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**COUNTING DEVICE SELECTION AND RELIABILITY:  
SYNTHESIS STUDY**

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16. Abstract <p>Accuracy in traffic data detection is important for transportation operations and planning. Currently, inductive loop detectors are the most commonly used traffic counting devices in the field. New technologies are being developed to meet growing data counting and traffic surveillance needs. They include passive infrared, active infrared, passive magnetic, Doppler microwave, radar, passive acoustic, pulse and Doppler ultrasonic, and video image processor. However, the relatively recent, but widespread, emergence of these technologies and the consequent sparseness in information on their performance characteristics preclude traffic agencies from making informed choices in the selection of traffic counting devices. This study performs a comprehensive survey of the currently available traffic counting products in terms of functional capabilities, technological focus, performance characteristics, and user perspectives. It identifies the major selection criteria and ranks them in the order of importance based on user feedback from agencies in six U.S. states. A two-step filtering selection procedure is proposed to provide guidelines for traffic agencies to decide the type and make of devices that satisfy their data collection needs and the associated field environment.</p>					
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## IMPLEMENTATION REPORT

A set of databases consisting of intrusive and non-intrusive traffic counting devices was created as part of this study. Currently, 99 products from 32 vendors are recorded in the databases. Detailed information on each device is provided using a set of attributes that characterize the capabilities, parameters, features, and performance of the devices. Users can retrieve, update or extend device-related information, and select, sort or filter data to identify devices according to their needs and preferences. The databases can serve as a starting point for counting device selection procedure by state and local agencies. Selection criteria were identified and ranked in the order of importance based on a user survey. A two-step filtering selection procedure was proposed to identify appropriate counting devices based on user needs and field conditions.

## TABLE OF CONTENTS

Description	Page
LIST OF TABLES.....	iii
LIST OF FIGURES.....	iv
CHAPTER 1 INTRODUCTION.....	1
1.1 Motivation and Problem Description.....	1
1.2 Literature Review .....	4
CHAPTER 2 REVIEW OF TRAFFIC COUNTING TECHNOLOGIES.....	7
2.1 Non-intrusive Technologies .....	7
2.1.1 Infrared (Active, Passive) .....	7
2.1.2 Microwave (Doppler, Radar and Passive Millimeter).....	8
2.1.3 Passive Acoustic.....	9
2.1.4 Ultrasonic (Pulse and Doppler).....	9
2.1.5 Video Image Processors.....	9
2.2 Intrusive Technologies.....	10
2.2.1 Magnetic (Passive) Detectors.....	11
2.2.2 Inductive Loop (Active Magnetic).....	11
2.2.3 Pneumatic Road Tube.....	12
CHAPTER 3 SELECTION CRITERIA AND PROCEDURE.....	13
3.1 Selection Factors.....	13
3.1.1 Device-related Factors .....	13
3.1.1.1 Cost.....	13
3.1.1.2 Accuracy and Reliability.....	14
3.1.1.3 Ease of Installation and Maintenance.....	14
3.1.1.4 Portability and Storage.....	14
3.1.1.5 Ease of Data Retrieval.....	14
3.1.1.6 Data Type and Functional Capabilities.....	15
3.1.1.7 Amenability to Future Technological Advances.....	15
3.1.1.8 Ease of Use and Personnel Training Needs.....	15
3.1.2 Environment-related Factors .....	15
3.1.2.1 Traffic Characteristics.....	16
3.1.2.2 Roadway Type.....	16
3.1.2.3 Installation Location and Position.....	17
3.1.2.4 Weather Conditions.....	17
3.1.2.5 Traffic Direction.....	18
3.2 Selection Procedure .....	18
3.2.1 Two-step Filtering Selection Procedure.....	18
3.2.2 Technology-specific Filtering.....	19
3.2.3 User-specific Filtering.....	22

3.3 Implementation Example.....	26
3.3.1 User Survey.....	26
3.3.2 Ranking of Attributes .....	28
3.3.3 Product Evaluation.....	32
CHAPTER 4 TRAFFIC COUNTING DEVICE DATABASES.....	34
4.1 Descriptions of the Traffic Counting Device Databases.....	34
4.1.1 Product Table.....	34
4.1.2 Vendor Table.....	36
4.1.3 Software Table.....	37
4.1.4 Product Evaluation Table.....	37
4.2 Custom Queries and Relationships of Traffic Counting Device Databases.....	37
4.3 Further Improvements to the Traffic Counting Device Databases.....	39
CHAPTER 5 CONCLUSIONS.....	41
LIST OF REFERENCES.....	44
APPENDIX A: Product Information by Technology Category.....	47
Infrared.....	48
Magnetic.....	49
Microwave.....	52
Passive Acoustic.....	54
Ultrasonic.....	55
Video Image Processor.....	56
Inductive Loop.....	59
APPENDIX B: Vendor Information.....	67
APPENDIX C: User Survey.....	71
APPENDIX D: Product Evaluation.....	74
APPENDIX E: User Manual for the Databases in Microsoft Access .....	78
1 Basic Concepts of Microsoft Access.....	79
2 General Instructions.....	80

## LIST OF TABLES

Table	Page
Table 3.1 Advantages and Disadvantages of Various Technologies.....	23
Table 3.2 Recommended Technologies for Different Applications.....	25
Table 3.3 Ranking of Factors based on the Survey .....	30

## LIST OF FIGURES

Figure	Page
Figure 3.1 Flow Chart of Two-step Filtering Selection Procedure.....	20
Figure 3.2 Ranking of Selection Factors.....	31
Figure 4.1 Example of Built-in Queries.....	38
Figure 4.2 Relationships in Product Databases.....	39
Figure E-1 Example of Access Datasheet.....	79
Figure E-2 Access Application Window.....	80
Figure E-3 Access Database Window.....	81
Figure E-4 Opening Data Table.....	81

## **CHAPTER 1 INTRODUCTION**

### **1.1 Motivation and Problem Description**

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) stipulated requirements for state level Traffic Monitoring Systems (TMS) with an aim to systematize the collection, analysis and summary of person and vehicular data on public highways and streets. This mandate compounded by the growing need to more efficiently manage our existing transportation infrastructure is necessitating accurate, reliable and comprehensive traffic related data. Traffic data is used for a wide variety of purposes including traffic operation and control, geometric design, pavement design, highway- and land-use planning, resource allocation, and intelligent transportation systems (ITS) research and implementation.

In the context of ITS, traffic-related data needs from different roadway and environment types (scenarios) vary according to the transportation management phases (FHWA, 1995). For example, in the highway engineering management phase, short-term traffic counting and vehicle classification data are needed for highway geometry, pavement, and structural design. For the planning, legislation and safety phases, long-

term traffic data is collected for infrastructure systems design, signal control systems design, and traffic demand forecasts. For traffic operation, control, and traveler information provision purposes, real-time data on speed, travel time, volume, density, and incidents is essential. Permanent (fixed position) and temporary (portable) devices are used to collect traffic data on various facilities such as highways, freeways, intersections, and city/town streets. Several terms, such as traffic counting device, monitoring device, surveillance device, measuring device, sensor, and detector, are used to name these devices. This taxonomy is typically exchangeable and is normally not differentiated in many cases, though trivial differences do exist in terms of the scenarios where they are used. For example, counting device is often used to refer to devices installed on freeways and/or highways to record the vehicle counts, while detector is typically used to refer to those detecting the presence of vehicles at intersections. However, these differences are not emphasized in the context of this study. We use the term “counting device” to generically refer to all devices that are permanently or temporarily installed in different scenarios to collect traffic data.

Traffic counts are generally classified into three categories according to the duration and area over which the counting equipments are deployed (FHWA, 1995): (i) a relatively limited continuous count program, (ii) an extensive coverage count program, and (iii) a flexible special needs program. Continuous counting locations have typically used the traditional automatic traffic recorders (ATR) permanently installed at various locations of the road network. They consist of an assembly of axle sensors and inductive loops of the bending plate or piezo-electric variety. The more extensive coverage count programs have normally used portable equipment. Traditionally these have included

portable counters and pneumatic tubes that are installed across the roadway by mobile crews. However, there are some important drawbacks of using traditional intrusive counting devices. First, these devices are not easy to install and are often hazardous to the mobile crews especially under congested conditions. Second, being intrusive devices, they often cause some disruption of prevailing traffic flow even under moderate to light traffic conditions. Third, these equipment are known to malfunction under extreme temperature conditions. Fourth, the data types that these devices are able to detect are normally limited and cannot satisfy the increasing need of more sophisticated and comprehensive data for ITS applications. As a result, city and state agencies increasingly prefer newer and non-intrusive equipment based on radar, magnetic imaging, microwave and infrared technologies. Non-intrusive devices, by definition, are those that do not need to be installed in or on the pavement but can be mounted overhead, to the side, or beneath the pavement by “pushing” the device in from the shoulder (FHWA Study, 1997).

Notwithstanding the availability of these newer technologies for traffic monitoring and data collection, most state agencies lack a rigorous set of guidelines for the selection of traffic counting devices. This is primarily due to the relatively recent, though widespread, emergence of these technologies and the consequent sparseness in reliable information on their performance. Considering the wide range of currently available technologies, a uniform set of guidelines based on a series of criteria including cost, accuracy, reliability, durability, flexibility, and ease of use can be invaluable to system operators.

This study performs an extensive survey of available intrusive and non-intrusive counting technologies and develops a broad set of selection criteria which can be used for

traffic measuring device selection. The survey includes a detailed literature review of existing evaluation techniques. It also includes e-mail surveys of some state/local agencies from six states: California, Florida, Indiana, Minnesota, New York, and Texas. The surveys record their experience with traffic counting devices and identify additional practical issues. In addition, the study presents comprehensive product information to compare traffic measuring devices.

## **1.2 Literature Review**

A few recent studies on non-intrusive and intrusive traffic counting devices have shown wide variations in the performance of these technologies under varying conditions of traffic, weather, and geometry. Some of these studies (Faghri et al., 1996) are localized in that their conclusions apply only to a specific region or to specific traffic conditions. Some others have either neglected important emerging technologies (Hallenbeck, 1985) or draw product specific insights that cannot be extrapolated to the technology in use (FHWA Study, 1997).

Hughes (1993) conducted an extensive survey of vehicle detector technologies available up to 1993. It collected information on intrusive and non-intrusive detectors, including video image, ultrasonic, sonic, infrared, and microwave radar. A major component of the study was the collection of manufacturer specification sheets for over 80 traffic devices. These specification sheets provided detailed information on the detectors, in terms of functions, features, operating conditions, parameters, installation/operation instructions, data communication, and other related technical data. A primary drawback of the study is that few analyses, evaluations, and/or comments were provided on the performance of the different technologies and/or devices. Another

drawback is that detector information from the vendor specification sheets was not summarized or classified, precluding retrieval of useful information and/or efficient product comparison. The third drawback is the limited discussion on non-intrusive devices, given the sparse installation of such devices at the time of the study. Over 80% of the total devices listed were inductive loop detectors or inductive loop vehicle identification systems. The fourth drawback is that no selection criteria and/or selection procedure were provided. However, some simple criteria, rather than a generic user selection procedure, were used to select sample devices for a further field test. The five criteria used were availability, demonstrated capability, compatibility with controllers in place at the field test locations, representative of current technology, and vendor support.

Another study on traffic counting devices was conducted for the Federal Highway Administration (FHWA Study, 1997) by the Minnesota Department of Transportation, the Minnesota Guidestar Program, and the SRF Consulting Group. Its main objective was to provide practitioners with useful information on the performance of emerging non-intrusive technologies, and some specific devices within each technology category. It focused on passive infrared, active infrared, passive magnetic, Doppler microwave, radar, passive acoustic, pulse ultrasonic, and video image detector technologies. One or two representative products were selected from each technology category, and tested on freeways as well as traffic intersections to examine the performance of these devices under different situations. The capabilities and limitations were analyzed under various conditions, and basic information on the suitability of a technology for various data collection needs was provided. However, akin to the Hughes study, it does not provide selection criteria or procedures for users with specific functional needs. Another potential

shortcoming is that the test used an inductive loop as the benchmark to test the counting accuracy of each non-intrusive detector. This presumes that the inductive loop is 100% accurate under all circumstances, which is not necessarily true.

An on-going FHWA “Vehicle Detector Clearinghouse” (Mimbela and Klein, 2000) pooled-fund project treats the vehicle detection and surveillance technologies as integral parts of ITS. The project includes an extensive product database stored in Microsoft Excel format, called the Clearinghouse database. Products are classified into different categories including inductive loops, magnetometers, micro-loop probes, pneumatic road tubes, piezoelectric cables, microwave radar, infrared, ultrasonic, acoustic, and video image. For each product, information on vendor contacts, software version, general description, sensor installation, maximum number of lanes monitored simultaneously, product capabilities/functions, recommended applications, data output methods/formats, and states currently using the equipment, are provided. Currently, there are approximately 80 products recorded in the Clearinghouse database. Akin to the previous efforts, no selection criteria or procedure are provided though the advantages and disadvantages of all technologies are summarized and compared.

There have been some past studies in Indiana related to traffic detector evaluation. Krogmeier et al. (1996) evaluate the performance of various non-intrusive devices on the Borman Expressway (I-80/94). Hypothesis-based procedures were used to analyze their reliability. Grenard et al. (2001) evaluate the performance of selected video detection systems at signalized intersections.

## **CHAPTER 2 REVIEW OF TRAFFIC COUNTING TECHNOLOGIES**

As the first step in the development of guidelines for traffic counting device selection, an extensive review of available detection technologies was conducted. It includes intrusive and non-intrusive detection technologies, though the non-intrusive detectors are emphasized to ensure that state-of-the-art technologies are considered in the evaluation process. The survey suggests that information on the performance of emerging detection technologies is, currently, sparse and difficult to obtain.

### **2.1 Non-intrusive Technologies**

Non-intrusive technologies represent the emerging detection technologies, and are so labeled because they are not physically present on the pavement. Hence, they do not interfere with traffic flow, both for operational and maintenance purposes.

#### **2.1.1 Infrared (Active, Passive)**

Infrared devices are available for overhead mounting to view approaching or departing traffic from a side-looking configuration. Passive infrared devices detect the presence of vehicles by comparing the infrared energy naturally emanating from the road surface with the change in energy caused by the presence of a vehicle. Since the roadway may generate either more or less radiation than a vehicle depending on the season, the contrast in heat energy is detected. Active infrared devices detect the presence of vehicles by emitting a low-energy laser beam(s) at the road surface and measuring the time for the reflected signal to return to the device. Passive infrared detectors provide data on vehicle presence at traffic signals, volume counts, vehicle length, and queue measurements. Active infrared detectors are capable of providing speed measurements in addition to the

data captured by passive infrared devices. Previous studies (Bahler et al., 1998) have reported infrared technology as being suitable for monitoring traffic in urban areas, but performance varies under severe weather conditions.

The main advantage of infrared devices is that they can cover multiple lanes simultaneously. Under normal weather conditions, they can accurately measure vehicle position, speed, and class. The main disadvantage is the lack of accuracy under weather conditions such as rain and fog because the associated changes in air conditions may influence the reflection of the infrared beam.

#### 2.1.2 Microwave (Doppler, Radar and Passive Millimeter)

Microwave detectors are generally mounted either directly overhead or on the side of the roadway. Doppler microwave devices transmit low-energy microwave radiation at a target area on the pavement and then analyze the signal reflected back to the detector. These devices can be used for volume and speed measurements. Radar devices have the ability to sense the presence of stationary vehicles and to sense multiple zones through their range-finding ability. A third type of microwave detector, passive millimeter, operates at a shorter wavelength than the other microwave devices. It detects the electromagnetic energy in the millimeter radiation frequencies from all objects in the target area.

Analogous to infrared devices, microwave devices can cover multiple lanes and generally perform well at freeway sites. Another advantage of this technology class is that they are normally insensitive to bad weather. However, they are known to fail for urban traffic especially at intersections with complex geometries (Bahler et al., 1998). Also, the usage of microwave is limited because the antenna beam width and transmitted

waveform must be suitable for the application. Besides, Doppler sensors cannot detect stopped vehicles.

### 2.1.3 Passive Acoustic

Passive acoustic devices consist of an array of microphones aimed at the traffic stream. They are passive in that they seek the sound energy of passing vehicles. Mounted from a side-fire position, they can be used to obtain volume, speed, occupancy, and classification information. They allow multiple lane operation and are easy to install. However, they tend to undercount at low temperatures and under snowy conditions (Bahler et al., 1998).

### 2.1.4 Ultrasonic (Pulse and Doppler)

Pulse devices emit pulses of ultrasonic sound energy and measure the time for the signal to return to the device. Doppler ultrasonic devices emit a continuous ultrasonic signal and utilize the Doppler principle to measure the shift in the reflected signal.

Mounted either directly overhead or from a side-fire position, these devices are able to provide surveillance on multiple lanes and are known to provide fairly accurate counts. However, some environmental conditions such as temperature changes and extreme air turbulence can affect the performance of these detectors. This situation is mitigated by the employment of temperature compensation algorithms in some models. Another weakness of this class is that large pulse repetition periods may degrade occupancy measurements on freeways for vehicles traveling at moderate to high speeds.

### 2.1.5 Video Image Processor

Video devices use a microprocessor to analyze the video image input from a video camera. Two basic analysis techniques that are used are: (i) tripline, and (ii) tracking.

Tripline techniques monitor specific zones on the video image 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. Video detection devices generally use one or both of these techniques.

The primary advantage of video detection is the wide range of data it can provide. Apart from the usual data on volume, presence, occupancy, density, speed and classification, other data such as vehicle identification, incident detection, and origin-destination information can be obtained. At present, video detection techniques are highly reliable for freeway sites but less reliable for urban areas. In addition, several environmental factors such as lighting, wind and precipitation are known to affect video detection performance. Inclement weather, shadows, vehicle projection into adjacent lanes, occlusion, day-to-night transition, vehicle/road contrast, shaking of camera caused by wind, and water, salt, dirt, grime, icicles, and cobwebs on camera lens are problematic. Thus, a video image detector requires more maintenance efforts to assure reasonably good performance. Besides, cameras need to be typically mounted at heights of 50 to 60 feet, which restricts the flexibility of the use of these products. Another issue is the comparatively high cost when more detection is needed in a zone.

## **2.2 Intrusive Technologies**

Intrusive technologies interfere with traffic flow for their installation and maintenance. They represent the traditional detection technologies, and are predominantly employed as counting devices currently.

### 2.2.1 Magnetic (Passive) Detectors

Passive magnetic devices measure the change in the earth's magnetic flux created when a vehicle passes through a detection zone. Due to the mechanism used to detect vehicles, these devices are normally installed under the pavement. Though they are capable of giving accurate volume counts, they are intrusive and are known to be affected by extreme weather conditions. Passive magnetic devices cannot detect stopped vehicles.

### 2.2.2 Inductive Loop (Active Magnetic)

Active magnetic devices, such as inductive loops, apply a small electric current to a coil of wires and detect the change in inductance caused by the passage of a vehicle. The inductive loop detector is the most commonly used traffic counting device. It usually consists of one or more turns of insulated wire buried in a shallow saw-cut in the roadway, a lead-in cable that runs from a roadside pull box to the controller cabinet, and an electronics unit located in the controller cabinet. The wire loop is excited with signals whose frequencies range from 10KHz to 50KHz, and functions as an inductive element in conjunction with the electronics unit. When a vehicle stops on or passes over the loop, the inductance of the loop is decreased. The decreased inductance increases the oscillation frequency and causes the electronics unit to send a pulse to the controller, indicating the presence or passage of a vehicle.

The technology of inductive loop is very mature and is proved to have good performance on detecting volume, presence, occupancy, speed, headway and gap. The cost of inductive loop sensors is low compared to that of non-intrusive sensors. The drawbacks of inductive loop detectors are the typical drawbacks of intrusive devices. They include the interruption of traffic during installation, the damage to the road

surface, and safety issues for installation personnel. Also, detector failures have been observed under poor pavement surface conditions and due to the penetration of water into the saw-cut under rain. In addition, resurfacing of roadways and utility repairs may entail the need to reinstall the sensors.

### 2.2.3 Pneumatic Road Tube

The pneumatic road tube sensor sends a burst of air pressure along a rubber tube when a vehicle's tires pass over the tube. The pulse of air pressure closes an air switch, producing an electrical signal that is transmitted to a counter or analysis software.

The pneumatic road tube is easy to install, and has good portability both for permanent and temporary data recording. It is a low cost device and is simple to maintain. But the accuracy of such detectors is low when truck and bus volumes are high because of the physical characteristics of these vehicles. Also, the device is easily influenced by weather.

## **CHAPTER 3 SELECTION CRITERIA AND PROCEDURE**

Over the past decade, several traffic counting devices of different technologies have become commercially available. A common concern of many state and local transportation agencies is the type of technology and the characteristics of the devices to consider while upgrading current traffic systems or building new ones. However, systematic methods to select traffic counting devices have received little attention in the past. In this chapter, a systematic selection procedure is proposed, and examples of implementation are discussed.

### **3.1 Selection Factors**

Several factors need to be considered when selecting traffic counting devices. They can be categorized into two main classes: device-related factors and environment-related factors.

#### **3.1.1 Device-related Factors**

Several device-related aspects influence the selection of traffic counting devices. They range from budget limits to data issues to ease of use.

##### **3.1.1.1 Cost**

An equitable cost comparison between the different device alternatives should consider the application for which they are intended. For example, although the cost of ultrasonic or microwave detectors may be much lower than that of a video image processor, the total costs of multiple microwave or ultrasonic detectors may far exceed that of a video image processor based setup for the same amount of data.

#### 3.1.1.2 Accuracy and Reliability

Accuracy and reliability are the basic requirements for any counting device. The accuracy is typically measured by the average percentage of overcounted or undercounted vehicles compared to the actual number of vehicles passing or present. Reliability is a proxy for how stable the counter performs. For some devices, while the average counting performance is good, they may constantly miss or double-count vehicles so that the missing and double-counting eliminate each other. For some others, the performance varies dramatically under different external conditions or during different periods in their life span. These devices are considered unreliable. A critical factor that affects the accuracy and reliability of traffic counting devices is the climatic conditions of the region. Past studies (FHWA Study, 1997) have shown that different devices may compare differently under different weather and traffic conditions.

#### 3.1.1.3 Ease of Installation and Maintenance

Many agencies cite ease of installation and maintenance as the primary reasons for rejecting some detection technologies. It is desirable that the employed device be mountable overhead or from a side-fire position to avoid cutting into the pavement.

#### 3.1.1.4 Portability and Storage

Temporary data collection for a specific time period is an important data collection category. In this context, the portability and storage of the devices is a key issue.

#### 3.1.1.5 Ease of Data Retrieval

Compatibility of the traffic counting device output with existing data collection programs is desirable. The data should be easily downloadable into a popular database format. With the recent emergence of ITS, data obtained from these detectors are also being used for

real-time traffic operation and control. Therefore, it is also desirable that the technology used be able to provide data to a central location in a fast and reliable manner.

#### 3.1.1.6 Data Type and Functional Capabilities

A wide range of data (traffic flow, weather conditions, road surface conditions, etc.) can be measured using different counting devices. This requires the evaluation of the amount and versatility of data that can be collected by a traffic counting device relative to its other characteristics (such as cost, accuracy, ease of installation, etc.) and the functional needs of the traffic site.

#### 3.1.1.7 Amenability to Future Technological Advances

The traffic detection technology arena has been undergoing a rapid evolution over the past few years. One aspect that needs to be addressed in this context is the evaluation of the various devices in terms of their adaptability and amenability to future advances in detection and data retrieval technologies.

#### 3.1.1.8 Ease of Use and Personnel Training Needs

In the absence of specific standards, a key issue with the use of counting devices manufactured by different vendors is the need for training field personnel. This is because that each vendor may have counting devices characterized by unique technology, features, and software. This also raises the issue of ease-of-use of a certain product.

### 3.1.2 Environment-related Factors

A FHWA study (FHWA Study, 1997) indicates that the performance of different intrusive and non-intrusive technologies depends explicitly on several environment-related factors including the prevailing weather and traffic conditions. When selecting

counting devices, these factors should be considered based on the specific conditions in a region. The factors are:

#### 3.1.2.1 Traffic Characteristics

The performance of many devices is influenced by the traffic characteristics being detected. These characteristics include vehicle speeds, congestion levels, and vehicle class percentages. For instance, the passive acoustic and microwave detectors are observed to consistently undercount vehicles under high congestion levels (FHWA Study, 1997) because continuous traffic flows with very small headways may have the same reflection character as a single vehicle. Thereby, they are treated as a unit by these devices. Some pulse ultrasonic devices tend to miss vehicles with high speeds as these devices dismiss ultrasonic waves of certain frequencies. When the frequency is larger than the time taken for the vehicle to pass the detection zone, potential missed counts may occur. Some video image process devices double count slow-moving vehicles due to flaws in the image processing logic. The percentages of vehicles of different classes may also influence detection performance. Passive infrared, radar and pulse ultrasonic devices may overcount trucks and buses because multiple reflections from a single vehicle may be received. Trucks and buses may also be double counted because they may intrude into neighboring lanes due to the size of these vehicles. Thus, these devices may perform unevenly when high percentages of trucks and buses are present in the traffic stream.

#### 3.1.2.2 Roadway Type

The performance of some devices varies on different types of roadways as different types of roadways have their own flow and geometry characteristics. For instance, Doppler microwave technology can detect freeway traffic well. However, it performs poorly at

intersections where the associated devices have been observed to undercount or overcount vehicles (FHWA Study, 1997). Some pulse ultrasonic devices overcount between 10 and 30 percent at intersections, though they perform well on freeways.

#### 3.1.2.3 Installation Location and Position

The installation location affects the performance of some counting devices. Some passive acoustic devices perform significantly better when located at the median pole site than on bridges (FHWA Study, 1997). For some pulse ultrasonic detectors, overhead mount with the detector aimed straight down is preferred because this offers a perpendicular vehicle surface for reflecting the ultrasonic signal.

Some devices are very sensitive to the position of sensors or cameras. Positions and angles need to be carefully adjusted and calibrated to obtain optimal performance. For example, the mounting height is an important factor vis-à-vis accuracy for passive infrared detectors.

#### 3.1.2.4 Weather Conditions

Inclement weather affects the accuracy of many traffic counting devices. Also, different weather conditions have different impacts on various technologies. Hence, the local climate is critical to the selection of a traffic counting device. Snowfall, rain and freezing rain are correlated with either undercounting or overcounting (FHWA Study, 1997) for many counters. Snow and rain have been observed to affect passive magnetic device performance. This is most likely due to water entering the device, and does not reflect a limitation of the technology itself. A correlation was found between low temperatures and undercounting for passive acoustic devices. The presence of snow on the roadway is also correlated with undercounting. Snow or rain caught by video image cameras may be

processed as vehicles thus lead to overcounting, and a heavy fog may cause total failure of such devices.

#### 3.1.2.5 Traffic Direction

Some passive infrared devices are designed to face oncoming traffic. These devices cannot be used to detect departing traffic. By contrast, some Doppler microwave devices were observed to detect departing vehicles more accurately (FHWA Study, 1997). However, they overcount traffic in the oncoming direction.

### **3.2 Selection Procedure**

Based on the selection criteria described in the previous section, a two-step procedure is proposed to select traffic counting devices.

#### 3.2.1 Two-step Filtering Selection Procedure

The selection of a specific traffic counting device depends on the functional capabilities of the associated technology vis-à-vis the field conditions, and user data needs and constraints. Devices in a technology category typically have some common characteristics such as type of data detected, installation position, detection accuracy and reliability, cost, and operation/maintenance requirements. As described in chapter 2, each technology can only collect certain types of traffic data, and is sensitive to the type of roadway (such as intersection or freeway) and congestion conditions. Also, the performance of some technologies is affected by weather or climate conditions. Hence, the technology-related filter uses the following criteria to select the technology alternatives for the selection of the traffic counting device: data needs and purpose, weather/climate conditions, traffic conditions, and roadway type. This is illustrated further in Figure 3.1 which details the two-step selection procedure. The technology-

specific product information in Appendix A is filtered using Microsoft Access features for this purpose. The vendor information of corresponding products is listed in Appendix B.

The second step of the selection procedure uses user-specific filtering criteria to identify candidate counting device products. The criteria include detection accuracy and reliability requirements, budget constraints, personnel training requirements, and data format and processing capabilities.

Within each step, the criteria can further be ranked by order of importance as identified by the user. The Microsoft Access based database developed in the study enables this capability.

### 3.2.2 Technology-specific Filtering

In the first step of the selection procedure, traffic counting devices in the candidate database are filtered based on user data collection needs, roadway type, field traffic conditions, and the climatic conditions of the region.

The inductive loop detector is the most commonly used counting device. The data detected by these devices typically includes vehicle passage, presence, count, and occupancy. Vehicle speed can be measured by using more than one detector at various locations. Vehicle classification is supported by newer inductive loop detector models.

Passive magnetic detectors mainly refer to the two-axis fluxgate magnetometer. They detect most of the data that can be detected by inductive loop detectors; however, they normally fail to detect stopped vehicles since they require the vehicles to be moving to generate a magnetic field.

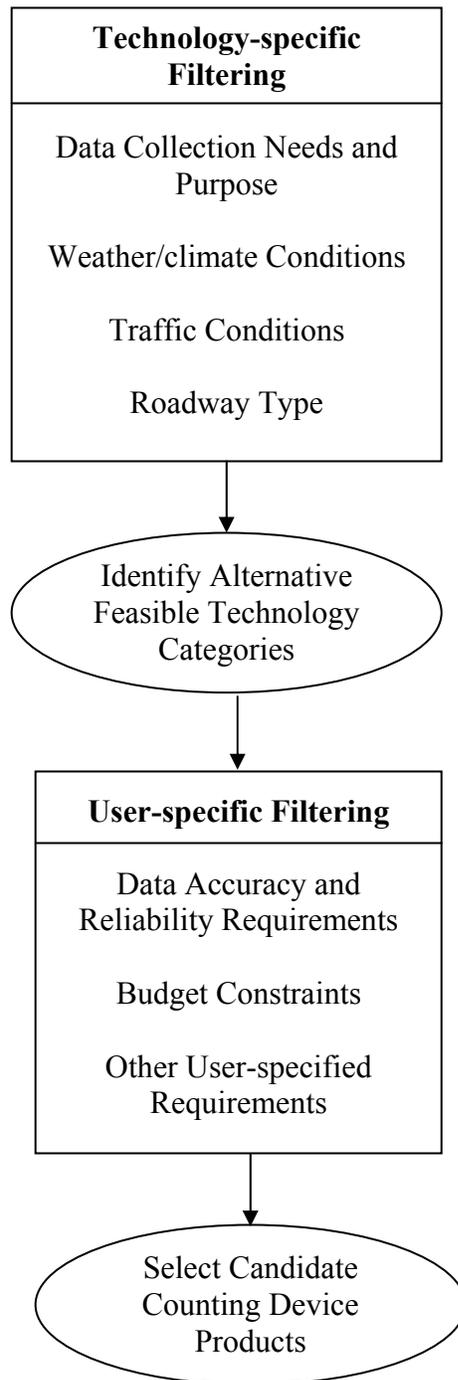


Figure 3.1 Flow Chart of Two-step Filtering Selection Procedure

The pneumatic road tube is commonly used for short-term traffic counting and vehicle classification. Some models gather data to calculate vehicle gaps, intersection delay, stop sign delay, saturation flow rate, speed, and travel time by employing algorithms.

Active infrared sensors provide vehicle presence, count, volume, speed, length assessment, queue, and occupancy. Some modern laser sensors produce two-dimensional or three-dimensional images of vehicles which enables vehicle classification. Passive infrared devices measure speed and vehicle length as well as other conventional data such as volume and lane occupancy.

Microwave sensors (Doppler, Radar, and Passive Millimeter) can be mounted over lanes or other locations to measure approaching or departing traffic data in multiple lanes. The data types measured by microwave sensors depend on the waveform used to transmit the microwave energy. The Doppler microwave detector detects vehicle passage, speed, volume, count, presence, occupancy, and classification.

Passive acoustic detectors can detect passage, presence, and speed of vehicles. The speed of a detected vehicle is determined using an algorithm based on the average vehicle length. The vehicle presence is detected through an optically isolated semiconductor.

In ultrasonic detectors, pulse energy transmitted at a certain frequency is used to calculate the vehicle speed. However, stopped or slow vehicles may be ignored. Other data that can be detected include count and occupancy.

One video image processor can detect traffic conditions at the entire intersection or over a long freeway segment. Hence, it can replace several inductive loop detectors.

Some video image processor systems can process data from several video cameras. Video image processors can measure several data types including vehicle counts, vehicle length, presence, classification, occupancy, and speed. Hence, data can be obtained by vehicle classes. Some newer models can identify the vehicle registration plate numbers.

The counting devices in each technology category have some common advantages and disadvantages. Table 3.1 summarizes the advantages and disadvantages of each technology category. Table 3.2 identifies recommended technologies for various applications.

### 3.2.3 User-specific Filtering

The second step of the selection procedure is user-specific filtering. After the selection of candidate technologies, the feasible set of potential devices needs to be analyzed using user criteria. User-specific filtering can be divided into 3 steps.

In the first step, a set of selection criteria are decided according to the data needs and environmental/traffic conditions. As described in Section 3.1, the possible selection factors include both device-related and environment-related factors. However, depending on the actual application scenario, a user may consider different factors when selecting products. For example, some users emphasize the price, maintenance cost, and personnel training requirements, while other users pursue the quality of data and emphasize data versatility, accuracy, and the reliability of the devices irrespective of the price.

In the second step, the relative weight of each criterion in the selection procedure is decided. This is done by evaluating the specific user objectives. Based on the user survey conducted in this study, a set of recommended relative weight values for selection factors is proposed in Section 3.3.

Table 3.1 Advantages and Disadvantages of Various Technology Categories

(based on Mimbela and Klein, 2000)

Technology	Advantages	Disadvantages	Performance
Inductive Loops	<ul style="list-style-type: none"> <li>• Mature and well-developed</li> <li>• Well-known to engineers</li> <li>• Low cost</li> <li>• Basic traffic data</li> <li>• Accurate and reliable</li> </ul>	<ul style="list-style-type: none"> <li>• Installation deteriorates pavement</li> <li>• Poor performance under bad pavement conditions</li> <li>• Disturbs traffic</li> <li>• Installation personnel safety issues</li> <li>• Requires multiple detectors for a location</li> <li>• Water penetration affects performance</li> </ul>	Potentially good performance on intersections and freeways
Passive Magnetic	<ul style="list-style-type: none"> <li>• Accurate and reliable</li> </ul>	<ul style="list-style-type: none"> <li>• Extensive effort for installation</li> <li>• Some models need pavement cutting</li> <li>• Disturbs traffic</li> <li>• Cannot detect stopped vehicles</li> </ul>	Potentially good performance for intersections and freeways
Microwave	<ul style="list-style-type: none"> <li>• Flexible installation position</li> <li>• Generally insensitive to inclement weather</li> <li>• Single detector sufficient to measure speed</li> <li>• Multiple lane coverage</li> </ul>	<ul style="list-style-type: none"> <li>• Restriction of antenna beam bandwidth</li> <li>• Doppler sensors cannot detect stopped vehicles</li> </ul>	Potentially good performance on freeways

Table 3.1 Advantages and Disadvantages of Various Technology Categories

(continued)

Technology	Advantages	Disadvantages	Performance
Infrared	<ul style="list-style-type: none"> <li>• Accurate measurement of vehicle position, speed and vehicle class</li> <li>• Multiple lane coverage</li> </ul>	<ul style="list-style-type: none"> <li>• Active detector may be affected by fog or snow</li> <li>• Sensitivity to vehicles reduces in rain and fog for passive detector</li> </ul>	Potentially good performance on intersections and freeways
Ultrasonic	<ul style="list-style-type: none"> <li>• Multiple lane coverage</li> </ul>	<ul style="list-style-type: none"> <li>• Some environmental conditions such as temperature change and extreme air turbulence affect performance</li> <li>• Problems on freeways when vehicles travel at moderate to high speeds</li> </ul>	Potentially good on intersections and freeways
Acoustic	<ul style="list-style-type: none"> <li>• Multiple lane coverage</li> </ul>	<ul style="list-style-type: none"> <li>• Cold temperature affects accuracy</li> <li>• Some models have poor performance for slow traffic</li> </ul>	Moderate potential on intersections and freeways
Video Image Processor	<ul style="list-style-type: none"> <li>• Multiple lane coverage</li> <li>• Rich data types</li> <li>• Multi-media data</li> </ul>	<ul style="list-style-type: none"> <li>• Affected by inclement weather, shadows, vehicle projection, and time of day</li> </ul>	Moderate potential on intersections and freeways

Table 3.2 Recommended Technologies for Different Applications (based on Klein, 2002)

Applications	Assumptions	Recommended Technologies
<ul style="list-style-type: none"> <li>• Signalized intersection control</li> </ul>	<ul style="list-style-type: none"> <li>• Detect stopped vehicles</li> <li>• Weather not a major factor</li> </ul>	<ul style="list-style-type: none"> <li>• Microwave radar</li> <li>• Passive infrared</li> <li>• Laser radar</li> <li>• Ultrasound</li> <li>• Video image processor</li> </ul>
<ul style="list-style-type: none"> <li>• Signalized intersection control</li> </ul>	<ul style="list-style-type: none"> <li>• Detect stopped vehicles</li> <li>• Inclement weather</li> </ul>	<ul style="list-style-type: none"> <li>• Microwave radar</li> <li>• Ultrasound</li> <li>• Long-wavelength imaging infrared video processor</li> </ul>
<ul style="list-style-type: none"> <li>• Signalized intersection control</li> </ul>	<ul style="list-style-type: none"> <li>• Detection of stopped vehicles not required</li> <li>• Inclement weather</li> </ul>	<ul style="list-style-type: none"> <li>• Microwave radar</li> <li>• Doppler microwave detector</li> <li>• Ultrasound</li> <li>• Long-wavelength imaging infrared video processor</li> </ul>
<ul style="list-style-type: none"> <li>• Real-time adaptive signal control</li> </ul>	<ul style="list-style-type: none"> <li>• Desirable for detector footprint to emulate a 6-ft by 6-ft inductive loop</li> <li>• Side-mounting capability</li> </ul>	<ul style="list-style-type: none"> <li>• Video image processor</li> <li>• Microwave radar</li> <li>• Passive infrared (with suitable aperture beamwidth)</li> </ul>
<ul style="list-style-type: none"> <li>• Vehicle counting (surface street or freeway)</li> </ul>	<ul style="list-style-type: none"> <li>• Detect and count vehicles traveling at speeds greater than 2 to 3 miles/hour</li> </ul>	<ul style="list-style-type: none"> <li>• Microwave radar</li> <li>• Doppler microwave</li> <li>• Passive infrared</li> <li>• Laser radar</li> <li>• Ultrasound</li> <li>• Video image processor</li> </ul>

Table 3.2 Recommended Technologies for Different Applications (continued)

Applications	Assumptions	Recommended Technologies
<ul style="list-style-type: none"> <li>• Vehicle speed measurement</li> </ul>	<ul style="list-style-type: none"> <li>• Detect and count vehicles traveling at speeds greater than 2 to 3 miles/hour</li> </ul>	<ul style="list-style-type: none"> <li>• Microwave radar</li> <li>• Doppler microwave detector</li> <li>• Laser radar</li> <li>• Video image processor</li> </ul>
<ul style="list-style-type: none"> <li>• Vehicle classification</li> </ul>	<ul style="list-style-type: none"> <li>• By length</li> </ul>	<ul style="list-style-type: none"> <li>• Video image processor</li> <li>• Laser radar</li> </ul>
<ul style="list-style-type: none"> <li>• Vehicle classification</li> </ul>	<ul style="list-style-type: none"> <li>• By profile</li> </ul>	<ul style="list-style-type: none"> <li>• Laser radar</li> </ul>

The third step involves collecting the relevant attribute data for each product. This is difficult because the product information specified varies across vendors. Also, some attributes such as accuracy, reliability, ease of installation, and personnel training requirements, are not easily quantifiable, making product comparison relatively difficult.

### 3.3 Implementation Example

As an example implementation of the two-step selection procedure, a survey was conducted to elicit user opinions on selection factors, criteria weights, data needs, and product evaluation.

#### 3.3.1 User Survey

As shown in Appendix C, this survey consists of four sets of questions. The first set collects information on the respondents including employer, position, work type, and years of experience with traffic data collection/traffic counting devices. The second set of

questions requires the respondents to rate the importance of different factors when purchasing traffic counting devices. The factors specified are: price, accuracy, durability, reliability, portability, ease of data retrieval, ease of installation, functionality, personnel training needs, and maintenance requirements. The third question set seeks information on the type of traffic data needed by the respondents for their work. The last question set asks respondents to evaluate the traffic counting devices being used in their state or district. For each product, the overall performance, accuracy, reliability, lifecycle costs, training requirements, ease of installation/maintenance, and data collection ability are scored using grades A, B, C, D and E. Here, “A” represents the most favorable grade and “E” represents the least favorable one.

The survey was sent using e-mail to personnel who responsible for traffic data collection in various districts or regional subdivisions of the departments of transportation in six states including California, Florida, Indiana, Minnesota, New York, and Texas. These states were chosen either because they were involved in previous efforts on traffic counting device evaluations, or because they are representative of the various U.S. geographical regions. 47 e-mails were sent and 24 responses were obtained through e-mail or regular mail. Of these, 20 responses were complete and 4 were partly incomplete.

The state-wise break-up of the 24 respondents is as follows: California (5), Florida (4), Indiana (3), Minnesota (4), New York (3), and Texas (5). 18 out of the 24 respondents are involved in traffic operations. The average work experience of the respondents in traffic data collection and/or traffic counting devices is 8 years.

### 3.3.2 Ranking of Attributes

As stated in Section 3.2, a key step in the traffic counting device selection process is the identification of the relative importance of each factor that needs to be considered. The respondents were asked to rate the ten factors listed in the survey. A rank of 1 implied most important, and 10 implied least important. Table 3.3 shows the associated results based on the 20 complete responses. Based on the survey, the average relative importance of the various factors is listed below in a descending order: accuracy, reliability, durability, functionality, data retrieval, ease of installation, price, portability, maintenance needs, and personnel training needs. This is further highlighted in Figure 3.2.

Not surprisingly, the most important factor identified in the survey is the data accuracy. This is because constant overcounting or undercounting seriously affects the effectiveness of an associated strategy for traffic operations. For example, failure to detect vehicle presence may lead to extra delay for certain directions. Overcounting may cause unnecessary budget allocations for a less congested facility.

Reliability is rated as the second most important factor. It typically implies the stability of performance, the ability to work properly under most environmental and weather conditions, and the capability to resist external disturbances. The accuracy of the devices should not be very sensitive to changing weather conditions. This requirement is especially important in certain areas where a specific weather characteristic occurs frequently, such as snow in Minnesota in winter or rain in Florida in summer.

Durability and functionality are ranked tied as the third important factors. Durability implies a common desire that the devices work correctly for long time periods, thereby precluding frequent purchase/installation costs, and calibration efforts.

Table 3.3 Ranking of Factors based on the Survey

User ID	Work Type	Experience	Price	Accuracy	Durability	Reliability	Portability	Data Retrieval	Installation	Functionality	Training	Maintenance
1	1	2	7	1	3	2	4	6	9	5	10	8
2	1		3	1	8	2	10	5	7	4	6	9
3	1	10	5	3	2	1	4	6	7	8	9	10
4	1	8	6	1	3	2	8	4	7	5	9	6
5	1	20	5	1	4	3	10	6	7	8	9	2
6	3	9	5	1	2	1	9	8	5	2	5	2
7	1	9	8	2	3	1	5	7	4	6	10	9
8	1	4	7	6	8	4	9	3	2	1	5	10
9	1	20	6	1	3	2	10	5	8	4	9	7
10	1	3	9	1	6	2	7	5	3	4	8	10
11	2	15	10	1	2	2	6	4	9	5	7	8
12	1	10	4	1	7	2	6	5	3	8	10	9
13	1	10	3	1	2	1	2	4	3	4	3	7
14	1	7	9	1	3	2	8	6	5	4	10	7
15	1	10	3	1	2	1	5	3	1	2	5	3
16	1	8	6	5	3	1	5	1	2	3	3	6
17	4	15	10	1	8	2	5	6	4	3	7	9
18	1	4	3	1	2	4	6	5	7	8	10	9
19	1	2	3	2	5	1	10	4	6	7	9	8
20	1	2	8	3	4	1	6	5	2	7	10	9
Average		8.84	6.00	1.75	4.00	1.85	6.75	4.90	5.05	4.90	7.70	7.40
Rank			7	1	3	2	8	5	6	4	10	9

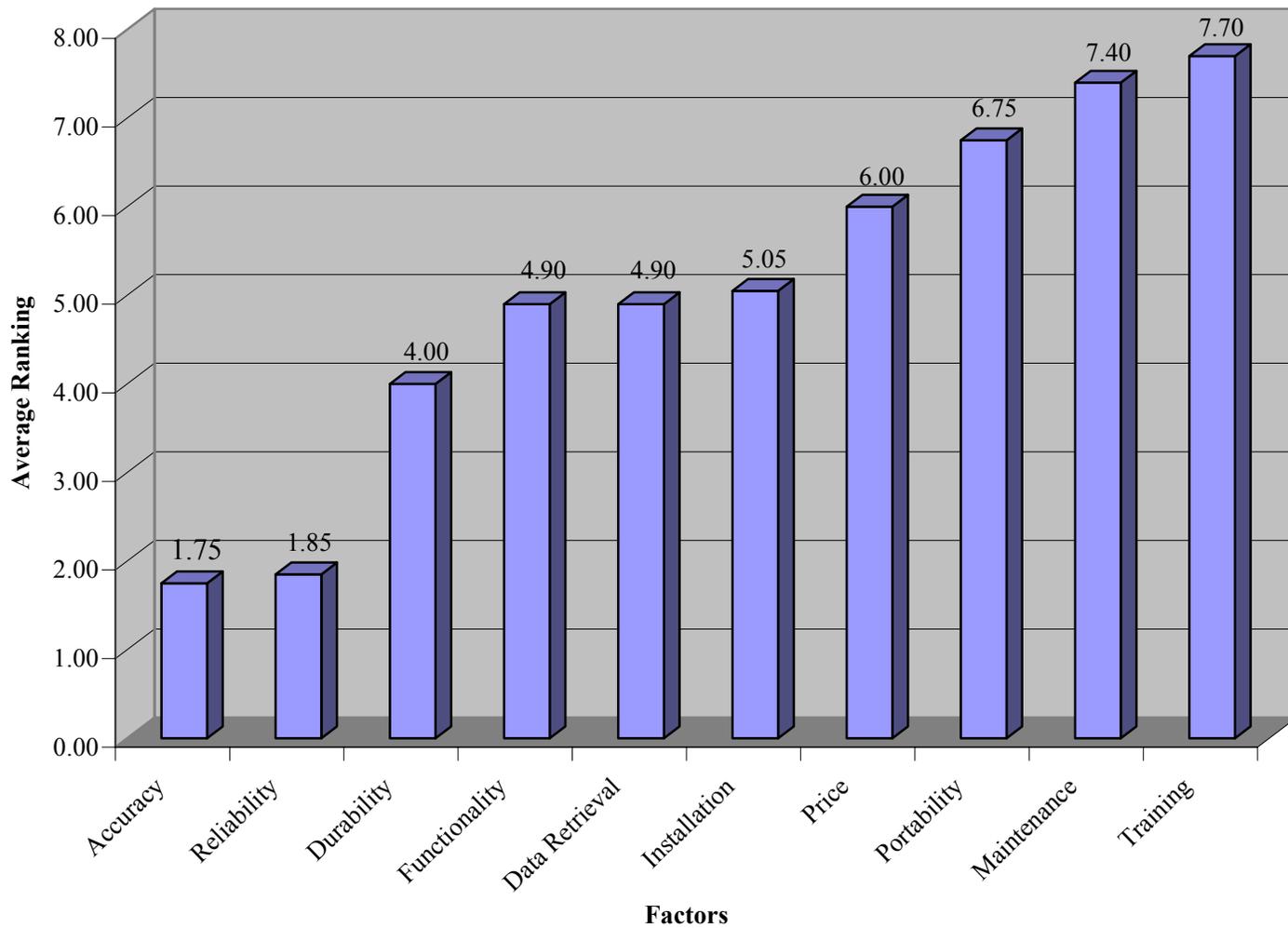


Figure 3.2 Ranking of Selection Factors

Functionality reflects the need for more comprehensive traffic-related data under ITS for transportation system operations. While most traditional counting devices can measure speed, volume, density, and occupancy, recent applications entail the need for vehicle classification, vehicle identification, queue detection, and weather/environment information. Thus, the versatility of the device is an important factor.

Ease of data retrieval and ease of installation are the next two important factors. A traffic counting device with efficient and user-friendly software interface to manipulate the collected data is desired. The ease of installation focuses primarily on the range of locations that a device can be mounted at, the effort needed for installation, the disturbance to the ambient traffic during installation, the damage to the roadway surface, and the safety of installation personnel.

Surprisingly, the equipment price was not significantly emphasized by the users. This implies the willingness to pay more for accurate, reliable, and versatile counting devices. Portability, maintenance needs, and personnel training needs are rated among the least important factors. This suggests that traffic agencies are willing to invest more in maintenance and training efforts if accurate and reliable data can be ensured.

The survey rating of factors is subjective, and is based on the generic need for traffic counting devices. However, some users may have specific data needs or objectives and/or specific environmental conditions. Hence, such users may rank the various factors differently.

The third question set in the survey was aimed at eliciting the traffic data needs of the users. Traffic volumes, speed, classification, vehicle counts, gap, and turning movement counts are the most commonly mentioned needs. Most respondents indicate

that their current counting devices address the basic data needs. However, some mention the need for more accurate, economical or advanced traffic counting devices with the progress of technology.

### 3.3.3 Product Evaluation

An important step in the two-step selection procedure is to rate each device on each factor. This step is difficult because: (i) factor characteristics; it is difficult to obtain quantitative values for some factors, (ii) incomplete specification; vendors may not provide all the required data, and (iii) subjectivity; the performance of a product may vary across users due to the specific field conditions in each situation.

In the user survey, the fourth set of questions asked respondents to evaluate the traffic counting devices being used in their state/district. The performance of each model is evaluated by rating some major factors. 45 evaluations were received for 20 products. The survey shows that inductive loops are the primary detector devices currently.

The product evaluation results are listed in Appendix D. They indicate that even for the same products, different users may have very different evaluations. It should be noted that the product evaluation results represent only the opinions of the individuals who answered the survey questions based on their experience with traffic counting devices at particular locations. Hence, the results are subjective. Also, the performance of a single unit of a device under specific circumstances may not necessarily represent the typical performance of that technology or model under other circumstances. Hence, the evaluation results are not comprehensive and can only be used as a reference to select counting devices. This emphasizes the sparseness in studies related to the evaluation of

traffic counting devices. It also indicates the need for a nation-wide study and a standard evaluation system to provide guidance for the selection of traffic counting devices.

## CHAPTER 4 TRAFFIC COUNTING DEVICE DATABASES

Based on a thorough search of available traffic counting devices, traffic counting device databases were built using Microsoft Access. Some basic aspects of Microsoft Access vis-à-vis this study are introduced in Appendix E. Currently 99 products from 32 vendors are recorded in the database. The information for the database was obtained from: (i) the Internet, (ii) existing reports, surveys and databases, and (iii) vendor product brochures.

### 4.1 Descriptions of the Traffic Counting Device Databases

The traffic counting device databases provided along this report were created using Microsoft Access (2000 version) which is part of the Microsoft Office 2000 Professional suit. The databases can also be accessed through Access XP or converted into Access 97 format. There are 4 major components in the database file: Product, Vendor, Software, and Product Evaluation tables.

#### 4.1.1 Product Table

The product database contains detailed data on the traffic counting devices. Currently, this table has 99 products. The fields in this table are classified into four groups:

##### Group 1: Basic Information

- 1) Product ID (primary key)
- 2) Vendor ID (the ID number of the vendor that produces this product)
- 3) Model Name (the model name specified by the vendor)
- 4) Detector Type (1-infrared, 2-magnetic, 3-microwave, 4-passive acoustic, 5-ultrasonic, 6-video, 7-inductive loop, 8-other, specify)
- 5) Price (unit price, in U.S. Dollar); Price Basis (per lane and/or installation fee)

## Group 2: Functions and Applications

- 6) Traffic Data (the traffic data types that the detector can collect. May includes vehicle counting, density, speed, volume, occupancy, headway, queue length, pedestrian presence, etc.)
- 7) Vehicle Information (registration plate number identification, vehicle classification and/or class counting, vehicle passenger occupancy, or vehicle conditions)
- 8) Weather Data (Y if weather-related data can be recorded; otherwise N)
- 9) Roadway Condition (Y if roadway pavement conditions can be measured; otherwise N)
- 10) Incident Detection (Y if incident can be detected or recreated; otherwise N)
- 11) Other Data

## Group 3: Features

- 12) Installation Position (1-overhead, 2-roadside, 3-underground, 4-mobile, 5-other)
- 13) Ease of Installation (Y/N; Y if it is easy to install)
- 14) Ease of Operation (Y/N; Y if simple to operate)
- 15) Coverage (number of lanes that can be covered)
- 16) Count per Second (maximum number of vehicles that can be counted in one second)
- 17) Detecting Speed (speed range that can be captured; in miles/hour)
- 18) Working Temperature (temperature range in which the detector can work properly; in °C)
- 19) Humidity Range (humidity range the detector can work properly; in percentage)

- 20) Auxiliary Devices (special devices or communication connection needed)
- 21) Software Support (description of software functions and output if support software is available)
- 22) Personnel Training (Y if special personnel training is needed; otherwise N)
- 23) Maintenance Needs (Y if regular maintenance needed; otherwise N)
- 24) Other Main Features (may include special installation requirements, waterproofing, flexibility in customization and optimization, mobility, etc.)

#### Group 4: Main Parameters

- 25) Life Span (duration of service; in years)
- 26) Year First Produced (the year the product was first produced)
- 27) Size (maximum outer box size; length×width×height, in ft<sup>3</sup>)
- 28) Power Supply (battery life span or electrical power consumed)
- 29) Other Parameters
- 30) Other Remarks

#### 4.1.2 Vendor Table

The vendor database provides information about the vendors. It contains 32 records with six fields. The fields include:

- 1) Vendor ID (primary key)
- 2) Company Name (the full name of the vendor)
- 3) Address
- 4) Phone (10-digit phone number)
- 5) E-mail address
- 6) URL (address)

There is a relationship between the Vendor Database and the Product Database. The vendor ID of a certain device in the Product Database is the primary key of this vendor in the Vendor Database.

#### 4.1.3 Software Table

Some vendors provide software packages along with traffic counting devices to retrieve, process, analyze or store traffic data. This database contains the following 5 fields:

- 1) Software ID (primary Key)
- 2) Vendor ID (the ID of vendor who provides this software)
- 3) Name (the software name)
- 4) Capabilities (the functions of this software)
- 5) Output (the output data of this software)

Currently, there are 14 software records in this database. The Software Database is related to the Vendor Database through the Vendor ID.

#### 4.1.4 Product Evaluation Table

The Product Evaluation table contains data on user feedback on some products from the survey responses.

### **4.2 Custom Queries and Relationships for Traffic Counting Device Databases**

Users can create custom queries according to their specific requirements on some attributes of the counting devices. For example, they can query for devices with particular price range, or the traffic data type needed. In this study, we provide some built-in queries based on the device technology category. The products satisfying these queries are listed in different query tables. In order to open a built-in query, user can click “Queries” entry in the main database window, and open corresponding query tables. A

view of built-in query is shown in Figure 4.1. Products in each technology category were filtered into different query sheets. A user needs to just click on a particular technology query sheet to see all the products in this technology category. User-specified queries can be built by clicking “Create query in design view” in the database window under “Queries” mode. Microsoft Access will allow users to select data table(s) on which the query is built, and then select the attribute whose value is used as criteria to make the query. Query can also be made based on multiple attributes. New query on existing queries is also available, which makes multi-step filtering possible. To make a multi-step query, user just needs to select existing query table instead of data table when building the new query.

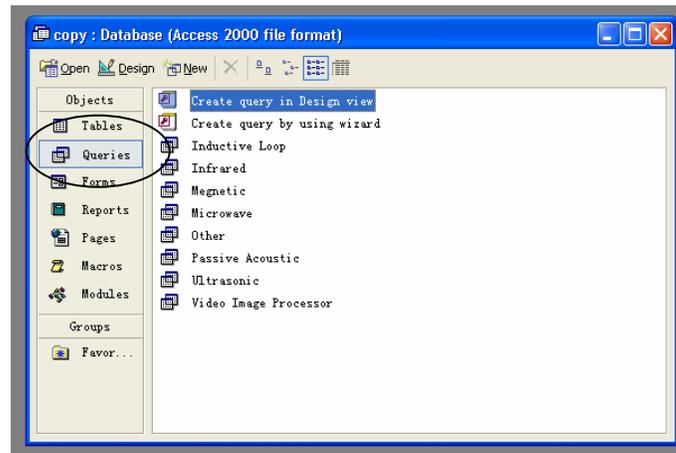


Figure 4.1 Example of Built-in Queries

Tables in the same database file may be connected through some common fields. This is called the *relationship* between the tables. The relationships among the main tables in the traffic counting device databases are shown in Figure 4.2. The Product table and the Vendor table are connected through the field “Vendor ID”. Similarly, the Product

table is connected to the Product Evaluation table through “Product ID”, and the Vendor table is connected to the Software table through “Vendor ID”.

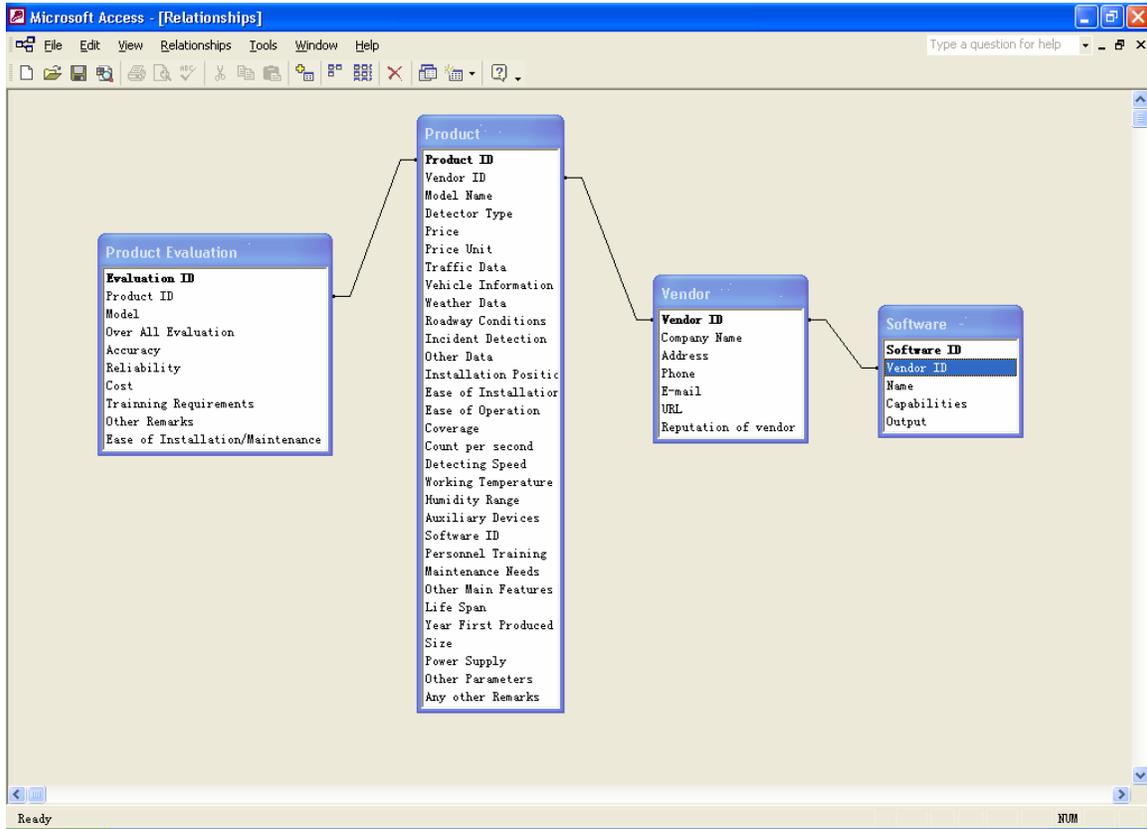


Figure 4.2 Relationships in Product Databases

### 4.3 Further Improvement to the Traffic Counting Device Databases

The traffic counting device databases contain a comprehensive listing of the devices that are currently available in the market. However, currently, some products have incomplete information due to the limited information provided by the vendors. Hence, some attributes of some products are not specified. Second, the various attributes may not have a consistent basis across vendors because different vendors specify different aspects of an attribute. For example, some vendors provide the price of one unit of a device, while

others show the cost per lane and view costs in terms of lane coverage. Other vendors provide the price of an integrated system including probes, data processing equipment, and sometimes even installation cost. This makes comparison difficult unless the various aspects can be separated. Third, some attributes lack numerical values and can only be evaluated through description. Users need to convert them into comparable values before being able to rate the products. Despite these problems, to our knowledge, the database is the most complete one in literature in terms of the number of products recorded and the amount of information collected. It can be used as an auxiliary tool to select traffic counting devices.

## CHAPTER 5 CONCLUSIONS

Accurate traffic data detection is essential for the successful implementation of ITS. The collection of real-time traffic data is an integral part of ATIS and ATMS, and is necessary for the validation of these technologies. In addition, the collection and processing of historical traffic data is essential for transportation system planning and operation.

Currently, inductive loop detectors are the most commonly used traffic counting devices in the field. Being a mature technology, the traditional intrusive device has many advantages such as low cost, high accuracy and stable performance. However, there are some important drawbacks of using intrusive devices. They include the labor-intensive nature of installation, interruption of traffic, damage to road surface, geographical restrictions, and limited data type. New technologies are being developed to meet growing data counting and traffic surveillance needs. They include passive infrared, active infrared, passive magnetic, Doppler microwave, radar, passive acoustic, pulse and Doppler ultrasonic, and video image. Each has its advantages and disadvantages, and is suitable under some circumstances or for certain data collection needs. However, due to the lack of widespread development of these technologies, their relative novelty, rapid proliferation, and lack of homogeneity in standards, systematic selection guidelines are unavailable for these devices.

There are some studies in the literature that collect information on available detectors and/or evaluate their performance through field tests. However, no study specifically addresses detector selection criteria and selection process.

This study first identifies the factors that influence the selection of traffic counting devices. Device-related factors include accuracy and reliability, cost, ease of installation and maintenance, portability and storage, data retrieval, data type and functional capabilities, amenability to future technological advances, and personnel training needs. Besides these factors, the performance of traffic counting devices is also influenced by some environment-related factors such as weather conditions, traffic characteristics, roadway type, installation location and position, and traffic direction. To generate a practical selection procedure, a user survey was conducted among district and/or regional subdivisions of the departments of transportation of six states including California, Florida, Indiana, Minnesota, New York, and Texas. The survey was designed to collect the opinions and experience of these agencies on the relative importance of various factors. In addition, the survey sought feedback on the performance of traffic counting devices currently being used by these agencies. The various factors listed in the descending order of importance based on the survey are: accuracy, reliability, durability, functionality, data retrieval, ease of installation, price, portability, maintenance needs, and personnel training needs.

A selection procedure was proposed based on the survey results. An important step in the selection procedure is the comprehensive understanding of the various technologies and products currently available in the market. To accomplish this objective, a set of traffic counting device databases was built using Microsoft Access. Currently 99 products from 32 vendors are recorded in the databases. Detailed information on each device model is recorded and classified using the various attributes. The databases

represent a comprehensive collection of traffic counting devices that are currently available in the market.

The study concludes that there are still some barriers to the systematic evaluation and informed selection of traffic counting devices. They include lack of universal standards, incomplete specification of product parameters, inconsistent bases to describe attributes among vendors, and the difficulty in obtaining quantitative values for some important attributes. These issues preclude a consistent comparison between the candidate products. They indicate the need for a nation-wide comprehensive study of traffic counting devices that involves setting homogenous standards, developing consistency in the description of product parameters, and systematic tests of the various products under different environmental and traffic conditions.

## **Appendix A: Product Information by Technology Category**

Infrared										
Product ID	Company Name	Model Name	Detector Type	Price	Price Unit	Traffic Data	Installation Position	Coverage	Other Main Features	Any other Remarks
1002	ASIM Technologies Ltd	IR 250 Series Multichannel PIR Vehicle Detector	1	737		presence, count, speed	1, 2	1 lane	mounting height from 4 to 10 meters, static and dynamic sensors, IP 64 splash proof	temperature contrast compensation,
1003	ASIM Technologies Ltd	DT 270 Series Dual technology PIR and US detectors	1, 5	681		presence & queue detection, count,	1, 2	1 lane	horizontal or vertical mounting, IP 64 splash proof, static presence and distance dependant detection	easy mounting
1004	ASIM Technologies Ltd	TT 260 Series Triple technology PIR / US / MW detectors	1, 3, 5	1786		Count, speed, presence & queue detection, occupancy & time gap detection	1	1 lane	IP 64 splash proof, mounting height, detection of ghost riders, detection of alternating traffic, self calibrating	Easy installation
1014	Diamond Traffic Products	TT-3	1, 8-seismic	210		count	4 (on pavement)	1 lane	waterproof, magnetic zero reset, aluminum case with lock and cover,	6 digit liquid crystal display, best suited for counting low volumes. ease of installation
1085	Scientific Technologies, Inc.	VS6500 Vehicle Scanner	1				2	1 lane	specifically designed for vehicle detection and classification in automated toll systems, Fan prevents overheating in summer	rugged stainless steel design or aluminum with corrosion resistant paint, Three separate outputs: RS-232 or RS-422 serial data, parallel data, and relay

Magnetic										
Product ID	Company Name	Model Name	Detector Type	Price	Price Unit	Traffic Data	Installation Position	Coverage	Other Main Features	Any other Remarks
1000	3M, Intelligent Transportation Systems	3M™ Traffic Sensing System (Model 701)	2			speed, counting, ramp metering passage detection	3		invasive, count performance regardless of weather	0.25" saw cuts need to be made and a 1" diameter hole @ 20" deep, protected from severe traffic and environment
1001	3M, Intelligent Transportation Systems	3M™ Traffic Sensing System (Model 702)	2			vehicle presence, count, speed, length, roadway occupancy	3		non-invasive micro loop, minimal interruption of traffic, maintenance can be performed on the side of the road	protected from severe traffic and environment, readily removed, replaced, or repositioned, efficient remote diagnostics, installed using horizontal drilling, vdc- 93
1041	Midian Electronics, Inc.	Self-Powered Vehicle Detector	2	600	per lane	count, presence	3	1 lane	temperature stable and self-calibrating	requires a 6" diameter hole to be drilled in the traffic lane to a depth of 14 inches below the asphalt, used in WA, FL, CN. vdc-95
1056	Nu-Metrics, Inc - A Quixote Company	HI-STAR (NC-47 & NC-97)	2	975	per lane	volume, speed, presence	4	1 lane	no tubes, locks or chains, simple programming, collect data at any location	Vehicle Magnetic Imaging (VMI) technology, 15 speed categories, 8 length categories, Real-Time-Clock, used: PA, NC, MO, IL, FL, TX, AL, CA, CO, AZ, NV, LA

**Magnetic**

Product ID	Company Name	Model Name	Detector Type	Price	Price Unit	Traffic Data	Installation Position	Coverage	Other Main Features	Any other Remarks
1057	Nu-Metrics, Inc - A Quixote Company	COUNTCARD NC-30X	2	275	per lane	volume	4	-	simple two button operation, programmable start count hour, auto stop at 1, 6, 12 hours, 1 to 7 days	operated by two keys and a 6-digit display, real time quartz clocks, maximum count 999,999 vehicles
1058	Nu-Metrics, Inc - A Quixote Company	GROUNDHOG G1	2	975	per lane. installation: 150	volume counts, gap	3	1 lane	license free spread spectrum RF, no loops, tubes or chains, time period data (1-120 minutes), used: Penn DOT	vehicle detection and measurement are accomplished by Vehicle Magnetic Imaging (VMI™) Technology, stores accurate and essential real-time traffic data
1059	Nu-Metrics, Inc - A Quixote Company	GROUNDHOG G2	2	1695	per lane. installation: 150	volume counts, speed, gap	3	1 lane	license free spread spectrum RF, no loops, tubes or chains, time period data (1-120 minutes), used Penn DOT	vehicle detection and measurement are accomplished by Vehicle Magnetic Imaging (VMI™) Technology
1060	Nu-Metrics, Inc - A Quixote Company	GROUNDHOG G2WX	2	1800	per lane	volume counts, speed	3	1-64 (BSR/RFM- 915 required)	license free spread spectrum RF, no loops, tubes or chains, time period data (1-120 minutes),	vehicle detection and measurement are accomplished by Vehicle Magnetic Imaging (VMI™) Technology, stores accurate and essential real-time traffic conditions
1061	Nu-Metrics, Inc	GROUNDHOG	2			volume	3	-	license free	vehicle detection and

Magnetic										
Product ID	Company Name	Model Name	Detector Type	Price	Price Unit	Traffic Data	Installation Position	Coverage	Other Main Features	Any other Remarks
	- A Quixote Company	G3				counts			spread spectrum RF, no loops, tubes or chains, time period data (1-120 minutes),	measurement are accomplished by Vehicle Magnetic Imaging (VMI™) Technology, stores accurate and essential real-time traffic conditions
1062	Nu-Metrics, Inc - A Quixote Company	GROUNDHOG G3WX	2			volume counts	3	-	license free spread spectrum RF, no loops, tubes or chains, time period data (1-120 minutes),	vehicle detection and measurement are accomplished by Vehicle Magnetic Imaging (VMI™) Technology, stores accurate and essential real-time traffic conditions

Microwave										
Product ID	Company Name	Model Name	Detector Type	Price (\$)	Price basis	Traffic Data	Installation Position	Coverage	Other Main Features	Any other Remarks
1026	EIS, Electronic Integrated Systems Inc.	RTMS/FTMS	3			volume, speed, gap	2	8 lanes	accurate in all weather conditions, low cost, mounting: Side-fired or Forward-looking	output information is provided to existing controllers via contact pairs and to computer systems via a RS-232 serial communications port
1027	EIS, Electronic Integrated Systems Inc.	RTMS-WATER	3			count, occupancy, speed, presence	2	8 lanes	accurate measurement in all weather conditions, few leased-lines required, Flexible: Scalable system for easy growth	data in real-time, Cluster Controllers: concentrate data from many stations, Alarm and special occurrence reporting, vdc-166
1028	EIS, Electronic Integrated Systems Inc.	RTCP	3			volume, speed	2	8 lanes	accurate all-weather operation, no lane closures during installation, high capacity: 7 days at 5-minute intervals	solar generator/charger options, power-fail data protection, Laptop PC or modem data retrieval, MS Access 97-based analysis and report software
1038	Microwave Sensors, Inc	TC-20 Vehicle Detector	3	629	per lane. Installation: \$500		1, 2 (portable)	up to 6 lanes	adjustable range, no seasonal tuning required, no external amplifier required, Doppler	aluminum with stainless steel case, heavy-duty bracket (Predrilled & slotted for pole mount), detects smallest licensed vehicle
1039	Microwave Sensors, Inc	TC-26B Vehicle Detector	3	735	per lane Installation: \$500		1, 2 (portable)	up to 6 lanes	field adjustable range, directional scanning, no seasonal tuning required, no	aluminum with stainless steel case, heavy-duty bracket (Predrilled & slotted for pole mount), detects smallest licensed

Microwave										
Product ID	Company Name	Model Name	Detector Type	Price (\$)	Price basis	Traffic Data	Installation Position	Coverage	Other Main Features	Any other Remarks
									external amplifier required	vehicle, 5000+ installed in US
1040	Microwave Sensors, Inc	TC-30 & TC-30C Presence Sensors	3	475	per lane installation:: \$500	counts	1, 2 (portable)	1 lane	high speed transducer for target resolution, no seasonal tuning required, no external amplifier required	aluminum with stainless steel case, heavy-duty bracket (Predrilled & slotted for pole mount), detects smallest licensed vehicle

**Passive Acoustic**

Product ID	Company Name	Model Name	Detector Type	Price	Price Unit	Traffic Data	Installation Position	Coverage	Other Main Features	Any other Remarks
1066	PAT America, Inc.	ACOUSTIC SENSOR SAS-1	4			volume, lane occupancy, average vehicle speed	2	5 lanes	Built-in upgrade path for vehicle type identification, ideal back-fit for failed loops	aluminum case, wireless option eliminates home run cables, collects real time data, stores up to 60 days of data, item identical to SmarTek SAS-1
1086	SmarTek Systems, Inc.	ACOUSTIC SENSOR SAS-1	4	3500		volume by lane, lane occupancy, average vehicle speed, time	2	5 lanes	Built-in upgrade path for vehicle type identification, ideal back-fit for failed loops	aluminum case, wireless option eliminates home run cables, collects real time data, stores up to 60 days of data, item identical to PAT SAS-1, vdc-204

### Ultrasonic

Product ID	Company Name	Model Name	Detector Type	Price	Price Unit	Traffic Data	Installation Position	Coverage	Other Main Features	Any other Remarks
1003	ASIM Technologies Ltd	DT 270 Series Dual technology PIR and US detectors	1, 5	681		presence & queue detection, count,	1, 2	1 lane	horizontal or vertical mounting, IP 64 splash proof, static presence and distance dependant detection	menu guided configuration, easy mounting
1004	ASIM Technologies Ltd	TT 260 Series Triple technology PIR / US / MW detectors	1, 3, 5	1786		count (all kinds of vehicles), speed, presence & queue detection, occupancy & time gap detection	1	1 lane	IP 64 splash proof, mounting height, detection of ghost riders, detection of alternating traffic, self calibrating	easy mounting

### Video Image Processor

Product ID	Company Name	Model Name	Detector Type	Price	Price Unit	Traffic Data	Installation Position	Coverage	Other Main Features	Any other Remarks
1006	AVIAR, Inc.	COMBI speed / red light system	6, Piezo sensors			count, speed	2, 3, 4	3 lanes	provides traffic statistics such as the 85th percentile, average, highest and lowest speeds, and peak and average traffic flows	used in Texas and Florida, vdc-82
1008	Computer Recognition Systems Inc	TAS2	6-Video: RS-170, CCIR, NTSC, PAL	20000	including installation	count, speed, gap, length	1, 2 (permanent or portable)	32 lanes	remote data acquisition, remote control & programming, individual vehicle records, time-stamped sensor events	the system allows user defined reports & user definable, currently used in CA, MA & other countries, 4-16 MB storage capacity of onsite memory
1009	Computer Recognition Systems Inc	NRS, NRS2	6-Video Input RS-170, CCIR, NTSC, PAL	20000	including installation	count, speed, gap, travel time, weigh-in-motion	1, 2	1-8 lanes	remote data acquisition, remote control & programming, individual vehicle records, time-stamped sensor events	the system allows user defined reports & user definable, currently used in MA, KY, WA, LA, TA, FL, and other countries, 4-16 Mbyte Storage capacity
1024	Econolite Control Product, Inc.	Autoscope Solo Pro MVP	6	5000	per lane	count, speed, density,	1, 2	6-7 lanes	integrated color camera, zoom lens, directional real-time iris and shutter speed	rugged environmentally sealed enclosure, failsafe mode sends output to traffic

### Video Image Processor

Product ID	Company Name	Model Name	Detector Type	Price	Price Unit	Traffic Data	Installation Position	Coverage	Other Main Features	Any other Remarks
									control	control, performs self test and detects component failure, vdc-141
1025	Econolite Control Product, Inc.	Autoscope 2004, ECP	6	5000	per lane	count, gap, speed	1,2	6-7 lanes	available in one, two, and four image sensor input model, Time-stamped sensor events	remote data acquisition, remote control and programming, used: AZ, CA, CO, FL, IL, IN, MD, MI, MN, MO, NV, NJ, NM, NC, OR, TX, WA, WI, vdc-141
1046	Nestor Traffic Systems, Inc.	RackStation™	6			counts, speed, vehicle headway, lane occupancy, lane changes	-	4 cameras covering 6 lanes each	rack mounted system without the added expense of conditioning for harsh climates, Intersection and Freeway configurations	supports a variety of camera locations, intersection and freeway configurations, not actively marketed
1047	Nestor Traffic Systems, Inc.	RoadSide Station™	6			counts, speed, vehicle headway, lane occupancy, lane changes	-	4 cameras covering 6 lanes each	rack mounted system equipped with environmental conditioning	optional surveillance package can equip RoadSide Station to transmit live digital video as well as traffic data back to a central monitoring facility, not actively marketed
1048	Nestor	TOCStation™	6	12000	or less	counts, speed,	-	2	no roadside	real-time traffic

### Video Image Processor

Product ID	Company Name	Model Name	Detector Type	Price	Price Unit	Traffic Data	Installation Position	Coverage	Other Main Features	Any other Remarks
	Traffic Systems, Inc.					lane changes		cameras covering 6 lanes each	electronics, runs on standard PC in Traffic Operation Center (TOC),	data accessible from LAN or serial ports, stores data in industry-standard formats, functions in all weather and low visibility conditions
1074	Peek Traffic Systems, Inc.	VideoTrak®-910	6			volume/counts, lane occupancy, speed, headway, delay, queue length	2	-	true "wide-area" detection via full-scene tracking, Proven tracking-based algorithms, Built-in image stabilization	real-time video information, provides up to 128 detection zones, allows 8 video inputs, 2 surveillance video inputs and 2 analog video outputs
1075	Peek Traffic Systems, Inc.	VideoTrak®-905	6			volume/counts, lane occupancy, speed, headway, delay, queue length	2	-	true "wide-area" detection via full-scene tracking, Proven tracking-based algorithms, Built-in image stabilization	real-time video information, provides up to 128 detection zones, allows 4 video inputs, 1 surveillance video input and 1 mixed analog video output
1092	Traffic Systems, Inc.	Model VIP3 Video Image Processor, Vehicle Presence Detector	6	5000		presence detection, counting, speed	-	8 lanes	available in self contained stand-alone units, multiple functions per camera, Central Computer	open error contact at the absence of the video signal or malfunction of the VIP board, easy keypad or laptop

### Video Image Processor

Product ID	Company Name	Model Name	Detector Type	Price	Price Unit	Traffic Data	Installation Position	Coverage	Other Main Features	Any other Remarks
									remotely programmable	computer programming, used : Florida, Georgia, vdc-153

### Inductive Loop

Product ID	Company Name	Model Name	Detector Type	Price	Price Unit	Traffic Data	Installation Position	Coverage	Other Main Features	Any other Remarks
1005	AVIAR, Inc.	TCL-300	7	5700	/lane, Permanent Temperory \$4500	count, time, direction, headway	3, 4 (on-pavement)	4 lanes	data of 20,000 individual vehicles can be stored into 256 KB of battery-powered memory, used in Michigan	vehicle data is classified and placed into bins within the instrument if a recording interval is selected and 8,000 summarized data records can be stored in this model. vdc-69
1012	Diamond Traffic Products	TT-77	7	259		count	3	1 lane	water-tight aluminum case with a lockable latch, counts axle or vehicle	8 digit solid-state LCD, a viewing port can be added so it can be read without opening the case
1015	Diamond Traffic Products	TT-21, TT-41	7	329		count	3	1 lane	water-tight aluminum case with a lockable latch	8 digit solid-state LCD, TT21 comes with optional time interval data recording ability

### Inductive Loop

Product ID	Company Name	Model Name	Detector Type	Price	Price Unit	Traffic Data	Installation Position	Coverage	Other Main Features	Any other Remarks
1016	Diamond Traffic Products	Pegasus, Unicorn	7, 8-road tube, Piezos, resistive sensors	695-875	Pegasus Unicorn \$1125-1345	count with intervals, Unicorn-speed & axle classification, gap, headway, and speed by axle type, WIM	4 (on or in pavement)	peg: 4 lanes unicorn: 2 lanes	time interval count mode or sensor count mode	record interval lengths of one minute to 24 hours in one minute increments, 68 KB of internal memory, 16-key watertight keyboard, used: CT, NY, SD, OK, AL, NV
1017	Diamond Traffic Products	Sprite	7, 8-road tube	475-725		count with intervals	4 (on or in pavement)	1 or 2 lanes	selectable date formats, cover and lock included,	two lines, 32 character alpha/numeric LCD, 99 files in 32 KB memory, manual or automatic daily file closure
1018	Diamond Traffic Products	Phoenix, Phoenix Rax	7, 8-road tube, Piezos, fiber optic, radar, resistive	1225-1695		count, speed, gap, headway, time stamp, binned data	3, 4 Rax: rack mounted for permanent installation	up to 16 lanes (classify up to 8 lanes)	two modes of count, three modes of classification,	record interval lengths of one minute to 24 hours in one minute increments, 68 K of counter memory, 16-key watertight keyboard, used: FL, AL, NY, OK, etc, vdc-80
1020	Diamond Traffic Products	TT-14	7	339		count	3	1 lane	waterproof, steel band and chain for locking	8 digit solid-state LCD.

**Inductive Loop**

Product ID	Company Name	Model Name	Detector Type	Price	Price Unit	Traffic Data	Installation Position	Coverage	Other Main Features	Any other Remarks
1021	Eberle Design Inc.	LM 331, LM 332	7			count, detection	3	2 lanes-2 channel, 4 lanes-4 channel	automatic tuning, environmental tracking, 15 or 16 levels of sensitivity, 3 selectable modes: pulse, short presence, long presence	331: 1 channel with system/count output, 332: 2 channel with system/count output, all-four loop frequencies
1022	Eberle Design Inc.	LM 634, LM 642	7			count, detection	3	2 lanes-2 channel, 4 lanes-4 channel	automatic tuning, environmental tracking, 15 levels of sensitivity, 3 selectable modes: pulse, short presence, long presence	2 channel, 4 loop frequencies
1023	Eberle Design Inc.	Oracle /2	7			detection	3	2 lanes-2 channel, 4 lanes-4 channel	LCD display of operational and diagnostic information, 15 levels of sensitivity, 3 selectable modes	2 channel, 8 loop frequencies
1033	JAMAR Technologies, Inc.	TRAX III Automatic Traffic Recorder	7, 8-road tube, Piezo	1395-1595		volume, speed, gap, length, binned data per-vehicle	3, 4 (on road)	1-8 lanes	real-time & date clock, programmable intervals, 2 to 4 loop inputs, 2 or 4 road tube inputs available,	cast aluminum housing, full numeric keypad, four line LCD display , FHWA or custom classification,

**Inductive Loop**

Product ID	Company Name	Model Name	Detector Type	Price	Price Unit	Traffic Data	Installation Position	Coverage	Other Main Features	Any other Remarks
									optional solar panel	1024 KB internal memory
1034	JAMAR Technologies, Inc.	TRAX TOTALIZER Automatic Traffic Recorder	7, 8-road tube	375-535		volume, speed, gap, length	3, 4 (on road)	1-8 lanes	1 or 2 road tube inputs, 1 or 2 loop inputs,	cast aluminum housing, able to record data without the need to download to a computer, LCD display, reviewable totals during or after count
1043	Mitron Systems Corporation	MSC4000 Scout system	7, 8-road tube or Piezo	1599	permanent. Portable: \$1779	count, speed, gap, headway	3, 4 (portable and permanent)	20 lanes	20-channel modular traffic recorder, rack-mount or portable, multiple studies performed simultaneously	time-stamped sensor events, waterproof connectors, real-time clock/calendar, multiple studies performed simultaneously
1049	Never-Fail Loop Systems, Inc.	Model A (Asphalt overlay)	7			-	3	-	patented expansion / contraction joints, Direct burial into sub-base or tie down to rebar	-
1050	Never-Fail Loop Systems, Inc.	Model F-38 (All above - plus	7			-	3	-	needs only a 3/8" (9.5 mm) saw-cut slot, Patented	-

**Inductive Loop**

Product ID	Company Name	Model Name	Detector Type	Price	Price Unit	Traffic Data	Installation Position	Coverage	Other Main Features	Any other Remarks
		temporary)							expansion / contraction capabilities	
1051	Never-Fail Loop Systems, Inc.	Model C (Concrete overlay)	7			-	3	-	patented expansion / contraction joints, Direct burial into sub-base or tie down to rebar	-
1052	Never-Fail Loop Systems, Inc.	Model F (Cut-in application)	7			-	3, 4	-	Patented expansion / contraction joints	-
1067	Peek Traffic Inc-Components	JR 161	7			count	4	-	-	padlock with 2 keys
1072	Peek Traffic Inc-Components	Idris Smart Loops	7			count, lane designation	2	8 lanes	capable of differentiation between two vehicles tailgating and a single vehicle towing a trailer	up to 16 inductive loop inputs, in a multi0lane environment, lane-straddling vehicles are distinguished from those traveling similar speeds in adjacent lanes, vdc-45
1076	Reno A & E	Model G/222 Series	7	146		count	-	-	two detector's channels in a single unit, 8	lightning protection, red, high intensity LED

**Inductive Loop**

Product ID	Company Name	Model Name	Detector Type	Price	Price Unit	Traffic Data	Installation Position	Coverage	Other Main Features	Any other Remarks
									levels of sensitivity per channel, two selectable output modes per channel	DETECT and Loop FAIL indicators, 2-channel rack mount type
1077	Reno A & E	Model L series	7	149		count	-	-	accumulated number of Loop Failures since the detector was last reset,	custom "Back-lit" LCD screen displays the complete status and function settings of the detector, 1-channel shelf mount type
1078	Reno A & E	Model C Series,	7	215		count	-	-	automatically tunes and is operational within 2 seconds after application of power or after being reset, directional logic	LCD display, built-in audible detect buzzer, third car passage logic, 2-channel rack mount type
1079	Reno A & E	Model U series	7	388		count	-	-	phase green loop compensation, phase green inputs for all channels, directional logic	custom "Back-lit" LCD screen displays the complete status and function settings of the detector, 4-channel shelf mount type

**Inductive Loop**

Product ID	Company Name	Model Name	Detector Type	Price	Price Unit	Traffic Data	Installation Position	Coverage	Other Main Features	Any other Remarks
1080	Reno A & E	Model T Series	7	100		count	-	-	external DIP switch for setting parameters	1 channel shelf mount type, solid state or relay versions.
1081	Reno A & E	Model E Series	7	329		count	-	-	built-in audible detect buzzer, phase green loop compensation, directional logic	custom "Back-lit" LCD screen displays the complete status and function settings of the detector, 4-channel rack mount type
1082	Reno A & E	Model S Series	7	279		count	-	-	phase green loop compensation, directional logic,	custom "Back-lit" LCD screen displays the complete status and function settings of the detector, 2-channel shelf mount type
1093	U.S. Traffic Corporation Manufacturers & System Engineers	919A	7	250	per lane installation: \$750	count	3	1 lane	ten levels of sensitivity, over an extended range, self-tuning and complete environmental tracking	red, high intensity LED Detect indicator, used: nationwide
1094	U.S. Traffic	272M	7	311	per lane.	count	3	2 lanes	eight levels of	red, high

**Inductive Loop**

Product ID	Company Name	Model Name	Detector Type	Price	Price Unit	Traffic Data	Installation Position	Coverage	Other Main Features	Any other Remarks
	Corporation Manufacturers & System Engineers				Installation: \$750				sensitivity per channel, self- tuning and complete environmental tracking	intensity LED DETECT indicator, used: nationwide
1095	U. S. Traffic Corporation Manufacturers & System Engineers	IVS 200	7	3000	per lane Instation: \$750-1500	gap, headway	-	-	operates with existing loops, self-tuning and completely environmental tracking, automatic switchover from two to one loop	red, high intensity LED light signals vehicle over loop, four frequencies per loop, faulty loop indicator
1096	MetroCount (USA) Inc.	DB-100 Turning Movement Counter	7							
1097	MetroCount (USA) Inc.	DB-400 Turning Movement Counter	7							
1098	MetroCount (USA) Inc.	TDC-8 Traffic Data Collector	7			turning movements, classification, gap, intersection stop delay, stop sign delay, spot speed with class, travel time and				

**Inductive Loop**

Product ID	Company Name	Model Name	Detector Type	Price	Price Unit	Traffic Data	Installation Position	Coverage	Other Main Features	Any other Remarks
						delay				

## **Appendix B: Vendor Information**

Vendor					
Vendor ID	Company Name	Address	Phone	E-mail	URL
100	3M, Intelligent Transportation Systems		1 (800) 927-5476 Robert L. Dreger		<a href="http://www.3m.com/its/">http://www.3m.com/its/</a>
101	ASIM Technologies Ltd	Ziegelhof-Strasse 30 CH-8730 Uznach Switzerland	+41-55-285 99 99	mguentensperger@asim.ch	<a href="http://www.asim-technologies.com">http://www.asim-technologies.com</a>
102	AVIAR, Inc.	PO Box 162184 Austin, TX 78716 USA	1 (512) 295-5285	sales@aviarinc.com	<a href="http://www.aviarinc.com/">http://www.aviarinc.com/</a>
103	Computer Expertise Corp.	PO Box 1899 North Windham, Me. 04062 USA	1 (207) 892-0740	cecorp@computerexpertise.com	<a href="http://www.computerexpertise.com/">http://www.computerexpertise.com/</a>
104	Computer Recognition Systems Inc	625 Massachusetts Avenue, Suite 5 Cambridge MA 02139 USA	1 (617) 491-7665	info@crs-its.com	<a href="http://www.crs-vision.com/">http://www.crs-vision.com/</a>
105	Diamond Traffic Products	P. O. Box 1455 Oakridge, OR 97463 USA	1 (541) 782-3903	diamondtrf@aol.com	<a href="http://www.diamondtraffic.com">http://www.diamondtraffic.com</a>
106	Eberle Design Inc.	3819 East La Salle Street Phoenix, AZ 85040 USA	1 (480) 968-6407	info@editraffic.com	<a href="http://www.editraffic.com/">http://www.editraffic.com/</a>
107	Econolite Control Product, Inc.	3360 East La Palma Ave. Anaheim, CA 92806 USA	1 (714) 630-3700	info@econolite.com	<a href="http://www.econolite.com/">http://www.econolite.com/</a>
108	EIS, Electronic Integrated Systems Inc.	150 Bridgeland Ave. #204 Toronto, M6A 1Z5 Canada	1 (416) 785-9248	sales@rtms-by-eis.com	<a href="http://www.rtms-by-eis.com/">http://www.rtms-by-eis.com/</a>
109	Electronic Control Measurement Inc.	P. O. Box 888, Manor, Texas 78653 USA	1 (512) 272 4346	ecmusa@io.com	<a href="http://www.ecm-france.com/">http://www.ecm-france.com/</a>
110	Golden River Traffic, Ltd. (Jamar in US)	Churchill Road Bicester, Oxfordshire OX26 4XT United Kingdom	+44-(0)1869- 362800	infor@goldenriver.com	<a href="http://www.goldenriver.com">http://www.goldenriver.com</a>
111	JAMAR Technologies, Inc.	151 Keith Valley Road Horsham, PA 19044-1411 USA	1 (800) 776-0940 1 (215) 491-4899	mail@jamartech.com	<a href="http://www.jamartech.com/">http://www.jamartech.com/</a>
112	MetroCount (USA) Inc.	17130 Moss Side Lane Olney, MD 20832-2937 USA	1 (800) 576-5692 1 (301) 570-2800	USAsales@metrocount.com	<a href="http://www.metrocount.com/">http://www.metrocount.com/</a>

Vendor					
Vendor ID	Company Name	Address	Phone	E-mail	URL
113	Microwave Sensors, Inc	7885 Jackson Road Ann Arbor Michigan48103 USA	1 (734) 426-0140	bhunter@microwavesensors.com	<a href="http://microwavesensors.com/">http://microwavesensors.com/</a>
114	Midian Electronics, Inc.		1 (520) 884-7981	sales@midelec.com	<a href="http://www.dp105.net/partners/midian.htm">http://www.dp105.net/partners/midian.htm</a>
115	Mitron Systems Corporation	9130-U Red Branch Road Columbia, Maryland 21045 USA	1 (800) 638-9665 1 (410) 992-7700	support@mitronsystems.com	<a href="http://www.mitronsystems.com/">http://www.mitronsystems.com/</a>
116	Nestor Traffic Systems, Inc.	One Richmond Square Providence, RI 02906 USA	1 (401) 331-9640	dwalker@nestor.com	<a href="http://www.nestor.com/nts/default.htm">http://www.nestor.com/nts/default.htm</a>
117	Never-Fail Loop Systems, Inc.	7911 NE 33rd Drive, Unit 160 Portland, OR 97211 USA	1 (503) 408-9248	general@neverfail.com	<a href="http://home.pacifier.com/~nfls/">http://home.pacifier.com/~nfls/</a>
118	Novax Industries Corporation	658 Derwent Way New Westminster, B.C., V3M 5P8 Canada	1 (604) 525-5644	heather_h@novax.com	<a href="http://www.novax.com/">http://www.novax.com/</a>
119	Nu-Metrics, Inc - A Quixote Company	518 University Drive Uniontown, PA 15401 USA	1 (724) 438-8750	sales@nu-metrics.com	<a href="http://www.nu-metrics.com/">http://www.nu-metrics.com/</a>
120	PAT America, Inc.	2402 Spring Ridge Dr. Suite E Spring Grove, IL 60081 USA	1 (877) 862-6868 1 (815) 675-1430	info@patamerica.com	<a href="http://internationaltraffic.com/">http://internationaltraffic.com/</a>
121	Peek Traffic Inc-Components	1500 N. Washington Blvd. Sarasota, FL 34236 USA	1 (800) 245-7660 1 (941) 366-8770	Pkeen@peektrafficinc.com	<a href="http://www.peektrafficinc.com/cover.htm">http://www.peektrafficinc.com/cover.htm</a>
122	Peek Traffic Systems, Inc.	3000 Commonwealth Blvd. Tallahassee, FL 32303 USA	1 (877) 490-PEEK 1 (850) 562-2253	info@peek-traffic.com	<a href="http://www.peek-traffic.com/ptsi/">http://www.peek-traffic.com/ptsi/</a>
123	Reno A & E	4655 Aircenter Circle Reno, NV 89502 USA	1 (775) 826-2020	sales@renoae.com	<a href="http://www.renoae.com/">http://www.renoae.com/</a>
124	Schwartz Electro-Optics, Inc.	3404 N. Orange Blossom Trail Orlando, Florida 32804 USA	1 (407) 298-1802	customerservice@seo.com	<a href="http://www.seord.com/">http://www.seord.com/</a>
125	Scientific Technologies, Inc.	6550 Dumbarton Circle Fremont, CA 94555-3611 USA	1 (800) 221-7060 1 (510) 608-3400	sales@sti.com	<a href="http://www.sti.com/">http://www.sti.com/</a>
126	SmarTek Systems, Inc.	14710 Kogan Drive Woodbridge, VA 22193 USA	1 (410) 315-9727	sales@smarteksys.com	<a href="http://www.smarteksys.com/">http://www.smarteksys.com/</a>

Vendor					
Vendor ID	Company Name	Address	Phone	E-mail	URL
127	Spectra Research, Inc.	3085 Woodman Drive Dayton, OH 45420-1173 USA	1 (937) 299-5999	sstarr@spectra-research.com	<a href="http://www.spectra-research.com/">http://www.spectra-research.com/</a>
128	TimeMark, Inc.	PO Box 12947 Salem, OR 97309 USA	1 (800) 755-5882	Sales@TimeMarkInc.com	<a href="http://www.timemarkinc.com/Intro.html">http://www.timemarkinc.com/Intro.html</a>
129	Traffic Systems, Inc.	337 Skidmore Road Deer Park New York, 11729 USA	1 (516) 242-4292	Rich@trafficsystemsinc.com	<a href="http://www.trafficsystemsinc.com/">http://www.trafficsystemsinc.com/</a>
130	U.S. Traffic Corporation Manufacturers & System Engineers	9603 John Street Santa Fe Springs, CA 90670 USA	1 (800) 733-7872 1 (562) 923-9600	customer.service@idc-traffic.com	<a href="http://www.idc-traffic.com/">http://www.idc-traffic.com/</a>
131	International Traffic Co	2402 SpringRidge Drive Spring Grove, IL 60081	815-675-1430	ticsfo@ticsfo.co	<a href="http://www.ticsfo.com">http:// www.ticsfo.com</a>

## **Appendix C: User Survey**

July, 2001

Dear Sir/Madam,

We are working on an Indiana Department of Transportation project to evaluate traffic counting devices currently available in the market. Due to the fast-changing technological developments in this area, and a wide range of standards and technologies, there is a need to develop a systematic mechanism to evaluate traffic counting devices to aid future purchase decisions. This survey seeks your opinion on your experience with various traffic counting devices that are being used in your state or district. We would greatly appreciate it if you could take a few minutes to complete this brief survey.

Srinivas Peeta, Associate Professor, Ph.D.  
Pengcheng Zhang, Ph.D. Candidate  
David Burkett, Undergraduate Intern  
School of Civil Engineering, Purdue University  
West Lafayette, IN 47907

1. Personal information (optional):

- 1) Name: \_\_\_\_\_ 2) Employer: \_\_\_\_\_  
3) Position: \_\_\_\_\_  
4) Work Type (mark one): Operations \_\_\_\_\_ Research \_\_\_\_\_ Planning \_\_\_\_\_ Other \_\_\_\_\_  
5) Years of Experience in Traffic Data Collection/Traffic Counting Devices: \_\_\_\_\_

2. How would you rate the following factors when purchasing traffic counting devices?  
(1 being the most important factor, and 10 being the least important factor)

- Price \_\_\_\_\_ Accuracy \_\_\_\_\_ Durability \_\_\_\_\_ Reliability \_\_\_\_\_ Portability \_\_\_\_\_  
Ease of Data Retrieval \_\_\_\_\_ Ease of Installation \_\_\_\_\_ Functionality \_\_\_\_\_  
Less Personnel Retraining Needs \_\_\_\_\_ Maintenance Requirements \_\_\_\_\_

3. What traffic related data is generally needed in your work? Do your current traffic counting devices match the needs?

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4. Evaluation of the traffic counting devices being used in your state/district.

Please answer the following questions for each product.

(a) How would you rate the traffic counting device? (A-Excellent, B-Good, C-Average, D-Poor, E-Very poor)

(b) What data can the device collect? (1-vehicle counting, 2-volume, 3-vehicle speeds, 4-lane occupancy, 5-gap & headway, 6-vehicle classification, 7-vehicle identification, 8-weather and environment, 9-other, please specify.)

**Product 1:**

Vendor/Model \_\_\_\_\_

(a) Overall \_\_\_\_\_ Accuracy \_\_\_\_\_ Reliability \_\_\_\_\_ Lifecycle Costs \_\_\_\_\_

Training Requirements \_\_\_\_\_ Ease of Installation/Maintenance \_\_\_\_\_

(b) Data Collection \_\_\_\_\_

(c) Other Remarks \_\_\_\_\_

**Product 2:**

Vendor/Model \_\_\_\_\_

(a) Overall \_\_\_\_\_ Accuracy \_\_\_\_\_ Reliability \_\_\_\_\_ Lifecycle Costs \_\_\_\_\_

Training Requirements \_\_\_\_\_ Ease of Installation/Maintenance \_\_\_\_\_

(b) Data Collection \_\_\_\_\_

(c) Other Remarks \_\_\_\_\_

**Product 3:**

Vendor/Model \_\_\_\_\_

(a) Overall \_\_\_\_\_ Accuracy \_\_\_\_\_ Reliability \_\_\_\_\_ Lifecycle Costs \_\_\_\_\_

Training Requirements \_\_\_\_\_ Ease of Installation/Maintenance \_\_\_\_\_

(b) Data Collection \_\_\_\_\_

(c) Other Remarks \_\_\_\_\_

**Thank you for your time!! We really appreciate it.**

## **Appendix D: Product Evaluation**

**Product Evaluation**

ID	Product ID	Model	Overall Grade	Accuracy	Reliability	Cost	Training Requirements	Ease of Installation/Maintenance	Other Remarks
1	1018	DIAMOND	B	B	B	C	C	C	expensive but solid and reliable
2	1018	DIAMOND	C	B	D	C	B	B	
3	1018	DIAMOND PHOENIX	C	C	C	C	C	C	
4	1018	DIAMOND/PHOENIX	B+	A	B	B	B	B+	road tube, loop sensor & Piezo inputs
5	1016	DIAMOND/UNICORN	B+	A	B	B	B	B+	road tube & loop sensor inputs
6	1026	EIS RTMS	C	C	C	B	D	D	Side-fire radar-portable setup
7	1030	GOLDEN RIVER ARCHER TUBE	C	C	B	C	C	D	
8	1030	GOLDEN RIVER MARKSMAN 3031	B	A	B	A	B	B	
9		INTERNATIONAL TRAFFIC CO	C	C	A	C	C	B	software for processing data is not good
10		INTERNATIONAL TRAFFIC CO/MINI TRS	C	C	B	A	C	B	
11		INTERNATIONAL TRFFIC CO/TRS	D	D	D	B	C	C	
12	1096	JAMAR DB 100	B	B	B	B	B	B	
13	1097	JAMAR DB 400 & TDC-8	B	A	B	B	A	A	
14	1097	JAMAR DB-400	A	A	A				have secondary buttons which enables to track the movements of trucks, buses, and pedestrians separately
15	1097	JAMAR IMC-IV	B	B	A	B	B	B	
16	1098	JAMAR TDC-8	B	A	A	B	B	A	
17	1098	JAMAR TDC-8	B	B	B	B	B	B	portable and easy to use

**Product Evaluation**

ID	Product ID	Model	Overall Grade	Accuracy	Reliability	Cost	Training Requirements	Ease of Installation/Maintenance	Other Remarks
18	1098	JAMAR TDC-8	A	A	B	B	A	A	
19		NU-METRICS	B	A	B	B	B	B	
20		NU-METRICS	C	A	B	B	E	B	need much work on validation after installation
21	1056	NU-METRICS 90A	C	B	B	D	D	C	difficult to interface with and not being supported anymore
22	1057	NU-METRICS COUNT CARD NC30X	B	A	C-D	B	C	B-C	excellent technology; needs to be more reliable
23	1056	NU-METRICS HI-STAR NC-40	C	A	C	D	C	C	high maintenance costs
24	1056	NU-METRICS HI-STAR NC-90	C	A	C	D	C	C	high maintenance costs
25	1056	NU-METRICS/NC-97	B	B	C	B	A	B	
26		PEEK 141	D	D	D	D	D	D	
27		PEEK 241	A	C	B	A	B	A	tubes vandalized or removed during counts; caught in sweepers
28		PEEK 241	B	B	B	C	B	B	
29		PEEK 241 EZ	C	C	C	C	B	B	
30	1070	PEEK ADR 1000	B	A	C	C	B	C	
31	1070	PEEK ADR 1000	A	B	A	B	B	B	
32	1070	PEEK ADR 1000	A	A	B	B	C	B	
33	1070	PEEK ADR 1000	B	B	B	B	B	B	
34	1070	PEEK ADR 1000	A	A	A	B	B	B	
35	1070	PEEK ADR 1000 & 2000 SERIES	A	A	A	A	C-D	A	good technical support; software is complex
36	1069	PEEK ADR 2000	B	A	C	C	C	C	

**Product Evaluation**

ID	Product ID	Model	Overall Grade	Accuracy	Reliability	Cost	Training Requirements	Ease of Installation/Maintenance	Other Remarks
37		PEEK TRAFFICOMP III	C	C	B	B	B	C	
38		PEEK TRAFFICOMP III	B	B	D	C	C	B	
39		PEEK TRAFICOMP III/241	B	B	B	B	B	C	
40	1089	TIMEMARK DELTA 3	C	C	C	D	D	C	
41	1089	TIMEMARK DELTA AND LAMDA	A	A	A	A	A	A	battery charge is not convenient
42	1089	TIMEMARK DELTA I	A	A	B	A	A	B-C	
43	1089	TIMEMARK DELTA III	A	B	B		C	B	
44	1089	TIMEMARK DELTA III	B	A	B	B	A	A	
45	1090	TIMEMARK GAMMA COUNTER	A	B	B	B	C	A	

## **Appendix E: User Manual for the Databases in Microsoft Access**

## 1 Basic Concepts of Microsoft Access

Microsoft Access is a *relational database* management system. Relational databases are those where the data is held in a number of cross-referenced files in order to reduce duplication. This makes it easier to find, analyze, maintain and protect the data, and bridge the relationships between related databases.

The image shows a screenshot of the Microsoft Access interface displaying a table. The table has the following columns: Product #, Vendor #, Model Name, Detector Type, Price, Traffic Data, and Vehicle Information. The first row is highlighted. Arrows from the text 'Fields' point to the column headers, and arrows from 'Records' point to the rows.

Product #	Vendor #	Model Name	Detector Type	Price	Traffic Data	Vehicle Information
1000	100	3M™ Traffic Sensing System (Model 701)	2	-	speed, advance detection, counting, ramp metering passage detection	vehicle classification
1001	100	3M™ Traffic Sensing System (Model 702)	2	-	vehicle presence, count, speed, length, roadway occupancy	vehicle classification
1002	101	IR 250 Series Multichannel PIR Vehicle Detector	1	\$737	presence, count, speed	length classification, detects trailer hitch, height and separation
1003	101	DT 270 Series Dual technology PIR and US detectors	1,5	\$681	presence & queue detection, count,	classify by height
1004	101	TT 260 Series Trinla	1,3,5	\$1786	count (all kinds of vehicles), speed	vehicle classification

Figure E-1 Example of Access Datasheet

In Access, a collection of data about an individual item is called “*record*”. Data is stored in the form of files. Each file may contain one or more relational databases, which are represented by *tables*. The view of table is called a “*datasheet*”. Datasheet is the mechanism by which Access commonly stores and shows data. A datasheet typically composes of a set of related records that have some common attributes, or “*fields*”, which is a single item of data common to all records. Each record has some particular values for all the entries of its fields. “*Primary keys*” is one or more fields that uniquely identify each record in the table. Figure E-1 shows an example of a table (database) within which each row represents a record and each column represents a field within the record.

In order to manipulate, process, and represent the data, a tool called “*form*” is used. Form can be utilized to create database, and input, edit or view information in the

database record by record. After the construction of the database, information can be obtained according to particular criteria or usage. This procedure is called “*query*”. A “*report*” can be built to produce the information in the specified format. Report also provides group information or certain results such as totals and average.

## 2 General Instructions

To start Microsoft Access, locate the Microsoft Access icon from the Windows Start menu, and then click the Access icon. The initial screen will be displayed. The Access window follows the standard layout for all Microsoft Windows applications. A Title Bar is displayed at the top of the window with a Control Menu box to the left and Minimize, Restore and Close buttons to the right. Underneath is the Menu bar and below that is the Tool Bar (Figure E-2). The Microsoft Access toolbar contains buttons that provide shortcuts for commands found in the menu bar.

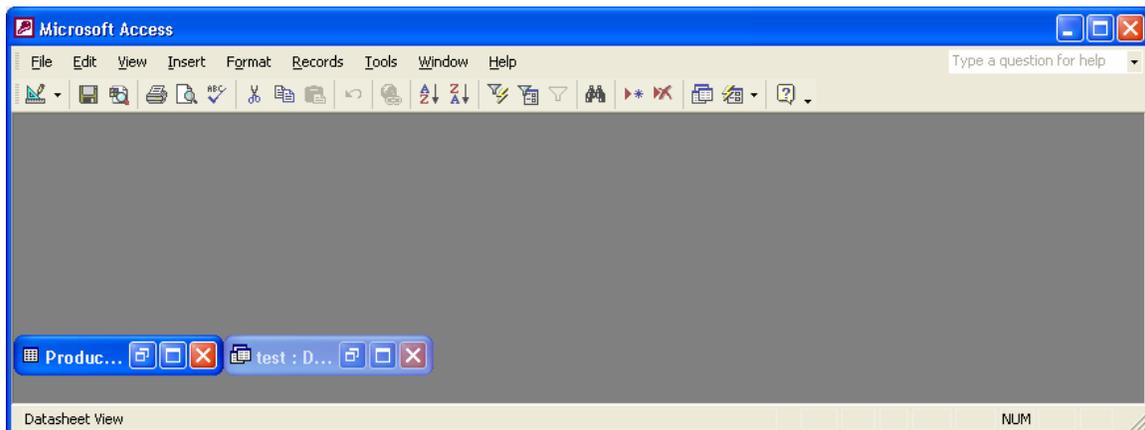


Figure E-2 Access Application Window

Following common Windows application procedures, an existing file can be opened or a new file can be created after Microsoft Access is started. For example, a data

file called “main.mdb” stored under the “Database” directory on CD-R (D: Drive) can be opened from the path “D:\Database\main.mdb”.

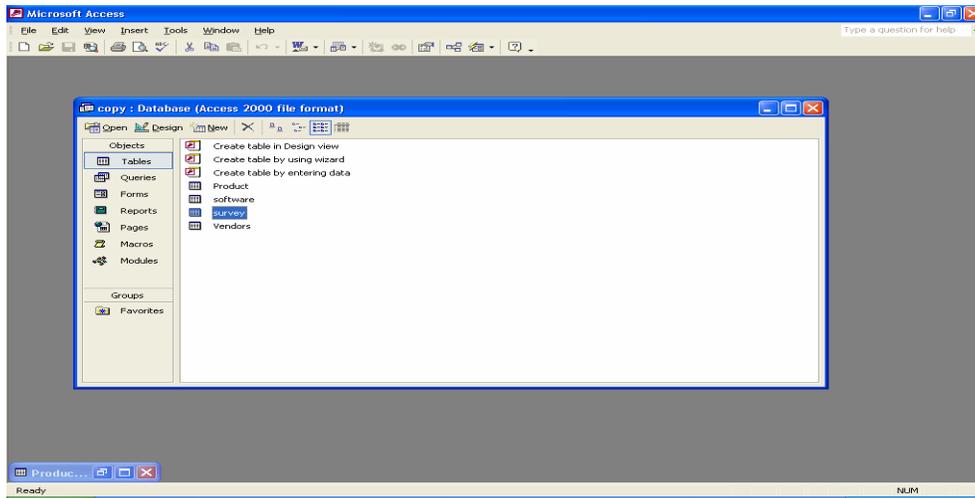


Figure E-3 Access Database Window

After opening a file, the Database Window appears within the Access application window (Figure E-3). Icons on the left hand side provide access to tables, queries, forms, reports, macros and modules. To open a table, click a table icon in the database window (Figure E-4).

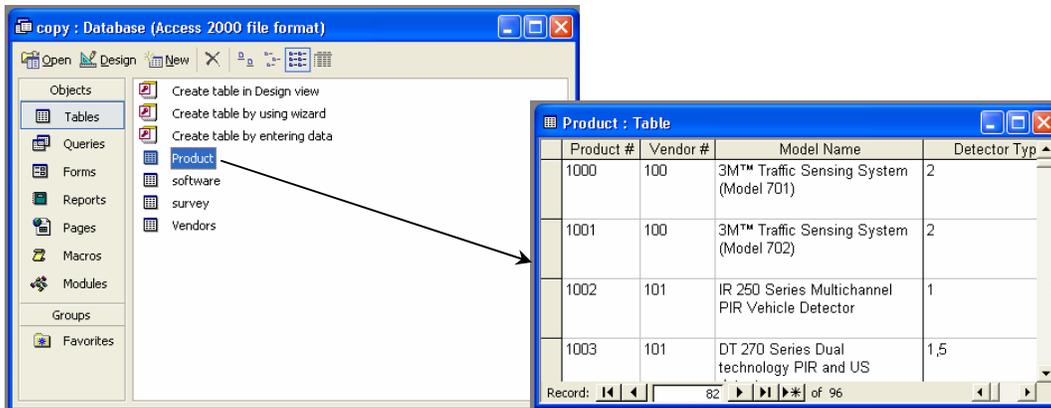


Figure E-4 Opening Data Table

A table opened from the database window appears as a datasheet. Column headings immediately beneath the title bar denote field names. Each row contains a

separate record. The table might have more columns than can be displayed in the window, in which case only the leftmost ones are visible. The shaded boxes to the left of the records are known as record selectors. An arrow symbol in the selector indicates the record currently selected. At the bottom of the window, immediately above the status line, a scroll bar provides navigation buttons and boxes showing the number of the current record and the total number of records in the table.

There are several ways to view or manipulate data. One of the most common ways is *query*, which provides a way to gather selected information from the database with respects to the values of some fields. Data can be selected from tables and can be combined together. One can specify criteria to limit the number of records and perform calculations to produce information not directly held in the underlying tables. A parameter query asks for criteria to be inserted by the user interactively. When the user runs the query, it displays a dialog box or boxes requesting the criteria. Another method to show information is *form*. Forms present the user with a friendlier view of the database. Forms can be used in a variety of ways including adding, deleting and modifying data; displaying data; controlling the way and order in which users access the database; and printing of information. All forms are based on one or more underlying tables whose structure is unaffected by the form design. A third way of showing data is through *reports*. Reports are the traditional form of output. Although they can be previewed on the screen, report is generally more useful for printing hard copy. It provides a convenient way to group, sort, and summarize huge amounts of information and present it in a readable format.

## LIST OF REFERENCES

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- Bahler, S. J., J. M. Kranig, and J. M. Minge, "Field Test of Non-intrusive Traffic Detection Technologies". Transportation Research Record No. 1643, Transportation Research Board, Washington D.C., 1998. pp. 161-170.
- Faghri, A., M. Glaubitz, and J. Parameswaran, "Development of an Integrated Traffic Monitoring System for the State of Delaware", Transportation Research Record No. 1536, Transportation Research Board, Washington D.C., 1998, pp. 40-44.
- Federal Highway Administration (FHWA), "Traffic Monitoring Guide, Third Edition", Publication Number FHWA-PL-95-031, FHWA, Washington, D.C., February 1995.
- Federal Highway Administration (FHWA), Minnesota Department of Transportation, Minnesota Guidestar Program, and SRF Consulting Group, Inc., "Field Test of Monitoring of Urban Vehicle Operations Using Non-intrusive Technologies", Final Report, Publication Number FHWA-PL-97-018, FHWA, Washington, D.C., May 1997.
- Grenard, J., A. Tarko and D. Bullock, "Evaluation of Selected Video Detection Systems at Signalized Intersections", Research Project FHWA/IN/JTRP-2001/22, File Number 8-4-52, Draft Final Report, Joint Transportation Report, Purdue University, West Lafayette, November 2001.
- Hallenback, M. E., "Development of an Integrated Statewide Traffic Monitoring System", Transportation Research Record No. 1050, Transportation Research Board, Washington D.C., 1995. pp. 5-12.
- Hughes Aircraft Corporation, "Select and Obtain Vehicle Detectors", Final Report, Hughes Aircraft Corporation and FHWA, Fullerton, California, 1993.
- Klein, L.A., Vehicle Detector Technologies for Traffic Management Applications, ITS online, [http://www.itsonline.com/detect\\_pt1.html](http://www.itsonline.com/detect_pt1.html), visited on January 8, 2002.
- Krogmeier, J.V., K.C. Sinha, M. P. Fitz, S. Peeta, and S. Y. Nof, "Borman Expressway ATMS Equipment Evaluation", Research Project FHWA/IN/JHRP-96/15, Final Report, Joint Transportation Research Project, Purdue University, West Lafayette, IN, August 1996.

Mimbela, L.E. and Klein, L.A., “Summary of Vehicle Detection and Surveillance Technologies used in Intelligent Transportation Systems”, The Vehicle Detector Clearing House Project, FHWA, New Mexico State University, Las Cruces, New Mexico, November 2000. <http://www.nmsu.edu/~traffic/>, visited on 2/5/2002.