“State-of-the-Art” Report on Non-Traditional Traffic Counting Methods

FINAL REPORT 503

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16. Abstract

The purpose of this report is to look at the state-of-the-art of non-traditional traffic counting methods. This is done through a three-fold approach that includes an assessment of currently available technology, a survey of State Department of Transportation practices, and a review of the literature.

Traditional traffic counting has utilized intrusive devices including bending plate, pneumatic road tube, inductive loops, and piezo-electric sensors. As safety, cost, increased traffic flow, complex road geometrics, and traffic disruption have become issues of concern, traffic counting professionals are looking more closely at alternatives to traditional methods of data collection. Such non-traditional traffic counting devices as video image detection, Doppler microwave, passive magnetic, passive acoustic, active and passive infrared, and active and passive ultrasonic are being considered due to their non-intrusive nature.

Information on available technology including cost, installation requirements, technical specifications, data retrieval, and limitations of the products are addressed. This information is followed by a summary of State practices that shows very limited usage of non-intrusive technology. Lastly, a review of the literature indicates there is little in the way of "new" technology. However, several evaluations of non-intrusive devices provide valuable information to traffic counting professionals that will assist in decision-making regarding upgrades to current practices.

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METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	2.54	centimeters	cm
ft	feet	0.3048	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	6.452	centimeters squared	cm^2
ft^2	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.395	hectares	ha
		MASS (weight)		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		VOLUME		
fl oz	fluid ounces	29.57	millimeters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0328	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

Note: Volumes greater than 1000 L shall be shown in m^3.

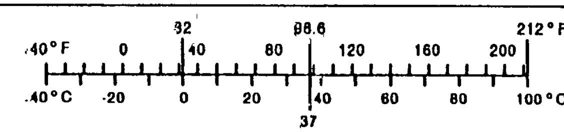
Symbol	When You Know	Multiply By	To Find	Symbol
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

These factors conform to the requirement of FHWA Order 5190.1A

*SI is the symbol for the International System of Measurements

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
yd	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
yd^2	kilometers squared	0.39	square miles	mi^2
ha	hectares (10,000 m^2)	2.53	acres	ac
		MASS (weight)		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME		
mL	millimeters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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EXECUTIVE SUMMARY

Any State using traffic data for the apportionment or allocation of Federal funds must have a traffic monitoring system that meets Federal Highway Administration requirements. As part of a traffic monitoring program, States are required to gather vehicle count, classification, and weight data. Since participation in federally funded programs is essential to the integrity of a State's highway systems, the accurate, efficient collection of traffic data becomes a critical component of transportation infrastructure management. This report looks at the state-of-the-art of non-traditional traffic counting methods to facilitate informed decision making regarding changes to existing practices.

The report is comprised of three sections—an evaluation of current technology, a survey of State Departments of Transportation (DOT) traffic counting practices, and a literature review. The evaluation of current technology was conducted through interviews with over fifty manufacturers of traffic counting devices as well as a review of the literature on existing technology. The survey of State DOTs involved sending a two-page survey to each of the fifty agencies requesting information on level of satisfaction with devices currently in use, disadvantages of the technology, manufacturer information, and data gathered using each device. Lastly, a literature review of new technology was conducted to uncover new trends in traffic counting practices.

Two main categories were identified—intrusive and non-intrusive data collection devices. Intrusive devices are those that involve placement of the sensor technology on top of or into the lane of traffic being monitored. Conversely, non-intrusive devices do not interfere with traffic flow either during installation or operation. The information gathered was differentiated into one of these two categories.

The type of traffic data collection devices available on the market has changed little in the past decade. The same thirteen technologies are still being utilized by State, county, city, and metropolitan organizations responsible for traffic monitoring operations. However, the devices have evolved as their use has come under greater scrutiny with the recent focus on "intelligent transportation systems." Such non-traditional technology as video image detection, Doppler microwave, passive magnetic, passive acoustic, active and passive ultrasonic, and active and passive infrared technology now are being used with increased frequency for data collection and traffic management.

The second section of the report deals with the Arizona Department of Transportation Traffic Counting Survey. All fifty States submitted responses to the survey. The results showed that less than half of all States are using non-intrusive (non-traditional) methods for gathering traffic data. Although the level of satisfaction with intrusive devices is relatively high, there is pressure to find methods of data collection that will keep traffic counting professionals out of the lanes of traffic. A few manufacturers were identified as leaders in the industry with current technology. It is yet to be seen if they will continue to lead as the move toward non-intrusive technologies begins to dominate the marketplace.

The last section of the report contains a review of the literature on emerging technology. There is little in the way of new devices; however, the information uncovered relates to improvements in existing technology. Manufacturers are looking toward “signatures” to improve on the accuracy of vehicle classification. This pattern matching technology is being used with inductive loops and passive acoustic devices to improve on current technology. Neural network software is able to use the unique characteristics of a vehicle designated as a “signature” to more accurately classify a vehicle even beyond the Federal Highway Administration’s thirteen classes. Piezo-electric sensors also have evolved with advances in the material used as the force transducer. Quartz materials, being highly insulated, are being employed to improve on the collection of weight-in-motion data.

New technology is followed by a review of recent research on evaluations of non-intrusive traffic data collection devices. Studies have been conducted by organizations involved the transportation industry including the Federal Highway Administration, State DOTs, universities, and private industry in an effort to determine if the newer non-intrusive technologies are capable of more cost-effectively collecting reliable traffic data. The studies show promising results from the non-intrusive technologies but continued research and development is needed to provide appropriate documentation to convince traffic counting professional that a transition to new technology is in their best interest.

In summary, the collection of accurate traffic data in a cost-effective manner is essential to the allocation of scarce resources needed to support an aging infrastructure. The pressure to move the industry forward will provide the impetus for manufacturers to continue to develop the newer non-intrusive technologies and show they can meet the stringent requirements set forth by today’s traffic counting professionals.

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this research project is to examine current state-of-the-art non-traditional traffic counting practices throughout the transportation industry. This information was gathered through interviews with manufacturers of existing technology and review of the literature. In addition, traffic counting professionals from state departments of transportation were surveyed to obtain information on their current practices and level of satisfaction with the systems they have in place. This report summarizes the information gathered and will be used during the decision making process involving the feasibility and cost effectiveness of improvements in Arizona Department of Transportation's current traffic counting practices.

1.2 BACKGROUND

The Federal-Aid Policy Guide established by the Federal Highway Administration mandates "requirements for development, establishment, implementation, and continued operation of a traffic monitoring system for highways and public transportation facilities and equipment in each State." Subchapter F of the Federal-Aid Policy Guide outlines general requirements for compliance with this policy. States must comply with these requirements when traffic data generated by the state are used for the following purposes:

- Traffic data are used in support of studies or systems which are the responsibility of the U.S. Department of Transportation;
- Collection of traffic data is supported by the use of Federal funds;
- Traffic data are used in the apportionment or allocation of Federal funds;
- Traffic data are used in design or construction of an FHWA funded project; or
- Traffic data are required as part of a federally mandated program.

A State's traffic monitoring procedures also apply to the "activities of local governments and other public or private non-State government entities collecting highway traffic data within the State" if the data are used for any of the purposes described above. Since participation in federally-funded programs is essential to the integrity of a State's highway systems, the accurate, efficient collection of traffic data becomes a critical component of transportation infrastructure management.

As part of a traffic monitoring system, States are required to record traffic volumes, vehicle classification, and vehicle weight data. This information is collected at short-term counting stations and at long-term, continuous counting stations. Short-term counts are then adjusted for seasonal, day-of-the-week, and other factors as assessed at continuous count stations to provide estimates of traffic patterns throughout the State's highway infrastructure. This information provides documentation to ensure the State receives appropriate levels of federal funding to maintain or expand its highway system. It also aids in the design of highway improvement projects.

Decisions made regarding upgrades to traffic counting practices should be based on accurate, up-to-date information. This report summarizes the current state-of-the-art in traffic enumeration devices to facilitate this decision making process.

1.3 PROJECT OVERVIEW

This report is comprised of three components—an evaluation of current technology, a literature review, and a survey of State Department of Transportation (DOT) practices. The first section summarizes information supplied by manufacturers of devices used to collect count, speed, classification, and/or weight-in-motion data. Each manufacturer was asked to provide information regarding sensor technology, applications, classification algorithm, lane-monitoring capability, price, installation requirements, telemetry, calibration, power requirements, temperature requirements, and limitations of the system for each product.

The second section contains the results of the Traffic Counting Survey circulated to the fifty State DOTs. Results were compiled in an Access database and summarized into tables for display in this report. The survey is included as Appendix A. Individual results from each state are included in Appendix B.

The last section contains information gathered through a review of books, journals, Internet websites, and interviews with traffic counting professionals. Due to rapid advances in the area of traffic management, the review was limited to information from the past five years. A bibliography of relevant journal articles and websites dealing with traffic counting devices and transportation technology is included as Appendices C and D.

2.0 CURRENT TRAFFIC DATA COLLECTION TECHNOLOGY

2.1 PRODUCT CLASSIFICATION

There are two main categories into which equipment for collecting traffic data can be placed—intrusive and non-intrusive devices. Intrusive (traditional) counting devices are those that involve placement of the sensor technology on top of or into the lane of traffic being monitored. They represent the most common devices used today including inductive loops, piezo-electric sensors and pneumatic rubber road tubes. Conversely, non-intrusive (non-traditional) counting devices such as passive acoustic and video image detection do not interfere with traffic flow either during installation or operation.

Within these two broad categories, thirteen different technologies were identified for classifying devices used for recording traffic data. The collection of count, speed, class, and weight-in-motion (WIM) data are the focus for this report.

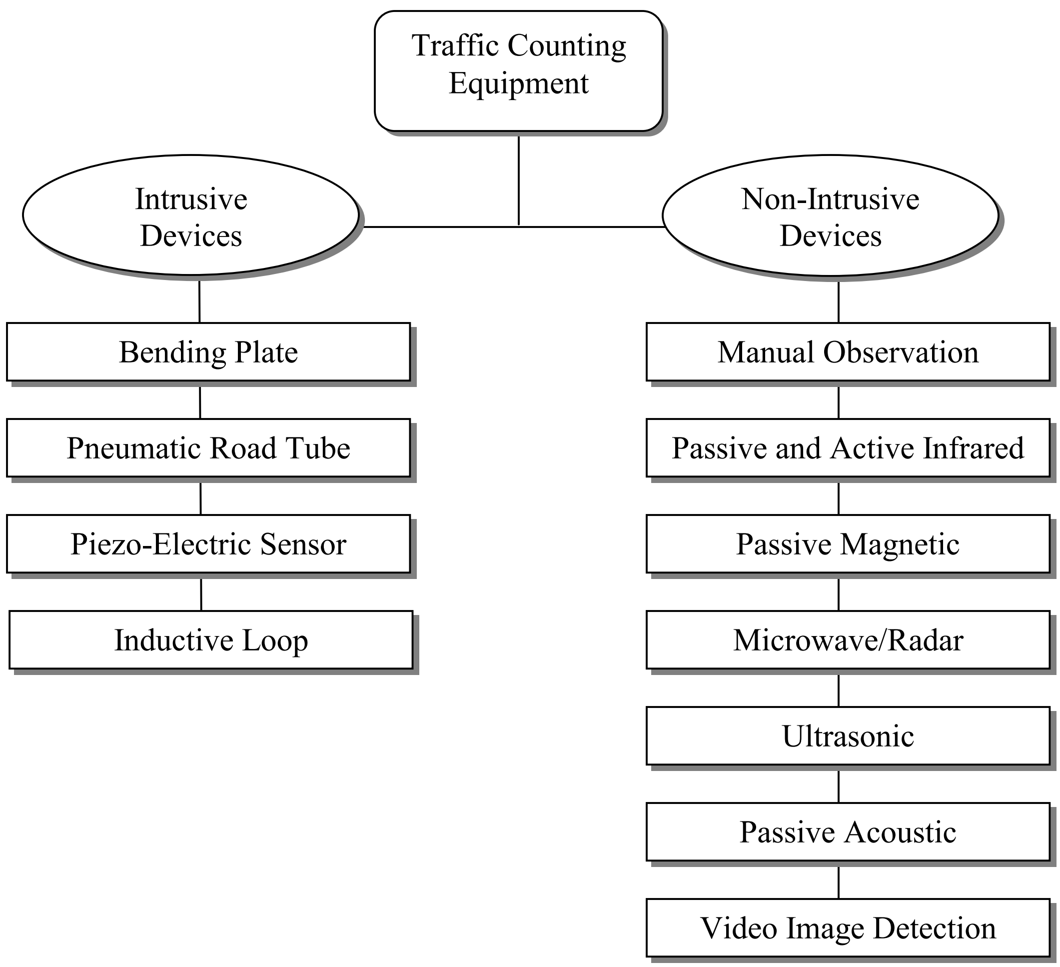

Figure 1. Product Classification

A definition of each category, as used for purposes of this report, is listed below

INTRUSIVE DEVICES

2.1.1 Bending Plate

Bending plate technology is most frequently used for collecting weight-in-motion data. The device typically consists of a weigh pad attached to a metal frame installed into the travel lane. A vehicle passes over the metal frame causing it to slightly “bend.” Strain gauge weighing elements measure the strain on the metal plate induced by the vehicle passing over it. This yields a weight based on wheel/axle loads on each of two scales installed in a lane. The devices also is used to obtain classification and speed data.

2.1.2 Pneumatic Road Tube

A pneumatic road tube is a hollow rubber tube placed across the roadway that is used to detect vehicles by the change in air pressure generated when a vehicle tire passes over the tube. A device attached to the road tubes is placed at the roadside to record the change in pressure as a vehicle axle. Axle counts can be converted to count, speed, and/or classification depending on how the road tube configuration is structured.

2.1.3 Piezo-Electric Sensor

Piezo-electric sensors are mounted in a groove that is cut into the roadway surface within the traffic lane. The sensors gather data by converting mechanical energy into electrical energy. Mechanical deformation of the piezo-electric material causes a change in the surface charge density of the material so that a change in voltage appears between the electrodes. The amplitude and frequency of the signal is directly proportional to the degree of deformation. When the force of the vehicle axle is removed, the output voltage is of opposite polarity. The change in polarity results in an alternating output voltage. This change in voltage can be used to detect and record vehicle count and classification, weight-in-motion and speed. [1]

2.1.4 Inductive Loop

An inductive loop is a wire embedded into or under the roadway in roughly a square configuration. The loop utilizes the principle that a magnetic field introduced near an electrical conductor causes an electrical current to be induced. In the case of traffic monitoring, a large metal vehicle acts as the magnetic field and the inductive loop as the electrical conductor. A device at the roadside records the signals generated. [2]

NON-INTRUSIVE DEVICES

2.1.5 Manual Observation

Manual observation involves detection of vehicles with the human eye and hand recording count and/or classification information. Hand-held devices are available for on-site recording of information gathered by one or more individuals observing traffic.

2.1.6 Passive and Active Infrared

Passive infrared devices detect the presence of vehicles by measuring the infrared energy radiating from the detection zone. A vehicle will always have a temperature contrast to the background environment. The infrared energy naturally emanating from the road surface is compared to the energy radiating when a vehicle is present. Since the roadway may generate either more or less radiation than a vehicle, the contrast in heat energy is detected. The possibility of interference with other devices is minimized because the technology is completely passive. Passive infrared detectors are typically mounted directly over the lane of traffic on a gantry, overpass or bridge or alternatively on a pole at the roadside.

Active infrared devices emit a laser beam at the road surface and measure the time for the reflected signal to return to the device. When a vehicle moves into the path of the laser beam the time it takes for the signal to return is reduced. The reduction in time indicates the presence of a vehicle. The mounting position for active infrared detectors is more variable. The Autosense devices from Schwartz Electro-Optics, Inc. are mounted over the lane(s) of traffic to be monitored or in a side-fire mount perpendicular to the lane of traffic. There also are portable, devices that are placed roadside so the laser beams are directed parallel to the road surface across the lane of traffic. Both active and passive infrared devices can be used to record count, speed, and classification data.

2.1.7 Passive Magnetic

Passive magnetic devices detect the disruption in the earth’s natural magnetic field caused by the movement of a vehicle through the detection area. In order to detect this change the device must be relatively close to the vehicles. This limits most applications to installation under or on top of the pavement, although some testing has been done with side fire devices in locations where they can be mounted within a few feet of the roadway. Magnetic sensors can be used to collect count, speed, and classification data.

2.1.8 Microwave - Doppler/Radar

Doppler microwave detection devices transmit a continuous signal of low-energy microwave radiation at a target area on the pavement and then analyze the signal reflected back. The detector registers a change in the frequency of waves occurring when the microwave source and the vehicle are in motion relative to one another. According to the Doppler principle, when a moving object reflects the radar beam emitted from the detector, the frequency of the reflected wave is changed proportionally to the speed of the reflecting object. This allows the device to detect moving vehicles and determine their speed. The only sensors identified using Doppler microwave are produced by Microwave Sensors, Inc. and are used primarily as a detection device designed to trigger operation of a traffic controller. In this capacity, they are placed in an overhead mounting position.

Radar (**ra**dio **d**etecting **a**nd **r**anging) is capable of detecting distant objects and determining their position and speed of movement. With vehicle detection, a device directs high frequency radio waves, either a pulsed, frequency-modulated or phase-modulated signal, at the roadway to determine the time delay of the return signal, thereby calculating the distance to the detected vehicle. Radar devices are capable of sensing the presence of stationary vehicles. They are insensitive to weather and provide day and night operation. The device is placed in a side-fire mount off the shoulder of the roadway. This technology is capable of recording count, speed, and classification data.

2.1.9 Ultrasonic and Passive Acoustic

Ultrasonic devices emit pulses of ultrasonic sound energy and measure the time for the signal to return to the device. The sound energy hits a passing vehicle and is reflected back to the detection device. The return of the sound energy in less time than the normal road surface background is used to indicate the presence of a vehicle. Ultrasonic sensors are generally placed over the lane of traffic to be monitored.

Passive acoustic devices utilize sound waves in a somewhat different manner. These systems consist of a series of microphones aimed at the traffic stream. The device detects the sound from a vehicle passing through the detection zone. It then compares the sound to a set of sonic signatures preprogrammed to identify various classes of vehicles. The primary source of sound is the noise generated by the contact between the tire and road surface. These devices are best used in a side fire position, pointed at the tire track in a lane of traffic to collect count, speed, and classification data.

2.1.10 Video Image Detection

Video image detection devices use a microprocessor to analyze the video image input from a camera. Two techniques, trip line and tracking, are used to record traffic data. Trip line techniques monitor specific zones on the roadway to detect the presence of a vehicle. Video tracking techniques employ algorithms to identify and track vehicles as they pass through the field of view. Different manufacturers technology may employ one or both of these techniques. Optimal mounting position for video image detectors is directly over the lane(s) to be monitored with an unobstructed view of traffic. Side mounting is feasible but large vehicles may obstruct detection zones. The mounting height is related to the desired lane coverage, usually 35 to 60 feet above the roadway. Video detection devices are capable of recording count, speed, and classification data.

2.2 MANUFACTURERS OF TRAFFIC COUNTING DEVICES

A list of manufacturers was compiled through an Internet search and by conversations with traffic counting professionals. Any manufacturer producing one or more devices for collection of count, speed, classification, and/or WIM data was considered. Many systems are "open systems" in that the sensors and data collection devices may be from different manufacturers. This is the case with most pneumatic rubber tube and inductive loop systems. In addition, the data collection devices employed by these systems may utilize more than one sensor type. For the most part, the more sophisticated the technology, the more likely the system will be a "closed" system.

Table 1 contains manufacturers identified by this researcher who were cooperative in supplying detailed product information and were responsive to questions regarding their products. The devices are categorized by their sensor technology; however, the product listing is limited to the devices used to interpret data output from the sensors. Manufacturers producing only sensors and not data recording devices were excluded from Table 1. A more detailed listing that includes contact name, address, telephone number, e-mail address, and website information for each manufacturer is included as Appendix E.

Table 1. Manufacturer List

- 3M, Intelligent Transportation Systems
- ASIM Technologies, Ltd.
- ATD Northwest
- Boschung America
- Computer Recognition Systems, Inc.
- Diamond Traffic Products
- Econolite Control Products, Inc.
- EFKON AG
- Electronic Integrated Systems, Inc.
- Electronique Controle Mesure (ECM)
- Eltec Instruments, Inc.
- Golden River TRAFFIC, Ltd.
- International Road Dynamics Inc.
- International Traffic Corp./ Pat America
- Iteris (formerly Odetics)
- JAMAR Technologies, Inc.
- Measurement Specialties, Inc.
- MetroCount
- Mikros Systems (Pty.), Ltd.
- Mitron Systems Corporation
- Nestor Traffic Systems, Inc.
- Nu-Metrics
- Peek Traffic Inc. - Sarasota
- Reno Detection Systems
- Schwartz Electro-Optics, Inc.
- SmarTek Systems, Inc.
- Spectra-Research
- Traficon
- U.S. Traffic Corporation

2.3 PRODUCT INFORMATION

Each manufacturer was contacted for product information for any device they distribute that is used to collect traffic count, speed, classification, and/or WIM data. The focus was on devices designed specifically for use in high speed, freeway applications. Devices used primarily for presence detection at intersections for traffic signal applications or on freeway entrance ramps for traffic management were not considered.

Table 2 summarizes devices currently on the market including manufacturer name, sensor type, and data collected. Although the devices are listed by sensor type, the emphasis was on acquiring information about the data recording and interpretation equipment that is attached to the various sensors. The sensor type used with a particular piece of equipment may or may not be made by the manufacturer listed. As previously stated, there is a wide range of open and closed systems available. Devices used for recording information obtained by manual observation were not included.

2.4 PRODUCT SPECIFICATIONS

Some issues that should be considered when selecting a particular product include traffic conditions at the site to be monitored, type of data to be collected, installation requirements, weather conditions, lane coverage, cost, and maintenance requirements. These requirements can determine whether a particular traffic counting device can or will work acceptably. It also is highly desirable for a new system to be field tested at the site in question prior to purchase of the device. Detailed information including technical specifications and installation requirements for each product in Table 2 are summarized in a Microsoft Access database.

Table 2. Product List

	Manufacturer	Product	Sensor	Function
Non-intrusive Devices	Peek Traffic Inc.	SafeCount	AI	Count, Speed, Class
	Schwartz Electro-Optics, Inc.	Autosense II, IIA, III	AI	Count, Speed, Class
	Spectra-Research	MLMS Multi-Lane Monitoring System	AI	Count, Speed, Class
	ASIM Technologies, Ltd.	DT 270 Series	IR/PU	Count, Class
	ASIM Technologies, Ltd.	IR 250 Series, TT 260 Series	IR/PU/DM	Count, Speed, Class
	International Road Dynamics Inc.	IRD SmartSonic	PA	Count, Speed, Class
	SmarTek Systems, Inc.	SmartTek Model SAS –1	PA	Count, Speed, Class
	Eltec Instruments, Inc.	Model 833	PI	Count, Speed
	EFKON AG	TOM 2000	PI	Count, Speed, Class
	3M, Intelligent Transportation Systems	3M Canoga	PM	Count, Speed, Class
	Nu-Metrics	HI STAR NC-47, NC-30X Countcard	PM	Count
	Nu-Metrics	HI STAR NC-97	PM	Count, Speed, Class
	EIS Electronic Integrated Systems.	RTMS Model X1	RA	Count, Speed, Class
	Econolite Control Products, Inc.	Autoscope 2004, Solo	VID	Count, Speed, Class
	Boschung America	BVS	VID	Count, Speed
	ATD Northwest	PATH CV-98 MK	VID	Count, Class
	Computer Recognition Systems, Inc.	TAS2	VID	Count, Speed, Class
	Nestor Traffic Systems, Inc.	Traffic Vision	VID	Count, Speed, Class
	Traficon	Trafficon VIP/D	VID	Count, Speed, Class
	Iteris	Vantage	VID	Count, Speed, Class
	Peek Traffic Inc.	Video Track 905, 910	VID	Count, Speed, Class
Intrusive Devices	Reno Detection Systems	C-1100, E-1100 Series	ILD	Count
	U.S. Traffic Corporation	IVS - 2000, 2001	ILD	Count, Speed, Class
	Golden River TRAFFIC, Ltd.	Marksman 360	ILD	Count
	Electronique Controle Mesure	HESTIA	ILD, PE	Count, Speed, Class, WIM
	Golden River TRAFFIC, Ltd.	Marksman 660, 660 WIM	ILD, PE	Count, Speed, Class, WIM
	Pat America Inc.	DAW 190	ILD, PE, BP	Count, Speed, Class, WIM
	ITC (Pat America)	Raktel, Tel	ILD, PE, BP	Count, Speed, Class, WIM
	TimeMark, Inc.	Delta III (L, B), Gamma Classifier	PRT	Count, Speed, Class
	International Road Dynamics Inc.	IRD TCU 1010	PRT	Count
	Golden River TRAFFIC, Ltd.	Marksman 400/410	PRT	Count, Speed, Class
	MetroCount (Australia)	MetroCount 5600 Series	PRT	Count, Speed, Class
	JAMAR Technologies, Inc.	TRAX Mite, TRAX I	PRT	Count, Speed, Class
	Diamond Traffic	Traffic Tally 2, 4, 6, 21, 41, 77, Sprite	PRT, ILD	Count
	JAMAR Technologies, Inc.	Totalizer	PRT, ILD	Count
	JAMAR Technologies, Inc.	TRAX III	PRT, ILD	Count, Speed, Class
	Peek Traffic Inc.	ADR - 1000	PRT, ILD, PE	Count, Speed, Class
	Peek Traffic Inc.	ADR - 2000, 3000 Plus	PRT, ILD, PE	Count, Speed, Class, WIM
	International Road Dynamics Inc.	IRD TC/C 540	PRT, ILD, PE	Count, Speed, Class
	Mitron Systems Corporation	MSC 3000	PRT, PE	Count, Speed, Class
	Mitron Systems Corporation	MSC 4000 SCOUT	PRT, ILD, PE	Count, Speed, Class, WIM
	ITC (Pat America)	T.R.S., Mini T.R.S, Traffic ACE	PRT, ILD, PE	Count, Speed, Class
	Diamond Traffic	Traffic Tally Pegasus	PRT, ILD, PE	Count
	Diamond Traffic	Traffic Tally Phoenix, Unicorn	PRT, ILD, PE	Count, Speed, Class

Key to Sensor Types:

AI	active infrared	PA	passive acoustic	PRT	pneumatic road tube
BP	bending plate	PE	piezo-electric sensor	PU	passive ultrasonic
DM	Doppler microwave	PI	passive infrared	RA	radar
ILD	inductive loop	PM	passive magnetic	VID	video image detection

General considerations addressed in the product database are reviewed below.

2.4.1 Installation

The installation requirements for each device are based on the type of sensor technology with a few exceptions. Looking first at traditional “intrusive devices,” all pneumatic road tube products identified require the sensor to be placed across the roadway and attached to a counting device that is placed along the roadside. Installation generally takes less than an hour but requires some intrusion into the flow of traffic. Placement of road tubes is easy, quick and requires minimal technical expertise.

Bending plates are much more labor-intensive to install. They require fixing the device to the roadway so intrusion in the flow of traffic is necessary. Piezo-electric sensors can be placed across the road surface or imbedded in the roadway. Imbedding the sensor requires cutting into the asphalt or concrete surface. The counting device is placed at the roadside. Installation can take less than an hour if the sensors are on top of the road surface or can take up to two days if placed into the roadway. Similar to some piezo-applications, inductive loop devices require the sensor to be imbedded in the roadway with the counting device placed at the roadside or in a nearby traffic cabinet. Again, inductive loop installation can take up to two days and will require lane closures.

The non-invasive, non-traditional technologies identified could be divided into three groups based on installation requirements. The video detection, passive infrared, and ultrasonic devices require mounting directly over the traffic lane(s) with an unobstructed view of the traffic being monitored. The optimal height is typically 35-45 feet. Two manufacturers indicated roadside mounting is permissible in the absence of an overhead structure; however, accuracy diminishes the further the device is from the most distant lane being monitored. Installation time was consistently given as two hours for system set-up with additional time dependent on the availability of a suitable mounting structure. In addition, the presence of a bucket truck and flag support maybe required dependent on the installation site.

Two manufacturers were identified who produced passive magnetic devices for freeway data collection—3M and Nu-Metrics. This technology requires that it be installed close to the road surface. The 3M Canoga micro-loop system is placed under the lane of traffic in PVC tubing without disrupting the road surface. A conduit is installed using horizontal directional drilling, without digging a trench. Nu-Metrics offers three passive magnetic devices that are installed by placing the small portable devices on or in the roadway. This technology is typically categorized as non-intrusive; however, placement of the sensors in the line of traffic seems to contradict this premise. Another manufacturer of passive magnetic devices, Safetran Traffic Systems, produces the IVHS sensor. However, the manufacturer recommends the device for detecting vehicle presence rather than highway traffic counting and classification.

The last group—radar, passive acoustic, and active infrared devices—are typically mounted roadside on an existing structure such as a street light or sign post.

Sensor placement will impact how many lanes of traffic can be successfully monitored. The time required for installation is similar to the video detection devices. Set-up of the device takes about two hours if there is an existing roadside structure for mounting the sensor. The only exceptions identified were the Multi-Lane Monitoring System (MLMS) by Spectra-Research and the SafeCount by Peek Traffic. These devices are portable, active infrared systems placed on the ground 10 to 15 feet from the lanes of traffic to be monitored. Installation time is less than one hour.

2.4.2 Power and Temperature Requirements

Power and temperature requirements for each of these devices did not seem to present limiting factors with respect to product selection. The majority of the devices that were placed free standing along the roadside were battery operated and offered several options related to battery size, solar power, and rechargeable varieties. It is likely that power requirements would be of most concern in remote areas where power sources are unavailable. In this case, short-term portable counting devices could be utilized. Most single channel permanent installations offered battery options but multi-channel devices require 120 VAC.

The operating temperature ranges for all devices were on the average from –30° to +65°C (-22° to +149°F). The Nestor Traffic Vision was a rare exception with an operating range of only +10° to +35°C (+50° to +95° F). Temperatures would be problematic only in regions of the country where weather extremes are frequent occurrences. However, it is important to keep in mind that the manufacturer's reported operating ranges may not take into account "real world" factors. Although the device may perform well in a test environment, there are "real world" conditions that can cause a device to fail. For example, the high summer temperatures in Arizona can cause the asphalt to shove leading to failure of inductive loops. Manufacturers may be unaware of these issues or reluctant to share them with potential buyers. Consequently, it is prudent to contact actual users for their experience prior to purchasing a new device. Table B24 in Appendix B lists the manufacturers of traffic counting devices used by each state to assist in this process.

2.4.3 Data Retrieval

Data retrieval techniques ranged in complexity from reading traffic counts from a visual display on the recording device to having the ability to remotely configure, perform diagnostics and extract data via modem, landlines or wireless connection. Most systems offer more than one option for data retrieval with the degree of flexibility dependent more on the data collection device rather than the sensor type. The number of data retrieval options available increases with the level of sophistication and complexity of the equipment.

The pneumatic road tube, inductive loop, and piezo-electric sensor systems consistently offer roadside data retrieval using data cards or a laptop. A few low cost models that record strictly traffic counts offer visual displays so that a computer is not necessary. With non-intrusive technology, remote data retrieval is more typically available. The minimum requirement is a receiving computer, either laptop or PC, with an RS-232 serial communication port being the most common standard for data retrieval. The purchase of additional software or data modules will increase the available options but also increases the price of the system. In general, most manufacturers are willing to work with the end user to configure a system that fits their data collection and retrieval needs as well as budget.

2.4.4 Price Information

Price information was requested from all manufacturers. The prices quoted were very dependent on site parameters that would be unique to a particular installation. There also were many issues that varied between manufacturers as to what was or was not included with the product. Some variables included data analysis software, types of sensors, rack or shelf mount format, data storage capacity and optional modules for data retrieval or WIM. Consequently, it was difficult to obtain information that was comparable across product lines.

In considering equipment cost, on the surface the prices for non-intrusive devices appear to be higher. But, this may not actually be the case. The Texas Transportation Institute (TTI) study addressed the issue of life-cycle cost in its report *Evaluation of Some Existing Technologies for Vehicle Detection.* In this study, inductive loops were compared to other non-intrusive detection systems in several districts throughout Texas representing different sized urban applications. The elements that were considered in the life-cycle cost of each device were installation cost, maintenance costs, traffic control, motorist delay and related excess fuel consumption, additional pavement maintenance costs, and costs related to increased crash rates during installation and maintenance of some detectors.

Table 3, reproduced from the TTI study, shows the per-lane cost comparison. It must be kept in mind that the TTI project summary covers the period from September 1996 to August 1999 so the price information is not current. However, it is possible to garner a relative cost comparison between the four different technologies. Readers should refer to the study for more information on specific details of how the figures were obtained.

Table 3. Freeway Detector Annualized Per-Lane Cost Comparison

Detector	Total Number of Freeway Lanes (Both Directions)			
	6	8	10	12
inductive loops	$746	$746	$746	$746
video image detection	$580	$604	$483	$402
EIS RTMS (radar)	$314	$236	$189	$157
IRD SmartSonic (passive acoustic)	$486	$448	$467	$476

[Source: 5]

One issue not addressed in the cost comparison is the level of expertise required for installation and operation. This may be a concern for some agencies. Although the non-intrusive technologies are more sophisticated, they are actually quite user-friendly. Set-up of most devices is with the use of intuitive, Windows-based software programs. Many vendors include in the price installation costs or the onsite presence of an individual during installation. There also are various end user training options available.

2.4.5 Product Limitations

As would be expected, each of the products listed in Table 2 has its limitations. Most manufacturers were reluctant to discuss limitations of their particular traffic data collection equipment but rather focused on general limitations of the technology. Familiarity with the limitations of each sensor type will help facilitate successful equipment selection. This information is listed in Table 4 on the following page.

Table 4. Limitations of the Technology

Sensor Technology		Limitations
Intrusive Devices	bending plate	• Installation requires working within the traffic lane • Equipment time consuming to install • Equipment expense high
	pneumatic road tubes	• May become displaced resulting in loss of data • Installation requires working within the traffic lane • Snow plows can damage road tubes • Limited lane coverage
	piezo-electric sensor	• Installation requires working within the traffic lane • If place on road surface, may become displaced resulting in loss of data • If imbedded in roadway, requires disruption of road surface integrity potentially decreasing the life of the pavement • Sensor installation may be compromised by old asphalt or concrete
	inductive loop	• Installation requires working within the traffic lane • Requires disruption of road surface integrity potentially decreasing the life of the pavement • Sensor installation may be compromised by old asphalt or concrete • Prone to installation errors that lead to high maintenance requirements [3] • Susceptible to damage by heavy vehicles, road repair, and utilities [3] • Potentially short life expectancy
Non-Intrusive Devices	passive/active infrared	• Lane coverage limited to one to two lanes • Active infrared sensors are generally limited to the same range in inclement weather as can be seen with the human eye [4] • Active infrared classification based on vehicle height rather than length • Passive infrared performance potentially degraded by heavy rain or snow [3]
	passive magnetic	• Difficulty in discriminating longitudinal separation between closely spaced vehicles
	Doppler microwave	• Unable to detect non-moving traffic • Difficulty in differentiating adjacent vehicles • Overhead installation requires the presence of existing structure for mounting the device
	radar	• Side-fire installation limited to only long and short vehicle classification • Overhead installation requires the presence of existing structure for mounting the device
	ultrasonic	• Performance may be degraded by variations in temperature and air turbulence [3]
	passive acoustic	• Signal processing of energy received requires removal of extraneous background sound and acoustic signature to identify vehicles [3]
	video image detection	• Overhead installation requires the presence of existing structure for mounting • Weather conditions that obstruct view of traffic can interfere with performance (i.e., snow, fog, sun glare on camera lens at sunrise and sunset • Large vehicles can mask trailing smaller vehicles

2.5 PERFORMANCE

Comparatively assessing the performance of traffic counting devices is difficult. The differences in the technology necessitate very different installations. Selecting one particular section of highway to test all devices would seem to be optimal for comparison purposes but may not be the best assessment of a particular device's capabilities. As has been stated previously, selection of a counting/classifying device should be based on several considerations, one of which is where the device will be installed. A site that may work well for video detection may not be optimal for passive infrared.

The Texas Transportation Institute took a comparative look at the use of detectors in a freeway application in its study *Evaluation of Some Existing Technologies for Vehicle Detection*. The selection guide that was developed is reproduced as Table 5. TTI points out in its report that the reader should keep in mind the subjective nature of the evaluations when reviewing the data. In addition, one should remember this assessment is "only a snapshot, and it will surely change" as the technology continues to evolve. [5]

Table 5. Application Guide for Detector Selection on Freeways

		Detection Accuracy						Mounting				
Detector Technology	**Life-Cycle Cost**	**Low Volume**	**High Volume**	**Failure Rate**	**Speed Accuracy**	**Incident Detection**	**Classification Accuracy**	**Overhead**	**Side-fire**	**Maintenance Requirements**	**Directional Detection**	**Effect of Weather**
Inductive loops	C	A	A	C	B	B	B	D	D	C	B	A
active infrared	C	A	A	U	B	B	A	A	D	A	D	B
Passive infrared	A	A	B	U	D	D	D	A	A	A	D	A
Radar	A	A	A	U	A/B*	B	B	A	A	A	D	A
Doppler microwave	A	A	B	U	A	A	D	A	C	B	B	A
Passive acoustic	B	B	B	U	C	C	C	A	B	A	D	C
pulse ultrasonic	A	A	A	U	D	D	D	A	B	U	D	U
video – tripwire	B	A	A	B	C	C	C	B	B	B	B	C
video – tracking	B	A	A	B	B	B	C	B	B	B	B	C

[Source: 5]

Code: A = Excellent; B = Fair; C = Poor; D = Nonexistent; U = Unknown
* A: Overhead mounting; B: Side-fire mounting

2.6 CONCLUSION

The type of traffic data collection devices available on the market has changed little in the past decade. The same thirteen technologies are still being utilized by State, county, city, and metropolitan organizations responsible for traffic monitoring operations. Some products have come and gone off the market and companies have been bought and sold, but the science remains pretty much the same.

This is not to say the industry has been at a stand still. The devices have evolved as their use has come under greater scrutiny with increased usage. But, the increased usage has been more likely due to the recent focus on “intelligent transportation systems” (ITS) and the use of these devices in support of this movement. This is particularly true in the area of advanced traffic management systems (ATMS) where video image detection, Doppler microwave, passive magnetic, and passive acoustic technology are being used for signalized intersection control, incident detection and management, speed traps, and freeway metering control. As the need for collection of accurate, reliable traffic data is realized as essential for allocating scarce resources to support an aging infrastructure, greater pressure will be placed on manufacturers to make the existing technology used for traffic data collection more efficient and cost-effective.

3.0 TRAFFIC COUNTING SURVEY

3.1 PURPOSE

The AZDOT Traffic Counting Survey was conducted to ascertain the current practices of State Departments of Transportation. In addition, each agency was asked their level of satisfaction with the technology in use, disadvantages identified, frequency of use and manufacturer name. The information will be used to assist in decision-making regarding changes to AZDOT's current traffic counting practices.

3.2 METHODOLOGY

A two-page survey was sent to the fifty state DOTs on January 29, 2001. Prior to distribution of the survey each agency was contacted to obtain the name and address of an individual capable of providing the required information. Participants were given four weeks to respond to the survey. A list of each agency and the individual(s) completing the survey follows:

Table 6. State Departments of Transportation

Department of Transportation	Web Site	Contact
Alaska Department of Transportation	www.dot.state.ak.us	Beverly N. Fantazzi
Alabama Department of Transportation	www.dot.state.al.us	Charles W. Turney
Arkansas Highway & Transportation Department	www.ahtd.state.ar.us	Keith Merritt
Arizona Department of Transportation	www.dot.state.az.us	Mark Catchpole
California Department of Transportation	www.dot.ca.gov	Joe Avis
Colorado Department of Transportation	www.dot.state.co.us	Dave Price
Connecticut Department of Transportation	www.state.ct.us/dot/	Joe Cristalli
Delaware Department of Transportation	www.state.de.us/deldot/	Jim Ho
Florida Department of Transportation	www.dot.state.fl.us/planning	Harshad Desai
Georgia Department of Transportation	www.dot.state.ga.us	Jerry Presley
Hawaii Department of Transportation	www.hawaii.gov/dot/	Goro Sulijoadikusumo
Iowa Department of Transportation	www.state.ia.us/government/dot/	Jim Majors
Idaho Transportation Department	www2.state.id.us/itd/	Scott Fugit
Illinois Department of Transportation	www.dot.state.il.us	Bob Kleinlein
Indiana Department of Transportation	www.state.in.us/dot	Lowell Basey
Kansas Department of Transportation	www.dot.state.ks.us	Bill Hughes
Kentucky Transportation Cabinet	www.kytc.state.ky.us	Dan Inabnitt
Louisiana Department of Transportation	www.dotd.state.la.us	Robert Smith
Massachusetts Highway Department	www.state.ma.us/mhd	William Mitchell
Maryland State Highway Administration	www.sha.state.md.us	Barry Balzanna
Maine Department of Transportation	www.state.me.us/mdot/	Debbie Morgan

Table 6. State Departments of Transportation (continued)

Department of Transportation	Web Site	Contact
Michigan Department of Transportation	www.mdot.state.mi.us	Bob Brenner, David Schade
Minnesota Department of Transportation	www.dot.state.mn.us	Curtis Dahlin
Missouri Department of Transportation	www.modot.state.mo.us/	Allan Heckman
Mississippi Department of Transportation	www.mdot.state.ms.us/	Carolyn Thornton
Montana Department of Transportation	www.mdt.state.mt.us	Dan Bisom
North Carolina Department of Transportation	www.dot.state.nc.us	Jim Canty
North Dakota Department of Transportation	www.state.nd.us/dot	Shawn Kuntz
Nebraska Department of Roads	www.dor.state.ne.us	Terry L. Guy
New Hampshire Department of Transportation	www.state.nh.us/dot	Robert Lyford
New Jersey Department of Transportation	www.state.nj.us/transportation/	Louis C. Whitely
New Mexico State Highway Department	www.nmshtd.state.nm.us/	Alvaro Vigil
Nevada Department of Transportation	www.nevadadot.com	Mike Lawson
New York State Department of Transportation	www.dot.state.ny.us/	Todd Westhuis
Ohio Department of Transportation	www.dot.state.oh.us	Michael Phillips
Oklahoma Department of Transportation	www.okladot.state.ok.us	Lester Harragarra
Oregon Department of Transportation	www.odot.state.or.us/tddtrandata	Tim Thex
Pennsylvania Department of Transportation	www.dot.state.pa.us	Tom Reindollar
Rhode Island Department of Transportation	www.dot.state.ri.us/	Michael Sprague, Paul McEnanly
South Carolina Department of Transportation	www.dot.state.sc.us/	Joseph Boozer
South Dakota Department of Transportation	www.state.sd.us/dot/	Kenneth E. Marks
Tennessee Department of Transportation	www.tdot.state.tn.us/	Ray Barton
Texas Department of Transportation	www.dot.state.tx.us	Jeff Reding
Utah Department of Transportation	www.sr.ex.state.ut.us	Gary Kuhl
Virginia Department of Transportation	www.vdot.state.va.us/	Richard Bush
Vermont Agency of Transportation	www.aot.state.vt.us/	David M. Gosselin
Washington Department of Transportation	www.wsdot.wa.gov	John Rosen
Wisconsin Department of Transportation	www.dot.state.wi.us	John Williamson
West Virginia Department of Transportation	www.wvdot.com	Jerry L. Legg
Wyoming Department of Transportation	www.dot.state.wy.us/	Kevin Messman, Bill Gribble

All fifty States returned survey results. The data were entered in a Microsoft Access database and summarized for this report. Following review of the results, individuals responsible for completing the survey were contacted for clarification of responses and to obtain additional or missing information.

3.3 SURVEY INSTRUMENT

The AZDOT Traffic Counting Survey included three questions. The questions are shown below with an example of the response format accompanying each. Only a small sample of each question type is included below. The complete survey is included as Appendix C.

1. How satisfied are you with the data collection device(s) currently employed by your agency to collect traffic data?

	very satisfied 5	4	3	2	*very dissatisfied* 1
manual observation	5	4	3	2	1

2. Please check any specific ***disadvantages*** you have noted with your use of the equipment types listed below.

	weather interference	**equipment cost**	**data accuracy**	**system failure**	**installation requirements**	**number lanes monitored**	**maintenance requirement**	**ease of calibration**
manual observation								

3. Please indicate the ***approximate percentage*** each method represents of results reported and the manufacturer(s) of the equipment currently used to interpret your traffic data. (Mark only those used.)

	Count	***Speed***	***Weight***	***Class***	***Manufacturer***
manual observation	□ < 25% □ 25-50 □ 51-75 □ >75	□ < 25% □ 25-50 □ 51-75 □ >75	□ < 25% □ 25-50 □ 51-75 □ >75	□ < 25% □ 25-50 □ 51-75 □ >75	

3.4 SURVEY DATA

3.4.1 Question 1

All fifty states returning results responded to question 1. The question asked agencies to rate their level of satisfaction (LOS) with each method for collecting traffic data. Responses were only to be given if the agency was actually using the equipment listed. The rating scale was from 1 to 5 with 1 being "very dissatisfied" and 5 being "very satisfied." Of the thirteen sensor technologies listed, no state reported using passive infrared, active infrared, Doppler microwave or pulse ultrasonic. Answers to the first question are shown in Table 7 on the following page.

Table 7. Level of Satisfaction by State

State DOT	manual observation	bending plate	pneumatic rubber tube	piezo-electric sensor	inductive loop	passive infrared	active infrared	passive magnetic	radar	Doppler microwave	pulse ultrasonic	passive acoustic	video image detection
AK	5		5		5								
AL	4		5	4	5								
AR			4	5	5				3				
AZ	4	4	2	1	4							3	
CA		5	5	3	4								
CO	3		3	4	4				3				
CT			4	4	5								
DE	4		4	4	5				4				
FL	3	4	2	3	4				3				
GA	3		4	5	5				3				
HI	1	5	3	3	5								
IA	4		3	4	4								
ID	5		4	3	3								
IL	2		3	3	4			5					
IN		1	3	4	4								
KS	4	5	4	3	5				4				
KY	4	4	3	3	4			1	4				
LA			4		3				4				
MA	4		3	3	4								
MD	3		3	5	5								
ME	5		4	3	5								
MI	3	5	4	2	5			5					
MN	4	1	4	3	4								
MO			4	3	5				3				
MS		5	3	2	3								
MT	3	4	4	4	4								
NC	4	3	4	3	4				3			2	3
ND	5	1	4	4	5								
NE	4		4	4	4				4				
NH	5		4	4	5								
NJ	4	1	4	4	5								2
NM	4		4	3	3								
NV	5	5	5	4	5								4
NY	5	2	4	3	4								
OH	3	3	4	4	4				3			3	
OK	3	1	3	4	4				4				
OR	5	4	4	4	5								4
PA	4		4	2	4								
RI	4		4	3	4								2
SC	3	3	3	4	5								
SD	5	5	5		5				4				
TN	5			4	4								
TX	5	4	2	4	4								
UT	4		4	3	5								
VA	4		4	4	4			2	5			3	
VT			5	5	4								

Table 7. Level of Satisfaction by State (continued)

State DOT	manual observation	bending plate	pneumatic rubber tube	piezo-electric sensor	inductive loop	passive infrared	active infrared	passive magnetic	radar	Doppler microwave	pulse ultrasonic	passive acoustic	video image detection
WA	5	3	5	4	5				3				
WI		4	5	4	5								
WV	4	3	4	3	3								
WY	4		3	3	5				1				
Total	41	25	49	47	50	--	--	4	17	--	--	4	5

The number and percent of states using each technology and the average level of satisfaction with each device is listed in Table 8. The methods have been arranged from left to right in decreasing frequency of usage among States.

Table 8. Usage and Average Level of Satisfaction

	inductive loop	pneumatic rubber tube	piezo-electric sensor	manual observation	bending plate	radar	video image detection	passive acoustic	passive magnetic
Number of States Using Device	50	49	47	41	25	17	5	4	4
Percent Usage	100.0	98.0	94.0	82.0	50.0	34.0	10.0	8.0	8.0
Average LOS	4.4	3.8	3.5	4.0	3.4	3.4	3.0	2.8	3.2

According to the survey results, pneumatic rubber tubes, piezo-electric sensors and inductive loops are the most prevalent sensor technologies in use for collecting traffic data. Each is used by greater than 90% of the states reporting results with inductive loops the highest at 100%. The popularity of inductive loops is not surprising as it "continues to be the best all-weather, all-light condition sensor for many applications." [5]

Participants were asked to rate their level of satisfaction with the thirteen technologies listed. Inductive loops achieved the highest score of all sensor types with consistent ratings of 3, 4, or 5 by all states and an average LOS of 4.4. Manual observation ranked second highest in LOS with an average of 4.0. This seems surprising due to the inherent inaccuracy and lack of consistency between observers that occur with any manual process. It definitely outperformed the more sophisticated technologies.

The newer non-intrusive technologies—radar, video image detection, passive acoustic, and passive magnetic—rated consistently lower with the average LOS ranging from 2.8 to 3.4. This may be due to a number of factors such as complexity of the installation process, maintenance requirements, expense, or lack of experience and familiarity with the newer technology. However, with so few states reporting use of the later three technologies it is difficult to draw many conclusions from the results.

3.4.2 Question 2

The second survey question requested each state to indicate any disadvantages with their use of the different data collection devices. A summary of the results is shown in Table 9. The sensor types are listed on the left in order of decreasing frequency of usage. The devices with the greatest number of disadvantages per category as a percentage of the number of users have been shaded.

Table 9. Disadvantages Reported by Technology

Sensor Technology	number of States reporting	weather interference	equipment cost	data accuracy	system failure	installation requirement	lanes monitored	maintenance requirement	ease of calibration
inductive loop	50	2	4	4	7	21	1	13	2
pneumatic rubber tube	49	30	1	27	8	11	32	2	
piezo-electric sensor	47	12	8	12	25	22		18	16
manual observation	41	17	4	14	1	1	13		
bending plate	25	2	18	3	7	13		13	6
radar	17	4	6	7	2	6	2	1	8
video image detection	5	3	3	2	2	4			1
passive acoustic	4	1	2	1		3	1		1
passive magnetic	4		1	2	1	1			

Pneumatic rubber tube and piezo-electric sensor consistently were reported to have the greatest number of disadvantages by the greatest percentage of users. Lane monitoring capability, weather interference, and data accuracy were reported as disadvantages by 65.3%, 61.2%, and 55.1%, respectively, of the 49 states that use pneumatic rubber tubes. System failure, installation requirements, and ease of calibration were reported by 53.2%, 46.8%, and 34.0%, respectively, of the 47 states that use piezo-electric sensors for collection of traffic data. Equipment cost and maintenance requirements were reported most frequently for bending plate technology with 72.0% and 52.0%, respectively, of users reporting these factors as disadvantages.

In looking at individual results by state, there does not appear to be any correlation between the manufacturer of the equipment used by the state and the disadvantages reported. For example, data accuracy was reported as a disadvantage of pneumatic road tube use. This was reported across the most prominent manufacturers and throughout geographic locations. It seems likely the disadvantages reported are a function of the type of technology rather than any other factor identified by this survey.

There also are survey results for which there is no explanation such as system failure and installation cost reported as a disadvantage of manual observation. These results are likely information entry errors on the part of the participating DOTs.

3.4.3 Question 3

The third survey question requested three pieces of information—type of traffic data collected, frequency of method use, and device manufacturer. Participants were asked to indicate what type of data they gather using each of the thirteen sensor technologies and approximate percent of results reported using each method. Forty-nine states reported results for question 3. Individual results reported by each state are listed in Appendix B. A summary of all results is provided in the Table 10 below.

Table 10. Method of Data Collection

	Number of States Reporting			
Sensor Technology	**Count**	**Speed**	**Weight**	**Class**
manual observation	26	5	6	29
bending plate	15	11	23	20
pneumatic rubber tube	47	20	4	43
piezo-electric sensor	28	23	39	40
Inductive loop	47	32	14	24
passive magnetic	3	1	0	1
radar	15	3	0	0
passive acoustic	4	1	0	0
video image detection	2	1	1	4

According to these data, the most popular methods for vehicle counts reported by 47 out of 50 states are pneumatic rubber tubes and inductive loops. Inductive loops are the most popular for reporting speed data. As would be expected, piezo-electric sensors and bending plates were the most frequently used for reporting weight. Lastly, vehicle classification is most commonly reported using pneumatic rubber tubes and piezo-electric sensors.

In reporting the type of data collected, participants also had to indicate the approximate frequency of use of each sensor type. Unfortunately, this section of the survey caused respondents some confusion. The intent of the question was to ascertain what percentage of vehicle counts are reported using each sensor type. For example, under vehicle count, a DOT may report < 25% using pneumatic rubber tubes, 51-75% using inductive loops, and < 25% using piezo-electric sensors. The total of the three sensor types approximates 100%. However, this was not the case for approximately 30% of the survey respondents.

Instead of reporting totals across data type, the results appear to reflect percentage of results reported across sensor type. For example, under inductive loop, one participant reported that 25-50% of loop data are vehicle counts, < 25% are speed data, and 25-50% are classification data. The approximate total across sensor type totals 100%. It also appears that some States may have ignored the percentage descriptor and selected responses as though the quantities were absolute values. The respondents may have been trying to record the number of sensors in use rather than the percentage of the total results. Regardless, caution must be taken when attempting to draw conclusions from the complete set of results shown in Appendix B.

In order to draw meaningful conclusions, results that were obviously incorrectly reported were eliminated from the summary in Table 11. The following numbers of States were included in each summary: count - 29, speed - 22, weight - 31, class - 28. The number of States reporting < 25%, 25-50%, 51-75%, or > 75% to indicate the percentage of data reported by a particular method are listed in the columns below.

Table 11. Frequency of Method Use

		Number of States Reporting			
Testing Method		< 25%	25-50%	51-75%	> 75%
Count	manual observation	13			
	bending plate	10			
	pneumatic rubber tube	2	5	6	17
	piezo-electric sensor	17			
	inductive loop	18	9	2	2
	passive magnetic	3			
	radar	8			
	passive acoustic	1	1		
	video image detection	1			
Speed	manual observation	1			
	bending plate	7			
	pneumatic rubber tube	7		2	4
	piezo-electric sensor	10	1		2
	inductive loop	8	2	3	8
	passive magnetic			1	
	radar	2			
	passive acoustic		1		
	video image detection				

Table 11. Frequency of Method Use (continued)

	Testing Method	Number of States Reporting < 25%	25-50%	51-75%	> 75%
Weight	manual observation	4			
	bending plate	10	1	2	4
	pneumatic rubber tube	3			
	piezo-electric sensor	4	3	5	17
	inductive loop	4	1	1	5
	passive magnetic				
	radar				
	passive acoustic				
	video image detection				
Class	manual observation	14	3		1
	bending plate	11			
	pneumatic rubber tube	6	3	5	12
	piezo-electric sensor	14	4	4	1
	inductive loop	8	2		
	passive magnetic				1
	radar				
	passive acoustic				
	video image detection	2			

Whereas Table 10 showed how States are using each sensor technology, Table 11 shows the frequency with which each device is used within a particular State for collecting a specific type of traffic data. The results show that the majority of States are using pneumatic rubber tubes to collect more than half of their vehicle count data, inductive loops for speed, piezo-electric sensors for weight, and pneumatic rubber tubes for the majority of classification data.

The last portion of question 3 asked for information on equipment manufacturers. The intent was to gather information on the manufacturer of the data-recording device rather than the sensor. This was not clear to some respondents. Those reporting the manufacturer of their sensors were contacted for additional information. Some of the most commonly reported sensor manufacturers were Measurement Specialties, Vibracoax, Sperry Rubber, Trigg Industries and Hanna Rubber. Table 12 summarizes the manufacturers used by all States reporting results. The list is in alphabetic order by manufacturer name. Note that many States reported using more than one manufacturer's equipment for collecting a particular type of data. A list of the equipment used by each state is included in Appendix B.

Table 12. Device Manufacturers

Manufacturer	manual observation	bending plate	pneumatic rubber tube	piezo-electric sensor	inductive loop	passive magnetic	radar	passive acoustic	video image detection
No manufacturer provided	18		1						
Unknown device	1			1					
Contractor provided service	2		1						
In-house laptop	2								
3M, Intelligent Transportation Systems						2			
ATD Northwest									1
Diamond Traffic	2		25	10	17				
EIS Electronic Integrated Systems							17		
Electronique Controle Mesure (ECM)				12	2				
GK			3		1				
Golden River TRAFFIC			3		3				
International Road Dynamics (IRD)		13		11	6			1	
ITC / Pat America	1	18	5	7	6				
JAMAR Technologies	11		1		1				
Kustom Signal *(hand-held device)*							1		
MetroCount			1						
Mikros Systems				2					
Mitron Systems					1				
Nestor Traffic Systems									1
Nu-Metrics						2			
Peek Traffic Inc. - Sarasota		1	28	20	34				2
SmarTek Systems								3	
TimeMark Inc.			1						
Traficon									1

It is apparent when reviewing the survey results that a few manufacturers dominate the State DOT market. For bending plates, International Road Dynamics (42%) and ITC/Pat America (58%) were the only manufacturers reported. With pneumatic rubber tubes, the leaders are Peek Traffic and Diamond Traffic. Both companies manufacture cost-effective, easy-to-use devices for counting and classifying traffic. Unfortunately, the intrusive nature of road tubes makes them potentially dangerous for the road workers who install and maintain them.

These two manufacturers showed similar market dominance with inductive loop sensors. Peek Traffic held 47% of the market with Diamond Traffic coming in second at

22%. The distribution of manufacturers among States using piezo-electric sensors is more wide spread. Peek Traffic remains the leader with 33% of the market and Diamond Traffic, Electronic Controle Mesure, and International Road Dynamics each having close to 19% each.

The market for non-intrusive devices was quite different. In several cases, a particular technology may only be produced by one manufacturer. For instance, EIS Electronic Integrated Systems was the only company identified who distributed radar traffic data collection equipment. A similar situation exists with passive magnetic and passive acoustic technology. Nu-Metrics and 3M are the only two manufacturers producing passive magnetic. Electronic Integrated Systems is the only company producing passive acoustic equipment.

There also have been some acquisitions over the past decade. Pat America purchased International Traffic Corporation in 2000 so these results have been combined throughout the report. In addition, StreeterAmet was purchase by Peek Traffic. These results have similarly been combined and listed under Peek Traffic. Lastly, GK, a British manufacturer, no longer produces counting devices for rubber tubes and loops.

3.5 CONCLUSION

Less than half of all State DOTs (24 out of 50) are using non-intrusive methods for gathering traffic data. This may be due to the lack of comparative data showing the accuracy of these new technologies as compared to standard road tubes, inductive loops, and piezo-electric sensors. Other factors contributing to the reluctance to convert to non-intrusive technology may be cost and the level of technical expertise required to operate the devices. Both issues were addressed in Section 2.0.

Inductive loops are probably the most consistently accurate device for vehicle counting applications. However, the newer non-intrusive technologies show great promise. As they show increased usage, they will continue to evolve and improve. Unfortunately, manufacturers cannot afford to invest in the research and development needed to continue to improve these devices without the assurance that a tangible market for their product exists. Additional cooperative studies validating the accuracy, reliability, and cost-effectiveness of these devices need to occur so that both groups will benefit. [3]

4.0 LITERATURE REVIEW

4.1 PURPOSE AND METHODS

The purpose of the literature review is to explore advances in traffic counting technology that go beyond the traditional inductive loops and pneumatic road tubes. This was done through an extensive search of books and journal articles as well as websites associated with the transportation industry. State and federal transportation agencies, professional associations, and manufacturers of traffic counting devices were included in the search.

As the goal of the review is to focus on "new developments" in traffic counting, this reviewer concentrated on information published after 1995. Due to ongoing advances in technology, anything beyond five years would likely be technologically outdated. This report reviews some of the important articles on advances in technology; however, it is recommended that a complete copy of these reports be obtained for a more detailed discussion of these in-depth evaluation projects. Information is provided on the report content and where the reader can find each report. Also, bibliographies of informative articles and websites are included in Appendices C and D for those who wish to read further and continue watching for new developments.

4.2 NEW AND IMPROVED TECHNOLOGY

Despite extensive research, little was uncovered in the way of "new technology." Rather, the information found relates to improvements in existing technology. As the need for non-intrusive traffic detection devices becomes increasingly important with the evolution of ITS, the pressure is on manufacturers to invest in research and development to improve existing technology. Improvements have been made to the traditional inductive loop and piezo-electric sensors. Non-intrusive devices that have failed to catch on due to their high upfront cost and undocumented field performance also are under scrutiny.

4.2.1 Inductive Loops

Some inductive loop manufacturers are looking toward using "signatures" to improve vehicle classification accuracy. Each vehicle has a characteristic signature resulting from its unique features. Aside from length, trucks have axle and hitch combinations that are unique to the vehicle type. [6] Partners for Advanced Transit and Highways (PATH) headquartered at the University of California in Berkeley and the University of Florida are both heavily involved in research to improve the classification ability of inductive loops.

Two examples of classification devices using forms of this technology are the Peek's Idris® Smart Loops AVC System and U.S. Traffic Corporation's IVS-2000. With the Smart Loop System, the classification scheme is based on a per vehicle record which is comprised of vehicle length, number and spacing of axles, presence of dual tires and vehicle profile. Smart Loops use a special loop array per lane, 6’6’’ (2m) square and 6’6” (2m) apart with two optional axles loops in-between to reliably separate, profile and track each vehicle as it passes through the station. The system can be set-up and operated by remote telemetry. The manufacturer claims separation accuracy at > 99.96% and axle class accuracy at > 99.4%. [4,7]

The IVS-2000 system uses a complete “inductive signature” to classify vehicles using advanced neural network software. The system classifies vehicles into 23 different classes—13 FHWA plus ten additional classes. The accuracy rate is reported by the manufacturer to be 85 to 90 percent using one or two loops. With the IVS system, a per vehicle, time-stamped record is created that is used to process classification data. The system operates with one or two loops per lane and can be used with existing loops. [4]

4.2.2 Passive Acoustic Devices

The concept of neural networks for data collection and interpretation has potential beyond inductive loops. This pattern matching technology also is being used with acoustic sensors to improve on vehicle classification accuracy. Similar to the inductive loops, an “acoustic signature” is developed with the use of microphones and digital audiotape records. The neural net then uses this information to classify vehicles based on their unique acoustic signature. [8]

4.2.3 Piezo-Electric Sensors

In the area of piezo-electric sensors, Kistler Instruments Corporation is using quartz-based material in its force transducer design. Since the piezo-electric force transducers are ideally suited for measuring dynamic events, they cannot perform truly static measurements. The charge from a static load can be registered; however, it cannot be stored for an indefinite period of time. In this situation, “highly insulated materials are required to ensure a maximal discharge time constant and optimal operation of the charge amplifier (i.e., minimal drift).” Quartz has an ultra high insulation resistance that makes it ideal for static measurements. The Kistler system can routinely measure large forces for minutes and perhaps even hours. The quartz sensor can be used for either direct or indirect force measurements. [9]

The Maine Department of Transportation reports having considerable success with the use of quartz sensors for collection of weight data. Readers interested in pursing use of quartz sensors may wish to contact the agency for more information on their experience.

4.3 RECENT RESEARCH

Non-intrusive traffic data collection devices were first employed in the 1940s with the use of magnetic sensors. Twenty years later, ultrasonic and microwave sensors came into use. [10] However, none of these devices came close to competing with the inductive loop in terms of accuracy and reliability. More recently, as safety, cost, increased traffic flow, complex road geometrics and traffic disruption have become issues of concern, traffic counting professionals are looking more closely at alternatives. Several studies were identified that deal with these concerns and evaluate the feasibility of replacing traditional inductive loops and pneumatic road tubes with non-intrusive devices for traffic data collection.

4.3.1 Comparative Evaluations

One of the first projects to evaluate traffic detection technologies was the Hughes Aircraft project, *Detection Technology for IVHS*, sponsored by the Federal Highway Administration. The 1996 study involved evaluating various devices at freeway and surface street arterial sites in Minnesota, Florida, and Arizona. The technology evaluated in the study included ultrasonic, microwave radar, infrared laser radar, nonimaging passive infrared, video image processing with visible and infrared spectrum imagery, acoustic array, microloop, and magnetometer detector technologies. In addition to these non-intrusive devices, high sampling rate inductive loop and conventional inductive loop devices were included as representing the “most consistently accurate” technology at the time. [3]

The specific objectives of the project were:

1. Determine the traffic parameters and their corresponding accuracy specifications needed for future IVHS applications;

2. Perform laboratory and field tests with detectors that apply technologies compatible with above-the-road, surface, and subsurface mounting to determine the ability of state-of-the-art detectors to measure traffic parameters with acceptable accuracy, precision, and repeatability; and

3. Determine the need and feasibility of establishing permanent vehicle detector test facilities.

The study focused on evaluating current technology for its acceptability in replacing inductive loops at permanent data collection sites for Intelligent Vehicle Highway Systems (IVHS) applications now know as Intelligent Transportation Systems (ITS). The evaluation centered on assessing performance in various weather and traffic conditions. Recommendations are given for best performance for low and high volume count and speed determination and in inclement weather. A qualitative assessment of the results is shown in Table 13. Although the study provides valuable information on performance, it does not address practical considerations related to ease of installation, calibration, and cost. The document can be obtained at TRIS Online through the search function, http://199.79.179.82/sundev/search.cfm.

Table 13. Qualitative Assessment of Best Performing Technologies for Gathering Specific Data

Technology	Low-Volume Count	High-Volume Count	Low-Volume Speed	High-Volume Speed	Best In Inclement Weather
ultrasonic	--	--	--	--	--
Doppler microwave*	X	X	X	X	X
microwave true presence	X	X			X
passive infrared	--	--	--	--	--
active infrared	--	--	--	--	-
visible VIP (video image processing)	X	X			--
infrared VIP					
acoustic array	--	--			
SPVD magnetometer	X	--	--	--	X
inductive loop	X	X	--	--	X

[Source: 3]

X indicates the best performing technologies.
-- Indicates performance not among the best, but may still be adequate for the application.
No entry indicates not enough data reduced to make a judgment.
* Does not detect stopped vehicles.

In May 1997, the report *Field Test of Monitoring of Urban Vehicle Operations Using Non-Intrusive Technologies* was published by the Minnesota Department of Transportation, Minnesota Guidestar and SRF Consulting. This report documents the results of a two-year study of non-intrusive traffic data collection devices. Each of seventeen different devices representing eight non-intrusive technologies was evaluated under differing traffic conditions including both intersection and highway locations. The report does not include a product-to-product comparison or evaluate one technology against another. Rather, it provides information on ease of system set-up and use, general system reliability, and system flexibility for the devices evaluated. [10]

Even though the study was completed as recently as 1997, several of the devices are either no longer sold or have been revamped. The devices evaluated in the study include the following:

Table 14. Devices Evaluated in MnDOT Study

Sensor Technology	Devices Evaluated	Current Availability
passive infrared	Eltec 833 and 842	Both are currently available on the market
	ASIM IR 224	No longer distributed, replaced by new models
active infrared	Schwartz Autosense I	Currently available on the market
passive magnetic	Safetran IVHS Sensors	Yes, recommended for presence detection only
Doppler microwave	Peek PODD	No longer distributed
	Whelen TDN-30, TDW-10	Yes, recommended for speed monitoring
	Microwave Sensors TC-26B	Yes, recommended for presence detection
radar	EIS RTMS	Currently available on the market
passive acoustic	IRD Smartsonic	Currently available on the market
pulse ultrasonic	Microwave Sensors TC-30	Yes, recommended for presence detection
	Novax Lane King	Yes, recommended for presence detection
video image detection	Peek VideoTrak 900	Currently available on the market
	Econolite Autoscope 2004	Currently available on the market
	Eliop Trafico EVA	Status unknown
	Rockwell International TraffiCam S	Product line divested to Iteris

The study was comprised of two separate field tests—an Initial Field Test of selected devices from the list above and an Extended Field Test that included all devices on the list. The Initial Field Test was conducted on an interstate highway using an overpass bridge and installed poles for mounting locations. The traffic conditions included low-volume free flow and high-volume congestion. The test periods included both 24-hour and continuous counting intervals. Six inductive loops, originally installed as part of the previously mentioned Hughes' project, were used to provide baseline count and speed data. Manual counts and speed observations were used to validate the accuracy of the loops. [10]

The Extended Field Test was conducted at the same interstate highway location as the Initial Field Test but in addition an adjacent intersection site was added to the project. The intent of the Extended Field Test was to test the technologies under a variety of traffic and environmental conditions over a one-year period. The longer test period allowed for testing the devices against the harsh winter weather conditions of Minnesota that include snow, rain, fog, sleet, and high winds. In addition, the impact of various lighting conditions associated with seasonal positioning of the sun could be assessed. [10]

Some of the most important conclusions of this study involved recommendations on device selection. The study found that the performance of one device over another within a particular technology type was more significant a factor than differences between technology types. The emphasis should be on choosing a well-designed and reliable product rather than limiting the selection to a particular technology. [10] In addition, the compatibility of the device with its intended use and installation site will also dictate how well it meets performance criteria established by the user. The "CONCLUSIONS" section of the Executive Summary from the MnDOT Study is reproduced in Appendix F. A copy of the 288-page report can be ordered directly over the Internet from the Minnesota Department of Transportation at http://www.dot.state.mn.us/guidestar/nitfinal/order.htm.

The need to identify technology that can safely be installed without interrupting the flow of traffic continues to be a priority. Consequently, a second project continuing the work of this first study has been planned. Phase Two will continue to focus on historic data used primarily for planning purposes as well as investigate real-time ITS data collection applications. The five goals identified in the October 24, 2000 *Draft Evaluation Test Plan* are:

1. Develop Standardized Evaluation and Reporting Procedures
2. Assess the Performance of Non-Intrusive Technologies in Historical Data Collection Applications
3. Assess the Performance of Non-Intrusive Technologies in ITS Applications
4. Document Non-Intrusive Technology Deployment Issues
5. Document Non-Intrusive Technology Costs

Readers should watch closely for the results of the second project as it will likely provide additional valuable information for decision makers in traffic monitoring divisions of State, county and municipal agencies. [11]

Two years after the initial MnDOT study, the Texas Transportation Institute (TTI) in cooperation with the Federal Highway Administration and the Texas Department of Transportation published *An Evaluation of Some Existing Technologies for Vehicle Detection*. This report takes the Minnesota Guidestar report a step further by determining strengths and weaknesses of competing technologies. In particular, the study addresses reliability in the form of failure rates, accuracy rates, and cost comparisons. There also are selection criteria for decision-makers faced with replacing or upgrading existing traffic detection devices. The information is included in Table 5 of this report.

Texas Transportation Institute extensively tested inductive loops and selected non-intrusive devices including the Accuwave 150LX Presence Detector, Nestor Traffic Vision Video Detector, Eagle Traffic Passive Infrared Detector (PIR-1), Electronic Integrated Systems RTMS, and International Road Dynamics Smart Sonic. In addition, there is a secondary discussion on the Econolite Control Products Autoscope video detection device based on its use by the Road Commission of Oakland County (RCOC), Michigan as part of their FAST-TRAC. However, RCOC uses the device primarily for adaptive signal control applications. [5]

There are two particularly interesting parts of this report aside from the evaluation of non-intrusive devices. The first is the specification document for video image detection devices provided in the appendices. The specification document outlines procurement, installation, and performance requirements. This information is essential for transportation professionals who are considering the purchase of video image detection devices.

The second part is the extensive discussion on TTI's inductive loops experience and comparative assessment of ILDs against non-intrusive devices. It is TTI's contention that a better understanding of ILD operation "should result in improved performance and longevity." [5] In addition, the "reliability and useful life" are directly related to the quality of the installation process. [3] The TTI report is available through the National Technical Information Service (NTIS) at http://www.ntis.gov, publication number PB2000-106667INZ.

4.3.2 Single Product Evaluations

There have also been studies focusing on individual products and/or technologies. One of these tests is documented in the report *Field Evaluation of a Microloop Vehicle Detection System* from the Florida Department of Transportation. This July 2000 report tested the 3M Canoga® Vehicle Detection System Model 702. The study showed the microloop system detects the presence of slow moving vehicles and those passing at normal speeds very well. However, the system was not able to provide true presence of stopped vehicles. The system is also able to record average speed at accuracy levels very close to those of inductive loops. The ability to assess vehicle length for purposes of vehicle classification was questionable. Those considering this device should review the findings of this report for more detail. [12] The report can be downloaded at http://www.dot.state.fl.us/trafficengineering/terl.htm.

California Polytechnic State University conducted a series of studies on the use of video image processing for traffic detection. The study was initiated in 1991 and has been ongoing as Cal Poly's contract with the California Department of Transportation (Caltrans) is extended. The project has gone through several phases and continues to evolve as the technology evolves. The video image detection devices involved in 1997 phase III of the study include Rockwell TrafficCam System, Transyst Peek System, Econolite Autoscope, and Odetics Vantage. Although some of the earlier results are dated, the reports provide good background information for anyone considering the use of this technology. There also is an installation guidelines document in progress that gives detailed information on the intricacies of properly installing video devices. The reports can be found at http://gridlock.calpoly.edu.

4.3.3 Additional Information Resource

New Mexico State University maintains the Vehicle Detector Clearinghouse (VDC) that is dedicated to providing information to transportation agencies on the capabilities of commercially available vehicle detectors. The VDC is a state pooled-fund project whose mission is "to provide information to transportation agencies on the capabilities of commercially available vehicle detectors by gathering, organizing, and sharing information concerning tests and test procedures in a timely, efficient, and cost-effective manner. Equipment types included in the VDC are devices that detect vehicle presence, speed, axles, classification (AVC), and weight (WIM). The clearinghouse will be a catalyst for developing standard test protocols."

Until very recently (June 2001), no modifications had been made to the information on the VDC website, http://www.nmsu.edu/~traffic, for the past year despite the fact that the December 1999 newsletter indicates that a new contract provides for funding through December 2002. This may be due to the fact that the information was being assembled into the report *A Summary of Vehicle Detection and Surveillance Technologies Used in Intelligent Transportation Systems*, produced by the Southwestern Development Technology Institute at New Mexico State University. The report can be obtained at http://www.fhwa.dot.gov/ohim//tvtw/vdstits.htm. The VDC website has the potential to be an invaluable resource for monitoring new trends in the area of traffic data collection devices.

An additional resource that was identified for new technology is the book *Advanced Traffic Detection: Emerging Technologies and Market Forecast* published by Scientific American Newsletters. According to the publisher this document is for "a user of detection equipment seeking guidance through a complex range of product offerings." It contains sections on Technology & Market Analysis, Market Share Data, Installation Details, and Individual Vendor Profiles. The book can be ordered on line for $1,995 at http://www.sanewsletters.com/its/ATDsummary.html. [13]

4.4 CONCLUSION

The state-of-the-art of traffic counting devices is changing rapidly. There is a new focus in the industry to develop reliable, non-intrusive devices that are easy to use and cost effective to operate. However, there is much to be learned through the experiences of those who have evaluated these devices. It is recommended that the reader obtain the reports listed in this section to learn from the experiences of those who have installed and operated these devices in the field. The reports provide valuable practical information that can only be gained from working directly with the equipment.

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APPENDIX A
SURVEY INSTRUMENT

Arizona Department of Transportation Traffic Counting Survey

The *Arizona Department of Transportation* is gathering information the traffic counting practices employed by other states. We would appreciate your response to the following questions. This information will be used to assist AZDOT in improving future traffic counting practices.

1. How satisfied are you with the data collection device(s) currently employed by your agency to collect traffic data? (Mark only those used.)

	very satisfied 5	4	3	2	***very dissatisfied*** 1
manual observation	5	4	3	2	1
bending plate	5	4	3	2	1
pneumatic rubber tube	5	4	3	2	1
piezo-electric sensor	5	4	3	2	1
inductive loop	5	4	3	2	1
passive infrared	5	4	3	2	1
active infrared	5	4	3	2	1
passive magnetic	5	4	3	2	1
radar	5	4	3	2	1
Doppler microwave	5	4	3	2	1
pulse ultrasonic	5	4	3	2	1
passive acoustic	5	4	3	2	1
video image detection	5	4	3	2	1
other, specify below	5	4	3	2	1

2. Please check any specific ***disadvantages*** you have noted with your use of the equipment types listed below.

	weather interference	equipment cost	data accuracy	system failure	installation requirements	number lanes monitored	maintenance requirement	ease of calibration
manual observation								
bending plate								
pneumatic rubber tube								
piezo-electric sensor								
inductive loop								
passive infrared								
active infrared								
passive magnetic								
radar								
Doppler microwave								
pulse ultrasonic								
passive acoustic								
video image detection								

3. Please indicate the ***approximate percentage*** each method represents of results reported and the manufacturer(s) of the equipment currently used to interpret your traffic data. (Mark only those used.)

	Count	***Speed***	***Weight***	***Class***	***Manufacturer***
manual observation	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	
bending plate	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	
pneumatic rubber tube	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	
piezo-electric sensor	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	
inductive loop	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	
passive infrared	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75v	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	
active infrared	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	
passive magnetic	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	
radar	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	
Doppler microwave	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	
pulse ultrasonic	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	
passive acoustic	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	
video image detection	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	☐ < 25% ☐ 25-50 ☐ 51-75 ☐ >75	

APPENDIX B
TRAFFIC COUNTING SURVEY RESULTS

Question 1. How satisfied are you with the data collection device(s) currently employed by your agency to collect traffic data? (5 = very satisfied, 1 = very dissatisfied)

Table B1. Level of Satisfaction

State DOT	manual observation	bending plate	pneumatic rubber tube	piezo-electric sensor	inductive loop	passive infrared	active infrared	passive magnetic	radar	Doppler microwave	pulse ultrasonic	passive acoustic	video image detection
AK	5		5		5								
AL	4		5	4	5								
AR			4	5	5				3				
AZ	4	4	2	1	4							3	
CA		5	5	3	4								
CO	3		3	4	4				3				
CT			4	4	5								
DE	4		4	4	5				4				
FL	3	4	2	3	4				3				
GA	3		4	5	5				3				
HI	1	5	3	3	5								
IA	4		3	4	4								
ID	5		4	3	3								
IL	2		3	3	4			5					
IN		1	3	4	4								
KS	4	5	4	3	5				4				
KY	4	4	3	3	4			1	4				
LA			4		3				4				
MA	4		3	3	4								
MD	3		3	5	5								
ME	5		4	3	5								
MI	3	5	4	2	5			5					
MN	4	1	4	3	4								
MO			4	3	5				3				
MS		5	3	2	3								
MT	3	4	4	4	4								
NC	4	3	4	3	4				3			2	3
ND	5	1	4	4	5								
NE	4		4	4	4				4				
NH	5		4	4	5								

Table B1. Level of Satisfaction (continued)

State DOT	manual observation	bending plate	pneumatic rubber tube	piezo-electric sensor	inductive loop	passive infrared	active infrared	passive magnetic	radar	Doppler microwave	pulse ultrasonic	passive acoustic	video image detection
NJ	4	1	4	4	5								2
NM	4		4	3	3								
NV	5	5	5	4	5								4
NY	5	2	4	3	4								
OH	3	3	4	4	4				3			3	
OK	3	1	3	4	4				4				
OR	5	4	4	4	5								4
PA	4		4	2	4								
RI	4		4	3	4								2
SC	3	3	3	4	5								
SD	5	5	5		5				4				
TN	5			4	4								
TX	5	4	2	4	4								
UT	4		4	3	5								
VA	4		4	4	4			2	5			3	
VT			5	5	4								
WA	5	3	5	4	5				3				
WI		4	5	4	5								
WV	4	3	4	3	3								
WY	4		3	3	5				1				
Average	4.0	3.4	3.8	3.5	4.4	--	--	3.2	3.4	--	--	2.8	3.0

Question 2. Please check any specific disadvantages you have noted with the use of the equipment types listed.

Table B2. Disadvantages Reported Using Manual Observation

State DOT	weather interference	equipment cost	data accuracy	system failure	installation requirement	lanes monitored	maintenance requirement	calibration
AL	X	X	X			X		
DE	X							
GA	X		X			X		
HI	X					X		
IA		X		X				
ID	X					X		
IL			X					
KS					X			
KY		X						
MA			X					
MD	X					X		
ME	X					X		
MI		X	X					
MT			X					
NC	X		X					
ND	X							
NE	X							
NH	X							
NJ	X					X		
NM	X		X					
NY						X		
OH			X					
OK	X					X		
PA						X		
RI	X		X					
SC	X		X			X		
SD			X			X		
UT			X					
VA			X					
WY	X					X		
Total	**17**	**4**	**14**	**1**	**1**	**13**	**-**	**-**

Table B3. Disadvantages Reported Using Bending Plates

State DOT	weather interference	equipment cost	data accuracy	system failure	installation requirement	lanes monitored	maintenance requirement	calibration
AZ		X						
CA		X					X	X
FL		X						
HI		X					X	
IN				X	X		X	
KY		X			X		X	X
MI		X						
MN				X				
MS		X			X			
MT		X			X		X	
NC					X			
ND	X	X	X	X			X	X
NJ				X	X			
NV		X			X			
NY	X	X		X	X		X	X
OH		X			X		X	
OK		X		X			X	
OR		X						
SC		X	X	X	X		X	X
TN			X					
TX		X			X		X	
WA		X			X		X	
WI								X
WV		X			X		X	
Total	**2**	**18**	**3**	**7**	**13**	**-**	**13**	**6**

Table B4. Disadvantages Reported Using Pneumatic Road Tubes

State DOT	weather interference	equipment cost	data accuracy	system failure	installation requirements	lanes monitored	maintenance requirement	calibration
AL				X	X			
AR	X		X			X		
AZ			X	X			X	
CA	X					X		
CO			X			X		
CT	X		X	X				
DE	X		X			X		
FL			X					

Table B4. Disadvantages Reported Using Pneumatic Road Tubes (continued)

State DOT	weather interference	equipment cost	data accuracy	system failure	installation requirements	lanes monitored	maintenance requirement	calibration
GA	X		X			X	X	
HI	X		X		X	X		
IA			X					
ID	X	X		X	X			
IL			X	X		X		
IN			X		X			
KS	X					X		
KY			X			X		
LA	X					X		
MA	X		X		X	X		
MD	X		X		X	X		
ME	X		X			X		
MI	X		X					
MN	X					X		
MO						X		
MS	X		X	X				
MT	X			X		X		
NC	X					X		
ND	X							
NE	X					X		
NH	X		X	X	X	X		
NJ	X		X			X		
NM	X		X			X		
NY	X		X			X		
OH	X					X		
OK	X		X			X		
OR						X		
PA						X		
RI					X	X		
SC			X		X	X		
SD					X			
TN						X		
TX			X			X		
UT	X							
VA			X					
VT						X		
WA	X							
WI	X							
WV	X		X			X		
WY	X		X		X			
Total	**30**	**1**	**27**	**8**	**11**	**32**	**2**	**-**

Table B5. Disadvantages Reported Using Piezo-Electric Sensors

State DOT	weather interference	equipment cost	data accuracy	system failure	installation requirement	lanes monitored	maintenance requirement	calibration
AK	X	X			X			
AL				X			X	
AR	X			X			X	X
AZ				X	X		X	
CA	X		X	X	X		X	X
CO					X		X	
CT	X							
DE				X				X
FL			X	X	X			
GA		X		X	X			
HI				X			X	
IA								X
ID		X	X		X			
IL		X			X		X	X
IN				X				
KS			X	X			X	X
KY				X			X	X
LA		X			X		X	
MA					X		X	X
MD					X		X	X
ME			X	X			X	X
MI			X	X			X	
MN			X					
MO				X	X		X	
MS		X	X	X				X
MT				X				
NC		X		X				
ND	X							
NE					X			
NH					X			
NJ					X		X	X
NV				X				
NY	X			X	X			
OH				X	X			
OK	X							
OR			X		X			
PA			X	X				
RI	X							X
SC					X			
TN	X		X		X			
UT		X			X			X
VA			X	X				
VT	X			X				
WA	X							
WI				X			X	
WV							X	X
WY	X			X	X			X
Total	**12**	**8**	**12**	**25**	**22**	**-**	**18**	**16**

Table B6. Disadvantages Reported Using Inductive Loops

State DOT	weather interference	equipment cost	data accuracy	system failure	installation requirement	lanes monitored	maintenance requirement	calibration
AR	X			X				
AZ				X	X		X	
CA		X						
CO					X		X	
CT	X							
DE					X			
HI		X					X	
ID					X			
IL		X			X		X	
IN				X				
KS					X			
KY					X			
LA		X			X	X		
MA					X		X	
MD					X		X	X
ME							X	
MN							X	
MT			X	X				
NC				X				
NE					X			
NH				X	X			
NJ								X
NM			X					
NY					X			
OH					X			
OK					X		X	
OR			X					
PA					X		X	
RI				X	X		X	
SD							X	
TN					X			
VT			X					
WI					X			
WV					X		X	
WY					X			
Total	**2**	**4**	**4**	**7**	**21**	**1**	**13**	**2**

Table B7. Disadvantages Reported Using Passive Magnetic Devices

State DOT	weather interference	equipment cost	data accuracy	system failure	installation requirement	lanes monitored	maintenance requirement	calibration
IL		X						
KY			X	X				
MI					X			
VA			X					
Total	**-**	**1**	**2**	**1**	**1**	**-**	**-**	**-**

Table B8. Disadvantages Reported Using Radar

State DOT	weather interference	equipment cost	data accuracy	system failure	installation requirement	lanes monitored	maintenance requirement	calibration
AR	X	X	X	X			X	X
CO					X			
DE	X		X					
GA	X	X	X		X			X
KS								X
KY					X			X
MO		X		X				
NC			X		X	X		
OH		X	X					X
OK		X						
SD								X
WA	X		X		X	X		X
WY		X	X		X			X
Total	**4**	**6**	**7**	**2**	**6**	**2**	**1**	**8**

Table B9. Disadvantages Reported Using Passive Acoustic Devices

State DOT	weather interference	equipment cost	data accuracy	system failure	Installation requirement	lanes monitored	maintenance requirement	calibration
AZ	X	X						X
NC			X		X	X		
OH		X			X			
VA					X			
Total	**1**	**2**	**1**	**-**	**3**	**1**	**-**	**1**

Table B10. Disadvantages Reported Using Video Image Detection

State DOT	weather interference	equipment cost	data accuracy	system failure	installation requirement	lanes monitored	maintenance requirement	calibration
NC	X	X			X			
NJ	X	X	X		X			X
NV	X							
OR				X	X			
RI		X	X	X	X			
Total	**3**	**3**	**2**	**2**	**4**	**-**	**-**	**1**

Question 3. Indicate the approximate percentage each method represents of results reported and the manufacturer(s) of the equipment currently used to interpret the traffic data.

Table B11. Frequency of Method Use to Collect Count Data

State DOT	manual observation	bending plate	pneumatic rubber tube	piezo-electric sensor	inductive loop	passive magnetic	radar	passive acoustic	video detection
AL	< 25%		> 75%	< 25%	25 - 50%				
AR		< 25%	> 75%	< 25%	< 25%		< 25%		
AZ FMS					51 - 75%			25 - 50%	
AZ			51 - 75%		25 - 50%				
CA			25 - 50%	< 25%	51 - 75%				
CO			< 25%	< 25%	< 25%		< 25%		
CT			25 - 50%	< 25%	25 - 50%				
DE	25 - 50%		> 75%	51 - 75%	> 75%		> 75%		
FL					< 25%				
GA	< 25%		> 75%	< 25%	25 - 50%				
HI		< 25%	> 75%	< 25%	25 - 50%				
IA	> 75%		> 75%	> 75%	> 75%				
ID			25 - 50%		> 75%				
IL	< 25%		51 - 75%	< 25%	< 25%	25 - 50%			
IN			< 25%						
KS			51 - 75%		25 - 50%		< 25%		
KY	< 25%	< 25%	51 - 75%	< 25%	< 25%	< 25%	< 25%		
LA			51 - 75%	< 25%	25 - 50%		< 25%		
MA	< 25%		25 - 50%	< 25%	25 - 50%				
ME			> 75%		< 25%				
MI			> 75%		> 75%	< 25%			
MN			> 75%		< 25%				
MO			> 75%		< 25%		< 25%		
MS		< 25%	51 - 75%	< 25%	< 25%				
MT	< 25%	< 25%	25 - 50%	< 25%	25 - 50%				
NC	< 25%		51 - 75%		25 - 50%		< 25%	< 25%	
ND	< 25%	< 25%	51 - 75%	< 25%	< 25%				
NE	< 25%		> 75%		> 75%		< 25%		
NH	< 25%		> 75%		< 25%				
NJ	< 25%	< 25%	> 75%	< 25%	< 25%				
NM	< 25%	< 25%	> 75%		51 - 75%				
NV			25 - 50%	< 25%	25 - 50%				
NY	< 25%		> 75%	< 25%	< 25%				
OH	25 – 50%		> 75%		> 75%		< 25%	< 25%	
OK			51 - 75%	25 - 50%	51 - 75%		< 25%		
OR	< 25%	25 - 50%	> 75%	< 25%	25 - 50%				< 25%
PA			> 75%		< 25%				
RI	< 25%		> 75%		< 25%				< 25%
SC	51 – 75%	51 - 75%	> 75%	> 75%	> 75%				
SD	< 25%	< 25%	> 75%		< 25%		< 25%		
TN	< 25%		> 75%		< 25%				

Table B11. Frequency of Method Use to Collect Count Data (continued)

State DOT	manual observation	bending plate	pneumatic rubber tube	piezo-electric sensor	inductive loop	passive magnetic	radar	passive acoustic	video detection
TX	< 25%	< 25%	> 75%		> 75%				
UT			> 75%		25 - 50%				
VA	< 25%		> 75%	< 25%	< 25%		< 25%	< 25%	
VT			< 25%	< 25%	> 75%				
WA	> 75%	< 25%	51 - 75%	25 - 50%	25 - 50%		< 25%		
WI		< 25%	> 75%	< 25%	< 25%				
WV	< 25%	< 25%	> 75%	< 25%	< 25%				
WY							< 25%		

Table B12. Frequency of Method Use to Collect Speed Data

State DOT	manual observation	bending plate	pneumatic rubber tube	piezo-electric sensor	inductive loop	passive magnetic	radar	passive acoustic	video detection
AR			> 75%	< 25%	< 25%				
AZ FMS					51 - 75%			25 -50%	
AZ			< 25%		> 75%				
CO					> 75%		< 25%		
CT				< 25%	< 25%				
DE			< 25%	51 - 75%					
FL		< 25%	51 - 75%		< 25%				
GA				< 25%	25 - 50%				
HI		< 25%	< 25%	< 25%	< 25%				
IA				> 75%	> 75%				
ID					> 75%				
IL			< 25%	< 25%		51 - 75%			
KY		< 25%	51 - 75%	< 25%	25 - 50%				
ME			< 25%						
MI					> 75%				
MN			> 75%		< 25%				
MO			< 25%		< 25%				
MS		< 25%							
MT				25 - 50%	51 - 75%				
ND	< 25%	< 25%	< 25%	> 75%	< 25%				
NJ			< 25%	> 75%	> 75%				
NM					> 75%				
NV			< 25%	< 25%	< 25%		< 25%		
NY			> 75%	< 25%	< 25%				

Table B12. Frequency of Method Use to Collect Speed Data (continued)

State DOT	manual observation	bending plate	pneumatic rubber tube	piezo-electric sensor	inductive loop	passive magnetic	radar	passive acoustic	video detection
OH				51 - 75%	> 75%				
OR	< 25%		25 - 50%	51 - 75%	25 - 50%				< 25%
PA				< 25%	51 - 75%				
RI					> 75%				
SC	51 - 75%	51 - 75%	> 75%	> 75%	> 75%				
SD	< 25%	< 25%	< 25%		> 75%				
TN			> 75%		< 25%				
TX		< 25%		25 - 50%					
UT				< 25%	> 75%				
VA			< 25%	< 25%	< 25%				
VT				< 25%					
WA	< 25%	< 25%	25 - 50%	25 - 50%	25 - 50%		< 25%		
WI		< 25%		< 25%	> 75%				
WV		< 25%	< 25%	> 75%	< 25%				

Table B13. Frequency of Method Use to Collect Weight Data

State DOT	manual observation	bending plate	pneumatic rubber tube	piezo-electric sensor	inductive loop	passive magnetic	radar	passive acoustic	video detection
AL	< 25%			51 - 75%					
AR				> 75%					
AZ		< 25%		> 75%					
CA		> 75%							
CO				> 75%					
CT				> 75%					
DE				> 75%	> 75%				
FL		< 25%		51 - 75%					
GA				> 75%	> 75%				
HI		< 25%		< 25%					
IA				< 25%	< 25%				
ID				> 75%					
IL				> 75%					
KS		< 25%		< 25%					
KY		< 25%		> 75%					
MD				> 75%	> 75%				
ME				> 75%					
MI		< 25%		51 - 75%					
MN		51 - 75%		< 25%					
MO				25 - 50%	25 - 50%				

Table B13. Frequency of Method Use to Collect Weight Data (continued)

State DOT	manual observation	bending plate	pneumatic rubber tube	piezo-electric sensor	inductive loop	passive magnetic	radar	passive acoustic	video detection
MS		< 25%		51 - 75%	< 25%				
MT		< 25%		> 75%					
NC		< 25%		51 - 75%					
ND	< 25%	> 75%	< 25%	< 25%	< 25%				
NE				> 75%	> 75%				
NH				> 75%					
NJ		< 25%		> 75%					
NM				> 75%					
NV		< 25%		< 25%	51 - 75%				
NY		> 75%		< 25%					
OH		< 25%		51 - 75%					
OK				> 75%	25 - 50%				
OR	< 25%	25 - 50%	< 25%	51 - 75%	< 25%				< 25%
PA				> 75%					
SC	51 - 75%	51 - 75%		> 75%	> 75%				
SD	< 25%	> 75%			< 25%				
TN				> 75%					
TX		25 - 50%							
UT				> 75%					
VT				> 75%					
WA	< 25%	< 25%	< 25%	> 75%					
WI		51 - 75%		25 - 50%					
WV		25 - 50%	< 25%	25 - 50%	< 25%				

Table B14. Frequency of Method Use to Collect Classification Data

State DOT	manual observation	bending plate	pneumatic rubber tube	piezo-electric sensor	inductive loop	passive magnetic	radar	passive acoustic	video detection
AL	< 25%		> 75%	< 25%					
AR			> 75%	25 - 50%	< 25%				
AZ	> 75%	< 25%	< 25%	< 25%	< 25%				
CA			25 - 50%	< 25%					
CO					< 25%				
CT			25 - 50%	51 - 75%					
DE	25 - 50%		> 75%	> 75%	> 75%				
FL		< 25%		51 - 75%					
GA				> 75%	> 75%				
HI	< 25%	< 25%	< 25%	< 25%					
IA	< 25%		< 25%	> 75%	> 75%				

Table B14. Frequency of Method Use to Collect Classification Data (continued)

State DOT	manual observation	bending plate	pneumatic rubber tube	piezo-electric sensor	inductive loop	passive magnetic	radar	passive acoustic	video detection
ID	< 25%		25 - 50%	25 - 50%	51 - 75%				
IL	< 25%		< 25%			> 75%			
IN		< 25%	> 75%	> 75%	> 75%				
KS	< 25%	< 25%	51 - 75%						
KY	25 - 50%	< 25%		< 25%	< 25%				
LA			51 - 75%						
MD				> 75%	> 75%				
ME	< 25%		> 75%	< 25%					
MI	< 25%		< 25%	25 - 50%					
MN	25 - 50%		51 - 75%						
MO			< 25%	25 - 50%	51 - 75%				
MS		< 25%	> 75%	51 - 75%	< 25%				
MT	< 25%	< 25%	25 - 50%	51 - 75%					
NC	< 25%	< 25%	25 - 50%	51 - 75%					< 25%
ND	< 25%	< 25%	< 25%	51 - 75%	< 25%				
NE			< 25%	> 75%	> 75%				
NH	< 25%		51 - 75%	< 25%					
NJ	< 25%	< 25%	51 - 75%	25 - 50%					
NM	< 25%		> 75%	25 - 50%					
NV	25 - 50%	< 25%	< 25%	< 25%	25 - 50%				< 25%
NY		< 25%	> 75%	< 25%	< 25%				
OH			> 75%	> 75%					
OK			< 25%	> 75%	25 - 50%				
OR	25 - 50%	25 - 50%	< 25%	> 75%	51 - 75%				< 25%
PA	< 25%		> 75%	< 25%					
RI			> 75%		< 25%				< 25%
SC	51 - 75%	51 - 75%	> 75%	> 75%	> 75%				
SD	< 25%	< 25%	> 75%		< 25%				
TN			> 75%	< 25%					
TX	51 - 75%	< 25%	< 25%	25 - 50%					
UT	< 25%		> 75%	< 25%					
VA	< 25%		> 75%	< 25%	< 25%				
VT			> 75%	< 25%					
WA	25 - 50%	< 25%	51 - 75%	25 - 50%					
WI		< 25%	51 - 75%	< 25%					
WV	< 25%	25 - 50%	51 - 75%	25 - 50%	< 25%				

Table B15. Traffic Data Reported Using Manual Observation

State DOT	Count	Speed	Weight	Class
AL	X		X	X
AZ				X
DE	X			X
GA	X			
HI				X
IA	X			X
ID				X
IL	X			X
KS				X
KY	X			X
MA	X			
ME				X
MI				X
MN				X
MT	X			X
NC	X			X
ND	X	X	X	X
NE	X			
NH	X			X
NJ	X			X
NM	X			X
NV				X
NY	X			
OH	X			
OR	X	X	X	X
PA				X
RI	X			
SC	X	X	X	X
SD	X	X	X	X
TN	X			
TX	X			X
UT				X
VA	X			X
WA	X	X	X	X
WV	X			X
WY	X			X
Total	**26**	**5**	**6**	**29**

Table B16. Traffic Data Reported Using Bending Plates

State DOT	Count	Speed	Weight	Class
AZ	X		X	X
CA			X	
FL		X	X	X
HI	X	X	X	X
IN				X
KS			X	X
KY	X	X	X	X
MI			X	
MN			X	
MS	X	X	X	X
MT	X		X	X
NC			X	X
ND	X	X	X	X
NJ	X		X	X
NM	X			
NV			X	X
NY			X	X
OH			X	
OR	X		X	X
SC	X	X	X	X
SD	X	X	X	X
TX	X	X	X	X
WA	X	X	X	X
WI	X	X	X	X
WV	X	X	X	X
Total	**15**	**11**	**23**	**20**

Table B17. Traffic Data Reported Using Pneumatic Road Tubes

State DOT	Count	Speed	Weight	Class
AL	X			X
AR	X	X		X
AZ	X			X
CA	X			X
CO	X			
CT	X			X
DE	X	X		X
FL		X		
GA	X			
HI	X	X		X
IA	X			X
ID	X			X
IL	X	X		X
IN	X			X
KS	X			X
KY	X	X		

Table B17. Traffic Data Reported Using Pneumatic Road Tubes (continued)

State DOT	Count	Speed	Weight	Class
LA	X			X
MA	X			
ME	X	X		X
MI	X			X
MN	X	X		X
MO	X	X		X
MS	X			X
MT	X			X
NC	X			X
ND	X	X	X	X
NE	X			X
NH	X			X
NJ	X	X		X
NM	X			X
NV	X	X		X
NY	X	X		X
OH	X			X
OK	X			X
OR	X	X	X	X
PA	X			X
RI	X			X
SC	X	X		X
SD	X	X		X
TN	X	X		X
TX	X			X
UT	X			X
VA	X	X		X
VT	X			X
WA	X	X	X	X
WI	X			X
WV	X	X	X	X
WY	X			X
Total	**47**	**20**	**4**	**43**

Table B18. Traffic Data Reported Using Piezo-Electric Sensors

State DOT	Count	Speed	Weight	Class
AL	X		X	X
AZ			X	X
CA	X			X
CO	X		X	
CT	X	X	X	X
DE	X	X	X	X
FL			X	X
GA	X	X	X	X
HI	X	X	X	X
IA	X	X	X	X
ID			X	X
IL	X	X	X	
IN				X
KS			X	
KY	X	X	X	X
LA	X			
MA	X			
MD			X	X
ME			X	X
MI			X	X
MN			X	
MO			X	X
MS	X		X	X
MT	X	X	X	X
NC			X	X
ND	X	X	X	X
NE			X	X
NH			X	X
NJ	X	X	X	X
NM			X	X
NV	X	X	X	X
NY	X	X	X	X
OH		X	X	X
OK	X		X	X
OR	X	X	X	X
PA		X	X	X
RI	X			
SC	X	X	X	X
TN			X	X
TX		X		X
UT		X	X	X
VA	X	X		X
VT	X	X	X	X
WA	X	X	X	X
WI	X	X	X	X
WV	X	X	X	X
WY	X			X
Total	**28**	**23**	**39**	**40**

Table B19. Traffic Data Reported Using Inductive Loops

State DOT	Count	Speed	Weight	Class
AL	X			
AR	X	X		X
AZ	X	X		X
CA	X			
CO	X	X		X
CT	X	X		
DE	X		X	X
FL	X	X		
GA	X	X	X	X
HI	X	X		
IA	X	X	X	X
ID	X	X		X
IL	X			
IN				X
KS	X			
KY	X	X		X
LA	X			
MA	X			
MD			X	X
ME	X			
MI	X	X		
MN	X	X		
MO	X	X	X	X
MS	X		X	X
MT	X	X		
NC	X			
ND	X	X	X	X
NE	X		X	X
NH	X			
NJ	X	X		
NM	X	X		
NV	X	X	X	X
NY	X	X		X
OH	X	X		
OK	X		X	X
OR	X	X	X	X
PA	X	X		
RI	X	X		X
SC	X	X	X	X
SD	X	X	X	X
TN	X	X		
TX	X			
UT	X	X		
VA	X	X		X
VT	X			
WA	X	X		
WI	X	X		
WV	X	X	X	X
WY	X	X		X
Total	**47**	**32**	**14**	**24**

Table B20. Traffic Data Reported Using Passive Magnetic Devices

State DOT	Count	Speed	Weight	Class
IL	X	X		X
KY	X			
MI	X			
Total	**3**	**1**	**-**	**1**

Table B21. Traffic Data Reported Using Radar

State DOT	Count	Speed	Weight	Class
AR	X			
CO	X	X		
DE	X			
KS	X			
KY	X			
LA	X			
MO	X			
NC	X			
NE	X			
NV		X		
OH	X			
OK	X			
SD	X			
VA	X			
WA	X	X		
WY	X			
Total	**15**	**3**	**-**	**-**

Table B22. Traffic Data Reported Using Passive Acoustic Devices

State DOT	Count	Speed	Weight	Class
AZ	X	X		
NC	X			
OH	X			
VA	X			
Total	**4**	**1**	**-**	**-**

Table B23. Traffic Data Reported Using Video Image Detection

State DOT	Count	Speed	Weight	Class
NC				X
NV				X
OR	X	X	X	X
RI	X			X
Total	**2**	**1**	**1**	**4**

Table B24. Manufacturers Utilized by Each State

State	Manual Observation	Bending Plate	Pneumatic Road Tube	Piezo-Electric Sensor	Inductive Loop
AK	None provided		Peek Traffic		Peek Traffic
AL	None provided		Diamond Traffic Peek Traffic	ECM, Inc.	Diamond Traffic Peek Traffic
AR			Diamond Traffic ITC (Pat America)	ITC (Pat America) Peek Traffic	Peek Traffic
AZ	Unknown device	International Road Dynamics Pat America, Inc.	Golden River TRAFFIC	Unknown device	Golden River TRAFFIC International Road Dynamics
CA		International Road Dynamics Pat America Inc.	Diamond Traffic Peek Traffic	Diamond Traffic Peek Traffic	Diamond Traffic Peek Traffic
CO			Diamond Traffic ITC (Pat America)	Diamond Traffic ECM, Inc. International Road Dynamics	Diamond Traffic
CT			Diamond Traffic	ITC (Pat America) Mikros Systems	ITC (Pat America) Peek Traffic
DE	None provided		Peek Traffic	Peek Traffic	Peek Traffic
FL		Pat America Inc.	Diamond Traffic Peek Traffic	Diamond Traffic Peek Traffic	Diamond Traffic Peek Traffic
GA	None provided		Peek Traffic	Peek Traffic	Peek Traffic
HI	JAMAR Technologies	Pat America Inc.	Peek Traffic	International Road Dynamics	Peek Traffic
IA	Diamond Traffic		Peek Traffic	Peek Traffic	Peek Traffic
ID	In-house laptop		Diamond Traffic	Mikros Systems ECM, Inc.	Diamond Traffic
IL	JAMAR Technologies		Diamond Traffic	ITC (Pat America) Peek Traffic	ITC (Pat America) Peek Traffic
IN		International Road Dynamics	None provided	Diamond Traffic International Road Dynamics	Diamond Traffic International Road Dynamics
KS	None provided	International Road Dynamics	Diamond Traffic	ECM, Inc. ITC (Pat America)	Diamond Traffic
KY	None provided	International Road Dynamics Pat America Inc.	Peek Traffic	Peek Traffic	Peek Traffic
LA			Peek Traffic	Peek Traffic	Peek Traffic
MA	JAMAR Technologies		Peek Traffic	ECM, Inc. International Road Dynamics	Peek Traffic
MD	Contracted service		Contracted service	Peek Traffic	Peek Traffic
ME	JAMAR Technologies		Pat America Inc. Peek Traffic	ECM, Inc. Measurement Specialties	Peek Traffic
MI	None provided	International Road Dynamics Pat America Inc.	Diamond Traffic Peek Traffic	Measurement Specialties	Diamond Traffic Peek Traffic
MN	None provided	International Road Dynamics	TimeMark Inc.	International Road Dynamics	Peek Traffic

Table B24. Manufacturers Utilized by Each State (continued)

State	Manual Observation	Bending Plate	Pneumatic Road Tube	Piezo-Electric Sensor	Inductive Loop
MO			Peek Traffic	International Road Dynamics Peek Traffic	International Road Dynamics Peek Traffic
MS		Pat America Inc.	ITC (Pat America)	ITC (Pat America) Peek Traffic	Mitron Systems Corporation
MT	JAMAR Technologies	Pat America Inc.	Diamond Traffic Peek Traffic	ECM, Inc. Diamond Traffic	Diamond Traffic ECM, Inc. Peek Traffic
NC	Petra	Peek Traffic	Diamond Traffic	Peek Traffic	Diamond Traffic
ND	JAMAR Technologies	International Road Dynamics Pat America Inc.	Diamond Traffic Peek Traffic	Peek Traffic	Peek Traffic
NE	None provided		Diamond Traffic	Diamond Traffic Peek Traffic	Diamond Traffic
NH	JAMAR Technologies		GK	ECM, Inc.	GK
NJ	JAMAR Technologies	International Road Dynamics Pat America Inc.	Golden River TRAFFIC Peek Traffic	International Road Dynamics	Golden River TRAFFIC International Road Dynamics ITC (Pat America) Peek Traffic
NM	None provided	International Road Dynamics	Peek Traffic	International Road Dynamics Peek Traffic	International Road Dynamics Peek Traffic
NV	None provided	Pat America Inc.	Diamond Traffic GK Golden River TRAFFIC	Vibracoax	Diamond Traffic Golden River TRAFFIC
NY	JAMAR Technologies	International Road Dynamics Pat America Inc.	Diamond Traffic ITC (Pat America) MetroCount	Diamond Traffic ITC (Pat America) Peek Traffic	Diamond Traffic ITC (Pat America) Peek Traffic
OH	JAMAR Technologies	Pat America Inc.	Diamond Traffic	Diamond Traffic	Diamond Traffic
OK			Diamond Traffic Peek Traffic	Measurement Specialties	Peek Traffic
OR	None provided	International Road Dynamics	Diamond Traffic Peek Traffic	International Road Dynamics	Peek Traffic
PA	ITC (Pat America)		Diamond Traffic ITC (Pat America) Peek Traffic	ITC (Pat America)	Diamond Traffic ITC (Pat America) Peek Traffic
RI	None provided		Peek Traffic	ECM, Inc.	Peek Traffic
SC	None provided	Pat America Inc.	Diamond Traffic	Measurement Specialties	Peek Traffic
SD	Electronic Control Board	Pat America Inc.	Diamond Traffic		Peek Traffic
TN	JAMAR Technologies		Diamond Traffic Peek Traffic	Peek Traffic	Streeter Telac
TX	Contracted service	Pat America Inc.	Peek Traffic	ECM, Inc. Peek Traffic	Peek Traffic

Table B24. Manufacturers Utilized by Each State (continued)

State	Manual Observation	Bending Plate	Pneumatic Road Tube	Piezo-Electric Sensor	Inductive Loop
UT	None provided		Peek Traffic	Peek Traffic	Peek Traffic
VA	None provided		Peek Traffic	Peek Traffic	Peek Traffic
VT			JAMAR Technologies	International Road Dynamics	JAMAR Technologies
WA	Diamond Traffic	International Road Dynamics	Diamond Traffic GK	Diamond Traffic International Road Dynamics Measurement Specialities	Diamond Traffic International Road Dynamics Measurement Specialties
WI		Pat America Inc.	Peek Traffic	Measurement Specialities	Peek Traffic
WV	None provided	Pat America Inc.	Peek Traffic	ECM, Inc. Measurement Specialities	ECM, Inc. Peek Traffic ITC (Pat America)
WY	In-house laptop		Diamond Traffic	Diamond Traffic ECM, Inc.	Diamond Traffic

Table B24. Manufacturers Utilized by Each State (continued)

State	Passive Magnetic	Radar	Passive Acoustic	Video Image Detection
AR		EIS Electronic Integrated Systems		
AZ			SmarTek Systems International Road Dynamics	
CO		EIS Electronic Integrated Systems		
DE		EIS Electronic Integrated Systems		
FL		EIS Electronic Integrated Systems		
GA		EIS Electronic Integrated Systems		
IL	Nu-Metrics			
KS		EIS Electronic Integrated Systems		
KY	3M	EIS Electronic Integrated Systems		
LA		EIS Electronic Integrated Systems		
MI	3M			
MO		EIS Electronic Integrated Systems		
NC		EIS Electronic Integrated Systems	SmarTek Systems	Traficon
NE		EIS Electronic Integrated Systems		
NJ				Peek Traffic (Evaluation Unit only)
NV		Kustom Signal		ATD Northwest
OH		EIS Electronic Integrated Systems	SmarTek Systems	
OK		EIS Electronic Integrated Systems		
OR				Peek Traffic
RI				Nestor Traffic Systems
SD		EIS Electronic Integrated Systems		
VA	Nu-Metrics (Evaluation Unit only)	EIS Electronic Integrated Systems	International Road Dynamics	
WA		EIS Electronic Integrated Systems		
WY		EIS Electronic Integrated Systems		

APPENDIX C
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http://www.bts.gov/

CENET: Electronic Information Interchange for the Design and Construction Industry
http://www.cenet.org/

Civil Engineering Research Foundation
http://www.cerf.org

Federal Highway Administration (FHWA)
http://www.fhwa.dot.gov/

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http://www.cerf.org/hitec/

Institute of Traffic Engineers (ITE)
http://www.ite.org/

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http://www.itsa.org/home.nsf

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http://www.dot.state.mn.us/guidestar/

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http://www.ntis.gov

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APPENDIX F
MNDOT REPORT CONCLUSIONS

V. CONCLUSIONS

The following factors must be considered when evaluating the non-intrusive devices tested in this project.

- Level of expertise required and time spent installing and calibrating a device,
- Reliability of a device,
- Number of lanes a device can detect,
- Mounting options such as overhead, side-fire and height,
- Ease of installation and moving from one location to another,
- Capability for remote adjustment of calibration parameters and trouble shooting,
- Wireless communication to simplify the data retrieval process,
- Solar powered or battery powered devices for temporary counts in locations without an accessible source of power,
- Type of traffic data provided,
- Performance in various weather and traffic conditions, and
- The intended use for a particular device; a device used to actuate a signal must meet a different set of performance criteria than a device used to collect historical traffic data. Some devices are also designed to offer real time information for ITS applications.

The following lists the major conclusions from the test:

- Most of the devices tested in this project are well-suited for temporary counting situations. Ease of installation and flexibility in mounting locations and power supplies are important elements in selecting a device to install quickly and move from location to location.
- The devices that use Doppler microwave, active infrared, and passive infrared technologies have a simple “point-and-shoot” type of setup.
- Passive magnetic, radar, passive acoustic and pulse ultrasonic devices require some type of adjustment once the device is mounted. In most cases this adjustment must be performed over a serial communication line.
- Video devices require extensive calibration over serial communication lines and are not well-suited for temporary counting.
- Extensive installation work is required for video and passive magnetic devices, making them less suitable for temporary data collection.
- From an overhead mounting location at the freeway test site, the video and passive acoustic devices have been found to count to between 4 and 10 percent of baseline volume data.
- Pulse ultrasonic, Doppler microwave, radar, passive magnetic, passive infrared, and active infrared have been found to count within 3 percent of baseline volume data.

- The count results are more varied at the intersection test site. The pulse ultrasonic, passive acoustic, and video devices were generally within 10 percent of baseline volume data while one of the passive infrared devices was within 5 percent.
- Speed data were collected from active infrared, passive magnetic, radar, Doppler microwave, passive acoustic and video devices at the freeway test site. In general, all of the devices were within 8 percent of the baseline data. Radar, Doppler microwave, and video were the most accurate technologies at measuring vehicle speeds.
- Video and radar devices have the advantage of multiple-lane detection from a single unit. Video has the additional advantage of providing a view of the traffic operations at the test site.
- Weather variable were found to have minimal direct affect of device performance, but snow on the roadway caused some vehicles to track outside of their normal driving patterns, affecting devices with narrow detection zones.
- Lighting conditions were observed to affect some of the video devices, particularly in the transition from day to night.
- Extremely cold weather made access to devices difficult, especially for the magnetic probes installed under the pavement.
- Urban traffic conditions, including heavy congestion, were found to have little affect on the device performance.
- In general, the differences in performance from one device to another within the same technology were found to be more significant than the differences from one technology to another.
- It is more important to select a well-designed and highly reliable product than to narrow a selection to a particular technology.

There are ongoing developments in non-intrusive vehicle detection technologies. Devices are now available that incorporate multiple technologies within a single device. Developments in other technologies, such a passive millimeter microwave and infrared video, will produce additional entries into the market. At the same time, existing technologies are continually being improved upon.