334-8250
USA/Nevada	Cecil Crandel	(775) 888-7155
USA/Washington	John Rosen	(360) 753-6100
USA/Colorado	Steve Plasten	(303) 757-9467
USA/Nebraska	Terry Guy	(402) 479-4509
USA/Connecticut	Erick Glover	(860) 594-2088
USA/Wyoming		(307) 777-4433

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 2/29/00

Manufacturer	Sales representative
Manufacturer name: Truvelo Manufacturers (Pty) Ltd.	Sales representative name(s): James E. Kelly, AVIAR inc
Address: P.O. Box 14183, Lyttelton 0140, South Africa	Address: P.O. Box 162184, Austin, TX 78716
Phone number: 011-27-11-314-1405	Phone number: (512) 295-5285
Fax number: 011-27-11-314-1409	Fax number: (512) 295-2603
e-mail address: rudi@truvelo.co.za	e-mail address: aviar@aviarinc.com
URL address: www.truvelo.co.za	URL address: www.aviarinc.com

PRODUCT NAME/MODEL NUMBER: The Combi Speed/red Light Camera System

FIRMWARE VERSION/CHIP NO.: N/A

SOFTWARE VERSION NO.: N/A

GENERAL DESCRIPTION OF EQUIPMENT: Automatic speed and/or traffic light violation recording system for portable and/or permanent installation in one compact unit.
Evidence of violation is shown on photograph.

SENSOR TECHNOLOGY AND CONFIGURATION: 3 or 4 piezo sensors for speed or 2 inductive loops/lane for presence at signalized intersection.

SENSOR INSTALLATION: Either surface mounted or cut into roadway surface

INSTALLATION TIME (Per Lane): Portable installation: 60 min. for 3 lanes
Permanent installation: 2 days

INSTALLATION REQUIREMENTS: N/A

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: 3 lanes

PRODUCT CAPABILITIES/FUNCTIONS: Monitor traffic for speed violations or red light violations.

RECOMMENDED APPLICATIONS: Speed and red light enforcement

POWER REQUIREMENTS (watts/amps):
Portable: 12 volts D.C.
Permanent: Either 12 volts D.C. or 220-240 volts single phase A.C.

POWER OPTIONS: Either 12 volt battery or commercial source

CLASSIFICATION ALGORITHMS: N/A

TELEMETRY: N/A

COMPUTER REQUIREMENTS: Internal microprocessors

DATA OUTPUT: Photo evidence plus location code, time, date, speed, photo counter, traffic counter, statistical data (lowest/highest speed, average speed, 85 percentile speed, vehicle speed distribution)

DATA OUTPUT FORMATS: On photo or on instrument display

SUPPORTING DATA BASE MANAGEMENT SYSTEM: N/A

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):
Contact Truvelo for cost information.

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/Florida	Chief Tony Sparks Bartow Police Dept.	(941) 534-5034
USA/Texas	Walter Ragsdale City of Richardson	(972) 238-4273

MANUFACTURER AND VENDOR INFORMATION

Effective Date: February 2000

Manufacturer name: Jamar Technologies	Sales representative name(s): James E. Martin
Address: 151 Keith Valley Road, Horsham, PA 19044	Address: same
Phone number: (215) 491-4899	Phone number: same
Fax number: (215) 491-4889	Fax number:
e-mail address: sales@jamartech.com	e-mail address:
URL address:	URL address:

PRODUCT NAME/MODEL NUMBER: TRAXPRO

FIRMWARE VERSION/CHIP NO.: TRAX Type III

SOFTWARE VERSION NO.: TRAXPRO Version 1.1

GENERAL DESCRIPTION OF EQUIPMENT: Counter Classifier designed to record traffic in multiple lanes and save the data in a format that can be processed by the TRAXPRO program to give the user reports that include volumes, classification, speeds, gaps, and headways.

SENSOR TECHNOLOGY AND CONFIGURATION: Piezo and loop technology in most of the standard configurations

SENSOR INSTALLATION: Embedded in the road surface. Portable sensors due on the market in later 2000

INSTALLATION TIME (Per Lane): For permanent sites approximately 2 hours per lane, depending on configuration

INSTALLATION REQUIREMENTS: Good road surface with little or no rutting and no paving fractures

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Eight

PRODUCT CAPABILITIES/FUNCTIONS: Volume, speed, classifications, gaps and headways.

RECOMMENDED APPLICATIONS: Any permanent or semi-permanent site

POWER REQUIREMENTS (watts/amps): 15 MA battery powered, solar option available. A/C power optional

POWER OPTIONS: See above

CLASSIFICATION ALGORITHMS: FHWA and custom ones per your needs

TELEMETRY: Availability late 2000

COMPUTER REQUIREMENTS: Pentium

DATA OUTPUT: ASCII & Binary

DATA OUTPUT FORMATS: Standard

SUPPORTING DATA BASE MANAGEMENT SYSTEM: Processed data files may be exported to Excel, Quattro-Pro, Lotus programs

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):
One- lane — approximately $4,000.00 and four - lane — approximately $6,000.00

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/Vermont	Dave Gosselin	(802) 828-2694

MANUFACTURER AND VENDOR INFORMATION

Effective Date: March 22, 2000

Manufacturer name: International Road Dynamics, Inc.	Sales representative name(s): Rod Klashinsky
Address: 702 43rd Street East Saskatoon SK, S7K 3T9 Canada	Address:
Phone number: 306-653-6600	Phone number:
Fax number: 306-242-5599	Fax number:
e-mail address: info@irdinc.com	e-mail address:
URL address: www.irdinc.com	URL address:

PRODUCT NAME/MODEL NUMBER: IRD Truck Advisory Safety Systems

FIRMWARE VERSION/CHIP NO.: NA

SOFTWARE VERSION NO.: NA

GENERAL DESCRIPTION OF EQUIPMENT: The IRD Truck Advisory Safety Systems determine truck speed, weight, height and classification (based on axle configuration). Using this information the systems are capable of displaying messages on a roadwide sign to instruct drivers to slow down prior to a sharp turn in the road or to proceed at a recommended speed prior to a steep decline in the road.

SENSOR TECHNOLOGY AND CONFIGURATION: The system typically uses an inductive loop-Class I piezo sensor- Class I piezo sensor-loop configuration.

SENSOR INSTALLATION: Sensors are saw-cut and grouted into the roadway. Sensor leads are run through conduit to a roadside cabinet.

INSTALLATION TIME (Per Lane): Depending on the application, installation of the in-road sensors, signs and associated electronics may take from 2-weeks to a month.

INSTALLATION REQUIREMENTS: Please see attached product information for details.

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Typically only a single lane of in-road equipment is required for the IRD Safety Systems.

PRODUCT CAPABILITIES/FUNCTIONS: Truck Rollover Advisory, Downhill Truck Speed Advisory, and Runaway Truck Traffic signal control.

RECOMMENDED APPLICATIONS: Truck Rollover Advisory, downhill Truck Speed Advisory, and runaway Truck Traffic Signal control.

POWER REQUIREMENTS (watts/amps): 2.5 Amps/35 Watts (For the WIM electronics)

POWER OPTIONS: 100-240 VAC, 50-60 Hz. (For the WIM electronics).

CLASSIFICATION ALGORITHMS: Vehicles can be classified based on axle weights, axle spacings, axle groupings and GVW.

TELEMETRY: Terminal software and standard telephone line with modem are required.

COMPUTER REQUIREMENTS: Pentium II or better, 400 MHz min., 32 Mb RAM min., Expansion slots 1 ISA, 3 PCI, 1 ISA/PCI.

DATA OUTPUT: Individual vehicle and vehicle summary data are stored on the WIM computer which can be retrieved through a modem. Individual vehicle data can also be sent to an RS 232 port on the WIM in real-time.

DATA OUTPUT FORMATS: The vehicle information is stored on disk files in a compressed format developed by IRD. Software is available to convert the data to CSV (Comma, Sparated Value) file. Several industry standard formats are available for the WIM vehicle data transmitted through the RS 232 port.

SUPPORTING DATA BASE MANAGEMENT SYSTEM: Report generation software is available from IRD that reads the compressed vehicle data files directly. Raw data can also be exported to a file which can be read by any database system.

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):
1-lane: $ 150,000 US and 4-lane: $ 300,000 US

STATES CURRENTLY USING THIS EQUIPMENT: (Use back of page if needed)

Country/State	Contact name	Telephone number
USA/Pennsylvania (PennDot)	Jim Garling	(717) 787-3656
USA / Colorado (CDOT)	Dave Judy	(303) 512-5813

Magnetic Sensors

Principles of Operation

Magnetic sensors are passive devices that indicate the presence of a metallic object by detecting the perturbation (known as a magnetic anomaly) in the Earth s magnetic field created by the object. Figure 7a shows the magnetic anomaly created by the magnetic dipoles, i.e., energy fields, on a steel vehicle when it enters the magnetometer s detection zone (Kell, 1990; Lenz, 1993; and Sampey, 1999). The upper part of Figure 7b indicates how the vector addition of the dipole magnetic field to the quiescent Earth s magnetic field produces the magnetic anomaly. The lower portion of the figure depicts several dipoles on a vehicle and their effect on compass readings and sensor output.

Figure 8 illustrates the distortion induced in the Earth s magnetic field as a vehicle enters and passes through the detection zone of a magnetic sensor. Figure 8a depicts the magnetic field as the vehicle approaches the sensor. Figure 8b shows the field lines of flux as the vehicle begins to pass through the sensor s detection zone. Figure 8c describes the lines of flux when the vehicle is over the sensor.

Application and Uses

Two types of magnetic field sensors are used for traffic flow parameter measurement. The first type, the two-axis fluxgate magnetometer, detects changes in the vertical and horizontal components of the Earth s magnetic field produced by a ferrous metal vehicle. The two-axis fluxgate magnetometer contains a primary winding and two secondary sense windings on a bobbin surrounding a high permeability soft magnetic material core. In response to the magnetic field anomaly, i.e., the magnetic signature of a vehicle, the magnetometer s electronics circuitry measures the output voltage generated by the secondary windings. The vehicle detection criterion is for the voltage to exceed a predetermined threshold. In the presence mode of operation, the detection output is maintained until the vehicle leaves the detection zone. Examples of sensors based on two-axis fluxgate magnetometers are shown in Figure 9.

The second type of magnetic field sensor is the magnetic detector, more properly referred to as an induction or search coil magnetometer. It detects the vehicle signature by measuring the change in the magnetic lines of flux caused by the change in field values produced by a moving ferrous metal vehicle. These devices contain a single coil winding around a permeable magnetic material rod core. Like the fluxgate magnetometer, magnetic detectors generate a voltage when a ferromagnetic object perturbs the Earth s magnetic field. However, most magnetic detectors cannot detect stopped vehicles, since they require a vehicle to be moving or otherwise changing its signature characteristics with respect to time. Examples of sensors that use the induction magnetometer principle are shown in Figure 10.

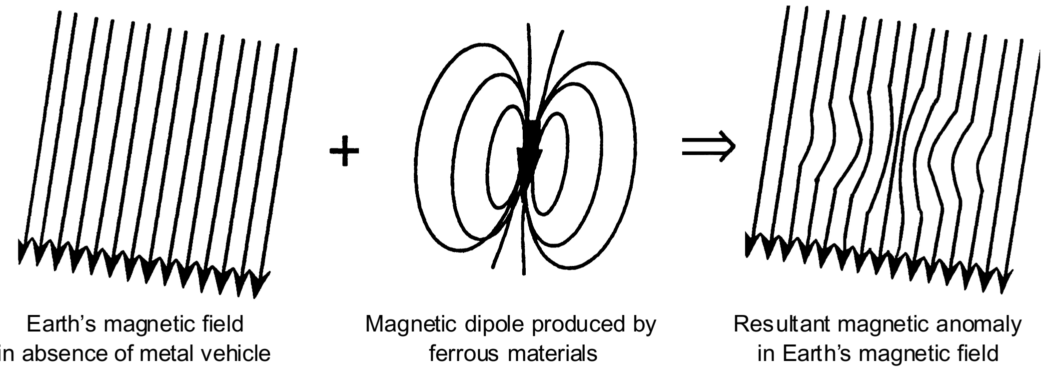
Advantages

The two-axis fluxgate magnetometer is less susceptible than loops to stresses of traffic. Also some models of the two-axis fluxgate magnetometer transmit data over wireless RF link.

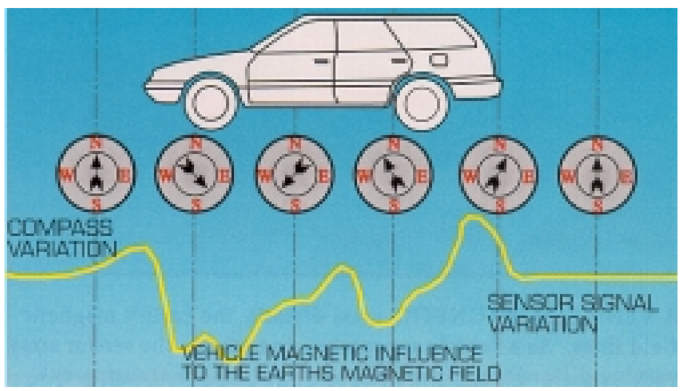
The induction or search coil magnetometer is also less susceptible than loops to stresses of traffic. The induction magnetometer can be used where loops are not feasible (e.g., bridge decks) and some models can be installed under the roadway without the need for pavement cuts.

Disadvantages

Installation of magnetic sensors requires pavement cut or tunneling under the roadway and thus requires lane closure during installation. Magnetic detectors cannot generally detect stopped vehicles. Also, some models have small detection zones.



(a) Magnetic anomaly induced in the Earth s magnetic field by a magnetic dipole



(b) Perturbation of Earth s magnetic field by a ferrous metal vehicle.
(Drawing courtesy of Nu-Metrics, Vanderbilt, PA).

Figure 7. Magnetic anomaly in the Earth’s magnetic field induced by magnetic dipoles in a ferrous metal vehicle.

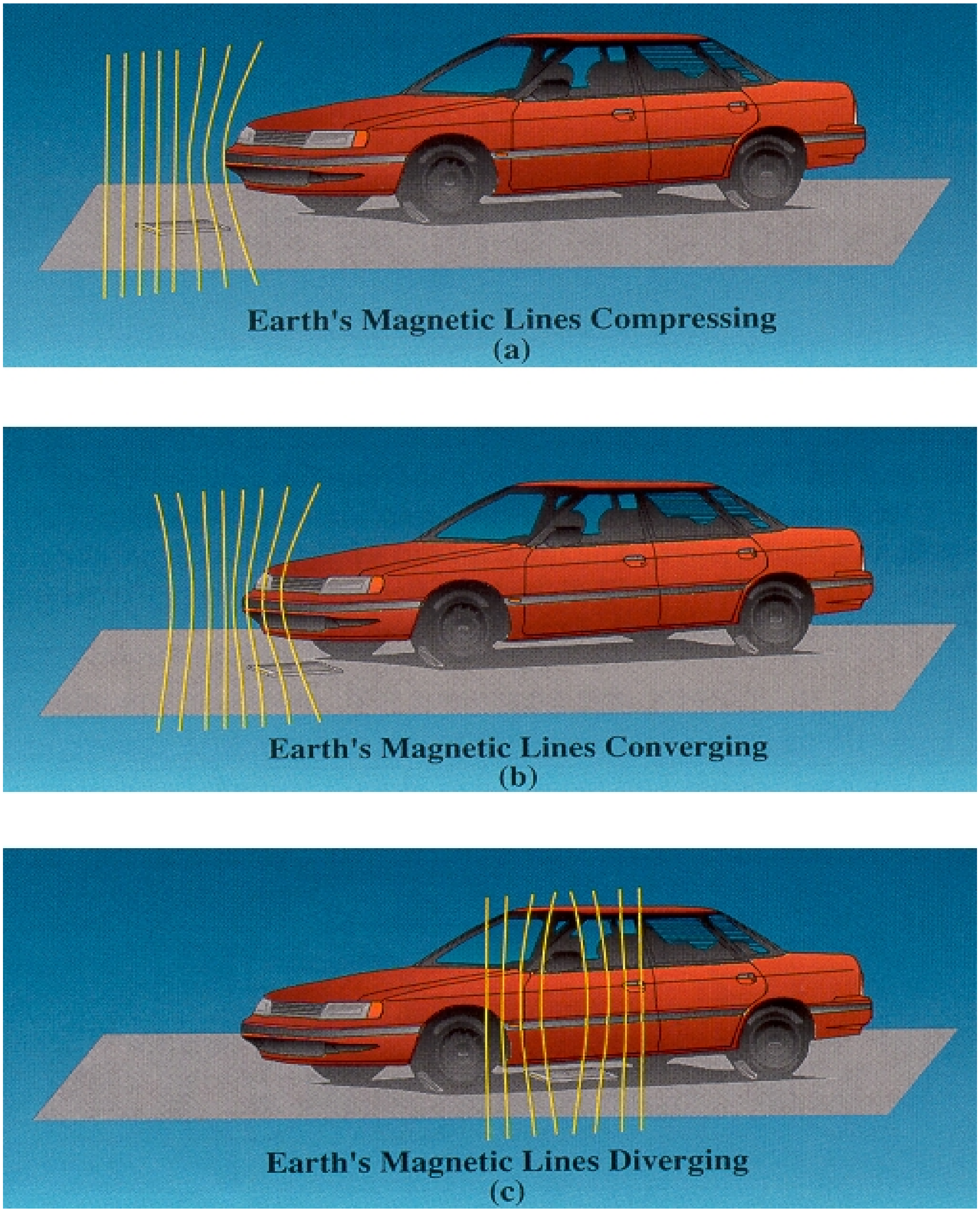
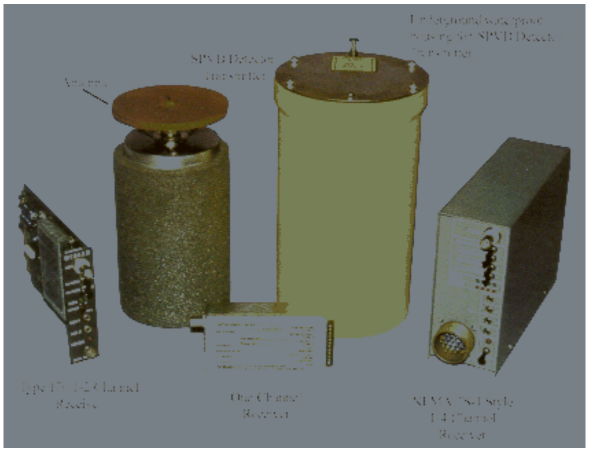
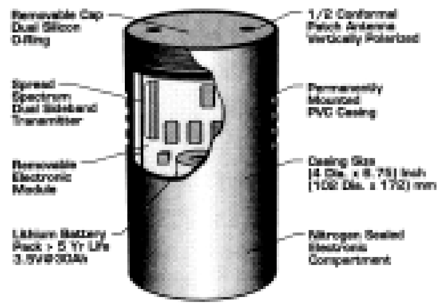


Figure 8. Distortion of Earth's magnetic field created as a vehicle enters and passes through the detection zone of a magnetic sensor. (Drawing courtesy of Nu-Metrics, Vanderbilt, PA).

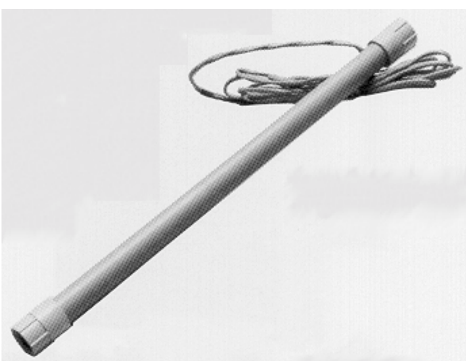


SPVD magnetometer system. (Photograph courtesy of Midian Electronics, Tucson, AZ).

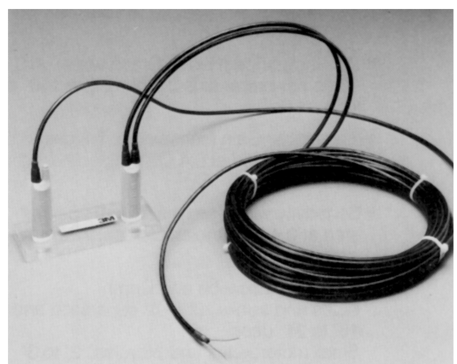


Groundhog magnetometer. (Photograph courtesy of Nu-Metrics, Uniontown, PA).

Figure 9. Two-axis fluxgate magnetometer sensors.



231E Detector Probe. (Photograph courtesy of Safetran Traffic Systems, Colorado Springs, Co).



Model 701 microloop probe. (Photograph courtesy of 3M Company, St. Paul, MN)

Figure 10. Induction magnetometer sensors.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 2/24/00

Manufacturer name: 3M Intelligent Transportation Systems	Sales representative name(s): D. Henderson/Sales Mgr.
Address: 3M Center, Bldg 225-4N-14, St. Paul, MN 55144-1000	Address: 3M ITS, same
Phone number: (800) 328-7098	Phone number:
Fax number:	Fax number:
e-mail address:	e-mail address:
URL address: www.mmm.com/ITS	URL address:

PRODUCT NAME/MODEL NUMBER: Canoga Vehicle Detection System Model 702 Non-invasive micro loop

FIRMWARE VERSION/CHIP NO.: N/A

SOFTWARE VERSION NO.: N/A

GENERAL DESCRIPTION OF EQUIPMENT: A small cylindrical sensor, a carrier system to be installed in 3 conduit under the road surface.

SENSOR TECHNOLOGY AND CONFIGURATION: Magnetic flux gate

SENSOR INSTALLATION: Soil piercing to install conduit

INSTALLATION TIME (Per Lane): Various

INSTALLATION REQUIREMENTS: Soil piercing to install conduit

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Unlimited

PRODUCT CAPABILITIES/FUNCTIONS: Various

RECOMMENDED APPLICATIONS: All presence and passage

POWER REQUIREMENTS (watts/amps): N/A

POWER OPTIONS: N/A

CLASSIFICATION ALGORITHMS: N/A

TELEMETRY: N/A

COMPUTER REQUIREMENTS: N/A

DATA OUTPUT: N/A

DATA OUTPUT FORMATS: N/A

SUPPORTING DATA BASE MANAGEMENT SYSTEM: N/A

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane): N/A

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number

CONTACT 3M FOR CURRENT LIST OF REFERENCES.

MANUFACTURER AND VENDOR INFORMATION

Effective Date:____________________

Manufacturer name: Midian Electronics, Inc.	Sales representative name(s): Michael Soulliard
Address: 2302 E. 22nd St. Tucson, AZ 85713	Address:
Phone number: (520) 884-7981	Phone number:
Fax number: (520) 884-0422	Fax number:
e-mail address: sales@midelec.com	e-mail address:
URL address: www.midelec.com	URL address:

PRODUCT NAME/MODEL NUMBER: The Road Runner Systems (SPVD-1, SPVDREC)

FIRMWARE VERSION/CHIP NO.: N/A

SOFTWARE VERSION NO.: N/A

GENERAL DESCRIPTION OF EQUIPMENT: Wireless Vehicle Detector

SENSOR TECHNOLOGY AND CONFIGURATION: Dual Axis Flux Gate Magnetometer

SENSOR INSTALLATION: Installed in the roadway using 6 core drill bit approximately 12 in depth.

INSTALLATION TIME (Per Lane): 30 minutes per lane and 45 minutes at the traffic control cabinet.

INSTALLATION REQUIREMENTS: See sensor installation above.

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: One lane per detector.

PRODUCT CAPABILITIES/FUNCTIONS: Detect vehicles for traffic counting or presence detection.

RECOMMENDED APPLICATIONS: Left-turn lane detection, advanced detection, through lane detection, counting, side street detection.

POWER REQUIREMENTS (watts/amps): SPVD-1 12v 15Ah battery
SPVDREC — 12 V 100 mA

POWER OPTIONS:

CLASSIFICATION ALGORITHMS:

TELEMETRY: 47 MHz — Part 90 FCC Rules & Regulations

COMPUTER REQUIREMENTS: N/A

DATA OUTPUT: Optoisolator Logic low input to controller

DATA OUTPUT FORMATS: N/A

SUPPORTING DATA BASE MANAGEMENT SYSTEM: N/A

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane): $600 per lane plus receiver cost (varies depending on requirements)

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/Washington	Brian Martin	(206) 440-4447
USA/Florida-SABCO	Randy Fortner	(321) 784-1100
USA/Conn- Signal Service	Wayne Halcombe	(860) 289-8033

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 2/24/00

Manufacturer name: 3M Intelligent Transportation Systems	Sales representative name(s): D. Henderson/Sales Mgr.
Address: 3M Center, Bldg 225-4N-14 St. Paul, MN 55144-1000	Address: 3M ITS same
Phone number: (800) 328-7098	Phone number:
Fax number:	Fax number:
e-mail address:	e-mail address:
URL address: www.mmm.com/ITS	URL address:

PRODUCT NAME/MODEL NUMBER: Canoga Vehicle Detection System Model 701 Microloop

FIRMWARE VERSION/CHIP NO.: N/A

SOFTWARE VERSION NO.: N/A

GENERAL DESCRIPTION OF EQUIPMENT: A small cylindrical sensor, to detect passage of vehicle. Installed in bored hole in pavement

SENSOR TECHNOLOGY AND CONFIGURATION: Induction magnetometer

SENSOR INSTALLATION: Bored hole/saw slot in pavement

INSTALLATION TIME (Per Lane): Various

INSTALLATION REQUIREMENTS: Same as wire loop

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Unlimited

PRODUCT CAPABILITIES/FUNCTIONS: Various

RECOMMENDED APPLICATIONS: All presence and passage

POWER REQUIREMENTS (watts/amps): N/A

POWER OPTIONS: N/A

CLASSIFICATION ALGORITHMS: N/A

TELEMETRY: N/A

COMPUTER REQUIREMENTS: N/A

DATA OUTPUT: N/A

DATA OUTPUT FORMATS: N/A

SUPPORTING DATA BASE MANAGEMENT SYSTEM: N/A

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane): N/A

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number

CONTACT 3M FOR CURRENT LIST OF REFERENCES.

Weigh-in-Motion (WIM)

Highway Weigh-in-Motion (WIM) systems are capable of estimating the gross vehicle weight of a vehicle as well as the portion of this weight that is carried by each wheel assembly (half-axle with one or more tires), axle, and axle group on the vehicle (ASTM E1318-94, 1994). WIM data are used by highway planners and designers, as well as by enforcement agencies (e.g. Department of Public Safety, etc.).

Application and Uses

WIM systems increase the capacity of weigh stations and are often utilized when heavy truck traffic volumes cannot otherwise be accommodated. WIM systems provide highway planners and designers with time and date of traffic volume, speed, vehicle classification based on number and spacing of axles, and the equivalent single axle loading (ESAL) that heavy vehicles place on pavements and bridges. The heavy truck axle load data are used by motor vehicle enforcement officers to plan enforcement activities (McCall & Vodrazka, 2000). Software is frequently provided by the manufacturers to aid in system calibration and data analysis. The categories of WIM systems are listed in Table 4 along with the corresponding data each provide (ASTM E1318-94, 1994). Table 5 gives the functional performance requirements of WIM systems as defined by ASTM (ASTM E1318-94, 1994). Some states may impose more strict requirements such as those in Table 6 (McCall & Vodrazka, 2000).

The accuracy of WIM systems is a function of four principal factors:

- Vehicle dynamics;
- Pavement integrity, composition, and design;
- Variance inherent in the WIM system; and
- Calibration.

Vehicle dynamics are dependent on road surface roughness, type of vehicle suspension, vehicle dynamic balance, vehicle weight, vehicle speed, driver maneuvering, etc. Although most agencies attempt to install WIM systems in good pavement, unexpected deterioration or structural anomalies sometimes occur. For instance, WIM measurements worsen when asphalt pavements soften in hot weather and long concrete sections rock along a central axis when a heavy truck passes over the end of the section. The inherent variance of the WIM system is a function of the technology utilized in the system to measure axle weight.

Table 4.
WIM System Categories, Applications, and Data Items.

	Category			
	Type I	**Type II**	**Type III**	**Type IV**
Speed range	16 to 113 km/h (10 to 70 mi/h)	16 to 113 km/h (10 to 70 mi/h)	24 to 80 km/h (15 to 50 mi/h)	24 to 80 km/h (15 to 50 mi/h)
Application	Traffic data collection	Traffic data collection	Weight enforcement	Weight enforcement
Number of lanes	Up to 4	Up to 4	Up to 2	Up to 2
Bending plate	x	x	x	x
Piezoelectric	x	x		
Load cell	x	x	x	x
Wheel load	x		x	x
Axle load	x	x	x	x
Axle-group load	x	x	x	x
Gross vehicle weight	x	x	x	x
Speed	x	x	x	x
Center-to-center axle spacing	x	x	x	x
Vehicle class (via axle configuration)	x	x		
Site identification code	x	x	x	x
Lane and direction of travel	x	x	x	x
Date and time of passage	x	x	x	x
Sequential vehicle record number	x	x	x	x
Wheelbase (front-to-rear axle)	x	x		
Equivalent single-axle load	x	x		
Violation code	x	x	x	x
Acceleration estimate			x	x

Table 5.
ASTM performance requirements for WIM systems

Function	Tolerance for 95% Probability of Conformity				
	Type I	Type II	Type III	Type IV	
				Value ≥ lb (kg)[a]	± lb (kg)
Wheel load	± 25%		±20%	5,000 (2,300)	250 (100)
Axle load	±20%	±30%	±15%	12,000 (5,400)	500 (200)
Axle load group load	±25%	±20%	±10%	25,000 (11,300)	1,200 (500)
Gross vehicle weight	±10%	±15%	± 6%	60,000 (27,200)	2,500 (1,100)
Speed	±1 mi/h (±2 km/h)				
Axle spacing	±0.5 ft (±150 mm)				

[a] Lower values are not usually a concern in enforcement.
Source: *Standard Specification for Highway Weigh-in-Motion* (*WIM*) *Systems with User Requirements and Test Method*, Designation E 1318-94, 2000 Annual Book of ASTM Standards, Vol. 04.03, West Conshohocken, PA: ASTM.

Table 6.
California Department of Transportation (Caltrans) performance requirements for WIM systems[a]

Parameter	Mean	Standard Deviation
Vehicle weight		
Single axle	±5 %	8%
Tandem axle	±5 %	6%
Gross weight	±5 %	5%
Axle spacing	±150 mm (6 in)	300 mm (12 in)
Vehicle length	±300 mm (12 in)	460 mm (18 in)
Vehicle speed	±1.6 km/h (1 mi/h)	3.2 km/h (2 mi/h)

[a] *Source*: McCall, W. and W.C. Vodrazka Jr., *States' Successful Practices Weigh-In-Motion Handbook*, Center for Transportation Research and Education (CTRE), Iowa State University, Dec. 15, 1997, http://www.ctre.iastate.edu/research/wim_pdf/ index.htm.

Table 7 gives typical values for the inherent variance component of the system accuracy (for a ± 1 standard deviation confidence interval) for piezoelectric, bending plate, and single load cell systems. The table shows that it is common for WIM systems to be less accurate when weighing individual axle groups than when measuring gross vehicle weight. The effect of vehicle speed on total system accuracy is accounted for later in Table 8. Time out factors are sometimes programmed into WIM systems to assist in separating the weight of one vehicle from another.

Table 7.
Inherent variance component of system accuracy [a]
(1 standard deviation confidence interval)

WIM System Technology	Axle Group WIM Accuracy (%)	GVW[b] WIM Accuracy (%)
Piezoelectric cable[c]	12	10
Bending plate	3	2
Single load cell	2	1

[a] *Source*: Bergan, A.T., C.F. Berthelot, and B. Taylor, Effect of Weigh in Motion Accuracy on Weight Enforcement Accuracy, *Proc. of 7th Annual Meeting*, ITS-America, Washington, D.C., 1997 and IRD Bending Plate and Load Cell Weigh-in Motion Scales Technical Specifications, Aug. 1997 and Jan. 1998.

[b] Gross vehicle weight

[c] By comparison, the Kistler piezoelectric quartz sensor specification for wheel load measurement accuracy is approx. ± 3 percent.

Calibration ensures that the estimation of static weight by the WIM system closely approximates the true static weight. Calibration accounts for site-specific effects such as pavement temperature, vehicle speed, and pavement condition. Calibration procedures may include an acceptance testing phase and a recalibration phase.

The acceptance testing phase used by Caltrans and reported in the *State s Successful Practices Weigh-in-Motion Handbook* (McCall & Vodrazka, 2000) has three stages: system component operation verification, initial calibration process, and a 72-h continuous operation verification.

- System component testing verifies the transmission of signals by the roadway sensors to the on-site controller and the conversion of the signals into the desired WIM data.

- Initial calibration consists of comparing data obtained when one or more trucks passes over the WIM sensors with measurements taken on a static scale. Several runs are made to measure weight and axle spacing in each lane equipped with WIM sensors at speeds that encompass the expected operational range. These data are utilized to compute the WIM weight factors that convert the dynamic measurements into static weights. The test vehicles make additional runs at each speed to verify the weight factor values. Weight factors can be adjusted to account for seasonal variations, changes in pavement condition, and unique vehicles.

- The 72-h calibration monitors WIM system operation to ensure continuous functioning within the required specifications. When this phase is completed, the system is ready for online operation.

The recalibration phase occurs throughout the design life of the WIM site. Weight factors are adjusted or repairs made to the system when problems are identified during regularly scheduled data reviews.

The four technologies used in WIM system weight measurement are bending plate, piezoelectric, load cell, and capacitance mat. Each is discussed in the following sections.

Bending Plate

Principles of Operation

Bending plate WIM systems utilize plates with strain gauges bonded to the underside. As a vehicle passes over the bending plate, as illustrated in Figure 11, the system records the strain measured by the strain gauges and calculates the dynamic load. The static load is estimated using the measured dynamic load and calibration parameters. The calibration parameters account for factors, such as vehicle speed and pavement/ suspension dynamics, that influence estimates of the static weight.

The accuracy of bending plate WIM systems can be expressed as a function of the vehicle speed traversed over the plates, assuming the system is installed in a sound road structure and subject to normal traffic conditions. The accuracy specifications in Table 8 apply to bending plate scales manufactured by IRD. They are based on a minimum sample of 50 vehicles loaded to within 75% of the legal allowable limit. Vehicles that traverse the scale with more than a 10% speed variation, live loads, or liquid loads are not permitted in the sample.

Table 8.
Accuracy specifications for bending plate and load cell WIM scales[a]
(1 standard deviation confidence interval)

Speed	Application	Load type	Bending Plate Accuracy	Load Cell Accuracy[b]
2 to 10 mi/h (3.2 to 16 km/h)	Low speed/slow roll just prior to static scales	Single axle Tandem axle Gross weight	± 3% of applied ± 3% of applied ± 2% of applied	± 2% of applied ± 1.5% of applied ± 1% of applied
11 to 25 mi/h (18 to 40 km/h)	Low speed ramp	Single axle Tandem axle Gross weight	± 4% of applied ± 4% of applied ± 3% of applied	± 4% of applied ± 3% of applied ± 2% of applied
26 to 45 mi/h (42 to 72 km/h)	Medium speed ramp	Single axle Tandem axle Gross weight	± 6% of applied ± 6% of applied ± 4% of applied	± 5% of applied ± 4% of applied ± 3% of applied
46 and above mi/h (74 and above km/h)	High speed ramp or mainline	Single axle Tandem axle Gross weight	± 8% of applied ± 8% of applied ± 5% of applied	± 6% of applied ± 5% of applied ± 4% of applied

[a] From IRD Bending Plate and Load Cell Weigh-in Motion Scales Technical Specifications

[b] Normally single load cell scales are calibrated for one of the speed ranges. If site conditions require more than one speed range, the system is calibrated for the range agreed to by the vendor and user.

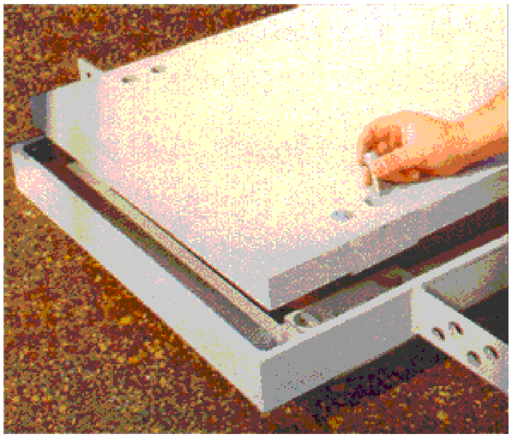


Figure 11. Bending plate sensor. (Photographs courtesy of IRD, Inc., Saskatoon, SK).

Bending plate WIM systems contain either one or two scales and two ILDs. A typical bending plate (or load cell) installation is shown in Figure 12. The scale is placed in the travel lane perpendicular to the direction of travel. When two scales are used in one lane, one scale is placed in each wheelpath of the traffic lane so that the left and right wheels are weighed individually. The pair of scales is placed in the lane side-by-side or staggered by 5 m (16 ft). Bending plate systems with one scale in the right or left wheelpath are usually used in low volume lanes. The inductive loops are placed upstream and downstream of the scales. The upstream loop detects vehicles and alerts the system to an approaching vehicle. The downstream loop determines vehicle speed based on the time it takes the vehicle to traverse the distance between the loops.

Advantages

Bending plate WIM systems can be used for traffic data collection as well as for weight enforcement purposes. The accuracy of these systems is higher than piezoelectric systems and their cost is lower than load cell systems. Bending plate WIM systems do not require complete replacement of the sensor but only refurbishing after 5 years.

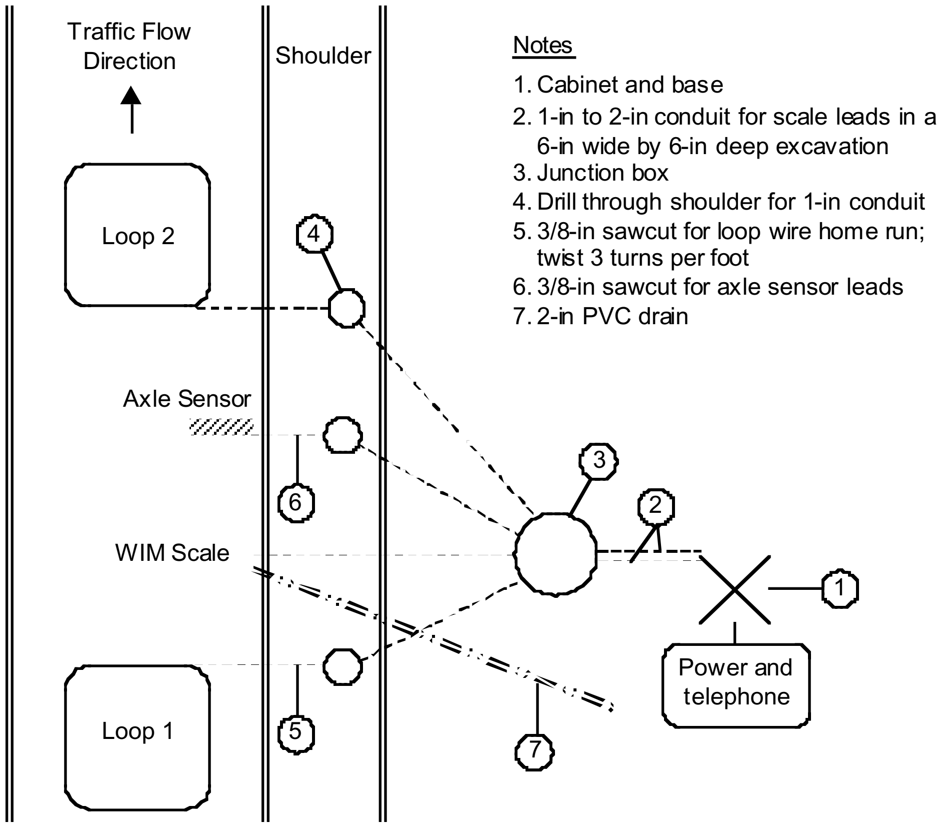


Figure 12. Bending plate or load cell WIM system (typical).

Disadvantages

Bending plate WIM systems are not as accurate as load cell systems and are considerably more expensive than piezoelectric systems.

Piezoelectric

Principles of Operation

Piezoelectric WIM systems contain one or more piezoelectric sensors that detect a change in voltage caused by pressure exerted on the sensor by an axle and thereby measure the axle s weight. As a vehicle passes over the piezoelectric sensor, the system records the sensor output voltage and calculates the dynamic load. As with bending plate systems, the dynamic load provides an estimate of the static load when the WIM system is properly calibrated.

The typical piezoelectric WIM system consists of at least one piezoelectric sensor and two ILDs. The piezoelectric sensor is placed in the travel lane perpendicular to the travel direction. The inductive loops are placed upstream and downstream of the piezoelectric sensor. The upstream loop detects vehicles and alerts the system to an approaching vehicle. The downstream loop provides data to determine vehicle speed and axle spacing based on the time it takes the vehicle to traverse the distance between the loops. Figure 13 shows a full-lane width piezoelectric WIM system installation. In this example, two piezoelectric sensors are utilized on either side of the downstream loop.

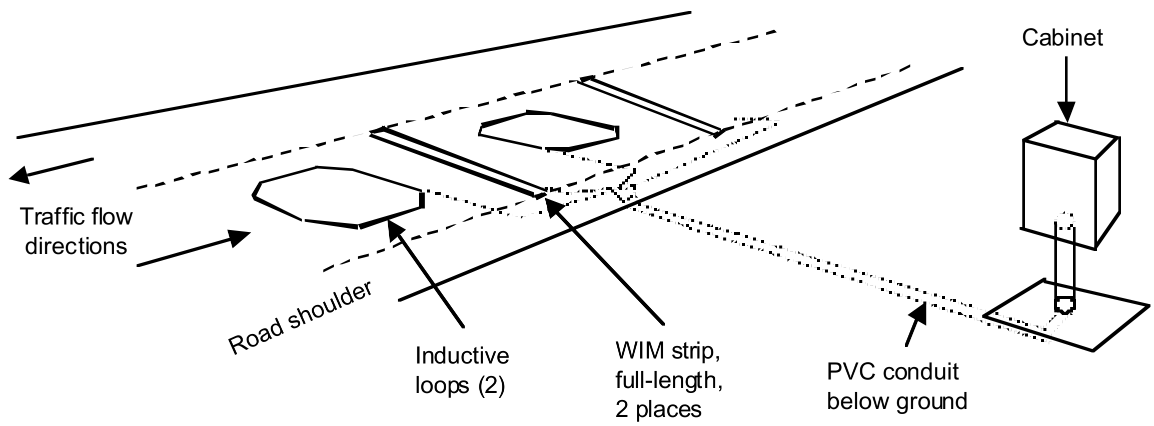


Figure 13. WIM installation with full-length piezoelectric sensors.

An emerging technology in piezoelectric WIM sensors is the LINEAS quartz sensors manufactured by Kistler. Piezoelectric LINEAS quartz sensors manufactured by Kistler contain a number of quartz crystal sensing elements mounted along the centerline of an aluminum core as shown in Figure 14 (Kistler, 1997 & Caldera, 1996). The sensor is installed in a slot cut into the road surface and is grouted with a proprietary compound of epoxy and silica sand. The elastic and thermal properties of the compound closely match those of road surfaces. The sensor is isolated from side forces by an elastic material to help eliminate errors caused by a volume effect. The load bearing pad composed of a mixture of quartz sand and epoxy can be ground even with the road surface.

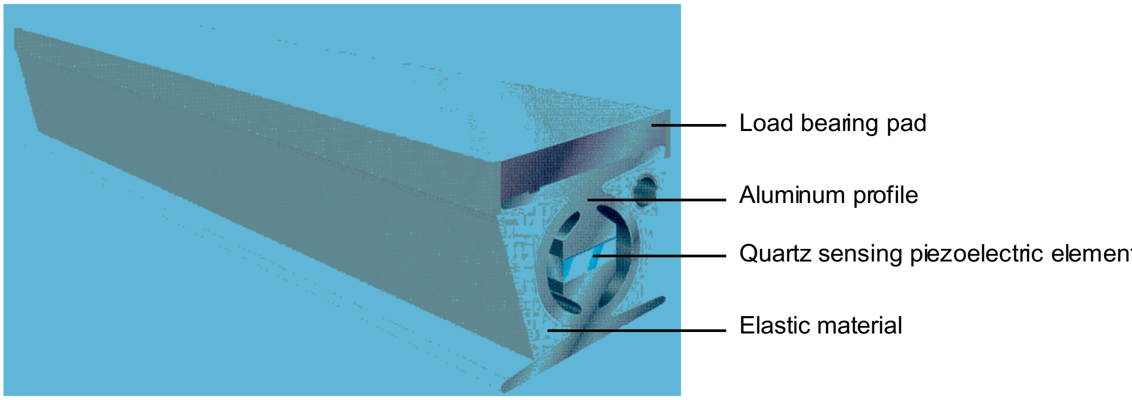


Figure 14. LINEAS quartz sensor (Drawing courtesy of Kistler Instruments AG Winterthur, Switzerland).

Advantages

Typical piezoelectric WIM systems are among the least expensive systems in use today in terms of initial capital costs and life cycle maintenance costs. Piezoelectric WIM systems can be used at higher speed ranges (10 to 70 mph) than other WIM systems. Piezoelectric WIM systems can be used to monitor up to four lanes.

Quartz sensors do not generally age or fatigue. Temperature effects are negligible as the temperature coefficient of quartz is approximately —0.02 %/K. Since quartz crystals have no pyroelectric effect, rapid changes in temperature do not cause a drift in output signal. Wheel load measurements are to within ±3 percent irrespective of the vehicle speed and position of the wheel along the sensor. The accuracy of these sensors makes them performance and cost competitive with the load cell WIM systems discussed in the next section.

Disadvantages

Typical piezoelectric systems (not quartz) are less accurate than load cell and bending plate WIM systems. Also, as discussed previously, piezoelectric sensors may be sensitive to temperature and speed variations. Piezoelectric sensors for WIM systems must be replaced at least once every 3 years.

Load Cell

Principles of Operation

A typical load cell WIM system includes a single load cell, at least one ILD, and one axle sensor. The load cell has two inline scales that operate independently. Off-scale sensors are integrated into the scale assembly to sense any vehicles that are not on the weighing surface. The single load cell system manufactured by IRD contains torsion bars within the WIM system frame that transmit all forces to the load cell. This load cell has a small amount of hydraulic fluid that causes a pressure transducer to relay weight information to roadside data analysis equipment. Load cells are durable and among the most accurate WIM systems as indicated in Table 4.

The load cell is placed in the travel lane perpendicular to the direction of travel. The inductive loop is placed upstream of the load cell to detect vehicles and alert the system of an approaching vehicle. If a second inductive loop is used, it is placed downstream of the load cell to determine axle spacing and vehicle speed. The axle sensor can utilize piezoelectric technology or technology based on the change of sensor resistance with pressure.

Advantages

The load cell system is the most accurate WIM system available. Therefore, the load cell WIM system can be utilized for traffic data collection as well as for weight enforcement purposes.

Disadvantages

The load cell is one of the most expensive WIM systems available today, in terms of initial capital costs and life cycle maintenance costs. Also, the load cell WIM system requires a complete replacement of the weighing mechanism after 5 years.

Capacitance Mat

Principles of Operation

A capacitance mat consists of a sandwich of metal steel sheets and dielectric material. In one configuration, displayed in Figure 15, a stainless steel sheet is surrounded by polyurethane dielectric material on either side. The outer surfaces of the polyurethane layers are enclosed by other stainless steel sheets. An a.c. voltage is applied across the sandwich of materials. When a vehicle passes over the mat, the spacing between the plates decreases and causes the capacitance to increase. This changes the resonant frequency of the electrical circuit of which the capacitance mat is a part. The resonant frequency, measured by the data analysis and recording equipment, is thus proportional to the axle weight. Capacitance mats are also manufactured utilizing aluminum plates separated by a grid of insulating material and air as the dielectric.

Figure 15. Capacitance mat sensor connected to data analysis equipment. (Photograph courtesy of LoadoMeter, Corp., Baltimore, MD).

Advantages

Capacitance mat sensors can be used for portable as well as permanent WIM applications. These systems can monitor up to four lanes simultaneously.

Disadvantages

Capacitance mat WIM systems are not as accurate as load cell and bending plate WIM systems for estimating weights. Also, the equipment and installation costs of these type of systems, whether portable or permanent, are similar to the load cell WIM system costs, which are among the most expensive WIM systems available.

Weigh-in-Motion System Costs

WIM system costs may be expressed in terms of the life cycle cost consisting of initial capital cost (in-road WIM equipment, installation labor and materials, initial calibration, and traffic control) and life cycle maintenance costs (labor and materials, traffic control, and system recalibration). Table 9 contains budgetary initial capital costs for piezoelectric, bending plate, and load cell technologies assuming typical road, traffic, and weather conditions. These costs may vary from manufacturer to manufacturer and with sensor model. Roadside cabinets, WIM electronics, power and communication connections, etc. are not included as these are common to all the technologies.

The life cycle maintenance costs vary due to differences in traffic volumes and truck weights, weather, original installation procedures, roadbed condition, onsite quality control, etc. Table 10 presents WIM system life cycle maintenance and repair costs averaged over North American installations. They assume that annual routine maintenance (e.g., road inspection and crack filling) is performed on the roadbed surrounding the WIM system. Piezoelectric sensors are assumed to require replacing every 3 years, bending plates refurbishing every 5 years, and single load cells replacing every 5 years. Life cycle maintenance costs may vary with manufacturer and sensor model.

Table 9.
Budgetary initial capital costs of WIM systems[a]

Capital Cost Component	Piezoelectric	Bending Plate	Single Load Cell
In-road equipment	$4,500	$13,000	$34,000
Installation labor and materials	$3,500	$6,500	$10,500
Traffic control	$1,000 (1 day)	$2,000 (2 days)	$4,000 (4 days)
Total capital cost	$9,000	$21,500	$48,000

[a] *Source*: Bergan, A.T., C.F. Berthelot, and B. Taylor, Effect of Weigh in Motion Accuracy on Weight Enforcement Accuracy, Proceedings of 1997 Annual Meeting of ITS-America.

Table 10.
Life cycle maintenance costs of WIM systems[a]

Cost Component	Piezoelectric (3 years)	Bending Plate (5 years)	Single Load Cell (5 years)
In-road equipment	$4,000	$6,000	$1,000
Labor and materials	$4,000	$5,500	$500
Traffic control	$1,500 (1 day)	$1,500 (1 day)	$750 (1/2 day)
Total life cycle cost	$9,500	$13,000	$2,250

[a] *Source*: Bergan, A.T., C.F. Berthelot, and B. Taylor, Effect of Weigh in Motion Accuracy on Weight Enforcement Accuracy, Proceedings of 1997 Annual Meeting of ITS-America.

The WIM system life cycle costs may be amortized over the life cycle. Based on the initial installation and life cycle maintenance costs shown in Tables 9 and 10 and a discount rate of 10 percent over a 20 year WIM system life cycle, the average annual cost for each WIM technology system is:

- Piezoelectric $3,092 per annum
- Bending plate $4,636 per annum
- Single load cell $5,982 per annum.

These figures show that the incremental cost for improved WIM system accuracy, durability, and reliability is small when compared to the annual operating budget of a weight enforcement facility. Costs over other life cycle intervals may be computed as required.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 2/29/00

Manufacturer	Sales representative
Manufacturer name: Truvelo Manufacturers (Pty) Ltd.	Sales representative name(s): James E. Kelly AVIAR inc
Address: P.O. Box 14183 Lyttelton 0140 South Africa	Address: P.O. Box 162184 Austin, TX 78716
Phone number: 011-27-11-314-1405	Phone number: (512) 295-5285
Fax number: 011-27-11-314-1409	Fax number: (512) 295-2603
e-mail address: rudi@truvelo.co.za	e-mail address: aviar@aviarinc.com
URL address: www.truvelo.co.za	URL address: www.aviarinc.com

PRODUCT NAME/MODEL NUMBER: Traffic Data Logger (TDL-500) Weigh-in-Motion

FIRMWARE VERSION/CHIP NO.: N/A

SOFTWARE VERSION NO.: Version 4.12

GENERAL DESCRIPTION OF EQUIPMENT: Capacitance mat weigh-in-motion system. Consists of electronics (TDL-500), Series 8 weight sensor, and inductive loops

SENSOR TECHNOLOGY AND CONFIGURATION: Capacitance mat (1/3 x 71 x 19) weighing 66 lbs.

SENSOR INSTALLATION: Temporary installation on surface of pavement or permanent installation in pavement surface.

INSTALLATION TIME (Per Lane): Temporary: 15 min/lane
Permanent: 2 hr/lane

INSTALLATION REQUIREMENTS: 200 smooth approach sensors and 100 departure from sensors

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: 4 lanes

PRODUCT CAPABILITIES/FUNCTIONS: 6-digit location code, date, time, lane, axle weight, axle spacing, speed, length, FHWA class, ESAL, wheel base, 512KB to 8MB battery backed-up memory, 36,000 to 650,000 individual vehicle records, option of a memory card that stores data and can be taken into an office to a computer.

RECOMMENDED APPLICATIONS: Weight data collection and vehicle screening at weight enforcement station

POWER REQUIREMENTS (watts/amps): 6-volt internal battery (rechargeable from 12-volt battery, commercial power or solar array)

POWER OPTIONS: See above

CLASSIFICATION ALGORITHMS: In accordance with the FHWA Traffic Monitoring Guide

TELEMETRY: Available by adding modem and telephone line

COMPUTER REQUIREMENTS: Compatible PC

DATA OUTPUT: See product capabilities

DATA OUTPUT FORMATS: ASCII or Binary

SUPPORTING DATA BASE MANAGEMENT SYSTEM: N/A

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

	Temporary		Permanent	
	1 Lane	4 Lane	1 Lane	4 Lane
Equipment costs	$12,000	$30,000	$13,000	$34,000
Installation costs	$1,000	$3,000	$3,000	$8,000

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/Alabama	Charles Turney	(334) 242-6393
USA/Kansas	Bill Hughes	(785) 296-6863
USA/Massachusetts	Philip Hughes	(617) 973-7330
USA/Michigan	Jim Kramer	(517) 322-1736
USA/North Carolina	Jerry Blackwelder	(919) 250-4094
USA/Rhode Island	Joseph Bucci	(401) 222-2694
USA/Tennessee	Ray Barton	(615) 741-2070

MANUFACTURER AND VENDOR INFORMATION

Effective Date: March 22, 2000

Manufacturer name: International Road Dynamics, Inc.

Address: 702 43rd Street East
Saskatoon SK, S7K 3T9 Canada

Phone number: 306-653-6600
Fax number: 306-242-5599
e-mail address: info@irdinc.com
URL address: www.irdinc.com

Sales representative name(s): Rod Klashinsky

Address:

Phone number:
Fax number:
e-mail address: rod.klashinsky@ird.ca
URL address:

PRODUCT NAME/MODEL NUMBER: IRD 1068 Piezoelectric WIM System

FIRMWARE VERSION/CHIP NO.: NA

SOFTWARE VERSION NO.: NA

GENERAL DESCRIPTION OF EQUIPMENT: The IRD 1068 Piezoelectric WIM system utilizes piezoelectric sensor technology to collect data on axle weights, vehicle classification (based on the number and spacing of axles) and vehicle speed. The system is accessible remotely using a standard telephone communication modem and PC for system monitoring, set-up and data collection.

SENSOR TECHNOLOGY AND CONFIGURATION: the system uses an inductive loop-class I piezo sensor-class I piezo sensor-loop configuration to collect traffic data.

SENSOR INSTALLATION: Please see attached product information for details.

INSTALLATION TIME (Per Lane): Approximately 1/2 day per lane.

INSTALLATION REQUIREMENTS: Please see attached product information for details.

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Eight

PRODUCT CAPABILITIES/FUNCTIONS: Vehicle WIM data collection.

RECOMMENDED APPLICATIONS: Vehicle WIM data collection.

POWER REQUIREMENTS (watts/amps): 2.5 Amps/35 Watts

POWER OPTIONS: 100-240 VAC, 50-60 Hz.

CLASSIFICATION ALGORITHMS: Vehicles can be classified based on axle weights, axle spacings, axle groupings and GVW.

TELEMETRY: Terminal software and standard

COMPUTER REQUIREMENTS: Pentium II or better, 400 MHz min., 32 Mb RAM min., Expension slots 1 ISA, 3PCI, 1 ISA/PCI.

DATA OUTPUT: Individual vehicle and vehicle summary data are stored on the WIM computer which can be retrieved through a modem. Individual vehicle data can also be sent to an RS 232 port on the WIM in real-time.

DATA OUTPUT FORMATS: The vehicle information is stored on disk files in a compressed format developed by IRD. Software is available to convert the data to CSV (Comma, Separated Value) file. Several industry standard formats are available for the WIM vehicle data transmitted through the RS 232 port.

SUPPORTING DATA BASE MANAGEMENT SYSTEM: Report generation software is available from Ird that reads the compressed vehicle data files directly. Raw data can also be exported to file which can be read by any database system.

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):
1-lane: $ 25,000 US
4-lane: $ 40,000 US

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/California (CALTRANS)	Rich Quinley	(916) 645-5651
USA/New Jersey (NJ DOT)	Lou Whiteley	(609) 530-3501
USA/Indiana (IN DOT)	Don Klepinger	(317) 594-5264

MANUFACTURER AND VENDOR INFORMATION

Effective Date: March 22, 2000

Manufacturer name: International Road Dynamics, Inc.	Sales representative name(s): Rod Klashinsky
Address: 702 43rd Street East, Saskatoon SK, S7K 3T9 CANADA	Address:
Phone number: 306-563-6600	Phone number:
Fax number: 306-242-5599	Fax number:
e-mail address: info@ird.ca	e-mail address: rod.klashinsky@ird.ca
URL address: www.irdinc.com	URL address:

PRODUCT NAME/MODEL NUMBER: Model 1070 Portable WIM System

FIRMWARE VERSION/CHIP NO.: NA

SOFTWARE VERSION NO.: WIM Data collection operation software MSDOS 6.22 operating system.

GENERAL DESCRIPTION OF EQUIPMENT: Portable Weigh-in-Motion and data collection unit.

SENSOR TECHNOLOGY AND CONFIGURATION: Uses Inductive Loops and Piezoelectric sensors. Most common configuration is Loop-Piezo-Piezo-Loop

SENSOR INSTALLATION: Portable (On road) Permanent (in-road).

INSTALLATION TIME (Per Lane): Approximately 5-6 hours in a permanent Loop-Piezo-Loop configuration. Approximately 20-30 minutes in a portable application.

INSTALLATION REQUIREMENTS: See attached installation sheet.

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: 4 lanes for weigh-in-motion and classifying.

PRODUCT CAPABILITIES/FUNCTIONS: Collects and stores vehicle weight data including axle and gross vehicle weights.

RECOMMENDED APPLICATIONS: Weight enforcement, Traffic planning, safety, and audit.

POWER REQUIREMENTS (watts/amps): AC power for 12 volt, rechargeable battery. 24 hours operation with standard battery pack.

POWER OPTIONS: Additional battery units, solar package.

CLASSIFICATION ALGORITHMS: See attached.

TELEMETRY: RS232 port with baud rates from 300-19,200.

COMPUTER REQUIREMENTS: MSDOS lap top

DATA OUTPUT FORMATS: Standard Data reporting package.

SUPPORTING DATA BASE MANAGEMENT SYSTEM: Dependent on customer requirements.

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane): Permanent one lane — approx. US $ 15,000.00, 4 lanes approx. US $ 25,000.00.

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/Nebraska		
USA/Colorado		
USA/North Carolina		
USA/West Virginia		
Canada/Saskatchewan		
Canada/Ontario		
Canada/New Brunswick		
Argentina		
Mexico		
Japan		
Korea		
India		

MANUFACTURER AND VENDOR INFORMATION

Effective Date: March 22, 2000

Manufacturer name: International Road Dynamics, Inc.	Sales representative name(s): Rod Klashinsky
Address: 702 43rd Street East, Saskatoon SK, S7K 3T9 CANADA	Address:
Phone number: 306-653-6600	Phone number:
Fax number: 306-242-5599	Fax number:
e-mail address: info@ird.ca	e-mail address: rod.klashinsky@ird.ca
URL address www.irdinc.com:	URL address:

PRODUCT NAME/MODEL NUMBER: Model 8000 Weigh-In-Motion Mat.

FIRMWARE VERSION/CHIP NO.: NA

SOFTWARE VERSION NO.: MS-DOS 6.2

GENERAL DESCRIPTION OF EQUIPMENT: Portable AC/DC powered vehicle weighing and screening device.

SENSOR TECHNOLOGY AND CONFIGURATION: Uses flat rectangular capacitance pads (2 per lane).

SENSOR INSTALLATION: Portable, lay flat on road.

INSTALLATION TIME (Per Lane): Set-up time-less than 10 minutes.

INSTALLATION REQUIREMENTS: Portable

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: One lane, slow speed (0-24 Km).

PRODUCT CAPABILITIES/FUNCTIONS: Weighs trucks to screen for overweight vehicles.

RECOMMENDED APPLICATIONS: Prescreening for Weigh Stations, Random Spot Checks, Mobile Weigh.

POWER REQUIREMENTS (watts/amps): AC Power or DC power (through automobile lighter)

POWER OPTIONS: AC or DC

CLASSIFICATION ALGORITHMS: See attached specifications

TELEMETRY: NA

COMPUTER REQUIREMENTS: Laptop computer supplied with system

DATA OUTPUT FORMATS: Vehicle information stored in data files and also sent to printer.

SUPPORTING DATA BASE MANAGEMENT SYSTEM: Dependent upon customer requirements.

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane): Equipment costs US $ 18,5000.00 for complete system.

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/Wisconsin		
USA/North Dakota		
Brazil		
Uruguay		
Korea		

MANUFACTURER AND VENDOR INFORMATION

Effective Date: March 22, 2000

Manufacturer name: International Road Dynamics Inc.

Sales representative name(s): Rod Klashinsky

Address: 702 43rd Street East
Saskatoon SK, S7K3T9 Canada

Phone number: (306) 653-6600
Fax number: (306) 242-5599
e-mail address: info@irdinc.com
URL address: www.irdinc.com

Address:
Phone number:
Fax number:
e-mail address: rod.klashinsky@ird.ca
URL address:

PRODUCT NAME/MODEL NUMBER: IRD 1068 Single Load Cell Scale (SLC) WIM System

FIRMWARE VERSION/CHIP NO.: N/A

SOFTWARE VERSION NO.: N/A

GENERAL DESCRIPTION OF EQUIPMENT: The IRD 1068 Single Load Cell (SLC) scale WIM system utilizes Single Load Cell (SLC) scale technology to collect data on axle weights, vehicle classification (based on the number and spacing of axles) and vehicle speed. The system is accessible remotely using a standard telephone communication modem and PC for system monitoring, set-up and data collection.

SENSOR TECHNOLOGY AND CONFIGURATION: The system uses an inductive loop Single Load Cell scale — piezo sensor loop configuration to collect traffic data.

SENSOR INSTALLATION: Please see attached product information for details

INSTALLATION TIME (Per Lane): Approximately 3 days per lane

INSTALLATION REQUIREMENTS: Please see attached product information for details

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: 6

PRODUCT CAPABILITIES/FUNCTIONS: Vehicle WIM data collection

RECOMMENDED APPLICATIONS: Vehicle WIM data collection

POWER REQUIREMENTS (watts/amps): 2.5 Amps/35 watts

POWER OPTIONS: 100-240 VAC, 50-60 Hz

CLASSIFICATION ALGORITHMS: Vehicles can be classified based on axle weights, axle spacings, axle groupings and GVW.

TELEMETRY: Terminal software and standard telephone line with modem required.

COMPUTER REQUIREMENTS: Pentium II or better, 400 MHZ min, 32 Mb RAM min, Expansion slots 1 ISA, 3PCI, 1 ISA/PCI.

DATA OUTPUT: Individual vehicle and vehicle summary data are stored on the WIM computer which can be retrieved through a modem. Individual data can also be sent to an RS 232 port on the WIM in realtime.

DATA OUTPUT FORMATS: The vehicle information is stored on disk files in a compressed format developed by IRD. Software is available to convert the data to CSV (Comma, Separated Value) file. Several industry standard formats are available for the WIM vehicle data transmitted through the RS 232 port.

SUPPORTING DATA BASE MANAGEMENT SYSTEM: Report generation software is available form IRD that reads the compressed vehicle data files directly. Raw data can also be exported to file which can be read by any database system.

EQUIPMENT COSTS (One-lane and four-lane):
1-lane: $75,000 US
4-lane: $215,000 US

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/Indiana (INDOT)	Don Klepinger	(317) 591-5264
USA/Minnesota (MNDOT)	Mark Novak	(651) 296-2607

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 3/1/2000

Manufacturer name: Haenni/Mikros	Sales representative name(s):
	Loadometer Corporation
	3-G Nashua Court
Address:	Address: Baltimore, MD 21221-3133
Phone number:	Phone number: (800) 753-6696
Fax number:	Fax number: (410) 574-2856
e-mail address:	e-mail address: gmuhler@loadometer.com
URL address:	URL address: www.loadometer.com

PRODUCT NAME/MODEL NUMBER: WL110, Low Speed Portable WIM

FIRMWARE VERSION/CHIP NO.:

SOFTWARE VERSION NO.:

GENERAL DESCRIPTION OF EQUIPMENT: System consists of 2 sensors, 4 leveling mats, connecting cables and hand held monitor.

SENSOR TECHNOLOGY AND CONFIGURATION: Capacitance mat, stainless steel construction

SENSOR INSTALLATION: None, aboveground

INSTALLATION TIME (Per Lane): 5 minutes

INSTALLATION REQUIREMENTS: None

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: One

PRODUCT CAPABILITIES/FUNCTIONS: Capable of providing wheel loads, axle loads, axle group loads, gross vehicle weight and violations per set parameters

RECOMMENDED APPLICATIONS: statistical gathering purposes and as screening device in commercial vehicle weight law enforcement

POWER REQUIREMENTS (watts/amps): Internal battery, external power supply

POWER OPTIONS: Internal battery, external power supply.

CLASSIFICATION ALGORITHMS:

TELEMETRY:

COMPUTER REQUIREMENTS:

DATA OUTPUT:

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):
Installation Costs: None, portable system
Equipment Cost: $20,000 maximum

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/Arizona	Sgt. Charles Blundell	(602) 773-3613
	Lt. Ken Barton	(602) 223-2522
USA/Exeter Township	Officer Chris Neidert	(617) 777-1490
USA/Falls Township Lt.	Charles Shaffner	(215) 949-9110
USA/Idaho DOT	Alan Frew	(208) 334-8694
USA/Kansas Hwy Patrol	Sgt. David McKee	(913) 296-7903
USA/Michigan St. Police	Lt. Jim Charles	(616) 784-8362
USA/Montana DOT	Gary Marten	(406) 444-6130
USA/Nebraska St. Patrol	Lt. Jim Doggtt	(402) 471-0105
USA/NH State Police Sgt.	Wayne Peasley	(603) 271-3339
USA/PA DOT	Lance McAffe	(717) 783-8776
USA/Uwchlan Township	Cpl. Buddy Mauger	(610) 524-1135
USA/Vermont DOT	Ron Macie	(802) 828-2067
USA/West VA DOT	Jeff Davis	(304) 558-3723

MANUFACTURER AND VENDOR INFORMATION

Effective Date: March 22, 2000

Manufacturer name: International Road Dynamics, Inc.	Sales representative name(s): Rod Klashinsky
Address: 702 43rd Street East, Saskatoon SK, S7K 3T9 Canada	Address:
Phone number: 306-653-6600	Phone number:
Fax number: 306-242-5599	Fax number:
e-mail address: info@irdinc.com	e-mail address: rod.klashinsky@ird.ca
URL address: www.irdinc.com	URL address:

PRODUCT NAME/MODEL NUMBER: IRD Dynamic Work-Zone Safety System

FIRMWARE VERSION/CHIP NO.: NA

SOFTWARE VERSION NO.: NA

GENERAL DESCRIPTION OF EQUIPMENT: The IRD Work-Zon e Safety System is a traffic control system for construction work zones. The system utilizes traffic detection sensors to detect traffic queue length and reduce the number of vehicles in the passing lane prior to work-zone approaches.

SENSOR TECHNOLOGY AND CONFIGURATION: The IRD Dynamic work-Zone Safety System utilizes traffic sensors to detect vehicles and activate flashing lights mounted on DO NOT PASS panel signs prior to construction zones. Alternately, CMS or VMS signs can be used.

SENSOR INSTALLATION: Sensors are mounted on roadside panel message signs.

INSTALLATION TIME (Per Lane): The system can typically be installed in 4-5 days.

INSTALLATION REQUIREMENTS: Please see attached product information for details.

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Only one lane is required to be monitored for this application.

PRODUCT CAPABILITIES/FUNCTIONS: Detection of vehicles prior to a work-zone to trigger flashing lights mounted on roadway panel signs to instruct vehicles to merge into one lane. Since the signs are regulatory signs, offences are enforceable by law.

RECOMMENDED APPLICATIONS: Detection of vehicles prior to a work-zone to trigger flashing lights mounted on roadway panel signs.

POWER REQUIREMENTS (watts/amps): 12-24 AC or DC

POWER OPTIONS: AC, DC, or solar.

CLASSIFICATION ALGORITHMS: NA

TELEMETRY: NA

COMPUTER REQUIREMENTS: Laptop may be used to access information using serial communications software such as HyperTerminal.

DATA OUTPUT: Serial or contact Closure.

DATA OUTPUT FORMATS: ASCII

SUPPORTING DATA BASE MANAGEMENT SYSTEM: NA

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):
Approximately $ 60,000 US depending on the requirements (trailer and sign costs not included).

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/Indiana (IN DOT)	Dan Shamo	(317) 232-5533

Chapter 5 — Non-intrusive Technologies

Non-intrusive technologies are those that do not require the installation of the sensor directly onto or into the road surface. The sensors for non-intrusive technologies are mounted overhead or on the side of the roadway. The video image processor, microwave radar, active and passive infrared sensors, ultrasonic sensors, and passive acoustic array sensors are discussed in the following sections.

Video Image Processor

Video cameras were introduced to traffic management for roadway surveillance because of their ability to transmit closed circuit television imagery to a human operator for interpretation. Present-day traffic management applications use video image processing to automatically analyze the scene of interest and extract information for traffic surveillance and control. A video image processor (VIP) system typically consists of one or more cameras, a microprocessor-based computer for digitizing and processing the imagery, and software for interpreting the images and converting them into traffic flow data.

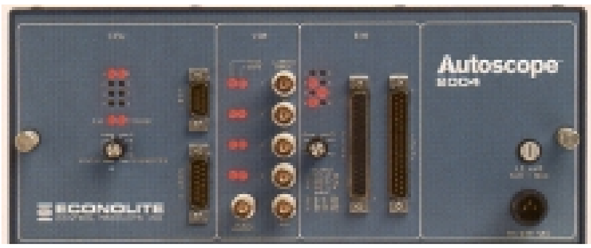
Principles of Operation

Video image processor systems detect vehicles by analyzing the imagery from a traffic scene to determine changes between successive frames. The image processing algorithms that analyze black and white imagery examine the variation of gray levels in groups of pixels contained in the video frames. The algorithms are designed to remove gray level variations in the image background caused by weather conditions, shadows, and daytime or nighttime artifacts and retain objects identified as automobiles, trucks, motorcycles, and bicycles. Traffic flow parameters are calculated by analyzing successive video frames. Color imagery can also be exploited to obtain traffic flow data. However, somewhat reduced dynamic range and sensitivity have so far inhibited this approach.

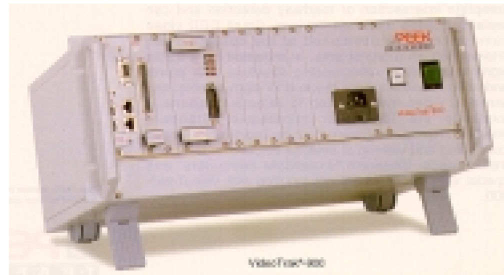
Three classes of VIP systems have been developed: tripline, closed-loop tracking, and data association tracking. Tripline systems operate by allowing the user to define a limited number of detection zones in the field of view of the video camera. When a vehicle crosses one of these zones, it is identified by noting changes in the pixels caused by the vehicle relative to the roadway in the absence of a vehicle. Surface-based and grid-based analyses are utilized to detect vehicles in tripline VIPs. The surface-based approach identifies edge features, while the grid based classifies squares on a fixed grid as containing moving vehicles, stopped vehicles, or no vehicles. Tripline systems estimate vehicle speed by measuring the time it takes an identified vehicle to travel a detection zone of known length. The speed is found as the length divided by the travel time (Klein, 2001).

The advent of the VIP tracking approaches has been facilitated by low-cost, high throughput microprocessors. Closed-loop tracking systems are an extension of the tripline approach that permits vehicle detection along larger roadway sections. The closed-loop systems track vehicles continuously through the field of view of the camera. Multiple detections of the vehicle along a track are used to validate the detection. Once validated, the vehicle is counted and its speed is updated by the tracking algorithm (MacCarley, 1992). These tracking systems may provide additional traffic flow data such as lane-to-lane vehicle movements. Therefore, they have the potential to transmit information to roadside displays and radios to alert drivers to erratic behavior that can lead to an incident.

Data association tracking systems identify and track a particular vehicle or groups of vehicles as they pass through the field of view of the camera. The computer identifies vehicles by searching for unique connected areas of pixels. These areas are then tracked from frame-to-frame to produce tracking data for the selected vehicle or vehicle groups. The markers that identify the objects are based on gradients and morphology. Gradient markers utilize edges, while morphological markers utilize combinations of features and sizes that are recognized as belonging to known vehicles or groups of vehicles (Wentworth, et. al., 1994). In the future, data association tracking may provide link travel time and origin-destination pair information by identifying and tracking vehicles as they pass from one camera s field of view to another s. Figure 16 shows two examples of video image processors that use the tripline approach.



Autoscope 2004 (Photograph courtesy of Econolite Control Products, Anaheim, CA)



VideoTrak-900 (Photograph courtesy of Transyt Corp., Tallahassee, FL)

Figure 16. Video image processors.

Signal Processing

Image formatting and data extraction are performed with firmware that allows the algorithms to run in real time. The hardware that digitizes the video imagery is commonly implemented on a single-formatter card in a personal computer architecture. Once the data are digitized and stored by the formatter, spatial and temporal features are extracted from the vehicles in each detection area with a series of image processing algorithms. In the concept illustrated in Figure 17, a detection process establishes one or more thresholds that limit and segregate the data passed on to the rest of the algorithms. It is undesirable to severely limit the number of potential vehicles during detection, for once data are removed they cannot be recovered. Therefore, false vehicle detections are permitted at this stage since the declaration of actual vehicles is not made at the conclusion of the detection process. Rather, algorithms that are part of the classification, identification, and tracking processes still to come are relied on to eliminate false vehicles and retain the real ones (Klein, 1997). Image segmentation is used to divide the image area into smaller regions where features can be better recognized. The features are analyzed to generate vehicle presence, speed, and classification data. VIPs with tracking capability use Kalman filter techniques to update vehicle position and velocity estimates. The time trace of the position estimates yields a vehicle trajectory, which can supply lane change and turning information.

A signal processing approach implemented by Computer Recognition Systems incorporates wireframe models composed of line segments to represent vehicles in the image. This approach claims to provide more unique and discriminating features than other computationally viable techniques. Alternatively, artificial neural networks can be trained to recognize and count different classes of vehicles and detect incidents (Chang & Kunhuang, 1993). The neural network approach is incorporated by Nestor Traffic Systems, Inc. in their VIP products. An advantage of the Nestor implementation is that the camera can be repositioned for data acquisition and surveillance (Nestor Corp., 1999). VIPs that utilize tracking offer the ability to warn of impending incidents due to abrupt lane changes or weaving, calculate link travel times, and determine origin-destination pairs. The tracking concept is found in the Mobilizer by CMS, MEDIA4 by Citilog, and IDET-2000 by Sumitomo (Klein, 2001)

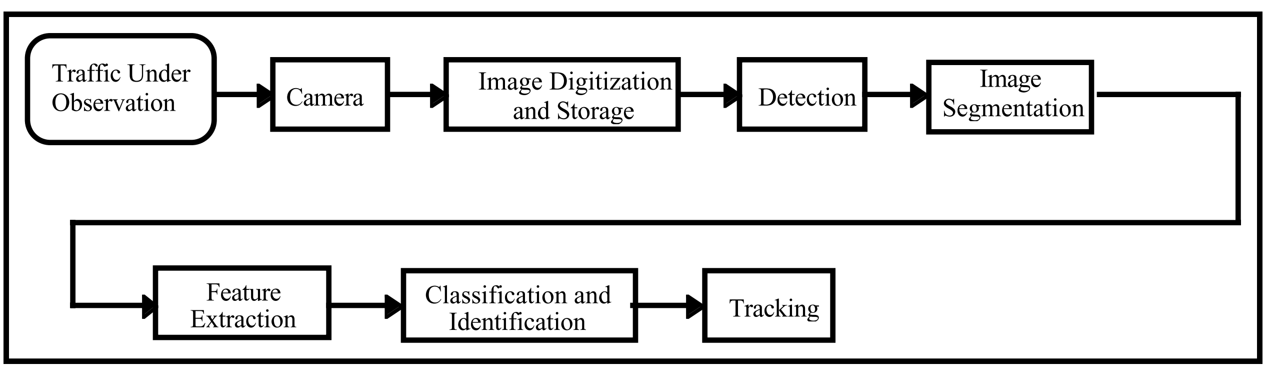


Figure 17. Conceptual image processing for vehicle detection, classification, and tracking.

Application and Uses

A VIP can replace several in-ground inductive loops, provide detection of vehicles across several lanes, and perhaps lower maintenance costs. Some VIP systems process data from more than one camera and further expand the area over which data are collected. VIPs can classify vehicles by their length and report vehicle presence, flow rate, occupancy, and speed for each class. Other potentially available traffic parameters that can be obtained by analyzing data from a series of image processors installed along a section of roadway are density, link travel time, and origin-destination pairs.

Mounting and Traffic Viewing Considerations

VIP cameras can be deployed to view upstream or downstream traffic. The primary advantage of upstream viewing is that incidents are not blocked by the resultant traffic queues as described in Table 11. However, tall vehicles such as trucks may block the line of sight and headlights may cause blooming of the imagery at night. With upstream viewing, headlight beams can be detected as vehicles in adjacent lanes on curved road sections. Downstream viewing conceals cameras mounted on overpasses so that driver behavior is not altered. Downstream viewing also makes vehicle identification easier at night through the information available in the taillights and enhances track initiation because vehicles are first detected when close to the camera.

Although some manufacturers quote a maximum surveillance range for a VIP of ten times the camera mounting height, conservative design procedures limit the range to smaller distances because of factors such as road configuration (e.g., elevation changes, curvature, and overhead or underpass structures), congestion level, vehicle mix, and inclement weather.

Other factors that affect camera installation include vertical and lateral viewing angles, number of lanes observed, stability with respect to wind and vibration, and image quality. VIP cameras can be mounted on the side of a roadway if the mounting height is high, that is 50 ft (15.2 m) or greater. For lower mounting heights of 20 to 30 ft (6.1 to 9.1 m), a centralized location over the middle of the roadway area of interest is required. However, the lower the camera mounting, the greater is the error in vehicle speed measurement, as the measurement error is proportional to the vehicle height divided by the camera mounting height. The number of lanes of imagery analyzed by the VIP becomes important when the required observation and analysis area is larger than the VIP s capability. For example, if the VIP provides data from detection zones in three lanes, but five must be observed, that particular VIP may not be appropriate for the application. VIPs that are sensitive to large camera motion may be adversely affected by high winds as the processor may assume that the wind-produced changes in background pixels correspond to vehicle motion. Image quality and interpretation can be affected by cameras that have automatic iris and automatic gain control. In tests conducted by California Polytechnic Institute at San Luis Obispo (Cal Poly SLO), these systems were disabled (Hockaday, 1991). In follow-up tests, Cal Poly SLO found VIPs better able to compensate for light level changes when the automatic iris was set to respond slowly to variations in light entering the camera.

Table 11.
Video image processor characteristics in upstream and downstream viewing.

Upstream Viewing	Downstream Viewing
• Headlight blooming, glare on wet pavement, headlight beams detected in adjacent lanes on curved road sections • More blockage from tall trucks	• Camera on overpass concealed from drivers • More information from tail lights available for braking indication, vehicle classification, and turning movement identification
• Traffic incidents are not blocked by resulting traffic queues • With long wavelength infrared imagery, similar information is available to a tracking algorithm from headlight and tail light viewing	• Easier to acquire vehicles that are closer to the camera for the tracking algorithm application • With visible imagery, more information is available to a tracking algorithm from tail light viewing

Advantages

VIP signal processing is continually improving its ability to recognize artifacts produced by shadows, illumination changes, reflections, inclement weather, and camera motion from wind or vehicle-induced vibration. However, artifacts persist and the user should evaluate VIP performance under the above conditions and other local conditions that may exist. In their 1998 report to the TRB Freeway Operations Committee, the New York State Department of Transportation (DOT) stated that one VIP model had difficulty detecting vehicles on a roadway lightly covered with snow in good visibility. Another model did not experience this problem. An example of the effect of day-to-night illumination change on VIP performance is illustrated in Figure 18. Shortly after 1900 hours, there are changes in the slopes of the vehicle count data produced by the VIPs due to either degradation in performance of the daytime algorithm or the different performance of the nighttime algorithm (Klein, 1996).

Heavy congestion that degraded early VIPs does not appear to present a problem to more modern systems. Combined results for clear and inclement weather show vehicle flow rate, speed, and occupancy measurement accuracies in excess of 95 percent using a single detection zone and a camera mounted at a sufficiently high height (Michalopoulos, et. al., 1993). VIPs with single or multiple detection zones per lane can be used to monitor traffic on a freeway. For signalized intersection control, where vehicle detection accuracies of 100 percent are desired, the number of detection zones per lane is increased to between two and four, dependent on the camera mounting and road geometry. Even with multiple detection zones, cameras used in a side-viewing configuration that are not mounted high enough, on the order of 30 ft (9 m) rather than 50 ft (15 m)] or are not directly adjacent to the roadway can degrade the vehicle detection accuracy to 85 percent or less (Klein, 1999 vols. 1&2). The study that produced these results also reported that vehicle detection was sometimes sensitive to the vehicle-to-road color contrast.

Disadvantages

Some disadvantages of the video image processor include its vulnerability to viewing obstructions; inclement weather; shadows; vehicle projection into adjacent lanes; occlusion; day-to-night transition; vehicle/road contrast; water; salt grime; icicles; and cobwebs on camera lens that can affect performance. Also, some models are susceptible to camera motion caused by strong winds. Furthermore, the installation of a video image processor requires 50 to 60-feet mounting height (in a side mounting configuration) for optimum presence detection and speed measurement. A video image processor arrangement is generally cost effective only if many detection zones are required within the field of view of the camera.

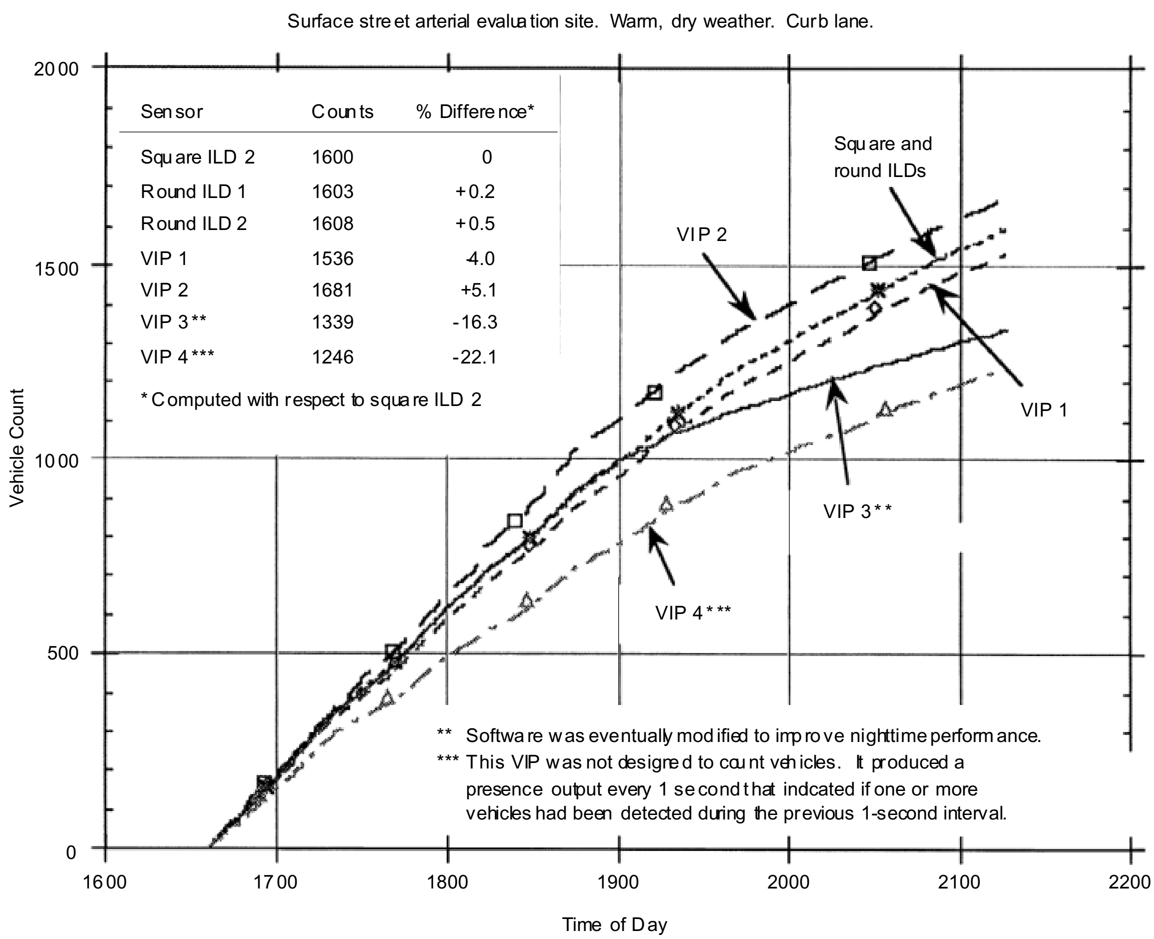


Figure 18. Vehicle count comparison from four VIPs and inductive loop detectors.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: April 4, 2000

Manufacturer name: Enerdyne Technologies, Inc

Address: 8402 Magnolia Avenue
Santee, CO 92071
Phone number: (619) 562-3061
Fax number:
e-mail address:
URL address:

Sales representative name(s): Robert Perez

Address: 8402 Magnolia Avenue
Santee, CO 92071
Phone number: (619) 562-3061
Fax number:
e-mail address: bperez@enerdyne.com
URL address: enerdyne.com

PRODUCT NAME/MODEL NUMBER: Linux Communication Server Lnx7000

FIRMWARE VERSION/CHIP NO.:

SOFTWARE VERSION NO.:

GENERAL DESCRIPTION OF EQUIPMENT: Stand alone high speed data server multipleasing and de-multiplying video, audio and data using IP. Supports mpeg 2/1 and mjpeg.

SENSOR TECHNOLOGY AND CONFIGURATION:

SENSOR INSTALLATION:

INSTALLATION TIME (Per Lane):

INSTALLATION REQUIREMENTS:.

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY:

PRODUCT CAPABILITIES/FUNCTIONS: Product supports mpeg —mpeg2 and mjpeg. IP based with a 10 baset and a 10/100 ethernet pint. Supports a single pumcia slot for options. Internal webserver.

RECOMMENDED APPLICATIONS: Traffic surveillance

POWER REQUIREMENTS (watts/amps): 11 watts

POWER OPTIONS:

CLASSIFICATION ALGORITHMS:

TELEMETRY:

COMPUTER REQUIREMENTS:

DATA OUTPUT:

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT COSTS (One-lane and four-lane): Equipment pricing range from mid $5,000 to approximately $7,000 per device.

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number

CONTACT ENERDYNE TECHNOLOGIES FOR CURRENT LIST OF REFERENCES.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 3/1/2000

Manufacturer name: Image Sensing Systems, Inc.	Sales representative name(s):
Address: 1600 University Avenue West 500 Spruce Tree Centre St. Paul, MN 55104-3823	Address:
Phone number: (651) 603-7700	Phone number:
Fax number: (651) 603-7795	Fax number:
e-mail address:	e-mail address:
URL address:	URL address:

PRODUCT NAME/MODEL NUMBER: Autoscope (5 models)
Autoscope — 2004, 2004LE, 2004ID
Autoscope — V8, Autoscope Solo

FIRMWARE VERSION/CHIP NO.: Various by model

SOFTWARE VERSION NO.: Various based upon model of Autoscope

GENERAL DESCRIPTION OF EQUIPMENT: Autoscope was the first video vehicle detection system introduced in 1989. Currently, Autoscope holds more than 60% global market share, with 3,000 systems installed globally

SENSOR TECHNOLOGY AND CONFIGURATION: Machine vision — video image processing, pixel tracking and tripline technology

SENSOR INSTALLATION: Existing signal poles, mast arm and luminaire standards

INSTALLATION TIME (Per Lane): 12 hours

INSTALLATION REQUIREMENTS: Minimum 25 ft. aboveground — preferably 1:10 ft ratio to detect

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Six to seven

PRODUCT CAPABILITIES/FUNCTIONS: Complete vehicle detection, preference, traffic control, speed, occupancy, headway, queue length travel time, classification, automatic incident detection, critical traffic alarms for intersection and freeway traffic, management, interface with scout, scats, spot.

RECOMMENDED APPLICATIONS: Intersection detection, freeway/tollways mgt. Construction zones, railway crossings, bridges, tunnels, security areas.

POWER REQUIREMENTS (watts/amps): 0.25 amps 110/220 50/60 MHz

POWER OPTIONS: AC

CLASSIFICATION ALGORITHMS: User selectable by length into 5 — 6 ins.

TELEMETRY: Proprietary based upon existing infrastructure

COMPUTER REQUIREMENTS: 486/Pentium minimum w/ Windows 98 or NT.

DATA OUTPUT: ASCI text format or compatible with multiple standard spreadsheet programs.

DATA OUTPUT FORMATS: Per above in time slices from 10-60 seconds and 5-60 minutes.

SUPPORTING DATA BASE MANAGEMENT SYSTEM: Contingent upon particular model

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):
1 lane: $5,000
4 lane: 14 approach intersection, $18,200

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number

CONTACT IMAGE SENSING SYSTEMS FOR CURRENT LIST OF REFERENCES.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 2/29/00

Manufacturer name: Sumitomo Electric.

Address: 1-1-3 Shimaya
Konohana-ku, Osaka 554-0024
Japan

Phone number: +81 6-6461-1031
Fax number: +81 6-6466-3305
e-mail address: www@prs.sei.co.jp
URL address: www.sel.co.jp

Sales representative name(s): Takehiko Barada

Address: 3235 Kifer Road
Suite 150
Santa Clara, CA 95051

Phone number: (408) 737-8517
Fax number: (408) 737-0134
e-mail address: barada@sumitomo.com
URL address: www.sumitomo.com/its/

PRODUCT NAME/MODEL NUMBER: IDET - 1000

FIRMWARE VERSION/CHIP NO.: N/A

SOFTWARE VERSION NO.: N/A

GENERAL DESCRIPTION OF EQUIPMENT: Imaging Processing Vehicle Detector with Multiple Features

SENSOR TECHNOLOGY AND CONFIGURATION: Video

SENSOR INSTALLATION: Overhead or sidefire

INSTALLATION TIME (Per Lane): N/A

INSTALLATION REQUIREMENTS: Pole arm

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Four

PRODUCT CAPABILITIES/FUNCTIONS: Presence, occupancy, classification (two-three), speed stopped vehicle detection (drive lanes, shoulders) queue length measurement, 1 still image transmission (JPEG format)

RECOMMENDED APPLICATIONS: Advanced traffic signal control, freeway monitoring, ramp control incident management, tunnel traffic flow monitoring

POWER REQUIREMENTS (watts/amps): 50 va

POWER OPTIONS: N/A

CLASSIFICATION ALGORITHMS: Vehicle length (daytime), width (night)

TELEMETRY:

COMPUTER REQUIREMENTS: PC with RS-232 for installation and adjustment

DATA OUTPUT: NEMA TS1, RS 232 custom

DATA OUTPUT FORMATS: N/A

SUPPORTING DATA BASE MANAGEMENT SYSTEM: N/A

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane): Approx. $18,000/four lane & installation cost & communication

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
Japan		

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 3/6/00

Manufacturer name: Iteris

Address: 1515 S. Manchester Avenue
Anaheim, CA 92802

Phone number: (800) 254-5487
Fax number: (714) 780-7246
e-mail address: vantage@iteris.com
URL address: www.iteris.com

Sales representative name(s):
Mary Griffin
Mike Volling

Address: same

Phone number: same
Fax number: same
e-mail address: mgl@iteris.com, mtv@iteris.com
URL address:

PRODUCT NAME/MODEL NUMBER: Vantage One Video Detection Systems

FIRMWARE VERSION/CHIP NO.: 1.07

SOFTWARE VERSION NO.: 1.07

GENERAL DESCRIPTION OF EQUIPMENT: Single camera shelf or rack mount video detection unit.

SENSOR TECHNOLOGY AND CONFIGURATION: Analog CCD — available in wired or wireless configuration.

SENSOR INSTALLATION: Pole mount

INSTALLATION TIME (Per Lane): 15 — 30 minute average

INSTALLATION REQUIREMENTS: Bucket truck and camera bracket

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: 1-6 lanes

PRODUCT CAPABILITIES/FUNCTIONS: Vehicle detection via camera, works in TS1 or 170/179 cabinet. Up to 24 zones, 8 outputs, remote access.

RECOMMENDED APPLICATIONS: Intersection and highway

POWER REQUIREMENTS (watts/amps): 24 VDC — processor
115 VAC, 60 Hz, 15 watt - camera

POWER OPTIONS:4 VDC – processor
220 VAC, 50 Hz, 15 watt - camera

CLASSIFICATION ALGORITHMS: Count, presence, extend, delay, and pulse detector types

TELEMETRY: Via RS 232

COMPUTER REQUIREMENTS: None for setup or operation

DATA OUTPUT: 8 outputs

DATA OUTPUT FORMATS: Contact closure

SUPPORTING DATA BASE MANAGEMENT SYSTEM: VRAS — Vantage Remote Access Software

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):
$5,000.00 0 $6,500.00 per approach (1-6 lanes)

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/Texas DOT	Dexter Turner	
USA/Virginia DOT	Bobby Perdue	
USA/City of Clovis, CA	Tim Barker	
USA/City of Victorville, CA	George Parmenter	

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 3/6/00

Manufacturer name: Iteris

Address: 1515 S. Manchester Avenue
Anaheim, CA 92802

Phone number: (800) 254-5487
Fax number: (714) 780-7246
e-mail address: vantage@iteris.com
URL address: www.iteris.com

Sales representative name(s):
Mary Griffin
Mike Volling

Address: same

Phone number: same
Fax number: same
e-mail address: mgl@iteris.com, mtv@iteris.com
URL address:

PRODUCT NAME/MODEL NUMBER: Vantage Edge Video Detection Systems

FIRMWARE VERSION/CHIP NO.: 1.07

SOFTWARE VERSION NO.: 1.07

GENERAL DESCRIPTION OF EQUIPMENT: Single camera rack mount video detection unit.

SENSOR TECHNOLOGY AND CONFIGURATION: Analog CCD camera available in wired or wireless configuration.

SENSOR INSTALLATION: Pole mount

INSTALLATION TIME (Per Lane): 15 — 30 minute average

INSTALLATION REQUIREMENTS: Bucket truck and camera bracket

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: 1-6 lanes

PRODUCT CAPABILITIES/FUNCTIONS: Vehicle detection via camera, works in TS1 or 170/179 cabinet. Up to 24 zones, 8 outputs, remote access.

RECOMMENDED APPLICATIONS: Intersection and highway

POWER REQUIREMENTS (watts/amps): 24 VDC — processor
115 VAC, 60 Hz, 15 watt - camera

POWER OPTIONS: 24 VDC — processor
220 VAC, 50 Hz, 15 watt - camera

CLASSIFICATION ALGORITHMS: Count, presence, extend, delay, and pulse detector types

TELEMETRY: Via RS 232

COMPUTER REQUIREMENTS: None for setup or operation

DATA OUTPUT: Contact closure; up to 8 outputs;

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM: VRAS — Vantage Remote Access Software

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):
$5,000.00 0 $6,500.00 per approach (1-6 lanes)

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/Texas DOT	Dexter Turner	
USA/Virginia DOT	Bobby Perdue	
USA/City of Clovis, CA	Tim Barker	
USA/City of Victorville, CA	George Parmenter	

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 3/5/00

Manufacturer name: Iteris

Address: 1515 S. Manchester Avenue
Anaheim, CA 92802

Phone number: (800) 254-5487
Fax number: (714) 780-7246
e-mail address: vantage@iteris.com
URL address: www.iteris.com

Sales representative name(s):
Mary Griffin
Mike Volling

Address: same

Phone number: same
Fax number: same
e-mail address: mgl@iteris.com, mtv@iteris.com
URL address:

PRODUCT NAME/MODEL NUMBER: Vantage Plus Video Detection Systems

FIRMWARE VERSION/CHIP NO.: 1.07

SOFTWARE VERSION NO.: 1.07

GENERAL DESCRIPTION OF EQUIPMENT: Video detection unit capable of 1-6 video inputs. Modular in design, shelf, or rack mount chassis.

SENSOR TECHNOLOGY AND CONFIGURATION: Analog CCD camera available in wired or wireless configuration.

SENSOR INSTALLATION: Pole mount

INSTALLATION TIME (Per Lane): 15 — 30 minute average

INSTALLATION REQUIREMENTS: Bucket truck and camera bracket

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: 1- 36

PRODUCT CAPABILITIES/FUNCTIONS: Vehicle detection via camera Works in TS1, TS2, or 170/179 cabinet. Up to 24 zones, 32 outputs, remote access.

RECOMMENDED APPLICATIONS: Intersection and highway

POWER REQUIREMENTS (watts/amps): 115 vac 60 Hz, 137 watt — processor
115 vac 60 Hz, 15 watts - camera

POWER OPTIONS: 220 vac, 50 Hz, 137 watt - camera
220 vac, 50 Hz, 15 watt - camera

CLASSIFICATION ALGORITHMS: Count, presence, extend, delay, and pulse detector types

TELEMETRY: Via RS 232

COMPUTER REQUIREMENTS: None for setup or operation

DATA OUTPUT: Contact closure or TS 2 (output); 32 outputs

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM: VRAS — Vantage Remote Access Software

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):
$5,000.00 0 $6,500.00 per approach (1-6 lanes)

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/Texas DOT	Dexter Turner	
USA/Virginia DOT	Bobby Perdue	
USA/City of Clovis, CA	Tim Barker	
USA/City of Victorville, CA	George Parmenter	

MANUFACTURER AND VENDOR INFORMATION

Effective Date: Fall 2000

Manufacturer name: Digital Image, Inc.	Sales representative name(s): Steven S. Suzuki
Address: 1005 N. Wolfe Road, SW2-240 Cupertino, CA 95014	Address: Same
Phone number: (408) 257-9057	Phone number: (408) 257-9057 ext. 306
Fax number: (408) 257-9674	Fax number:
e-mail address: sales@dii-megachips.com	e-mail address: ssuzuki@dii-megachips.com
URL address: www.dii-megachips.com	URL address:

PRODUCT NAME/MODEL NUMBER: MD-100

FIRMWARE VERSION/CHIP NO.:

SOFTWARE VERSION NO.:

GENERAL DESCRIPTION OF EQUIPMENT: Remote video sensor with audio support

SENSOR TECHNOLOGY AND CONFIGURATION: Video and audio

SENSOR INSTALLATION:

INSTALLATION TIME (Per Lane):

INSTALLATION REQUIREMENTS:

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY:

PRODUCT CAPABILITIES/FUNCTIONS: Four video inputs; full duplex audio support; RS232C Ports for 3rd party device control; 10 Base-T (Ethernet) port; video compression (RVC or JPEG); web browser (view and control 3rd party devices via Netscape Navigator or Internet Explorer); alarm events recording

RECOMMENDED APPLICATIONS: Traffic Monitoring: highways, intersections, toll booths. Video Surveillance: parking lots, day care centers, hotels, schools, stores. Remote Monitoring/Maintenance: production lines, ship yards, airports, railroads.

POWER REQUIREMENTS (watts/amps): A/C 120V $\pm$ 10%

POWER OPTIONS:

CLASSIFICATION ALGORITHMS:

TELEMETRY:

COMPUTER REQUIREMENTS: Windows PC/AT compatible. Operating systems: Windows 95 OSR2.1, Windows 98 2nd edition, Windows NT 4.0 service pack 5. Web browser: Internet Explorer 4.02 or 5.0, Netscape Communicator 4.7. Full duplex sound card capable of simultaneous recording and replay. Microphones and speakers capable of connecting to the above sound card. Minimum CPU: Pentium II 333 MHz or higher (Pentium III 500 MHz recommended). Memory: 64 MB (128 MB recommended)

DATA OUTPUT: Video and audio

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):
CONTACT DIGITAL IMAGE INC. FOR EQUIPMENT AND INSTALLATION COSTS.

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	**Contact name**	**Telephone number**

CONTACT DIGITAL IMAGE INC. FOR CURRENT LIST OF USERS.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: August 21, 2000

Manufacturer name: TraFicon

Address: Bissegemse Street 45
B-8501 Heule, Belgium

Phone number: 32-56 37 2200
Fax number: 32-56 37 2196
e-mail address: traficon@traficon.be
URL address: traficon.be

Sales representative name(s):
Mike Day: Control Technologies

Address: 2776 Financial Court
Sanford, Florida 32773

Phone number: (407) 330-2800
Fax number: (407) 330-2804
e-mail address: cttraffic@aol.com
URL address: www.cttraffic.com

PRODUCT NAME/MODEL NUMBER: VIP 3.1

FIRMWARE VERSION/CHIP NO.: 2.06e

SOFTWARE VERSION NO.: 2.06e

GENERAL DESCRIPTION OF EQUIPMENT: Single approach detection

SENSOR TECHNOLOGY AND CONFIGURATION: Video modular by approach

SENSOR INSTALLATION: Mast arm, side of pole

INSTALLATION TIME (Per Lane): One hour

INSTALLATION REQUIREMENTS: Bucket truck

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Eight

PRODUCT CAPABILITIES/FUNCTIONS: Presence detection, counting, video surveillance

RECOMMENDED APPLICATIONS: Presence detection, freeway management, counts, ramp metering detection, volume, speed

POWER REQUIREMENTS (watts/amps): 120 V, 5W

POWER OPTIONS: 12V D/C

CLASSIFICATION ALGORITHMS: Available

TELEMETRY: Available

COMPUTER REQUIREMENTS: Not mandatory

DATA OUTPUT: Presence, volume, speed

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM: Watts Traffic Management Software (PC - based)

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane): Approximately $5,000 per approach

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/Florida	Carl Morse	(850) 850-8871
USA/Florida	Garry Lester	(904) 736-5968
USA/Florida	Richard Epps	(941) 694-1332
USA/Geogia	B. Smith	(404) 635-8117

Microwave Radar

Microwave radar was developed for detecting objects before and during Word War II. The word radar was derived from the functions that it performs: *RA*dio *D*etection *A*nd *R*anging. The term microwave refers to the wavelength of the transmitted energy, usually between 1 and 30 cm. This corresponds to a frequency range of 1 GHz to 30 GHz, where the suffix GHz represents 10^9 Hz. Microwave sensors designed for roadside traffic data collection and monitoring in the U.S. are limited by FCC regulations to operating frequency bands near 10.5, 24.0, and 34.0 GHz. These requirements, as well as others that restrict the transmitted power, are satisfied by the sensor manufacturers. Thus, the end users are not required to possess special licenses or test equipment to verify the output frequency or power of the devices. Radars at frequencies above 30 GHz operate in the millimeter-wave spectrum since the wavelength of the transmitted energy is expressed in terms of millimeters. Most commercially available microwave radar sensors used in traffic management applications transmit electromagnetic energy at the X-band frequency of 10.525 GHz. Higher frequencies can illuminate smaller ground areas with a given size antenna and thus gather higher resolution data. Vehicle-mounted radars operating at 76 to 77 GHz support obstacle detection and automatic cruise control.

<u>Principles of Operation</u>

As shown in Figure 19, roadside-mounted microwave radar transmit energy toward an area of the roadway from an overhead antenna. The beamwidth or area in which the radar energy is transmitted, is controlled by the size and the distribution of energy across the aperture of the antenna. The manufacturer usually establishes the design constraints. When a vehicle passes through the antenna beam, a portion of the transmitted energy is reflected back towards the antenna. The energy then enters a receiver where the detection is made and vehicle data, such as volume, speed, occupancy, and length are calculated.

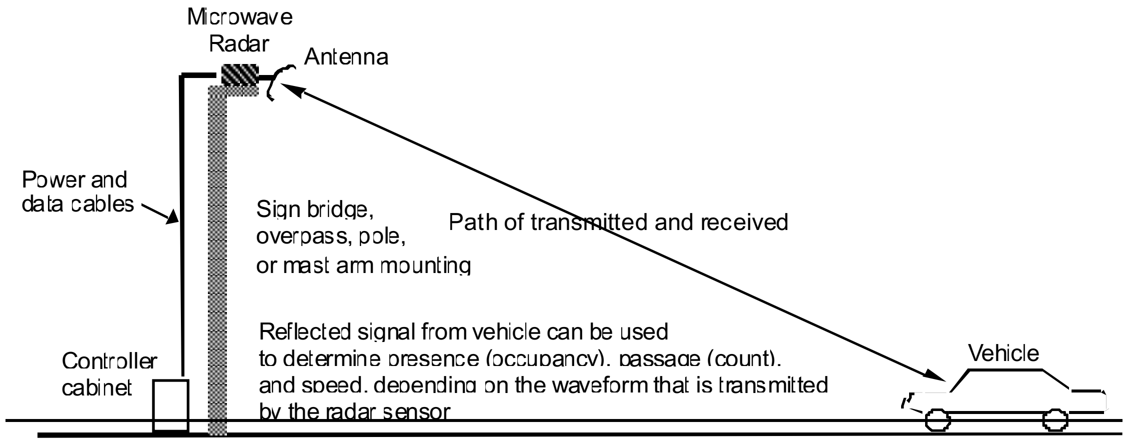
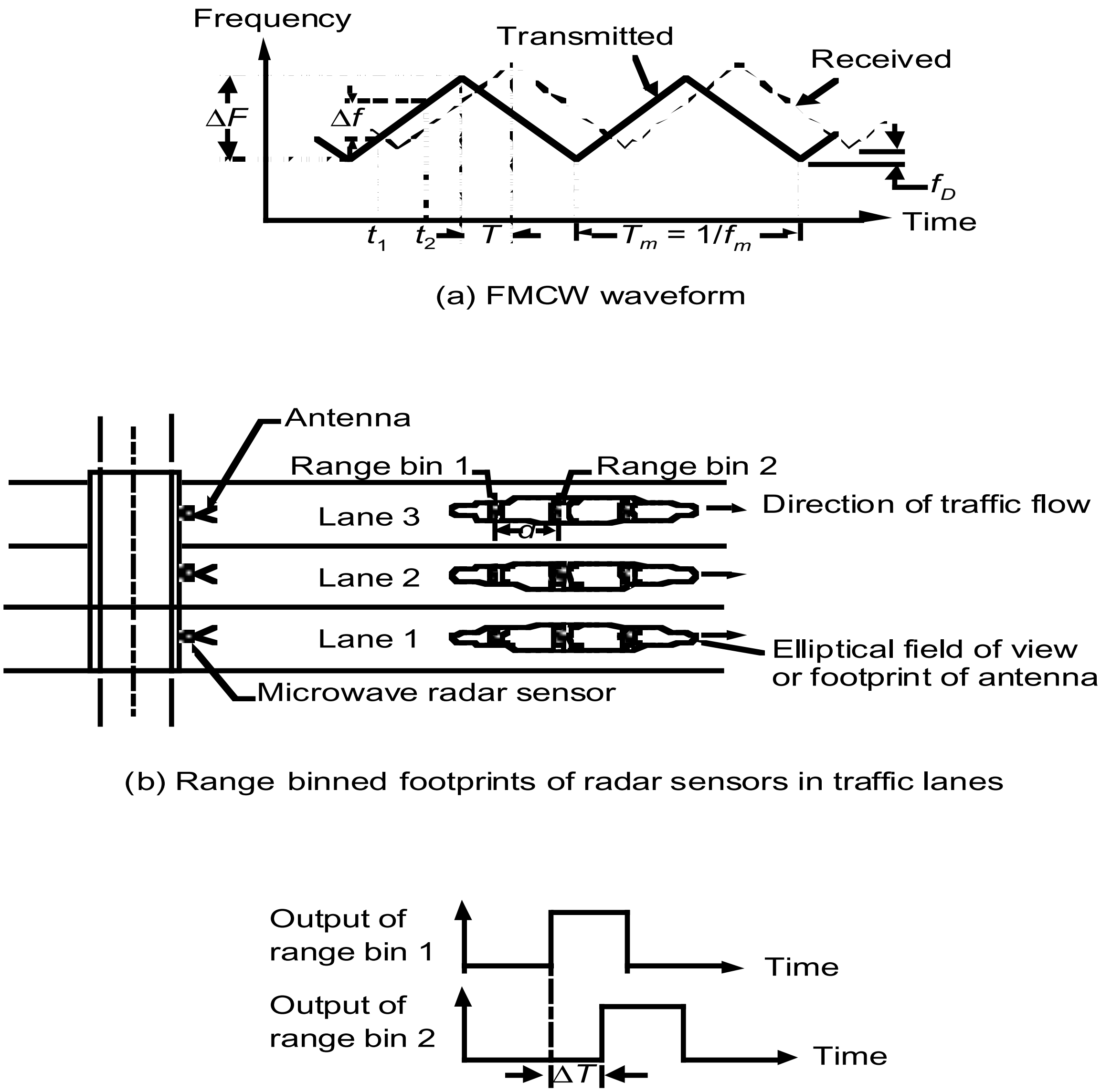


Figure 19. Microwave radar operation.

Two types of microwave radar sensors are used in roadside applications, continuous wave (CW) Doppler radar and frequency modulated continuous wave (FMCW) radar. The traffic data they receive are dependent on the shape of the transmitted waveform. The CW Doppler sensor transmits a signal that is constant in frequency with respect to time. According to the Doppler principle, the motion of a vehicle in the detection zone causes a shift in the frequency of the reflected signal (Klein and Kelly, 1996). This can be used to detect moving vehicles and to determine their speed. CW Doppler sensors that do not incorporate an auxiliary range measuring capability cannot detect motionless vehicles.

The frequency modulated continuous wave (FMCW) microwave radar sensor transmits a frequency that is constantly changing with respect to time, as illustrated in Figure 20. The FMCW radar operates as a presence detector and can detect motionless vehicles.



(a) FMCW waveform

(b) Range binned footprints of radar sensors in traffic lanes

(c) Time-phased outputs of range bins

Figure 20. Speed measurement with an FMCW microwave presence radar.

The forward-looking FMCW radar measures vehicle speed in a single lane using a range binning technique that divides the field of view in the direction of vehicle travel into range bins as shown in Figure 20b. A range bin allows the reflected signal to be partitioned and identified from smaller regions on the roadway. Vehicle speed S is calculated from the time difference ΔT corresponding to the vehicle arriving at the leading edges of two range bins a known distance d apart as shown in Figure 20c. The vehicle speed is given by

$$S = \frac{d}{\Delta T}, \qquad (6)$$

where

d = distance between leading edges of the two range bins and

ΔT = time difference corresponding to the vehicle s arrival at the leading edge of each range bin.

Side-looking configurations of the FMCW radar give multi-lane coverage.

Application and Uses

The radar sensor may be mounted over the middle of a lane to measure approaching or departing traffic flow parameters in a single lane, or at the side of a roadway to measure traffic parameters across several lanes. Forward-looking wide beamwidth radars gather data representative of traffic flow in one direction over multiple lanes. Forward-looking narrow beamwidth radars monitor a single lane of traffic flowing in one direction. Side-mounted, multiple detection zone radars project their footprint perpendicular to the traffic flow direction and provide data corresponding to several lanes of traffic, but generally not as accurately as can the same radar mounted in the forward-looking direction. Side-mounted, single detection zone radars are typically used to detect vehicle presence at signalized intersections.

The types of traffic data received by a microwave radar sensor are dependent on the waveform used to transmit the microwave energy. The CW Doppler microwave sensor detects vehicle passage or count by the presence of the Doppler frequency shift created by a moving vehicle as illustrated in Figure 21. Doppler radars are used to measure vehicular volume and speed on city arterials and freeways. Vehicle presence cannot be measured with the constant frequency waveform as only moving vehicles are detected. Two microwave radars that use the Doppler principle to measure speed are shown in Figure 22.

FMCW presence-measuring radars, such as the models illustrated in Figure 23, are used to control left turn signals, provide real-time volume and occupancy data for traffic adaptive signal systems, monitor traffic queues, and collect occupancy and speed (multizone models only) data in support of freeway incident detection algorithms. Multizone microwave presence radars can measure vehicle speed and are gaining acceptance in electronic toll collection and automated truck weighing applications that require vehicle identification based on vehicle length.

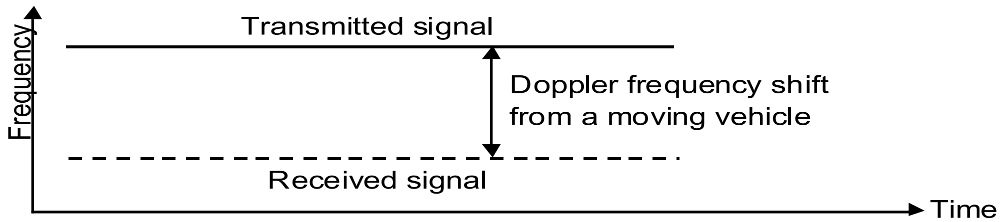
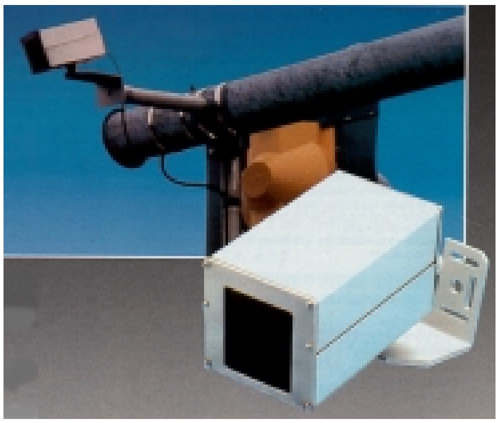


Figure 21. Constant frequency waveform.



TC-20 Doppler microwave radar (Photograph courtesy of Microwave Sensors, Ann Arbor, MI)

TDN-30 Doppler microwave radar (Photograph courtesy of Whelen Engineering Company, Chester, CT)

Figure 22. Doppler microwave radars.

RTMS multizone microwave presence radar. (Photograph courtesy of Electronic Integrated Systems, Toronto, ON Canada).

150LX single zone microwave presence radar. (Photograph courtesy of Naztec, Inc., Sugar Land, TX).

Figure 23. Microwave presence radars.

Advantages

One of the great advantages of microwave radar is that it is generally insensitive to inclement weather. Microwave radar provides a direct measurement of speed. Also, multiple lane operation models are available.

Disadvantages

Microwave radar applications must insure that antenna beamwidth and transmitted waveform are suitable for the application. Also, as mentioned previously, CW Doppler sensors cannot detect stopped vehicles unless equipped with an auxiliary device. Doppler microwave sensors have been found to perform poorly at intersection locations as volume counters (Kranig, et. al., 1997).

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 14 Mar. 2000

Manufacturer name: GMH Engineering

Address:
336 Mountain Way Drive
Orem, UT 84058
Phone number: (801) 225-8970
Fax number: (801) 225-9008
e-mail address: priz@gmheng.com
URL address: www.gmheng.com

Sales representative name(s):

Address:

Phone number:
Fax number:
e-mail address:
URL address:

PRODUCT NAME/MODEL NUMBER: Delta Speed Sensor, Model DRS1000

FIRMWARE VERSION/CHIP NO.:

SOFTWARE VERSION NO.:

GENERAL DESCRIPTION OF EQUIPMENT: The DRS1000 is a small, inexpensive non-contact speed sensor. The output from the sensor is a frequency pulse. Besides vehicle speed, the output can be used to determine vehicle count, distance between vehicles, and general vehicle classification.

SENSOR TECHNOLOGY AND CONFIGURATION: The Delta Speed Sensor utilizes Doppler radar technology. The sensor is mounted over the lane of traffic that you wish to monitor.

SENSOR INSTALLATION: The Delta Speed Sensor requires a 12 VDC power supply. It should be mounted over the lane of traffic one wishes to monitor. It is aimed at an angle looking up or down the road. The sensor monitors the traffic coming towards or moving away from the sensor.

INSTALLATION TIME (Per Lane): One hour

INSTALLATION REQUIREMENTS: 12 VDC and an overhead structure on which to mount the sensor (highway sign, overpass, etc).

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: One lane per sensor

PRODUCT CAPABILITIES/FUNCTIONS: The pulse output of the Delta Speed Sensor is proportional to both a speed measurement and a length measurement. The sensor has a frequency output directly proportional to speed. It gives out 211.6 pulses per second for every mile per hour of speed measured (131.5 pulses per second for every kilometer per hour of speed measured). Also, the total number of pulses is equal to the length of the vehicle passing under the sensor regardless of the speed of the vehicle. Every 144 pulses equal one foot of length (4.7 pulses equals one foot of length (4.7 pulses one centimeter). With this information, one may determine the speed of the vehicles passing under the sensor, the length of the vehicles (may be used for general vehicle classification), the distance between vehicles, and the number of vehicles.

RECOMMENDED APPLICATIONS: Anywhere traffic habits need to be monitored inexpensively, without tearing up the roadway, and without expensive maintenance costs.

POWER REQUIREMENTS (watts/amps): 9.5 to 16.5 VDC (200mA @ 12 VDC)

POWER OPTIONS:

CLASSIFICATION ALGORITHMS:

TELEMETRY:

COMPUTER REQUIREMENTS: If you wish to input the signal form the sensor into your computer, your computer will need to be able to accept a frequency or counter input. Or, we can provide you with a frequency counter with a RS232 output. They cost $180.00

DATA OUTPUT: 0 to 5 V square waves, differential line driver.

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

One Lane		
Cost of Delta DRS1000 Speed Sensor		$1,595.00
Cost of installation at $100.00/hr labor		$100.00
	TOTAL	$1,696.00*

Four lanes		
Cost of 4 Delta DRS1000 Speed Sensor		$6,380.00
Cost of installation at $100.00/hr labor		$400.00
	TOTAL	$6,780.00*

*Note: The above prices do not reflect any quantity discounts.

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number

This is a new product, but it is being tested and is being used in quite a few countries worldwide. Please contact us for references.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: April 1, 2000

Manufacturer name: Electronic Integrated Systems Inc. (EIS)	Sales representative name(s): Robert Bruce
Address: 150 Bridgeland Avenue, Toronto, Ontario, Canada M6A 1Z5	Address: 150 Bridgeland Avenue, Toronto, Ontario, Canada
Phone number: (416) 785-9248	Phone number: (416) 785-9248
Fax number: (416) 785-9332	Fax number: (416) 785-9332
e-mail address: info@rtms-by-eis.com	e-mail address: robertbruce@rtms-by-eis.com
URL address: www.rtms-by-eis-com	URL address: www.rtms-by-eis-com

PRODUCT NAME/MODEL NUMBER: EIS Remote Traffic Microwave Sensor (RTMS)

FIRMWARE VERSION/CHIP NO.: N/A

SOFTWARE VERSION NO.: N/A

GENERAL DESCRIPTION OF EQUIPMENT: The RTMS is a low-cost, all weather, true RADAR (Radio Detection And Ranging) device, which provides true presence, multiple zone, vehicle detection. Its ranging capability is achieved by frequency Modulated Continuous Wave (FMCW) operation. The RTMS is a versatile sensor, capable of detecting vehicles presence and measuring traffic parameters in multiple zones.

SENSOR TECHNOLOGY AND CONFIGURATION: The sensor transmits a microwave energy and receives energy reflected by vehicles and stationary objects in its path. The nominal 10.525 GHz frequency is varied continuously in a 45 MHz band. At any given time, there is a difference between the frequencies of transmitted and received signals. The difference in frequencies in proportional to the distance between the RTMS and the vehicle. The RTMS detects and measures that difference and computes range (distance) to the target. The range resolution if the RTMS is 2m (7 feet). The RTMS can detect both stationary and moving targets.

MOUNTING CONFIGURATION: The RTMS is an out-of-pavement or non-intrusive sensor, which can be mounted, in the following configurations.

Side-Fired: One RTMS unit, mounted on a road-side pole, aimed at the side of the vehicles, can monitor up to eight (8) lanes of traffic by mapping detection zones to lanes.
Forward-Looking: One RTMS unit, mounted on an overhead structure, aimed at the front or rear of the vehicles, will monitor one lane of traffic. This configuration provides greater per vehicle speed measurements

SENSOR INSTALLATION: See installation requirements

INSTALLATION TIME (Per Lane): Per sensor basis — 30 minutes (approx.)

INSTALLATION REQUIREMENTS: The RTMS can be mounted on light standard or poles (Side-Fired) or overhead structures (Forward-Looking). The recommended mounting height is 5 meters (17 feet) above the road. Side-fired requires a set-back from the first lane monitored. The set-back varies with the number of lanes monitored.

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: See MONITORING CONFIGURATIONS

PRODUCT CAPABILITIES/FUNCTIONS:
- Presence detection — Contact closure
- Traffic data accumulation during a programmed measurement period
  - Volume — Number of vehicles passing a detection zone
  - Occupancy — % of time a vehicle was present in the detection zone
  - Speed — Average speed of vehicles passing the detection zone
  - Vehicle class — Number of long vehicles (i.e. semi-trailer trucks) or Average time between vehicles (multiples of 0.1 seconds)
- Communication — Serial port RS232

RECOMMENDED APPLICATIONS:
- Multi-lane intersection control, stop-bar and advanced loop replacement
- Freeway traffic management and incident detection systems
- Ramp metering
- Off ramp queue control and signal control actuation
- Work zone and temporary intersection control
- Permanent and Mobile Traffic Counting Stations
- Enforcing of speed and red light violation

POWER REQUIREMENTS (watts/amps)/OPTIONS:
- Standard — 12-24 AC or DC derived from battery, solar, or controller
- Commercial AC — optional
- Power Drain — 6 watts

CLASSIFICATION ALGORITHMS: The RTMS statistically determines the length of an average vehicles. The Long Vehicle Count is incremented by vehicles deemed to be at least three times the average vehicle length.

TELEMETRY: Contact closures can be transmitted by optional communication systems (e.g. wireless system).

COMPUTER REQUIREMENTS:
- Sensor Set-up — DOS 3.x
- Data collection & Analysis — Windows

DATA OUTPUT: Asynchronous Binary Data at 9600 BPS

DATA OUTPUT FORMATS: 54 byte data packet

SUPPORTING DATA BASE MANAGEMENT SYSTEM: Optional data collection and analysis program can format traffic data in Paradox or Dbase.

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/California	TRAVINFO; Bay area	
USA/Colorado	I-25 Colorado Springs, Denver, Grand Junction	
USA/Florida	Various	
USA/Indiana	BORMAN	
USA/Kentucky	TRIMARC	
USA/Louisiana	Baton Rouge I-12	
USA/Maryland	CHART II	
USA/New Jersey	MAGIC 1 —80; NJ Turnpike; Garden City Parkway	
USA/New York	NY City (Intersections); Van Wyck Expressway, Long Island Expressway	
USA/North Carolina	CARAT	
USA/Missouri	Interstate — Metro St. Louis	
USA/Nebraska	Counting stations	
USA/Ohio	ARTIMIS: City of Jackson (Intersections)	
USA/Pennsylvania	TOP	
USA/South Carolina	Incident Detection System I 85, 77, and 26	
USA/South Dakota	Various	

Continued on next page

USA/Virginia	Hampton Roads Phases II and III
USA/Wisconsin	MONITOR
USA/Washington State	Various

Infrared Sensors

Active and *passive* infrared sensors are manufactured for traffic applications. The sensors are mounted overhead to view approaching or departing traffic or traffic from a side-looking configuration. Infrared sensors are used for signal control; volume, speed, and class measurement, as well as detecting pedestrians in crosswalks. With infrared sensors, the word detector takes on another meaning, namely the light-sensitive element that converts the reflected or emitted energy into electrical signals. Real-time signal processing is used to analyze the received signals for the presence of a vehicle.

<u>Active Infrared Sensor</u>

Principles of Operation

Active infrared sensors illuminate detection zones with low power infrared energy supplied by laser diodes operating in the near infrared region of the electromagnetic spectrum at 0.85 µm. The infrared energy reflected from vehicles traveling through the detection zone is focused by an optical system onto an infrared-sensitive material mounted at the focal plane of the optics.

The active infrared laser sensor has two sets of optics. The transmitting optics split the pulsed laser diode output into two beams separated by several degrees as displayed in Figure 24. The receiving optics has a wider field of view so that it can better receive the energy scattered from the vehicles. By transmitting two or more beams, the laser radars measure vehicle speed by recording the times at which the vehicle enters the detection area of each beam

Application and Uses

Active infrared sensors provide vehicle presence at traffic signals, volume, speed measurement, length assessment, queue measurement, and classification. Multiple units can be installed at the same intersection without interference from transmitted or received signals. Modern laser sensors produce two- and three-dimensional images of vehicles suitable for vehicle classification.

The laser radar illustrated in Figure 25a mounts 20 to 25 ft (6.1 to 7.6 m) above the road surface with an incidence angle (i.e., forward tilt) of 5 degrees Its ability to classify 11 types of vehicles has found use on toll roads. Another laser radar with similar capabilities is shown in Figure 25b. This device can transmit 2 to 6 beams, which control the length of the scan over the travel lane.

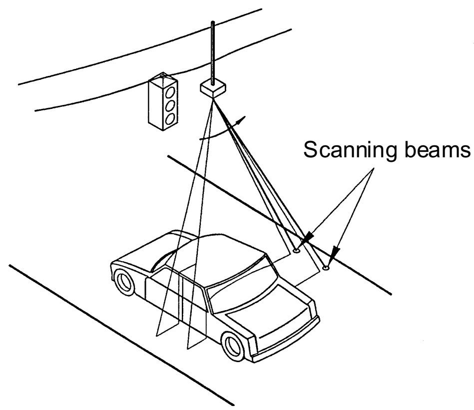


Figure 24. Laser radar beam geometry. (Drawing courtesy of Schwartz Electro-Optics, Orlando, FL).

(a) Autosense II laser radar sensor. (Photograph courtesy of Schwartz Electro-Optics, Orlando, FL).

(b) Traffic observation module (TOM) laser radar sensor. (Photograph courtesy of MBB SensTech, Munich, Germany).

Figure 25. Laser radar sensors.

Passive Infrared Sensors

Passive sensors detect the energy that is emitted from vehicles, road surfaces, other objects in their field of view, and from the atmosphere, but they transmit no energy of their own. Non-imaging passive infrared sensors used in traffic management applications contain one or several (typically not more than five) energy-sensitive detector elements on the focal plane that gather energy from the entire scene. The detector in a non-imaging sensor generally has a large instantaneous field of view. The instantaneous field of view is equal to the angle, e.g. in the x-y plane, subtended by a pixel. Objects within the scene cannot be further divided into sub-objects or pixels (picture elements) with this device.

Imaging sensors, such as modern charge-coupled device (CCD) cameras, contain two-dimensional arrays of detectors, each detector having a small instantaneous field of view. The two-dimensional array gathers energy from the scene over an area corresponding to the field of view of the entire array. Imaging sensors display the pixel-resolution details found in the imaged area.

Principles of Operation

Passive infrared sensors with a single-detection zone, measure volume, lane occupancy, and passage. The source of the energy detected by passive sensors is graybody emission due to the non-zero surface temperature of emissive objects. Graybody emission occurs at all frequencies by objects not at absolute zero (-273.15°C). If the emissivity of the object is perfect, i.e., emissivity = 1, the object is called a blackbody. Most objects have emissivities less than 1 and, hence, are termed graybodies. Passive sensors can be designed to receive emitted energy at any frequency. Cost considerations make the infrared band a good choice for vehicle sensors with a limited number of pixels. Some models, such as the one shown in Figure 26, operate in the long-wavelength infrared band from 8 to 14 μm and thus, minimize the effects of sun glint and changing light intensity from cloud movement.

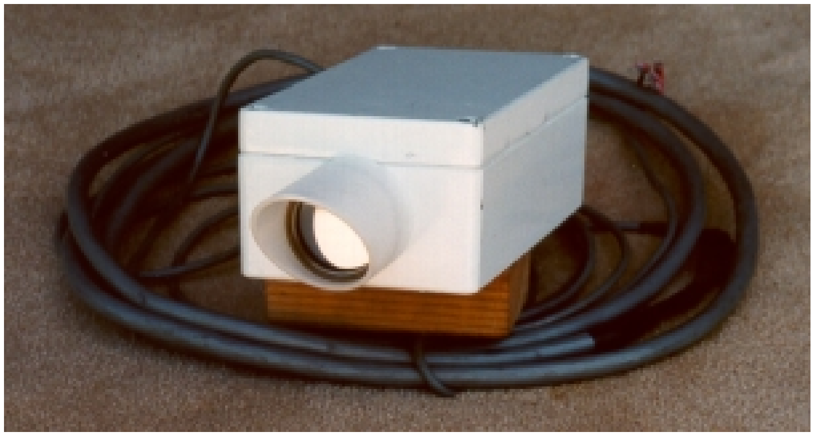


Figure 26. Eltec 842 passive infrared sensor.

When a vehicle enters the sensor s field of view, the change in emitted energy is used to detect the vehicle as illustrated in Figure 27. A vehicle entering the sensor s field of view generates a signal that is proportional to the product of an emissivity difference term and a temperature difference term when the surface temperatures of the vehicle and road are equal. The emissivity term is equal to the difference between the road and the vehicle emissivities. The temperature term is equal to the difference between the absolute temperature of the road surface and the temperature contributed by atmospheric, cosmic, and galactic emission. On overcast, high humidity, and rainy days, the sky temperature is larger than on clear days and the signal produced by a passing vehicle decreases. This, in itself, may not pose a problem to a properly designed passive infrared sensor operating at the longer wavelengths of the infrared spectrum, especially at the relatively short operating ranges typical of traffic management applications (Klein, 2001).

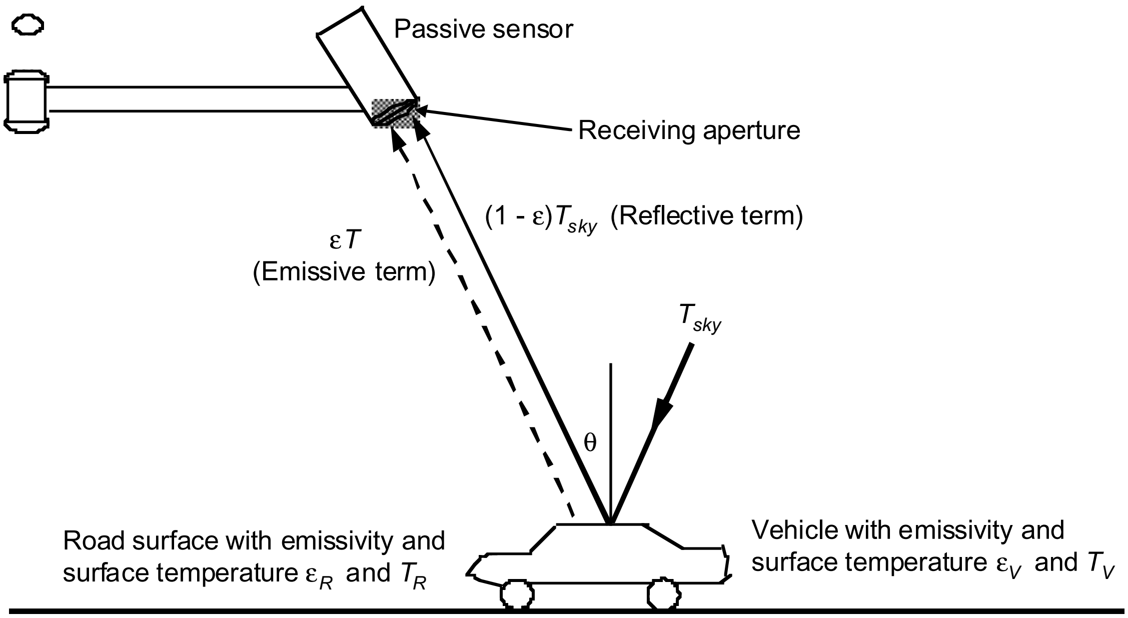


Figure 27. Emission and reflection of energy by vehicle and road surface.

Application and Uses

Multi-channel and multi-zone passive infrared sensors measure speed and vehicle length as well as the more conventional volume and lane occupancy. These models are designed with dynamic and static-thermal energy detection zones that provide the functionality of two inductive loops. Their footprint configuration is shown in Figure 28. The time delays between the signals from the three dynamic zones are used to measure speed. The vehicle presence time from the fourth zone gives the occupancy of stationary and moving vehicles.

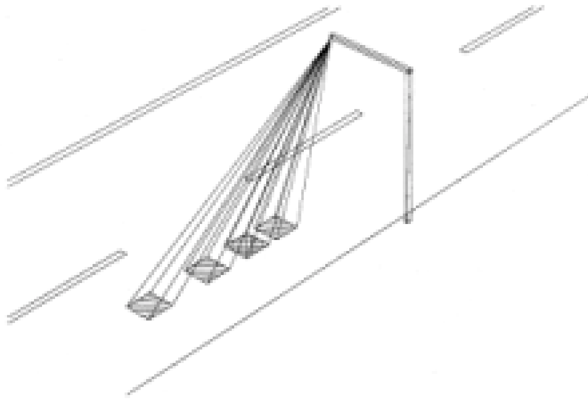


Figure 28. Multiple detection zone configuration in a passive infrared sensor.

Advantages

Installation of infrared sensors does not require an invasive pavement procedure. Some advantages of active infrared sensors are that they transmit multiple beams for accurate measurement of vehicle position, speed and class. Also, multi-zone passive infrared sensors measure speed. Multiple lane presence detection is available in side-looking models.

Disadvantages

Several disadvantages of infrared sensors are sometimes cited. Glint from sunlight may cause unwanted and confusing signals. Atmospheric particulates and inclement weather can scatter or absorb energy that would otherwise reach the focal plane. The scattering and absorption effects are sensitive to water concentrations in fog, haze, rain, and snow as well as to other obscurants such as smoke and dust. At the relatively short operating ranges encountered by infrared sensors in traffic management applications, these concerns may not be significant. However, some performance degradation in rain, freezing rain, and snow has been reported (Kranig, et al., 1997). A rule of thumb for gauging when an infrared sensor may experience difficulty detecting a vehicle is to note if a human observer can see the vehicle under the same circumstances. If the observer can see the vehicle, there is a high probability the infrared sensor will detect the vehicle.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 2/29/00

Manufacturer name: Schwartz Electro Optics	Sales representative name(s): Norman Abramson
Address: 3404 N. Orange Blossom Trail Orlando, FL 32804	Address:
Phone number: (407) 298-1802	Phone number:
Fax number: (407) 298-0144	Fax number:
e-mail address: abramson@seo.com	e-mail address:
URL address: seo.com	URL address:

PRODUCT NAME/MODEL NUMBER: Autosense IIA/19471300

FIRMWARE VERSION/CHIP NO.: 1.05.11

SOFTWARE VERSION NO.: N.A.

GENERAL DESCRIPTION OF EQUIPMENT: Scanning Laser Radar for counting axles and classifying moving vehicles. Detects and classifies vehicles and gives speed, direction, number of axles, camera trigger, distance between axles, tow bar detection and height over axle

SENSOR TECHNOLOGY AND CONFIGURATION: Scanning infrared laser — Two beams with 10 degree separation. Scans 30 degrees with each beam.

SENSOR INSTALLATION: Mounts adjacent to the traffic lane at a height of from 10 to 25 feet

INSTALLATION TIME (Per Lane): Approximately 20 minutes

INSTALLATION REQUIREMENTS: Need Autosense, mounting plate, power cable and signal cable

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: One

PRODUCT CAPABILITIES/FUNCTIONS:
Detection Accuracy: 99.9%
Axle Detection Accuracy 99.7%
Speed Accuracy: 1 mph @ 60 mph

RECOMMENDED APPLICATIONS: Electronic toll collection, traffic data studies, flow measurement, traffic monitoring.

POWER REQUIREMENTS (watts/amps): 35 watts (140 watts with heater)

POWER OPTIONS: 115 or 230 VAC (50-60 Hz)

CLASSIFICATION ALGORITHMS: FHWA 13 Scheme F or customer specified

TELEMETRY: RS-422 (RS-232 optional) serial interface at 19.2, 38.4 or 57.6 K or 1 mbps raw range and intensity data

COMPUTER REQUIREMENTS: 166 MHz, 486 or better

DATA OUTPUT: Fire data messages in normal mode or range and intensity in high-speed mode; data files each day — same as Trafficsense

DATA OUTPUT FORMATS: Binary data files

SUPPORTING DATA BASE MANAGEMENT SYSTEM: N/A

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/Illinois	Bruce Hedlund	(603) 505-8266
USA/New York	Jim Tate	(518) 471-4349
USA/Florida	Peter Zadarlik	(407) 481-9994

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 2/29/00

Manufacturer name: Schwartz Electro Optics	Sales representative name(s): Norman Abramson
Address: 3404 N. Orange Blossom Trail, Orlando, FL 32804	Address:
Phone number: (407) 298-1802	Phone number:
Fax number: (407) 298-0144	Fax number:
e-mail address: abramson@seo.com	e-mail address:
URL address: seo.com	URL address:

PRODUCT NAME/MODEL NUMBER: Autosense III/19401100

FIRMWARE VERSION/CHIP NO.: 1.04.08

SOFTWARE VERSION NO.: N/A

GENERAL DESCRIPTION OF EQUIPMENT: Active infrared overhead vehicle imaging sensor. Detects and classifies vehicles and gives speed, direction, lane position, left and right edge, camera trigger, length, width, height.

SENSOR TECHNOLOGY AND CONFIGURATION: Scanning infrared laser — Two beams with 10 degree separation. Scans 60 degrees for each beam.

SENSOR INSTALLATION: Mounts above multiple traffic lanes at heights from 20 to 35 feet

INSTALLATION TIME (Per Lane): Approximately 1/2 hour

INSTALLATION REQUIREMENTS: Need Autosense, mounting plate, power cable, signal cable

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Three

PRODUCT CAPABILITIES/FUNCTIONS:
Scan rate: 720 scans/sec
Field of regard: 80 degrees
Measures per scan: 90
Scanline separation: 10 degrees
Pixel resolution: 0.67 degrees
Detection Accuracy: 99.99%
Classification Accuracy 99%
Lane position accuracy: 0.67 degrees

RECOMMENDED APPLICATIONS: Multi-lane toll collection, traffic flow measurement, routing studies, traffic monitoring

POWER REQUIREMENTS (watts/amps): 40 watts (160 watts with heaters on)

POWER OPTIONS: 115 VAC or 230 VAC (50 — 60 Hz)

CLASSIFICATION ALGORITHMS: Based on length, width, height and vehicle shape

TELEMETRY: RS-422 (RS 232 optional) serial interface at 19.2, 38.4, or 57.6 K band or 1Mbps

COMPUTER REQUIREMENTS: 166 MHz, 486 or better

DATA OUTPUT: Five data messages in normal mode or range and intensity in high speed mode

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM: N/A

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/Florida	Haitham Al-Deck	(407) 823-2988
The Netherlands	Rune Lende	011-47-905-59-406

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 2/29/00

Manufacturer name:
Schwartz Electro Optics

Address: 3404 N. Orange Blossom Trail
Orlando, FL 32804

Phone number: (407) 298-1802
Fax number: (407) 298-0144
e-mail address: abramson@seo.com
URL address: seo.com

Sales representative name(s):
Norman Abramson

Address:

Phone number:
Fax number:
e-mail address:
URL address:

PRODUCT NAME/MODEL NUMBER: Autosense II/1947100

FIRMWARE VERSION/CHIP NO.: 1.01.XX (Depends on application)

SOFTWARE VERSION NO.: N/A

GENERAL DESCRIPTION OF EQUIPMENT: Active infrared overhead vehicle imaging sensor. Detects and classifies vehicles and gives speed, direction, lane position, left and right edge, camera trigger, length, width, height.

SENSOR TECHNOLOGY AND CONFIGURATION: Scanning infrared laser-two beams with 10 degree separation. Scans 30 degrees for each beam.

SENSOR INSTALLATION: Mounts above center of traffic lane at heights ranging from 20 to 25 feet.

INSTALLATION TIME (Per Lane): Approximately 1 hour

INSTALLATION REQUIREMENTS: Need Autosense, mounting plate, power cable, and signal cable

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: One

PRODUCT CAPABILITIES/FUNCTIONS:
Scan rate: 720 scans / sec; Field of Regard: 30 degrees; Measurements/scan: 30
Scanline separation: 10 degrees; Pixel resolution: 1 degree; Range Accuracy: 3
Detection Accuracy 99.99%
Classification Accuracy: 99%
Lane Position Accuracy: 1 degree

RECOMMENDED APPLICATIONS: Electronic toll collection, traffic management, bridge/tunnel clearance, traffic studies, traffic mounting

POWER REQUIREMENTS (watts/amps): 35 watts (140 watts with heater on)

POWER OPTIONS: 115 VAC or 230 VAC, 50-60 Hz

CLASSIFICATION ALGORITHMS: Based on vehicle length, width, height, and shape.

TELEMETRY: RS-422 (RS 232 optional) serial interface at 129.2, 38.4 or 57.6 K or 1 Mbps raw range and intensity data

COMPUTER REQUIREMENTS: 116 MHz, 486 or better

DATA OUTPUT: Five data messages in normal mode or range and intensity in high-speed mode.

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM: N/A

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
Canada/Ontario	A.J. Mohenred	(905) 265-1733
USA/Florida	Doug Martin	(805) 488-5687
USA/Colorado	Amos Pace	(609) 235-5252
USA/New York	Joe Lipari	(732) 287-8585
USA/California	Sialele Malope	(658) 646-4200
South Korea	Yang-Jong Park	011-02-531-8704
Italy	Stefano Zoppi	011-39-55-420-2322

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 2/29/00

Manufacturer name: Schwartz Electro Optics	Sales representative name(s): Norman Abramson
Address: 3404 N. Orange Blossom Trail, Orlando, FL 32804	Address:
Phone number: (407) 298-1802	Phone number:
Fax number: (407) 298-0144	Fax number:
e-mail address: abramson@seo.com	e-mail address:
URL address: seo.com	URL address:

PRODUCT NAME/MODEL NUMBER: Trafficsense

FIRMWARE VERSION/CHIP NO.: N/A

SOFTWARE VERSION NO.:

GENERAL DESCRIPTION OF EQUIPMENT: Advanced traffic data collection system. Collects traffic data on single and multi-lane highways. Data includes number of vehicles, vehicle class, speed, lane occupancy, headway.

SENSOR TECHNOLOGY AND CONFIGURATION: Scanning infrared laser sensors, data logging computer with wireless modem that connects to the internet

SENSOR INSTALLATION: Sensors mount above traffic lanes at heights from 20 to 35 feet. Computer and modem mount beside traffic lanes in a NEMA enclosure

INSTALLATION TIME (Per Lane): Approximately 2 hours

INSTALLATION REQUIREMENTS: Need Autosense sensors, mounting plates, signal cables, power cables, computer, wireless modem, NEMA enclosure

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Three

PRODUCT CAPABILITIES/FUNCTIONS:
Vehicle Detection Accuracy: 99.9%
Vehicle Classification Accuracy: 99%
Speed Accurcacy: 1 mph at 60 mph

RECOMMENDED APPLICATIONS: Traffic management, traffic monitoring, traffic studies

POWER REQUIREMENTS (watts/amps):
Sensors: 40 watts ead (180 watts with heaters)
Computer and modem: 150 watts

POWER OPTIONS: 115 VAC (230 VAC optional) 50-60 Hz

CLASSIFICATION ALGORITHMS: Eleven vehicle classes based on vehicle length, width, height shape

TELEMETRY: RS-422 from sensors to computers. Web browsing software with access

COMPUTER REQUIREMENTS: 166 MHz, Pentium or better

DATA OUTPUT: Data files for each day. Data summarized at 30 second intervals. Files can be down loaded over internet. Real time traffic data display

DATA OUTPUT FORMATS: Binary data files

SUPPORTING DATA BASE MANAGEMENT SYSTEM: Excel spreadsheet for display and graphing of data

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/Florida	Haitham Al-Deek	(407) 823-2988

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 20 March 2000

Manufacturer name: Infrared Technologies	Sales representative name(s): Carlos Ghigliotty
Address: 608 Washington Blvd., Suite 304 Laurel, MD 20707	Address: 608 Washington Blvd., Suite 304 Laurel, MD 20707
Phone number: (301) 470-4055	Phone number: (301) 470-4055
Fax number:	Fax number: (301) 470-4055
e-mail address:	e-mail address
URL address:	URL address:

PRODUCT NAME/MODEL NUMBER: Video mapping system

FIRMWARE VERSION/CHIP NO.: N/A

SOFTWARE VERSION NO.: N/A

GENERAL DESCRIPTION OF EQUIPMENT:

SENSOR TECHNOLOGY AND CONFIGURATION: Infrared/visible low light cameras integrated into a mapping system

SENSOR INSTALLATION: Inside the light bar or inside the car

INSTALLATION TIME (Per Lane): N/A

INSTALLATION REQUIREMENTS:.N/A

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Two

PRODUCT CAPABILITIES/FUNCTIONS: See literature

RECOMMENDED APPLICATIONS:

POWER REQUIREMENTS (watts/amps): 12V 20 watts

POWER OPTIONS: N/A

CLASSIFICATION ALGORITHMS: N/A

TELEMETRY: Available

COMPUTER REQUIREMENTS: P2 450

DATA OUTPUT: Video RS170 GPS Data

DATA OUTPUT FORMATS: 66A + TV6
RS120 or NTSC

SUPPORTING DATA BASE MANAGEMENT SYSTEM: N/A

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane): N/A

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number

CONTACT INFRARED TECHNOLOGIES FOR CURRENT LIST OF REFERENCES.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: February 2000

Manufacturer name: Eltec Instruments Inc.	Sales representative name(s):
Address: P.O. Box 9610 Daytona Beach, FL 32120-9610	Address:
Phone number: 800 874-7780	Phone number
Fax number (904) 258-3791	Fax number:
e-mail address:	e-mail address: URL address:
URL address:	URL address:

PRODUCT NAME/MODEL NUMBER: Model 862-61 Long Range Passive Infrared Telescope.

FIRMWARE VERSION/CHIP NO.:

SOFTWARE VERSION NO.:

GENERAL DESCRIPTION OF EQUIPMENT: Long range vehicle or personnel detection (500 ft.)

SENSOR TECHNOLOGY AND CONFIGURATION: Thermal infrared weatherproof tube.

SENSOR INSTALLATION: Overhead pole, mastarm, bridge, building wall.

INSTALLATION TIME (Per Lane): Install bracket and run wire, point to aim

INSTALLATION REQUIREMENTS: Table (non-swaying) structure

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY:

PRODUCT CAPABILITIES/FUNCTIONS: Upstream vehicle detection for traffic signal stretch. Range greater than 500 ft. for vehicles. Primarily designed for intrusion detection or signaling alert if vehicle enters forbidden zone (e.g. prior to blasting).

RECOMMENDED APPLICATIONS: Signal control at temporary construction sites, temporary replacement of failed lop detectors, side street demand only signal control.

POWER REQUIREMENTS (watts/amps): 10.5 to 28 VDC @ 75 MA max

POWER OPTIONS:

CLASSIFICATION ALGORITHMS:

TELEMETRY:

COMPUTER REQUIREMENTS:

DATA OUTPUT: Presence

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number

CONTACT ELTEC INSTRUMENTS FOR COMPLETE LIST OF REFERENCES.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: January 2000

Manufacturer name: Eltec Instruments Inc.	Sales representative name(s):
Address: P.O. Box 9610 Daytona Beach, FL 32120-9610	Address:
Phone number: 800 874-7780	Phone number
Fax number (904) 258-3791	Fax number:
e-mail address:	e-mail address:
URL address:	URL address:

PRODUCT NAME/MODEL NUMBER: Model 833 Passive Infrared Traffic Monitor

FIRMWARE VERSION/CHIP NO.:

SOFTWARE VERSION NO.:

GENERAL DESCRIPTION OF EQUIPMENT: Small optical vehicle detector

SENSOR TECHNOLOGY AND CONFIGURATION: Thermal infrared moving vehicle detector in weatherproof aluminum case.

SENSOR INSTALLATION: Overhead/pole or mast arm mount or bridge.

INSTALLATION TIME (Per Lane): Attach bracket and run wire

INSTALLATION REQUIREMENTS: Pole or mastarm

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: One

PRODUCT CAPABILITIES/FUNCTIONS: Traffic counting at highway or city speeds. Will not interfere with any other equipment (totally passive).

RECOMMENDED APPLICATIONS: Highway vehicle counting

POWER REQUIREMENTS (watts/amps): 115 VAC @ 2W max

POWER OPTIONS: 230 VAC @ 2W or 12VDC @ 22 MA max

CLASSIFICATION ALGORITHMS:

TELEMETRY:

COMPUTER REQUIREMENTS:

DATA OUTPUT: Presence

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number

CONTACT ELTEC INSTRUMENTS FOR CURRENT LIST OF REFERENCES.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: January 2000

Manufacturer name: Eltec Instruments Inc.	Sales representative name(s):
Address: P.O. Box 9610, Daytona Beach, FL 32120-9610	Address:
Phone number: 800 874-7780	Phone number
Fax number (904) 258-3791	Fax number:
e-mail address:	e-mail address
URL address:	URL address:

PRODUCT NAME/MODEL NUMBER: Model 842 Overhead Vehicle Presence Sensor

FIRMWARE VERSION/CHIP NO.:

SOFTWARE VERSION NO.:

GENERAL DESCRIPTION OF EQUIPMENT: Small, self-contained optical (mount and aim) sensor with relay output for vehicle presence detection.

SENSOR TECHNOLOGY AND CONFIGURATION: Passive thermal infrared sensor technology, overhead mount (pole/mast arm) configuration.

SENSOR INSTALLATION: Overhead/pole or mast arm mount, aimed at lane to be monitored.

INSTALLATION TIME (Per Lane): Attach bracket and run wire

INSTALLATION REQUIREMENTS: Pole or mastarm

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: One lane (ideal)

PRODUCT CAPABILITIES/FUNCTIONS: Vehicle presence sensor with relay output. (Multiple units at installation will not interfere with each other; device operation cannot interfere with radios or other electronic equipment).

RECOMMENDED APPLICATIONS: Signal control at temporary construction sites, temporary replacement of failed lop detectors, side street demand only signal control.

POWER REQUIREMENTS (watts/amps): 10.0 watts max. @120 VAC

POWER OPTIONS: 240 VAC, optional

CLASSIFICATION ALGORITHMS: N/A

TELEMETRY: N/A

COMPUTER REQUIREMENTS: N/A

DATA OUTPUT:

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/Florida		
USA/California		
USA/North Carolina		

Ultrasonic Sensors

Principles of Operation

Ultrasonic sensors transmit pressure waves of sound energy at a frequency between 25 and 50 KHz, which are above the human audible range. Most ultrasonic sensors, such as the model shown in Figure 29, operate with pulse waveforms and provide vehicle count, presence, and occupancy information. Pulse waveforms measure distances to the road surface and vehicle surface by detecting the portion of the transmitted energy that is reflected towards the sensor from an area defined by the transmitter s beamwidth. When a distance other than that to the background road surface is measured, the sensor interprets that measurement as the presence of a vehicle. The received ultrasonic energy is converted into electrical energy that is analyzed by signal processing electronics that is either collocated with the transducer or placed in a roadside controller.

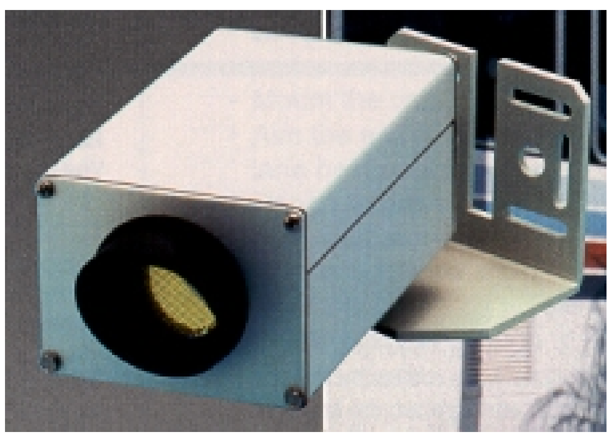


Figure 29. TC-30C ultrasonic range-measuring sensor. (Photograph courtesy of Microwave Sensors, Ann Arbor, MI).

Application and Uses

Pulse energy transmitted at two known and closely spaced incident angles allows vehicular speed to be calculated by recording the time at which the vehicle crosses each beam. Since the beams are a known distance apart, the speed is given by Eq. (6). Constant frequency ultrasonic sensors that measure speed using the Doppler principle are also manufactured. However, these are more expensive than pulse models.

The preferred mounting configurations for range-measuring, pulsed ultrasonic sensors are downward looking and side viewing as shown in Figure 30. The range-measuring ultrasonic sensor transmits a series of pulses of width T_p (typical values are between 0.02 and 2.5 ms) and repetition period T_0 (time between bursts of pulses), typically 33 to 170 ms. The sensor measures the time it takes for the pulse to arrive at the vehicle and return to the transmitter. The receiver is gated on and off with a user-adjustable interval that helps to differentiate between pulses reflected from the road surface and those reflected from vehicles. The detection gate is adjusted to detect an object at a distance greater than approximately 0.5 m above the road surface.

Automatic pulse-repetition frequency control reduces effects of multiple reflections and improves the detection of high-speed vehicles. This control is implemented by making the pulse repetition period as short as possible by transmitting the next pulse immediately after the reflected signal from the road is received (Kumagai, et al., 1992). A hold time T_h (composite values from manufacturers range from 115 ms to 10 s) is built into the sensors to enhance presence detection.

Advantages

Installation of ultrasonic sensors does not require an invasive pavement procedure. Also, some models feature multiple lane operation.

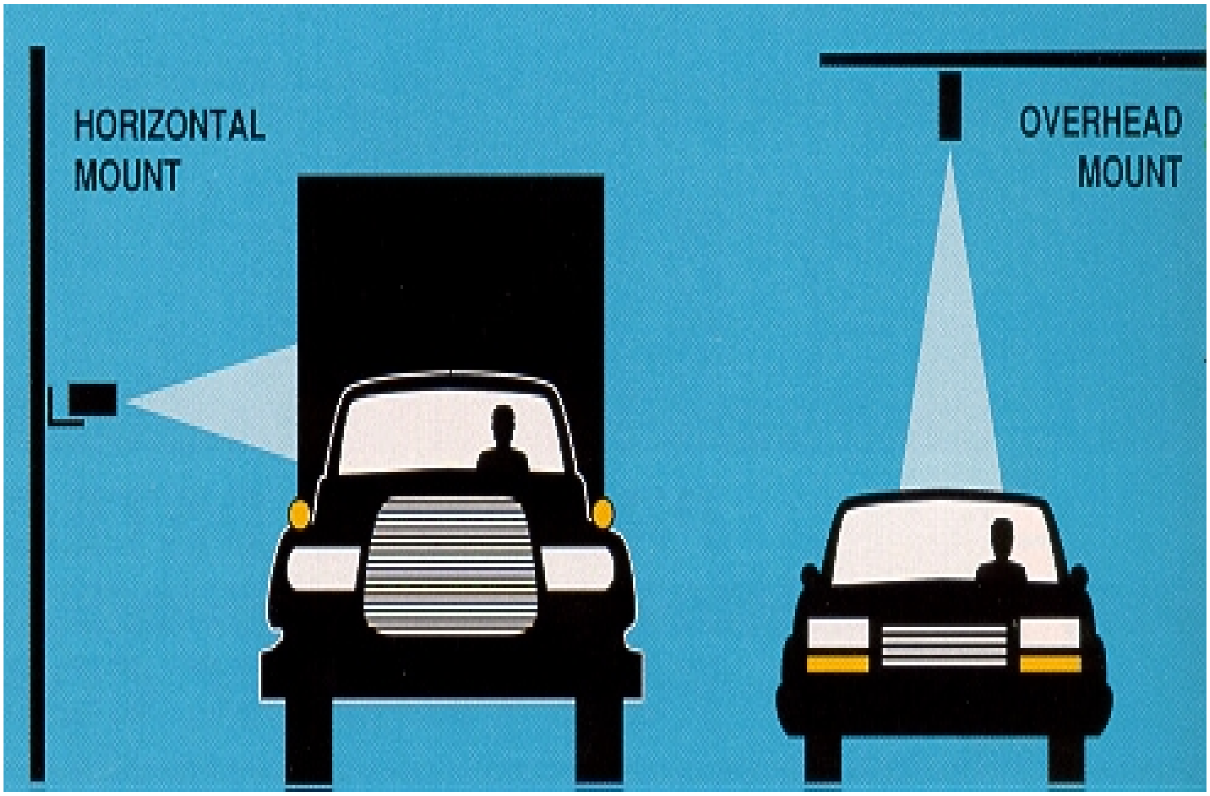


Figure 30. Mounting of ultrasonic range-measuring sensors. (Courtesy of Microwave Sensors, Ann Arbor, MI).

Disadvantages

Temperature change and extreme air turbulence may affect the performance of ultrasonic sensors. Temperature compensation is built into some models. Large pulse repetition periods may degrade occupancy measurement on freeways with vehicles traveling at moderate to high speeds.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: 2/29/00

Manufacturer name: Sumitomo Electric.	Sales representative name(s): Takehiko Barada
Address: 1-1-3 Shimaya Konohana-ku, Osaka 554-0024 Japan	Address: 3235 Kifer Road Suite 150 Santa Clara, CA 95051
Phone number: +81 6-6461-1031	Phone number: (408) 737-8517
Fax number: +81 6-6466-3305	Fax number: (408) 737-0134
e-mail address: www@prs.sei.co.jp	e-mail address: barada@sumitomo.com
URL address: www.sel.co.jp	URL address: www.sumitomo.com/its/

PRODUCT NAME/MODEL NUMBER: SDU-420

FIRMWARE VERSION/CHIP NO.: N/A

SOFTWARE VERSION NO.: N/A

GENERAL DESCRIPTION OF EQUIPMENT: Ultrasonic Vehicle Detector

SENSOR TECHNOLOGY AND CONFIGURATION: Ultrasound

SENSOR INSTALLATION: Overhead

INSTALLATION TIME (Per Lane):

INSTALLATION REQUIREMENTS: Pole arm

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: One lane/head

PRODUCT CAPABILITIES/FUNCTIONS: Presence, occupancy, classification (two)

RECOMMENDED APPLICATIONS: Advanced traffic signal control, freeway monitoring,

POWER REQUIREMENTS (watts/amps): 160 va
POWER OPTIONS: N/A

CLASSIFICATION ALGORITHMS: Vehicle height

TELEMETRY: N/A

COMPUTER REQUIREMENTS: NO

DATA OUTPUT: NEMA TS1, custom

DATA OUTPUT FORMATS: N/A

SUPPORTING DATA BASE MANAGEMENT SYSTEM: N/A

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):
Approx. $1,900/one lane & installation cost

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
Japan		

Passive Acoustic Array Sensors

Acoustic sensors measure vehicle passage, presence, and speed by detecting acoustic energy or audible sounds produced by vehicular traffic from a variety of sources within each vehicle and from the interaction of a vehicle s tires with the road. When a vehicle passes through the detection zone, an increase in sound energy is recognized by the signal-processing algorithm and a vehicle presence signal is generated. When the vehicle leaves the detection zone, the sound energy level drops below the detection threshold and the vehicle presence signal is terminated. Sounds from locations outside the detection zone are attenuated.

Principles of Operation

Two models of acoustic sensors are marketed. Both detect the sounds produced by approaching vehicles with a two-dimensional array of microphones. The SmartSonic acoustic sensor shown on the left in Figure 31 detects vehicles by measuring the time delay between the arrival of sound at the upper and lower microphones, which are arranged in a vertical and horizontal line through the center of the aperture. The time delay changes as the vehicle approaches the array. When the vehicle is inside the detection zone, the sound arrives almost instantaneously at the upper and lower microphones. When the vehicle is outside the detection zone, sound reception at the upper microphone is delayed by the intermicrophone distance. The size and shape of the detection zone are determined by the aperture size, processing frequency band, and installation geometry of the acoustic array. The SmartSonic sensor is tuned to a center frequency of 9 KHz with a 2 KHz bandwidth. Preferred mounting is at 10 to 30 degrees from nadir with a detection range of 20 to 35 ft (6 to 11 m).

Application and Uses

The speed of a detected vehicle is determined with an algorithm that assumes an average vehicle length. Vehicle presence detection is through an optically isolated semiconductor. When the optional acoustic sensor controller board is installed in a NEMA or 170 cardfile, two detection zones can be used in a speed trap mode to measure vehicle speed. The speed trap activates relay outputs that simulate two inductive loops connected to a NEMA or 170 controller. The SmartSonic is recommended for data collection applications on bridges and other roads where non-intrusive sensors are required and where slow moving vehicles in stop and go traffic flow are not present.

The SAS-1 acoustic sensor on the right in Figure 31 uses a fully populated microphone array and adaptive spatial processing to form multiple zones that receive the acoustic energy from up to 6 to 7 lanes when the sensor is mounted over the center of the roadway. Five lanes are the practical limit for the side-mounting configuration. During setup, the detection zones are steered to positions that correspond to the monitored traffic lanes. The detection zones are self normalized and polled for vehicles every 8 minutes. The detection zone is equivalent to that of a 6-ft inductive loop in the direction of traffic flow and is user selectable in the cross-lane direction.

SmartSonic acoustic sensor. (Photograph courtesy of IRD, Saskatoon, SK)

SAS-1 acoustic sensor. (Photograph courtesy of SmarTek Systems, Woodbridge, VA)

Figure 31. Acoustic array sensors.

Acoustic frequencies between 8 and 15 KHz are processed by this sensor, which accommodates mounting heights between 20 and 40 ft (6 to 12 m). The output data are volume, lane occupancy, and average speed for each monitored lane over a user-specified period (e.g., 20s, 30s, 1 min). Vehicle presence is provided by an optional relay interface.

Advantages

Installation of passive acoustic array sensors does not require and invasive pavement procedure. Acoustic sensors are insensitive to precipitation and multiple lane operation is available in some models.

Disadvantages

Cold temperatures have been reported as affecting the accuracy of the data from acoustic sensors. Also, specific models are not recommended with slow moving vehicles in stop and go traffic.

MANUFACTURER AND VENDOR INFORMATION

Effective Date: March 22, 2000

Manufacturer name: International Road Dynamics, Inc.

Address: 702 43rd Street East
Saskatoon SK, S7K 3T9 Canada

Phone number: 306-653-6600
Fax number: 306-242-5599
e-mail address: info@irdinc.com
URL address: www.irdinc.com

Sales representative name(s): Rod Klashinsky

Address:

Phone number:
Fax number:
e-mail address:
URL address:

PRODUCT NAME/MODEL NUMBER: IRD SmartSonic™ Vehicle Detection System

FIRMWARE VERSION/CHIP NO.: NA

SOFTWARE VERSION NO.: NA

GENERAL DESCRIPTION OF EQUIPMENT: The IRD Smartsonic™ Vehicle Detection System is based on acoustic-sensing and signal processing technologies. The SmartSonic™ sensors are mounted non-intrusively above or beside roadways on existing structures such as bridges, overhead traffic signs or light poles. Structures may be installed specifically to mount the sensors if required. IRD SmartSonic™ Vehicle Detection Systems are ideal for detection of vehicles on roadways where lane closure is not an option.

SENSOR TECHNOLOGY AND CONFIGURATION: SmartSonic™ detectors are acoustic-sensing technology for vehicle detection. A single detector provides vehicle detection per lane.

SENSOR INSTALLATION: Sensors may be installed above or beside roadways using existing structures or specifically installed structures.

INSTALLATION TIME (Per Lane): Typically 4 hours.

INSTALLATION REQUIREMENTS: Please see attached product information for details.

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Four (4) SmartSonic" sensors can interface to a single SmartSonic^{TM} controller to monitor 4 lanes.

PRODUCT CAPABILITIES/FUNCTIONS: Vehicle detection, Traffic counting, Occupancy Counts per lane of Traffic.

RECOMMENDED APPLICATIONS: Vehicle detection, Traffic counting, Occupancy Counts per lane of traffic in free-flow traffic at speeds of more than 30 MPH.

POWER REQUIREMENTS (watts/amps): 12-24 VDC

POWER OPTIONS: DC or solar.

CLASSIFICATION ALGORITHMS: Up to 3 classes.

TELEMETRY: Yes

COMPUTER REQUIREMENTS: A laptop computer may be used for information retrieval with serial communication software such as HyperTerminal.

DATA OUTPUT: Serial or contact closure.

DATA OUTPUT FORMATS: ASCII

SUPPORTING DATA BASE MANAGEMENT SYSTEM: NA

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):
1-lane: $ 4,000 US
4-lane: $ 12,000 US

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/Massachusetts		
USA/Texas		
USA/Arizona		

MANUFACTURER AND VENDOR INFORMATION

Effective Date: August 1, 2000

Manufacturer name: SmarTek Systems

Address: 14710 Kogan Drive
Woodbridge, VA 22193

Phone number: (703) 680-6554
Fax number:
e-mail address:
URL address:

Sales representative name(s):
Greg Pieper

Address: 295 Waycross Way
Arnold, MD 21072

Phone number: (410) 315-9727
Fax number: (410) 384-9264
e-mail address: sales@smarteksys.com
URL address: www.smarteksys.com

PRODUCT NAME/MODEL NUMBER: SAS-1

FIRMWARE VERSION/CHIP NO.:

SOFTWARE VERSION NO.: Revision 20

GENERAL DESCRIPTION OF EQUIPMENT: A passive acoustic, multilane, side fire vehicle detector/counter

SENSOR TECHNOLOGY AND CONFIGURATION: Passive acoustic

SENSOR INSTALLATION: Side Fire

INSTALLATION TIME (Per Lane): 5 minutes

INSTALLATION REQUIREMENTS: Pole mount; bucket truck

MAXIMUM NUMBER OF LANES MONITORED SIMULTANEOUSLY: Five

PRODUCT CAPABILITIES/FUNCTIONS: True presence, traffic count (volume), speed (average and per vehicle), lane occupancy, 15 — 60 day data storage (dependent on memory version)

RECOMMENDED APPLICATIONS: Traffic monitoring of highways, etc

POWER REQUIREMENTS (watts/amps):

POWER OPTIONS:

CLASSIFICATION ALGORITHMS:

TELEMETRY:

COMPUTER REQUIREMENTS:

DATA OUTPUT: See capabilities/functions

DATA OUTPUT FORMATS:

SUPPORTING DATA BASE MANAGEMENT SYSTEM:

EQUIPMENT AND INSTALLATION COSTS (One-lane and four-lane):

STATES CURRENTLY USING THIS EQUIPMENT:

Country/State	Contact name	Telephone number
USA/Arizona	Tim Wolf	(602) 712-6622
USA/Arizona	Glenn Jonas	(602) 712-6587
USA/California	Edward Fok	(213) 485-8609
USA/Idaho	Jim Larsen	(208) 387-6197
USA/Virginia	Cyndi Ward	(804) 692-0390
USA/Virginia	Mr. Stephany Hanshaw	(757) 464-9907
USA/New York	Bill Platt	(607) 324-8412

Chapter 6 - References

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APPENDIX A (hardcopy only):

Vendor/Manufacturer Database
Vendor Survey (Blank)
Vendor Form Letter