Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/TX-06/0-5002-1		

4. Title and Subtitle EVALUATION OF COST-EFFECTIVE TECHNOLOGIES FOR ADVANCE DETECTION	5. Report Date September 2005
	6. Performing Organization Code
7. Author(s) Srinivasa Sunkari, Ricky Parker, Hassan Charara, Trishul Palekar, and Dan Middleton	8. Performing Organization Report No. Report 0-5002-1
9. Performing Organization Name and Address Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. Project 0-5002
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, Texas 78763-5080	13. Type of Report and Period Covered Technical Report: September 2004-August 2005
	14. Sponsoring Agency Code

15. Supplementary Notes

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.

Project Title: Cost Effective Technologies for Advance Detection at Signalized Intersections

URL: http://tti.tamu.edu/documents/0-5002-1.pdf

16. Abstract

This project developed and evaluated various advance detection systems. The objective was to use off-the-shelf technology to develop these detection systems and evaluate their performance as well as their cost-effectiveness with respect to traditional advance inductive loop using lead-in wire. These systems were deployed on the northbound approach of the intersection of SH 6 and FM 185. The baseline system was the AWEGS detectors on this approach.

This project developed the installation guidelines for various detection systems. TTI researchers found that inductive loops with contact closure radio were very accurate in counts, classification, and speeds. Traficon video detection system was very accurate in counts and measuring vehicle lengths during daytime and measuring speeds during both daytime and nighttime. The counts and classification can improve by providing some ambient light near the detector station. SAS-1 acoustic detector can be very cost-effective as it contains detection as well as a communication system. However, the performance needs to be checked by requesting the vendor to provide individual vehicle speeds and classification which the unit is already measuring.

TTI researchers recommend that the user not only look at installation cost, but also at life cycle cost of the system. Some systems such as inductive loops can have a higher life cycle cost.

17. Key Words	18. Distribution Statement
Advance Detection, Inductive Loops, Road Runners, Video Detection, Contact Closure Radio, Serial Radio, Solar Power	No restrictions. This document is available to the public through NTIS: National Technical Information Service Springfield, Virginia 22161 http://www.ntis.gov

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	54	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

EVALUATION OF COST-EFFECTIVE TECHNOLOGIES FOR ADVANCE DETECTION

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Project 0-5002
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September 2005

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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

This report is not intended for construction, bidding, or permit purposes. The engineer in charge of the project was Srinivasa Sunkari, P.E. #87591. The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

ACKNOWLEDGMENTS

This research was conducted during a one-year study under a cooperative research program with TxDOT and FHWA. Davis Powell of the TxDOT Wichita Falls District was the project director. Larry Colclasure of the TxDOT Waco District was the project coordinator. Other TxDOT members of the project monitoring committee included Glenn Allbritton, David Mitchell, Frank Phillips, Larry Bettis, Mike McAnally, Roy Wright, and Wade Odell. Bob Brydia and Edward Brackin of Texas Transportation Institute also contributed to the project.

TTI researchers specifically thank Tim Schulte and his signal technicians from the Waco District for assisting us in the installation of the equipment for this project. This project would not have been implemented without their dedicated assistance. TTI researchers also thank the vendors for the Traficon unit, SAS-1 unit, and Wavetronix unit for lending us the equipment at no cost to test and evaluate their applicability in this project.

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

INTRODUCTION

Numerous projects sponsored by the Texas Department of Transportation (TxDOT) have developed strategies to improve signal operations and safety at isolated signalized intersections. A critical component of these strategies is advance detection, which is typically located at a distance of between 850 feet to 1200 feet from the intersection. Advance intersection control strategies so far have been installing inductive loops with wire-line communication for advance detection. However, the cost of installation of these advance detectors is a significant component of the cost of installation of the advance strategies. This project investigated off-the-shelf technologies to provide advance detection in a cost-effective manner. These technologies included both detection and wireless technology.

Background

The strategies developed to improve signal operations at isolated signalized intersections used different methodologies to address dilemma zone problems existing on the high-speed approaches to signalized intersections. These strategies include Detection Control System (DC-S) (*1*), Platoon Identification and Accommodation (PIA) System (*2*), and Advance Warning of End of Green System (AWEGS) (*3*). These projects have shown significant potential to TxDOT to improve safety while maintaining efficient signal operations. TxDOT has also started implementing some of these strategies at various locations. The following text describes the above-mentioned strategies.

DC-S is based in a computer, and housed in the signal controller cabinet (*1*). This computer uses a detector speed trap, located 700 to 1000 feet upstream of the intersection, to monitor approaching traffic and predict the time *each* driver is within a "dilemma zone" or the "indecision zone" on the intersection approach. At the same time that the new system is monitoring approaching vehicles, it is also searching for a time in the near future when the total number of drivers in their respective indecision zones is at a minimum. This future time is defined as the "best time to end the phase." Other factors that are also considered when deciding the best time to end the phase include: (1) whether the vehicle is a large truck and (2) the delay to drivers waiting on the minor road. DC-S depends on the upstream detectors to get vehicle speed and classification. This information is crucial for the functionality of DC-S and is obtained and used in real-time.

The most unique feature of DC-S is its ability to "dynamically" identify the indecision zone for *each* vehicle, in *real-time*, and *prior* to when the information is needed by the controller. This feature yields safe and efficient signal operation for the full range of intersection traffic volumes. DC-S was installed at two intersections in Texas and its operation studied extensively.

The second strategy, PIA, provides progression to a platoon of vehicles arriving at an intersection (*2*). Providing this progression requires the ability to detect each approaching platoon and ensure that the signal is green when the platoon arrives at the stop bar. This requirement warrants the installation of an advance detector trap. Furthermore, if the signal is serving a conflicting phase at the arrival time of the platoon, such a phase must be quickly, but safely, terminated to provide a green signal. Researchers decided to use signal preemption to achieve this objective.

An additional objective was to ensure that the system is able to operate under a wide variety of traffic conditions, without adversely affecting vehicles at conflicting phases. Achieving this objective required the ability to monitor phase and detector status in real-time and take appropriate action in real-time. In the system architecture, an external personal computer (PC) provides computational needs for executing these functions. Similar to DC-S, PIA is also housed in a computer located in the signal controller cabinet at the intersection. PIA was installed at two intersections in Texas and its performance was evaluated.

The third strategy, AWEGS, is different from DC-S and PIA (*3*). Unlike DC-S and PIA, strategies which actively control the operation of an isolated signal controller, AWEGS has minimal influence on a signal controller. The objective of AWEGS is to predict the operation of an isolated traffic signal controller and provide a warning about the end of green to motorists on the intersection approach. AWEGS provides this warning by flashing the beacons on a W3-4 sign a few seconds before the onset of yellow. AWEGS is unique in operation compared to other such Advance Warning Flasher (AWF) systems providing advance warning of the end of green. AWEGS maintains and enhances the existing dilemma zone protection while other AWF systems eliminate the existing dilemma zone protection.

AWEGS monitors the approaching traffic using a pair of advance detectors at about 850 to 1200 feet from the intersection. AWEGS also monitors the activity on all the remaining intersection detectors including the dilemma zone detectors and the signal controller status.

Based on actuations on the advance detectors, intersection detectors, and the signal controller status, AWEGS predicts the end of green and provides advance warning by flashing the beacons. AWEGS does apply a phase hold in very rare cases to ensure safe operations. However, the number of phase holds and the duration of phase holds are very small. Similar to the other strategies, AWEGS operates in a computer housed in a signal controller cabinet. AWEGS was installed at two locations in Texas (Figure 1) and continues to operate at those locations satisfactorily.

Figure 1. AWEGS Installation in Waco.

One of the critical components of these three advance strategies is the requirement of advance detection. For a high-speed approach, advance detection is usually required at a distance between 850 feet to 1200 feet from the intersection. There are similarities in the detection required by these various strategies. Typically, these strategies need to know the speed and classification of the vehicles actuating the advance detectors in real-time. These requirements drive the location, configuration, and settings of advance detectors.

The cost of installing advance detectors for a recent project was approximately $15,000 for a two-lane highway and $20,000 for a four-lane highway. Table 1 illustrates the typical cost of installation of advance inductive loops on an approach. As can be seen in Table 1, the cost of the transmission of the detection is significantly higher than the cost of detectors alone.

Table 1. Typical Cost of Installing Inductive Loops.

	Detector Cost	Transmission Cost	Total Cost
One-Lane Approach	$2,400	$11,480	$13,880
Two-Lane Approach	$4,800	$14,880	$19,680

Installing advance detection is often the predominant cost of implementing these projects. Reducing the cost of installing advance detection will allow TxDOT to increase the deployment of such strategies and will improve the benefit-to-cost ratios of such products. The objective of this research was to identify off-the-shelf products to provide vehicle information for traffic systems requiring advance detection in a cost-effective manner.

This project evaluated various detection and communication technologies to develop a more cost-effective means of providing advance detection. Past studies have used hard-wired communication, which required trenching and boring. Researchers will focus on a cheaper means of transmitting detections using wireless technology while maintaining the integrity of advance detection. Some of the issues to be addressed in this research include the real-time detection of vehicles, location of processing of detection, and power to the detectors and any field processors.

AVAILABLE TECHNOLOGIES

The Texas Transportation Institute (TTI) has been involved in detector research for more than 10 years, with early research addressing inductive loops and more recent research emphasizing non-intrusive detectors. This recent research investigated the accuracy, reliability, cost, and user-friendliness of various non-intrusive detectors in seeking viable replacements for inductive loops *(4, 5, 6)*. TTI tested several video image detection products such as the Traficon and Autoscope Solo Pro, acoustic detectors such as the SAS-1 by SmarTek, and radar detectors such as the SmartSensor by Wavetronics, among others. TTI initially field-tested these devices at the testbed in College Station. Most evaluations of non-intrusive detectors compare with inductive loops because loops are a mature technology and, when properly installed, serve as an adequate benchmark for test purposes.

Detection Systems

Inductive Loops – Reno

The inductive loop detector is composed of one or more turns of insulated loop wire installed in a shallow slot that is sawed in the pavement, a lead-in cable, and a detector electronic unit. Electrical induction in a traffic signal system is comprised of a detector unit that passes a current through stranded loop wire, thereby creating an electromagnetic field around the wire. Moving a conductive metal object, such as a vehicle, through this electromagnetic field disturbs the field, producing a change in energy level. As the vehicle enters the electromagnetic field of the loop, it causes a decrease in the inductance of the loop and an increase in the oscillation frequency. The inductive loop detector, introduced in the 1960s, continues today as the most commonly used form of detector, even though its weaknesses are widely recognized.

Acoustic Detection – SAS-1 by SmarTek

Passive acoustic devices incorporate an array of microphones aimed at the traffic stream. Vehicle detection occurs when the microphones detect the sound of the vehicle passing through the detection area. The optimum orientation for passive acoustic devices is in sidefire with microphones aimed at the tire track because the primary source of sounds for vehicle detection is the noise generated between the tire and the road surface.

The SAS-1 is a passive acoustic detector that monitors vehicular noise as vehicles pass the detection area. The detector can monitor as many as five lanes when oriented in a sidefire position. Precise alignment is not critical because the sensor can cover a wide area. Heights recommended by the vendor range from 25 feet to 40 feet, and the recommended offset range is 10 feet to 20 feet. Higher mounting positions can reduce the effects of occlusion in multiple lane applications.

Previous research by TTI had shown that the SAS-1 unit was undercounting during both peak as well as off-peak conditions. The unit was also producing error in operations during rain. Since then the manufacturer has made numerous improvements and this project will evaluate the modified and improved SAS-1 unit.

Magnetic Detection – Road Runners

A magnetometer consists of an intrusive sensor about the size and shape of a small can, a lead-in cable, and an amplifier. The cylinder portion of the magnetometer contains sensor coils that operate in a manner similar to inductive loops. These coils are installed in a small circular hole in the center of each lane and communicate with the roadside by wires or radio link. Magnetometers function by detecting increased density of vertical flux lines of the earth's magnetic field caused by the passage of a mass of ferrous metals, such as in a vehicle. They operate in either presence or pulse mode and are embedded in the pavement. Magnetometers are more durable than loop sensors, require less cutting of the pavement, are easier to install, and can be installed underneath bridge decks without damage to the deck. The disadvantages of magnetometers are similar to those of inductive loop detector systems, in that they sometimes doublecount trucks, and are less likely to detect motorcycles due to the vehicle's small detection zone *(7)*.

Radar Detection – Wavetronix

A radar detection system consists of a radar unit mounted on a roadside pole or traffic signal mast arm. The SmartSensor Advanced™ from Wavetronix, which TTI examined in this research project, can detect either approaching or receding vehicle speed and presence but not length. The sensor ignores vehicles moving in the direction opposite the one being detected. The radar is specifically designed to provide accurate vehicle speed and presence detection for intersection control applications using patented Digital Wave Radar™ technology. The

SmartSensor radar reports vehicle speed in up to eight user-definable zones out to a maximum distance of 500 feet from the sensor. When used for multilane speed detection, the detector will cluster together individual vehicles at the same range in adjacent lanes and report them as one speed in that particular zone.

Video Imaging Detection – Traficon

A video imaging detection system consists of one or more cameras providing a clear view of the detection area, a microprocessor-based system to process the video image, and a module to interpret the processed images *(8)*. Advanced video image detection systems can collect, analyze, and record traditional traffic data; detect and verify incidents; classify vehicle types by length; and monitor presence at intersections.

Tripwire systems, which were the first generation of video image processing systems, are the least demanding in terms of computer power and speed, and are the most commonly used type of video detection today. These systems operate by allowing the user to define a limited number of detection zones in the video camera field of view. When a vehicle enters a detection zone, it is identified in a manner analogous to inductive loops. In fact, tripwire systems are the functional equivalent of inductive loop systems and are intended to replace inductive loops in areas where a large number of loops are employed. A disadvantage of tripwire systems is that the systems provide data only in the form of counts and speeds which is very limited (other variables are calculated from these two variables) *(9)*.

TTI has evaluated the available video detection systems during numerous prior projects. Due to our prior experience, we recommended against the evaluation of Iteris system for advance detection in this project. We were in favor of testing either an Autoscope system or a Traficon system. After further evaluation of the systems, we found that Autoscope and its protocol would be more expensive than the Traficon system. Hence, we decided to evaluate the Traficon system.

Transmission Systems

Transmission technology using lead-in wire gets expensive as illustrated in Table 1. Wireless communication is the alternative technology to minimize the cost of advance detection systems. There are many wireless solutions in existence today. From high-bandwidth equipment using proprietary vendor protocols to lower bandwidth commercial off-the-shelf technology implementing open standards, solutions can be found for any need. The primary considerations in choosing an appropriate off-the-shelf solution should balance items such as cost, capability, reliability, ease of configuration, maintenance, and security.

In this project, the amount of data (vehicle detections) being sent from the upstream locations is not significant. While high-bandwidth solutions are not necessary, some vendor-specific implementations have unique advantages in that they directly read and send the contact closure from the loops that result from vehicle actuations. Similarly some vendors also have equipment that can send serial messages which can consist of speeds and classification information. These messages can be generated by some detectors like Traficon. Using off-the-shelf equipment has some definite advantages. The primary advantage is that the solution is off the shelf and exists. It does not have to be created. The same equipment is also likely to be available in a field-hardened version for being deployed in the field. One disadvantage of such a system is that the system may lock us with a specific vendor. Such systems may have a proprietary radio system and may have problems with interoperability between vendors. However, TTI researched and selected the wireless equipment that was widely being used by transportation agencies including TxDOT, and which also met the criteria for being economical.

In addition to the pros and cons listed above, the project evaluates the ease of installation, per unit cost, performance, bandwidth, transmission latency, configuration capabilities, and security. These items will not be fully known until field installations are in place and data are collected.

Contact Closure Radio

TTI researchers selected the ENCOM radios Model 2513-8 input contact closure (CC) pole-mount transmitter and Model 2028-8 output contact closure shelf mount receiver as the contact closure radio system. This contact closure system eliminates the "Home Run" cable for the advance inductive loops configured in trap mode. The Model 2513 transmitter has the capability to transmit individual actuations from any detection system like inductive loops as well as the Road Runner detector. Model 2028 functions as the receiver at the cabinet for the contact closure messages sent by the transmitter. TxDOT uses these transmitters and receivers at other applications, and they have been very reliable.

Figure 2 and Figure 3 illustrate the contact closure radio equipment.

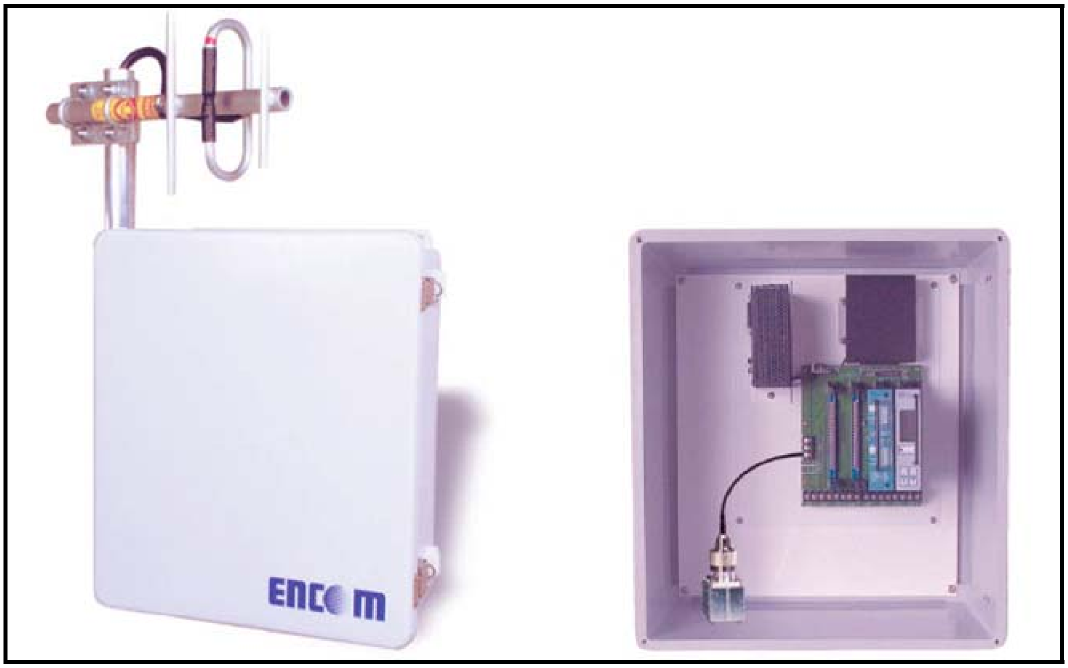

Figure 2. ENCOM Contact Closure Radio – Transmitter.

Figure 3. ENCOM Contact Closure Radio – Receiver.

Serial Radio

TTI researchers selected the ENCOM Model 5200 serial radio modem to send per vehicle detection messages from the detector station to the cabinet at the intersection. These radio units can transmit the serial messages provided by the Traficon video imaging system installed upstream of the intersection back to the AWEGS cabinet at the intersection where the industrial PC that collects the detection data resides. The ENCOM 5200 serial radio modem can be configured either as a transmitter or receiver using the Windows-based Control PAK software provided by ENCOM. Figure 4 illustrates the serial radio used in this project.

Figure 4. ENCOM Serial Radio.

IMPLEMENTATION

Researchers selected the intersection of SH 6 and FM 185 in Waco as the testbed for evaluating cost-effective detection and transmission technology. The testbed was installed on the northbound approach on SH 6. This site was selected for the following reasons.

- AWEGS is currently operational at this intersection. Hence, the AWEGS detectors can serve as the baseline detectors for evaluating other detection systems.
- Since AWEGS is functioning at this intersection, the signal cabinet has the necessary hardware to log the performance of AWEGS detectors as well as other detection systems.
- A telephone line is also available inside the cabinet at this location. This line was installed for the maintenance of AWEGS. The same telephone line was used to download data from the detection systems remotely.
- The location in Waco is about two hours away for the researchers in College Station. This close proximity facilitated TTI researchers to make day trips to the test site. This was particularly useful to troubleshoot some problems with both detectors as well as wireless units.

TTI researchers evaluated the detectors and wireless systems available in the industry and selected various systems for deployment. The detector systems to be deployed and evaluated included inductive loops with contact closure wireless system, Traficon video detector and Wavetronix radar detector with serial radio systems, and Road Runner detectors and SAS-1 acoustic detector with built-in wireless systems. The layout of the testbed in Waco is illustrated in Figure 5. The layout in Waco is described next.

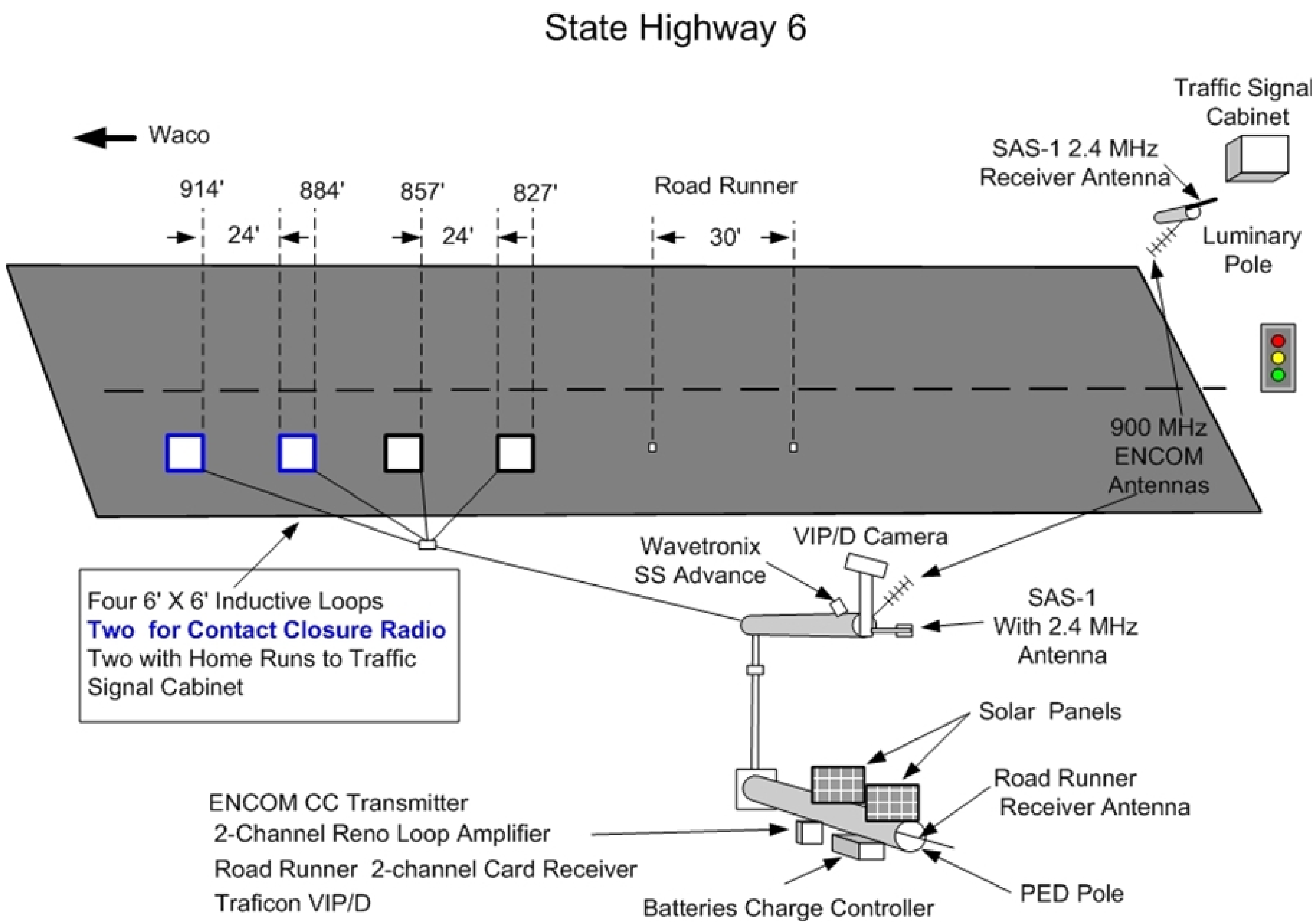

Figure 5. Layout of the Waco Testbed.

As mentioned earlier, AWEGS detectors at the testbed were used as the baseline system. These detectors are located at a distance of 827 feet and 857 feet from the stop bar. They are located 30 feet apart from trailing edge to trailing edge giving a clear spacing of 24 feet between the detectors. The spacing identifies trucks from non-trucks. The identification process was very simple and straight forward and is illustrated in Figure 6. The AWEGS algorithm monitors the presence time of the AWEGS detectors. If the algorithm sees a time interval between AWEGS detector 1 going off and AWEGS detector 2 coming on, the vehicle is classified as a car. On the other hand, if AWEGS detector 2 comes on before AWEGS detector 1 goes off, the vehicle is classified as a truck. The AWEGS algorithm also estimates the average speed of the vehicle from these two detectors. The design of the detector systems to be installed was based on the configuration of the AWEGS detectors.

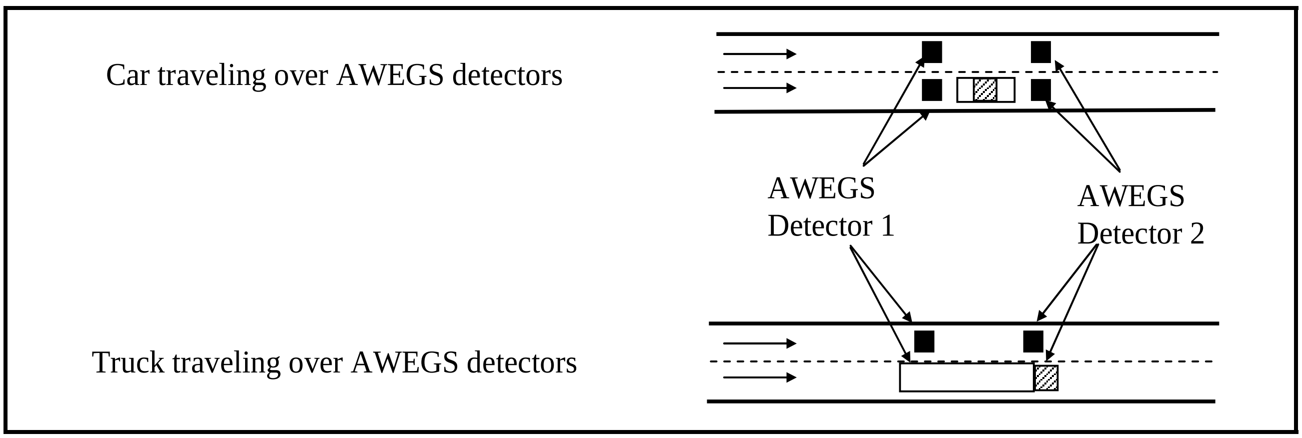

Figure 6. Vehicle Classification Methodology in AWEGS.

Installation of Detectors

Inductive Loops

A spare inductive loop was existing upstream of the AWEGS detectors at a distance of 884 feet from the intersection. TxDOT installed an additional inductive loop at a distance of 914 feet from the stop bar to obtain a spacing of 30 feet (trailing edge to trailing edge) between these two detectors. The objective was to transmit the activity on these detectors using a contact closure wireless system to the signal controller cabinet. The inductive loops installed for this project were 6 feet by 6 feet in size with four turns of International Municipal Signal Association

(IMSA) Specification 51-5 wire. The 12-gauge single conductor wire for the loop proper had a PVC/nylon tube jacket. Installers spliced the loop wires at the roadside pull box to IMSA Specification 50-2 two conductor shielded 12-gauge wire, which connects the pull box with the cabinet 70 feet away on a solar power pole. In the cabinet by the advance detectors, the loops were connected to a two channel rack mounted C/170 Reno inductive loop amplifier. The amplifier was programmed with “Option 4” (fast response time) enabled. Researchers initially set the amplifier sensitivity to “5,” but the presence times did not match the other inductive loops that were hard wired to the traffic cabinet. After reducing the loop amplifier sensitivity to “3,” the presence times closely matched the hard-wired loops, and it still held the call on high-bed trailers. Installers set the Reno Model S amplifier in the cabinet by the traffic signal controller sensitivity in the cabinet to “4,” which was the only setting where it would work properly. The long lead-ins (over 1000 feet) had so much resistance and inductance that any other setting either held the call or did not detect high-bed truck trailers.

Road Runner Detectors

TTI researchers developed the design of the installation of Road Runner detectors in consultation with the technical experts at Midian Electronics. The design involved installing the Road Runner detector with a saw-cut antenna. TTI researchers and a Midian representative tested the Road Runner detectors onsite with the recommended saw-cut antennas at approximately 1000 feet from the intersection before installing them in the pavement. The Road Runner detectors did not have the range the manufacturer claimed possible using saw-cut antennas. After experimentation, technicians concluded that the range was approximately 600 feet. The manufacturer’s representative then recommended using an external roadside pole-mounted antenna. The manufacturer sent one antenna for a range test which seemed to work at 1200 feet before installing in the pavement. After receiving and installing the second antenna and installing the Road Runner detectors, one of the Road Runner detectors still did not have the range to consistently reach the TRC-1000 shelf-mounted receiver in the traffic signal cabinet. The manufacturer subsequently affirmed that once installed the transmitter loses some of the transmission signal into the ground, and soil type and moisture content can cause increased attenuation of the signal. The next step to solving the range problem was to use a rack-mounted TRC-2000 Road Runner receiver in the roadside contact closure transmitter radio about 30 feet from the magnetometers with its antenna mounted on the pedestrian pole. The ENCOM contact closure transmitter radio relayed Road Runner detections to the ENCOM contact closure receiver radio in the traffic control cabinet.

SAS-1 Detector

The manufacturer of the SAS-1, SmartTek Systems, loaned the 2.4 GHz wireless SAS-1 mid-block detection system used for this project. When TTI researchers initially tested the range of the wireless SAS-1 in Waco, it did not have the range to reach the traffic signal cabinet. Researchers retested the unit in College Station for range and found that the range was greater than 1500 feet with the supplied antennas. Further research indicated that the Waco test site apparently had too much radio electromagnetic interference from transmission towers in the immediate area. TTI researchers then acquired a 2.4 GHz 18 Db Maxrad directional antenna to replace the 8 Db omni-directional Maxrad antenna. The subsequent test at the Waco site found that the new antenna had sufficient range to overcome the local interference. The Waco District's signal crew installed the SAS-1 detector 25 feet high on the luminaire pole (see Figure 7) and installed the receiver on the luminaire pole next to the traffic signal cabinet. The SAS-1 receiver connected to the SAS cabinet termination via a shielded twisted three-pair conductor, which in turn connects to a computer using a DB-9 serial port for configuration. TTI researchers configured the SAS-1 detection zones using an SAS monitor and setup software. The sensor was configured to push data every 80 milliseconds.

Wavetronix Detector

Wavetronix representatives provided, mounted, and configured the SmartSensor *Advance Model 1000* radar 20 feet high on the 35-foot luminaire pole (see Figure 7) facing the intersection with mounting assistance from TxDOT signal shop employees using a TxDOT bucket truck. The factory representatives created eight detection zones each 50 feet apart. The first zone is 100 feet from the sensor and the last zone is 500 feet away. Presence and speed are reported in each of the eight zones so data analysts can calculate acceleration and deceleration from the data. Wavetronix representatives set up and configured the SmartSensor radar using a laptop computer running Wavetronix auto-configuration software. Researchers transmitted real-time serial data from the SmartSensor radar to the traffic signal cabinet using the ENCOM 5200 serial data radios.

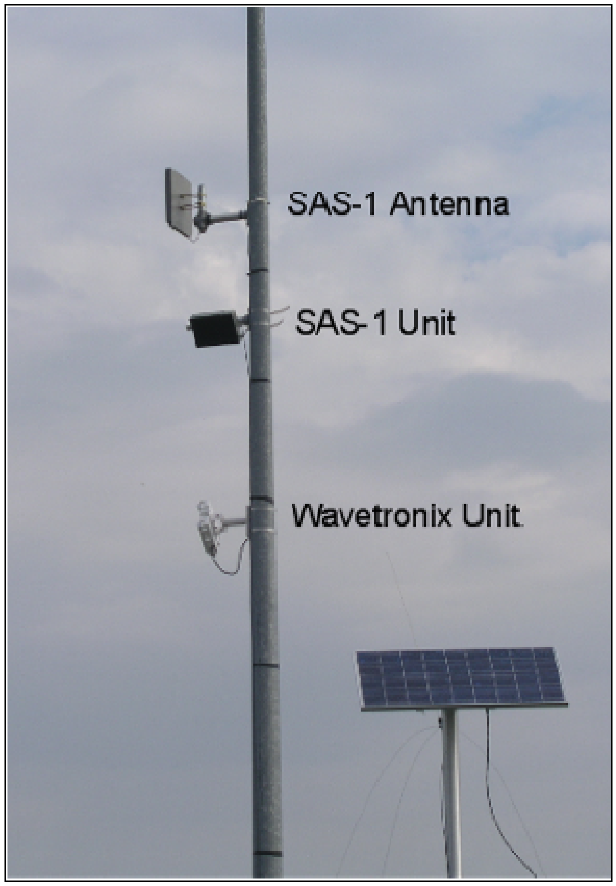

Figure 7. SAS-1 and Wavetronix Detectors.

Traficon Video Detector

The Traficon rack-mounted VIP/D unit used for this project can measure the traffic speeds for up to eight lanes, vehicle length, and the zone occupancy of the detection area. It automatically distinguishes five types of traffic flow (levels of service) based on flow speed and zone occupancy. A DB9 serial port in the front of the detector allows for monitoring of all alarms and flow data. The unit can store data internally or it can make it available at the serial port as ASCII text in real-time. TTI researchers chose the Traficon because it is the only video detector that could provide per vehicle data in real-time. Other video detectors could possibly provide the per vehicle data but not without additional hardware or software. Another reason for choosing the Traficon was its good performance on another research project. The local Traficon vendor, Control Technologies, provided, installed, and set up the Traficon system on the 35-foot steel luminaire pole with an 8-foot luminaire arm as seen in Figure 8 with assistance from the Waco TxDOT signal shop.

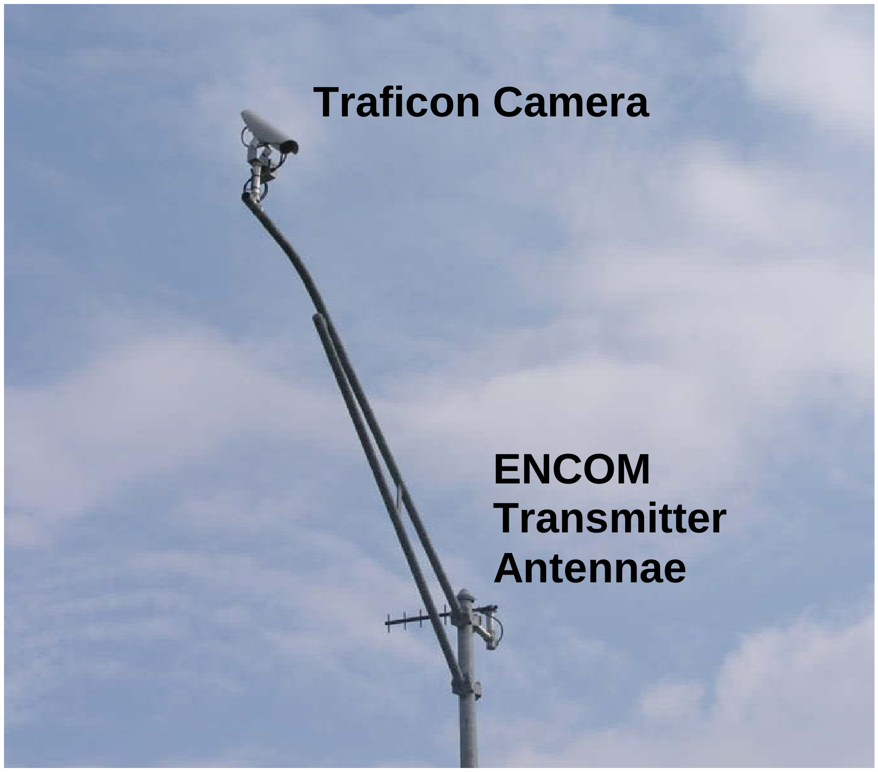

Figure 8. Traficon Camera Installation.

Solar Power Installation

TTI researchers designed a solar power supply to provide electrical power for wireless communications and five detectors tested during this project. Figure 9 illustrates the design of the solar power system. Researchers inspected the proposed location and selected a location that was not covered by shade from trees and signs. Researchers then calculated total power consumption for all five detectors and wireless communication radio from manufacturer specifications (1.34 continuous amps). Once the power requirements were known, the operating voltage to be used by each device was determined. It was found that 24 volts was an appropriate voltage to be used by each device. Further, a 24 volt system had less power loss due to resistance in the wiring than a 12 volt system. This resulted in a load of 32.16 amp-hours per day (1.34 * 24 hours) which is equivalent to 771.8 watt-hours per day (32.16 * 24 volts).

TTI researchers selected solar panels and batteries to power the detectors and communication equipment. Researchers configured two 120 watt photovoltaic solar panels to provide 1200 watt-hours per day (2 * 120 watts * 5 hours of sunshine). Assuming a power loss of 25 percent, the solar panels provided 900 watt-hours per day which exceeded the demand of 771.8 watt-hours per day. Researchers also configured four batteries rated at 86 amp-hours at 12 volts to provide power during cloudy days. These batteries would be charged by the solar panels. This resulted in 172 amp-hours (86 amp-hour * 4 batteries * 12 volts/24 volts). Assuming a discharge of 30 percent, power available is 120 amp-hours. The design of the batteries called for powering the equipment for at least three days without sunlight. With a demand of 32.16 amp-hours per day, the batteries very easily provide the power required.

			Units
Detector load			
	Reno 2-channel amplifier	0.10	Amps
	Road Runner receiver	0.06	Amps
	Traficon VIP/D amplifier	0.16	Amps
	Traficon camera	0.50	Amps
	SmartSensor	0.32	Amps
	SAS-1	0.10	Amps
	Total	1.24	Amps
Communication load			
	ENCOM CC radio or	0.10	Amps
	ENCOM serial radio	0.10	Amps
	Total	0.10	Amps
Total load	in Amps	1.34	Amps
Total load	in Amp-Hour/day (Amp * 24 hours)	**32.16**	Amp-Hour/day
Total load	in Watt-Hour/day (Amp-Hour/day * 24 volts)	**771.84**	Watt-Hour/day
Solar panel			
	Panel Wattage	120	Watts
	Number of panels	2	
	Hours of sunshine/day (average)	5	
	Generated solar power (120*2*5)	1200	Watt-Hour/day
	Loss	25%	
	Available solar power	**900**	Watt-Hour/day
Batteries			
	Rating of batteries (at 12 volts)	86	Amp-Hour
	Calculated rating at 24 volts (86*12/24)	43	Amp-Hour
	Number of batteries selected	4	
	Total Amp-Hours (43 * 4 batteries)	172	Amp-Hour
	Maximum allowable discharge	70%	
	Available Amp-Hours	120.4	Amp-Hour
	Amp-hours used after 3 days of no sunlight (32.16 * 3 days)	96.48	Amp-Hour
	Amp-hours to spare	**23.92**	Amp-Hour

Figure 9. Design of the Solar Power Unit.

TTI researchers assisted the TxDOT signal shop crew in preassembling the solar power equipment on the 4-inch pedestrian pole. TTI researchers installed the ENCOM contact closure radio enclosure on the pole, and installed the power inverter, fuse block, power distribution panel, and solar battery charge controller in the battery box while the equipment was still in the signal shop. TxDOT technicians then took the preassembled pole to the site, set the pole, and fixed in place the solar panels. TTI researchers then made a wiring harness and wired the four batteries to obtain 24 volts and connected them to the charge controller. Researchers also wired the solar panels in series and connected them to the charge controller as illustrated in Figure 10.

Late in the project the Samlex America model PST-60S-24A full wave power inverter that converted the 24 volt DC to 120 volts AC malfunctioned. The inverter was providing power to the Traficon camera and the ENCOM transmitter. Researchers quickly purchased a replacement and installed it. Researchers returned the original defective inverter under warrantee to the manufacturer's repair facility and received a replacement in two weeks.

Data Collection System

TTI researchers developed a data collection software system to collect data in real--time from the various detection systems installed in Waco. The data collection system resides and runs on an industrial PC that is housed in the cabinet at the intersection of SH 6 and FM 185 in Waco. The data collection system collected the real-time detection data from each detection system into separate daily log files. The daily log files were downloaded using the PCAnywhere software utility via the telephone line installed in the AWEGS cabinet. The data collection system consists of several modules, one for each detection system. The data collection modules include the Contact Closure Data Collection Module (CCDCM), the Traficon Data Collection Module (TDCM), the SAS-1 Data Collection Module (SDCM), and the Wavetronix Data Collection Module (WDCM). The reason for developing a separate data collection module for each detection system is that each one of them has a proprietary protocol to deliver its detection data. The following sections describe the data collection modules in detail.

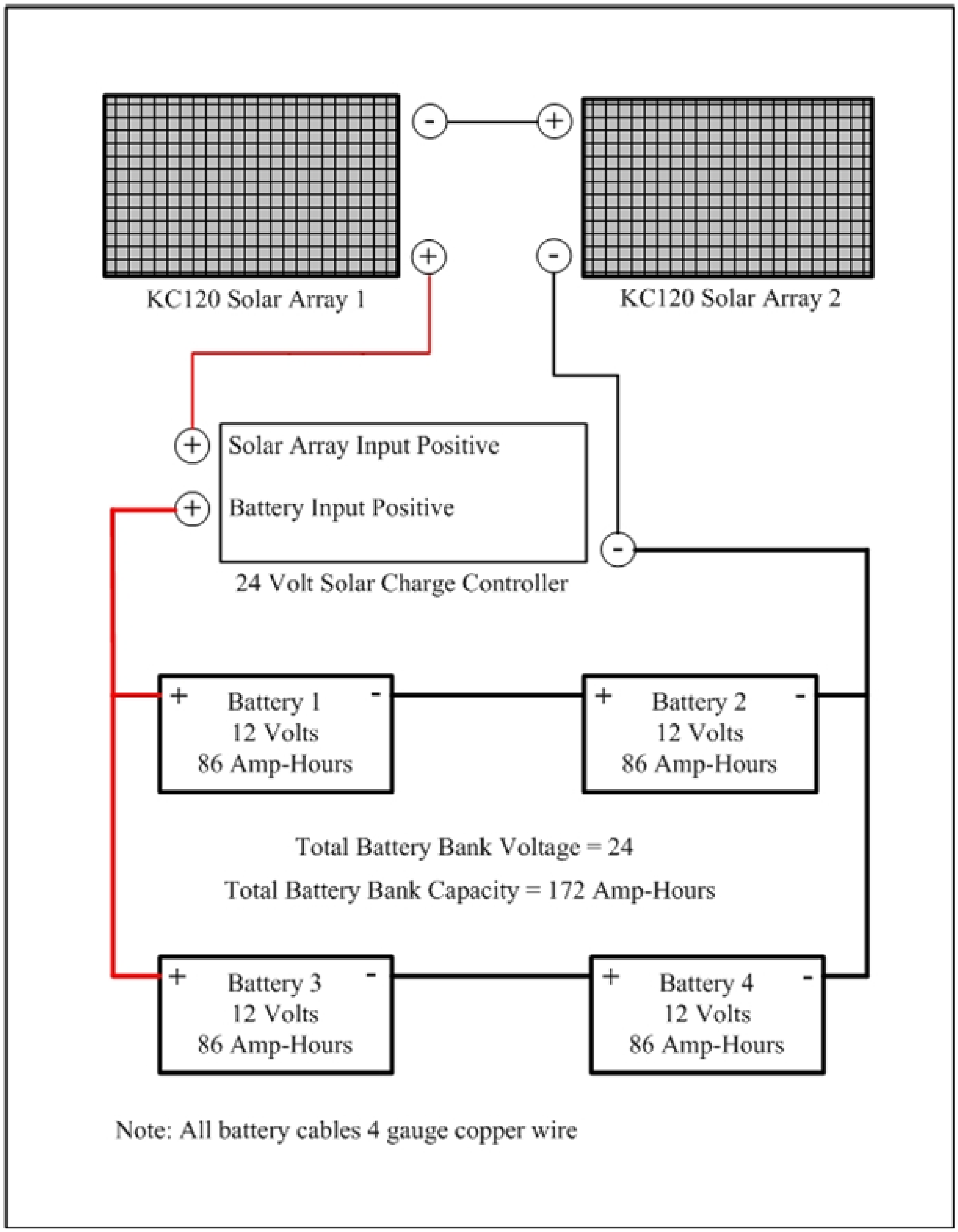

Figure 10. Array and Battery Drawing.

Contact Closure Data Collection Module

The CCDCM collected detector actuations from the inductive loops and Road Runner magnetometers (RRMs) whose actuations were transmitted to the AWEGS cabinet using the CC ENCOM radio Model 2513. The CCDCM checked the status of each one of the loops and the RRMs in real-time every 15 to 20 milliseconds. Any time a change in status was detected from either On to Off or vice versa, the CCDCM logged the change into the daily log file together with the loop or RRM identification (ID) along with a time-stamp using the industrial PC's local system time. Other information that was logged into the daily file together with the change in status included the presence time of a vehicle on a loop/RRM each time the status changed from On to Off, the length of the period of time a loop was not occupied any time the status changed from Off to On, a running total for the number of actuations for each loop/RRM during the day, classification of detected vehicles into truck or non-truck whenever the second loop/RRM in each trap was actuated, and the total number of cars and trucks detected by each trap during the day.

Traficon Data Collection Module

The Traficon video imaging system provided an ASCII message over a serial port each time it detected a vehicle in the zone of detection. The format of the per vehicle message sent by the Traficon system is described in Figure 11.

Event Number	Lane	Time	Frame	Speed	Length	Gaptime	Confidence	Detection Mode
e.g. 6280	2	13:55:39	32	73	49	4	9	D

Event Number	Incrementing counter starting from 1 to 65535
Lane	Lane number of the detected vehicle (1-8)
Time	hh:mm:ss starting from 00:00:00 to 23:59:59
Frame	Subdivision of one second in 50 parts from 0 to 49
Speed	The speed of the detected vehicle in KM/hr or miles/H
Length	The length of the detected vehicle in dm or feet
GapTime	Time between two vehicles from the same lane in 0.1 sec
Confidence	A value between 0 and 10 in function of the quality of the detection
Detection mode	Detection mode of the detector 'D'=day, 'N'=night, 'T'=night, 'T'=tunnel, 'A'=automatic

Figure 11. Format of the Fields in a Traficon per Vehicle Message.

The TDCM checks for messages received from the Traficon system over the serial ENCOM radio every 15 to 20 milliseconds. Any time a complete message is received, the message is logged into the Traficon daily log file with a time-stamp when it was received. Since the various detection systems clocks are not synchronized, the serial messages received from the Traficon, the SAS-1, and the Wavetronix systems and actuations received from the inductive loops or the RRMs over the ENCOM CC radio are time-stamped by the data collection modules running on the industrial PC using the industrial PC clock in order to have the same time reference.

SAS-1 Data Collection Module

The SDCM interfaces with the SAS-1 wireless receiver in the AWEGS cabinet over a serial port. The SAS-1 is configured to automatically send a binary message every 80 milliseconds that contains 10 samples of emulated trap detections for each lane in the detection zone sampled at 8 milliseconds apart. The SAS-1 system internally calculates the vehicle speed and length for each vehicle detected and converts the data into emulated trap detections for each lane in the detection zone. This information is then sent wireless over a serial port. The conversion is done because the SAS-1 system is geared to providing detection to legacy control systems that expect contact closure inputs from trap detectors. The SAS-1 emulated detection samples are processed to determine if the status of the emulated trap detectors in each lane monitored has changed or not. The change in status of each emulated loop is logged into the SAS-1 daily log file with a time-stamp. Other information that is logged into the SAS-1 log file includes the presence time for each emulated detector in a trap, the Off or non-occupied time, and the number of On and Off actuations per day.

EVALUATION

The detector systems configured and installed at the Waco testbed were evaluated for their performance. They were compared with the performance of AWEGS loops. The criteria used to compare these systems included vehicle counts, vehicle classification (truck or a non-truck), and vehicle speeds. Apart from these criteria, researchers also evaluated the messages received from these detection systems for latency. Latency was evaluated to ensure that the messages from the detection systems did not have any unusual time lag between the times the vehicle was sensed by the detector to the time the message was received at the cabinet. This is particularly critical for systems like DC-S and AWEGS where dilemma zone protection is provided on high-speed approaches.

The methodology described in the previous chapter was used to collect the data. This data was collected on an industrial PC located in the cabinet beside the signal controller cabinet. An application was developed to collect the data and log the data on a daily basis. Researchers downloaded these data from the PC remotely from College Station via a telephone modem using pcAnywhere software. The data downloaded was reduced by developing some software utilities to ease the data reduction process.

Inductive Loops Using Contact Closure Radio

The first detection system to be evaluated was the inductive loops using contact closure radio communication (here after called CC inductive loops). The output from this system has the same attributes as the baseline system, i.e., AWEGS loops. As described in the previous chapter, researchers monitored the presence times of the CC inductive loops as well as AWEGS loops and adjusted the sensitivity of the CC inductive loops to get the presence times close to the presence time of AWEGS. Researchers did not make any changes to the sensitivity of the AWEGS loops as they were stretched to their operational limits due to the long lead-in wire. Secondly, AWEGS loops were functioning satisfactorily as part of AWEGS, and hence, no changes were made to ensure that the integrity of AWEGS was maintained. Before any evaluation was made for the criteria mentioned earlier, researchers observed and logged the presence time of the CC inductive loops to ensure that they were close to the AWEGS loops. Figure 12 illustrates the presence times in the CC inductive loops and the AWEGS loops.

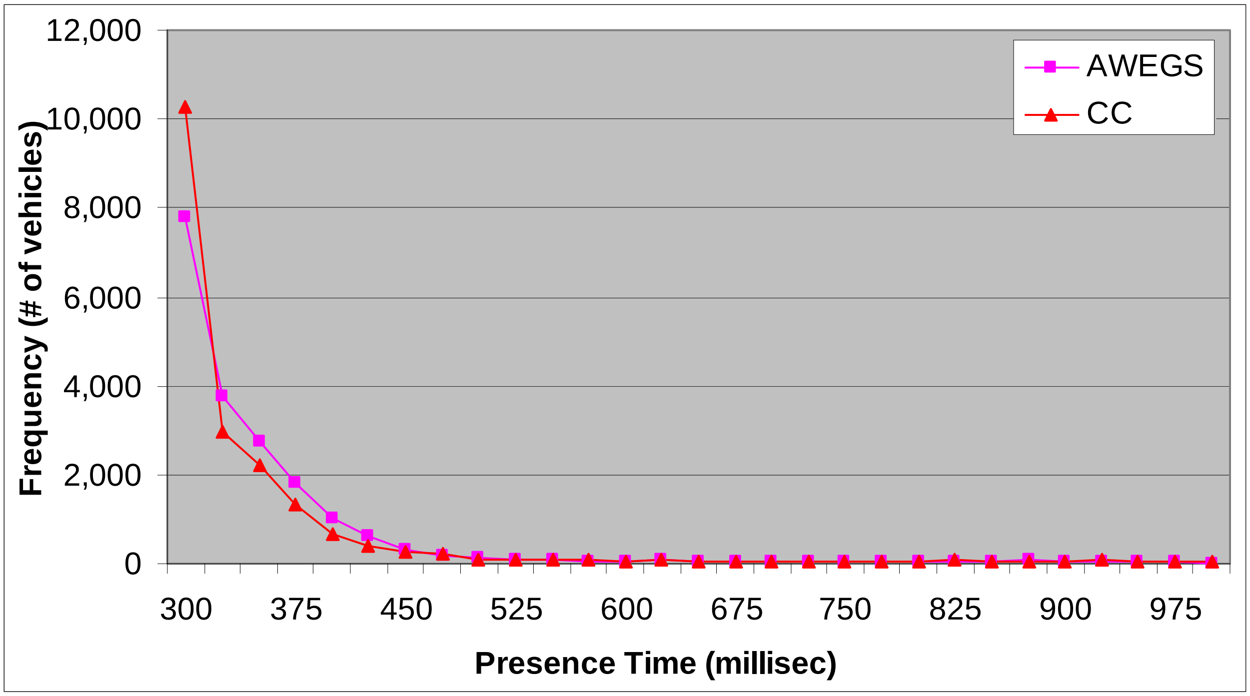

Figure 12. Presence Times on AWEGS Loops and Loops Using Contact Closure Radio.

It is seen from Figure 12 that the presence times for both systems are very close. Further analysis also indicated that the 85 percentile presence times for both the systems were very close at 391 milliseconds for AWEGS and 381 milliseconds for CC inductive loops. Similarly, the 50 percentile presence time for AWEGS detectors and CC inductive loops were 311 and 300 milliseconds, respectively. Such baseline verification was necessary to start evaluating the CC inductive loops for the appropriate criteria.

Figure 13 illustrates the performance of CC inductive loops with respect to AWEGS loops. The figure illustrates that the percentage error of total counts with CC inductive loops with respect to AWEGS loops is almost 0 percent. When the comparison was done by cars and trucks, the percentage error for cars is also below 0.5 percent. The truck counts were off by up to 3 percent. However, researchers noted that the identification of trucks by AWEGS is not perfect. AWEGS uses a very simple logic which was described earlier. Hence, an error of 3 percent can be considered negligible. An analysis of speeds was not conducted because in both cases, AWEGS loops and inductive loops calculate the speeds from the presence times of actuations which were found to be satisfactory.

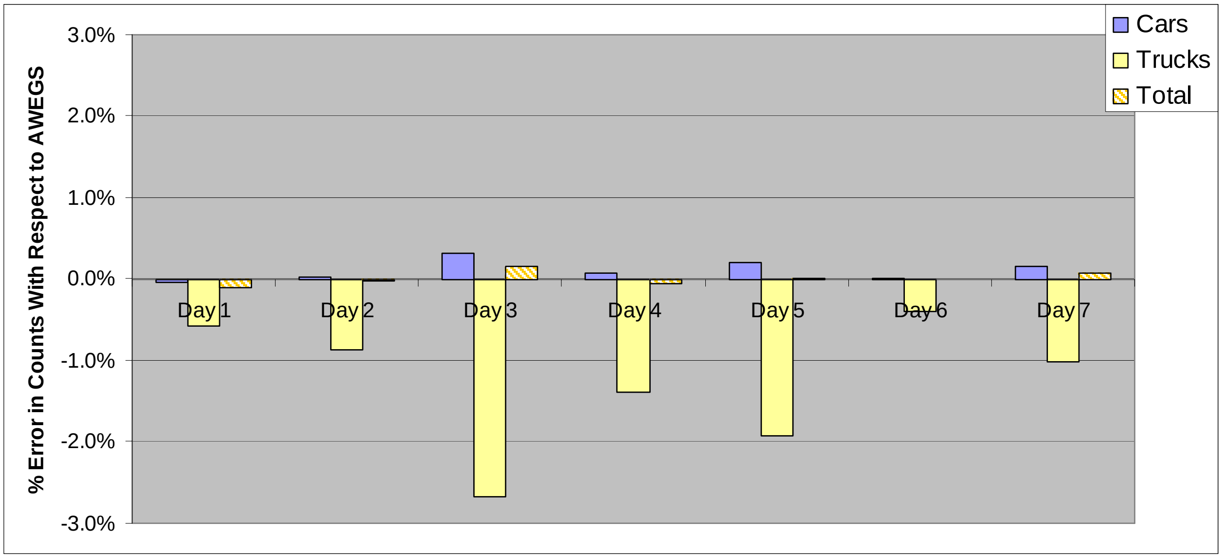

Figure 13. Percentage Error in Counts Using Inductive Loops with CC Radio With Respect to AWEGS Loops.

Road Runner Detectors

As described in the previous chapter, researchers had numerous difficulties in getting Road Runner detectors to work. Satisfactory detections were not obtained even after numerous configurations were tried. The final configuration involved burying a small loop antenna along the Road Runner detector and running that antenna to an external antenna on a nearby pole without any success. One of the primary problems was the large presence times for individual vehicles. The vendor had stated that the detection zone of a Road Runner detector was equivalent to a 6 foot by 6 foot inductive loop. Hence they were spaced 30 feet apart. But these large presence times resulted in classifying almost all vehicles as trucks using our same logic. It was not possible for the researchers to relocate a detector to achieve a different spacing due to time constraints as well as the fact that the vendor had placed upper limits on the length of the external antenna. Road Runner detectors frequently also had multiple actuations for a single vehicle. Due to the unsatisfactory results of the Road Runner detectors, no further analysis was conducted.

Traficon Video Detector

Data from the Traficon video detector was transmitted to the cabinet at the intersection using serial radio. Data from the detector consisted of vehicle speed and vehicle length. Video detectors have improved significantly over the years. However, their accuracy depends on the availability of ambient light at the location. Hence, TTI researchers designed the data reduction to take this factor into consideration during the data reduction.

Figure 14 illustrates the percentage error in counts using the Traficon detector with respect to AWEGS. As can be seen from the figure, the total counts during the entire day for a seven-day period were within 5 percent of AWEGS counts, and the video detector was overcounting consistently. However, upon closer examination, it is seen that the detector consistently undercounted during the daytime by about 5 percent and consistently overcounted during the nighttime by sometimes as high as 40 percent. The reason the full day counts were off by about 5 percent was because a majority of the traffic at this location was during the daytime. Hence, it is essential to look at the performance of video detectors during daytime as well as nighttime.

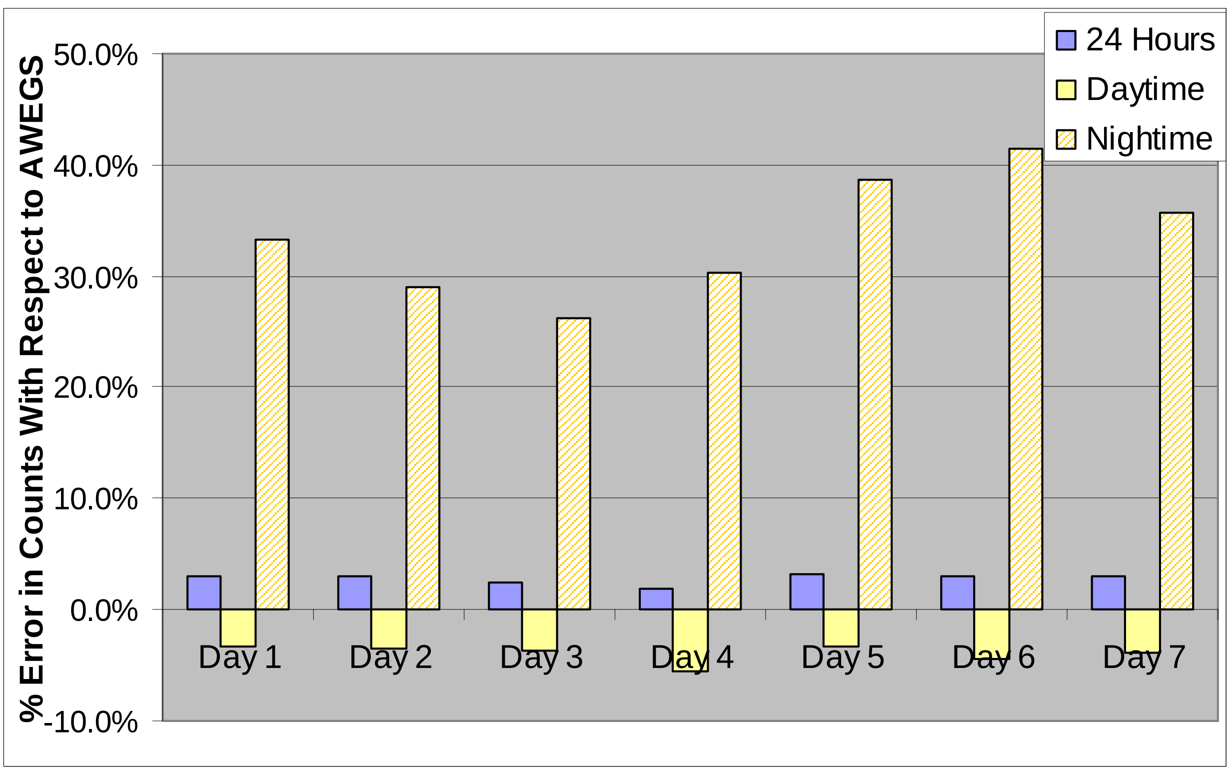

Figure 14. Percentage Error in Counts Using Traficon With Respect to AWEGS Loops.

Figure 15 illustrates the distribution of the vehicle length as measured by Traficon during the daytime and nighttime separately. The distribution of the vehicle length during daytime illustrates a median vehicle length of about 24 to 25 feet. While the length of the vehicle may not be exact, the distribution of the vehicle lengths on the approach appears to be satisfactory for the needs of systems such as DC-S, PIA, and AWEGS. However, upon examining the distribution of the vehicle length during the nighttime, it is seen that a large number of vehicles were classified as very short vehicles. This appears to be an anomaly of the video detector when operating at night. Apart from identifying a large number of vehicles as having a very short length, the Traficon detector appears to be doing a good job of measuring vehicle length.

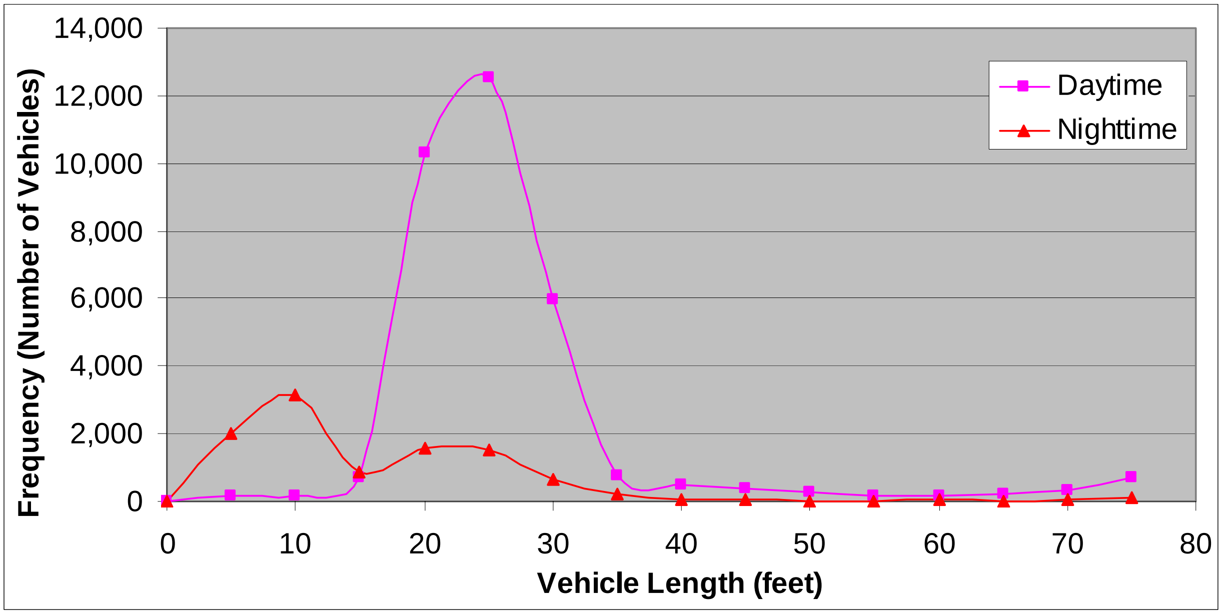

Figure 15. Measurement of Vehicle Length by Traficon Detector.

The next parameter to measure from the Traficon detector is the vehicle speed. TTI researchers again separated the speeds measured by Traficon into daytime and nighttime speeds. Such a data reduction procedure will identify any anomalies in the detector performance based on ambient light.

Figure 16 and Figure 17 illustrate the speeds measured by the Traficon detector during daytime and nighttime and compare them with the speeds calculated using AWEGS loops. As can be seen from both figures, speeds measured by Traficon match the speeds calculated using AWEGS detectors very closely during daytime as well as during nighttime. This comparison tells researchers that Traficon is pretty good at measuring vehicle speeds. The absence of ambient light has an impact on measuring vehicle length during nighttime. However this measurement can be improved by providing some lighting at the detector location.

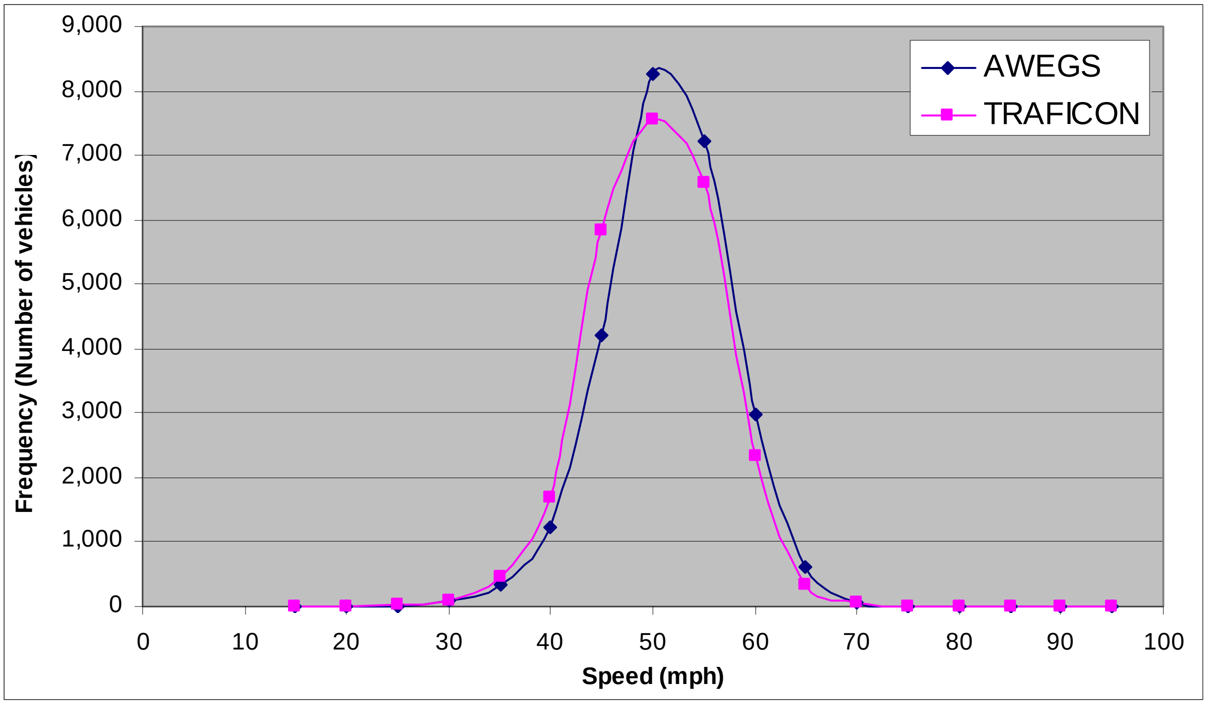

Figure 16. Speeds Measured by Traficon During Daytime.

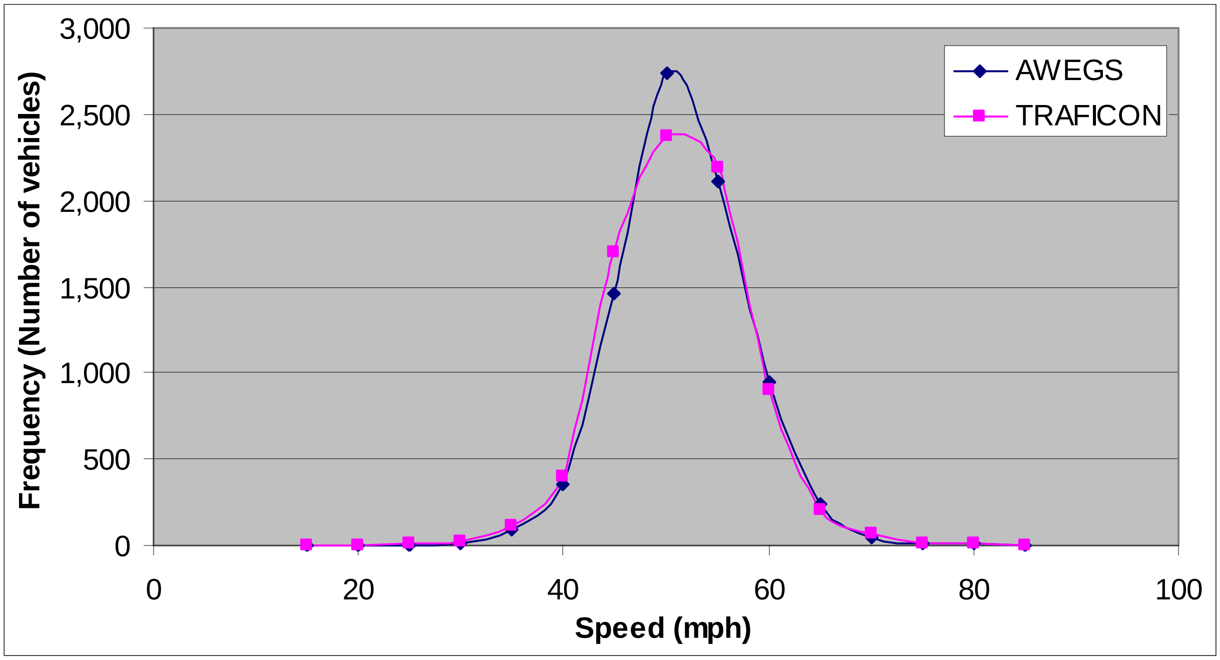

Figure 17. Speeds Measured by Traficon During Nighttime.

SAS-1 Detector

The SAS-1 detector typically measures the individual vehicle speeds and length. This information is then binned into user-defined intervals and provided to the user. However, the requirements of a detection system for this project required the attributes of individual vehicles and not any binned data. The SAS-1 has another module which takes the data the unit collects for each vehicle and emulates a speed trap in the detection zone. The detector unit then provides the activity of a vehicle over this virtual speed trap in the form of contact closure data. This data is then transmitted to the data collection station.

The SAS-1 detector has its own transmission module. It has a built-in wireless system that transmits the data to the receiver near the signal controller cabinet. TTI researchers collected over a week of data for comparing with AWEGS. However, due to some technical problems, SAS-1 data from the last two days was not valid. Hence, researchers will present only five days of data.

Figure 18 illustrates the percentage error in vehicle counts with respect to counts using AWEGS detectors. The figure illustrates that cars are typically being undercounted by the SAS-1. However, this error is just about 5 percent and may be acceptable. The figure illustrates that trucks are being overcounted using the simple logic described earlier.

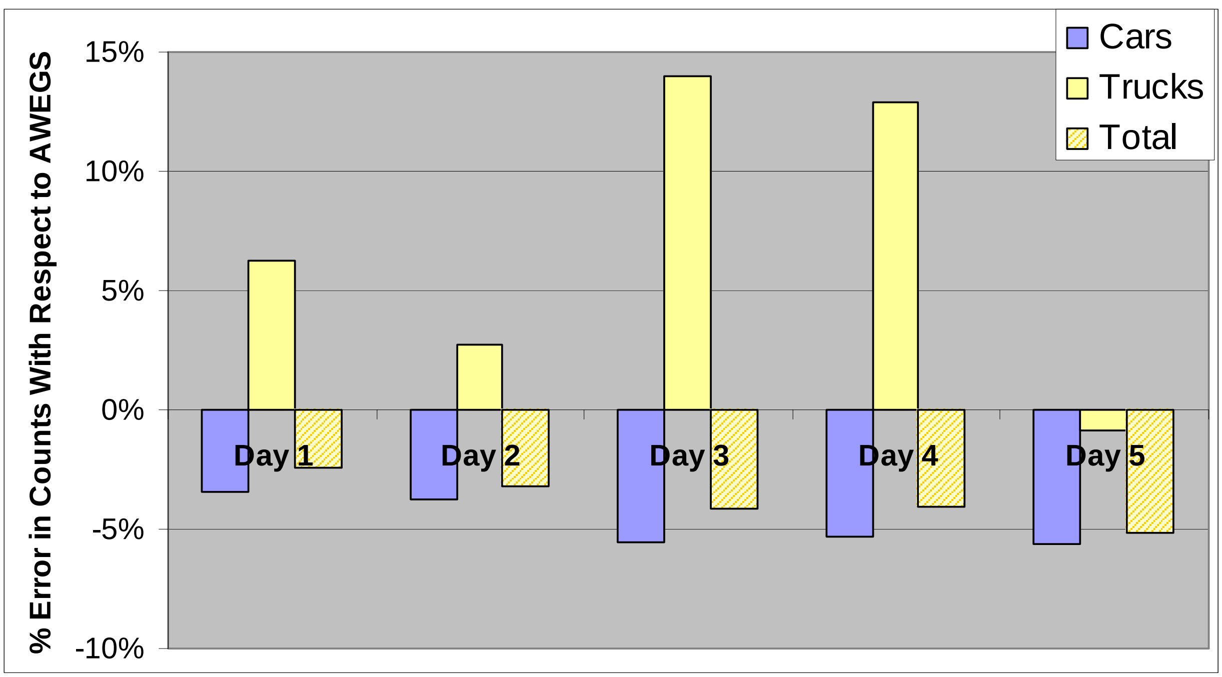

Figure 18. Percentage Error in Counts by SAS-1 With Respect to AWEGS Loops.

Figure 19 illustrates the comparison of speeds measured by the SAS-1 compared to speeds calculated using AWEGS detectors. It is clearly seen by the figure that SAS-1 speeds are significantly different from the speeds calculated using AWEGS detectors.

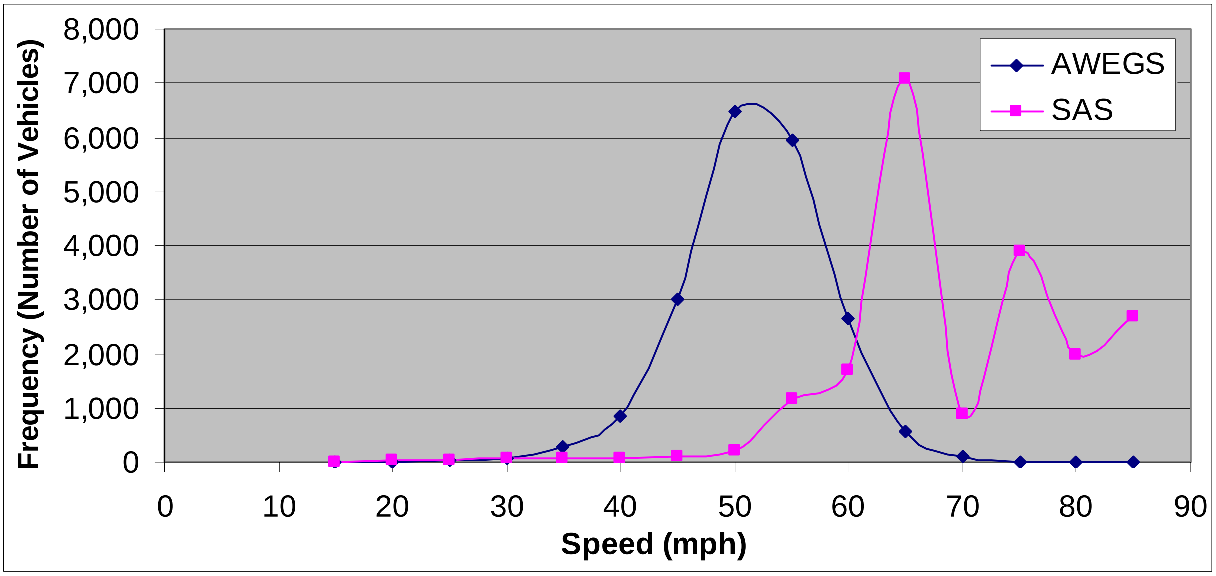

Figure 19. Speeds Measured by SAS-1 Detector.

Researchers noted that the SAS-1 detector is being used in a fashion that is much cruder than what it was designed for. Hence, the data being generated is not very accurate. The SAS-1 detector converts the internally calculated length and speed of detected vehicles into an 80-millisecond message transmitted over the serial port. The message consists of 10 samples of emulated trap detections for each lane in the detection zone sampled at 8 milliseconds apart. The serial interface does not provide the internally calculated per vehicle speed and length data directly over the serial port. TTI researchers believe if the SAS-1 detector provided the internally calculated length and speed serially instead of the emulated trap data, the comparison to AWEGS loops data may have been more accurate. Hence, while the current unit did not do a good job of counts, identifying trucks, and measuring speeds, further research is needed by using an SAS-1 unit that can provide actual vehicle lengths and speeds for each and every vehicle.

CONCLUSIONS AND RECOMMENDATIONS

This project developed and evaluated various advance detection systems. The objective was to use off-the-shelf technology to develop these detection systems and evaluate their performance as well as their cost-effectiveness with respect to traditional advance inductive loops using lead-in wire. These systems were deployed on the northbound approach of the intersection of SH 6 and FM 185. The baseline system was the AWEGS detectors on this approach.

Table 2 and Table 3 illustrate the cost of installing the various detection systems. The baseline system included 500 feet of trenching and 50 feet of boring for traditional inductive loops with lead-in wire. It is clearly seen from Table 2 that the cost of the baseline system was cheaper than most of the systems except the SAS-1 unit from SmarTek for a single-lane approach (two-lane highway). However, for a two-lane approach (four-lane highway) the cost of the baseline system becomes more expensive than the other detection systems. One significant cost component of the other detection systems is the solar power needed if there is no power at the detection station. If power is available at the detection station, other systems get more cost-effective at the installation stage itself.

Table 2. Cost of Detection Systems on a Single-Lane Approach.

	Baseline Inductive Loops with Lead-in Wire	Inductive Loops with CC Radio	Road Runners with CC Radio	Traficon - Video	SmarTek - Acoustic	Wavetronix - Radar
Detector Cost	$2,400	$2,400	$3,190	$5,430	$7,000	$7,900
Transmission Cost	$11,480	$8,485	$7,405	$3,090	$0	$3,090
Miscellaneous						
Solar power	$0	$1,950	$1,950	$1,950	$1,950	$1,950
Pole		$500	$500	$1,300	$1,300	$1,300
Miscellaneous Cost	$0	$2,450	$2,450	$3,250	$3,250	$3,250
Est. total cost without solar power	$13,880	$14,045	$11,595	$11,120	$9,600	$13,590
Est. total cost with solar power	**$13,880**	**$17,945**	**$15,495**	**$15,020**	**$13,500**	**$17,490**

Table 3. Cost of Detection Systems on a Two-Lane Approach.

	Baseline Inductive Loops with Lead-in Wire	Inductive Loops with CC Radio	Road Runners with CC Radio	Traficon - Video	SmarTek - Acoustic	Wavetronix - Radar
Detector Cost	$4,800	$4,800	$5,190	$5,430	$7,000	$7,900
Transmission Cost	$14,880	$8,485	$7,405	$3,090	$0	$3,090
Miscellaneous						
Solar power	$0	$1,950	$1,950	$1,950	$1,950	$1,950
Pole		$500	$500	$1,300	$1,300	$1,300
Miscellaneous Cost	$0	$2,450	$2,450	$3,250	$3,250	$3,250
Est. total cost without solar power	$19,680	$16,445	$13,595	$11,120	$9,600	$13,590
Est. total cost with solar power	**$19,680**	**$20,345**	**$17,495**	**$15,020**	**$13,500**	**$17,490**

Table 4 illustrates a summary of the capabilities and the cost-effectiveness of all the detection systems evaluated in this project. It is clearly seen that one system or a configuration does not stand out from the rest as being the best system. However, this project evaluated these various configurations and presented the results. TTI researchers are also working with Siemens on a separate TxDOT project in testing out a wireless detector similar to the Road Runner detector but which is easier to install. Once the testing is complete, TTI researchers will submit results for TxDOT's review.

Table 4. Summary of Detection Systems.

Systems	**Counts**	**Classification**	**Speeds**	**Cost**	**Comments**
Inductive Loops with CC Radio	Accurate	Accurate	Accurate (Calculated)	Moderate to high	Has the same drawback to installing inductive loops. However, minimizes the maintenance cost of a long lead-in cable.
Road Runners	Not accurate	Not accurate	Not accurate	Low	Not useful due to inaccurate performance.
Traficon	Accurate in daytime	Accurate in daytime	Accurate	Low to moderate	The detector can work very well with some ambient light for nighttime operations.
SAS-1 by SmarTek	Moderately accurate	Moderately accurate	Not accurate	Low	Recommend requesting the vendor to provide individual vehicle speed and length and evaluate.
Wavetronix	Not accurate	Not applicable	Not applicable	Moderate	Sensor doesn't classify by lane and also doesn't know the vehicle length.

It is essential that the engineer evaluate not only the installation cost of these systems but also the life-cycle cost of the system due to maintenance. Maintenance costs for some systems such as inductive loops can increase the life-cycle cost significantly. The appendix provides draft specifications for the installation of advance detectors. These specifications include the guidelines for estimating the cost of various detection systems.

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APPENDIX

PRODUCT 1 – DRAFT SPECIFICATIONS FOR INSTALLATION OF ADVANCE DETECTION

Advance Detection Systems

TTI researchers configured and evaluated numerous advance detection systems in this project and compared their performance and cost with the existing configuration of advance detection system. The baseline configuration consists of inductive loops with a lead-in wire. The alternative systems configured and evaluated are inductive loops with contact closure radio, Road Runner with contact closure radio, Traficon video detection with serial radio, SmarTek acoustic detection with built-in wireless communication, and Wavetronix Radar detector.

Purchasing Specifications for the Evaluated Equipment

Specifications of the equipment used in this project are detailed next. Equipment included communication equipment and detection equipment.

Contact Closure Radios

Model Number: ENCOM 2028 Receiver (now 4028)
ENCOM 2513 Transmitter (now 4513)

Manufacturer: ENCOM
Phone: 1-800-617-3487

Website: http://www.encomwireless.com/en/solutions/series/4000/4028/
http://www.encomwireless.com/en/solutions/series/4000/4513/

Description: This shelf mounted 2028 receiver is placed in the signal controller cabinet. An antennae placed on a pole close by was connected to the receiver. This unit worked flawlessly. The 2513 transmitter along with the pole mounted cabinet were installed on the solar panel pole. At the time of the publication of this report, ENCOM has renumbered the contact closure radios. ENCOM 2028 and ENCOM 2513 are now being marketed as ENCOM 4028 and ENCOM 4513.

Serial Radios

Model Number: ENCOM 5200 Transceiver

Manufacturer: ENCOM

Phone: 1-800-617-3487

Website: http://www.encomwireless.com/en/solutions/series/4000/4028/

Description: A shelf mounted 5200 transceiver was placed in the signal controller cabinet. An antennae placed on a pole close by was connected to the receiver. Another shelf mounted 5200 transceiver was placed in the pole mounted cabinet on the solar panel pole. Both the 5200 units functioned very well.

Magnetometer Detectors

Model Number: SPVD-2

Manufacturer: Midian Electronics Inc.

Phone: 1-800-MIDIANS

Website: http://www.midians.com/html/products.asp?cat=Traffic+Control+Equipment

Description: Midian's Road Runner System™ is a wireless vehicle detection system. This system is comprised of a detector/transmitter and a receiver. The in-road detector utilizes a highly reliable dual-axis magnetometer to detect vehicles. This magnetometer measures both the vertical and horizontal components of the Earth's magnetic field to detect the changes in the magnetic field caused by a passing vehicle. The detector/transmitter is battery powered and the battery life is approximately four years based on 20,000 data packets transmitted per day. The actuations sent by the detector are received by either a TCR 1000 shelf mounted receiver or TCR 2000 rack mounted receiver.

Video Detector

Model Number: VIP/D

Manufacturer: Traficon

Phone: 1-703-961-9617

Website: http://www.traficon.com/solutions/product.jsp?id=3

Description: The VIP/D combines traffic flow monitoring, traffic data collection, and loop emulation all in one single board. The user can easily specify several configuration and detection parameters. The user can even decide on the amount of information to be displayed on the monitor. All of these options are available via an extremely user-friendly, menu-driven set-up procedure using a VIP keypad or portable PC. The convenience of a remote set-up via the Ethernet communication module is also possible.

All alarms and flow data can be permanently monitored over a serial port. This includes relevant traffic data such as number of vehicles, speed, occupancy, classification, gap time, and headway. VIP/D measures both the traffic flow speeds between 0 and 150 km/h for up to eight lanes and the zone occupancy of the detection area. It automatically distinguishes five types of traffic flow (levels of service) based on flow speed and zone occupancy.

Acoustic Detector

Model Number: SmarTek Acoustic Sensor-Version 1 (SAS-1)

Manufacturer: SmarTek Systems Inc.

Phone: 1-410-315-9727

Website: www.smarteksys.com

Description: The SmarTek Systems Acoustic Sensor-Version 1 (SAS-1) is a novel multi-lane traffic monitoring system based on detecting the acoustic signals motor vehicles create and radiate during operation. The SAS-1 is a non-contact, passive acoustic (listen only) sensor and is mounted on existing overhead or roadside structures such as light poles, sign bridges, and overpasses. It is completely non-intrusive to the highway or to the travelers using the highway. The SAS-1 is a passive sensor (does not radiate signal) and as such requires very little power to operate. This coupled with a wireless "home run" option makes the SAS-1 very suitable for completely autonomous installation and operation using a small solar panel to keep an associated battery charged.

Radar Detector

Model Number: SmartSensor Advance Model 200

Manufacturer: Wavetronix

Phone: 1-801-764-0277

Website: www.wavetronix.com

Description: The SmartSensor Advance Model 200 brings the reliability and accuracy of the SmartSensor to dilemma zone and green light extension applications. SmartSensor Advance uses patented Digital Wave Radar™ technology to measure presence and speed of vehicles in motion and it is still the traffic industry's only patented auto-configuring traffic sensor. SmartSensor Advance installs aboveground and is specifically designed for installation at signal-controlled intersections. With a detection range of 500 feet, the SmartSensor Advance offers 5-foot zone resolution in up to eight user-definable zones, providing traffic managers with accurate detection and effective dilemma zone management.

Each of these systems has different costs to implement and depends on the numbers of lanes on which the system is being implemented and whether solar power is required. Table 5 and Table 6 detail the cost of implementing the systems evaluated for a two-lane highway and a four-lane highway. These costs are for advance detectors located at a distance of approximately 1000 feet from the intersection. These tables estimate the cost of the detections with and without the need for solar power equipment at the detection station.

Table 5. Cost of Installing Detection Systems for a Two-Lane Highway.

	Baseline Inductive Loops with Lead-in Wire	Inductive Loops with CC Radio	Road Runners with CC Radio	Traficon - Video	SmarTek - Acoustic	Wavetronix - Radar
Detector						
# of detectors per lane	2	2	2	-	-	-
# of lanes per approach	1	1	1	-	-	-
# of units per approach	2	2	2	1	1	1
# of approaches	2	2	2	2	2	2
# of units per intersection	4	4	4	2	2	2
Detector unit cost	$500	$500	$500	$2,715	$3,500	$3,950
Detector amplifier - Pole	$0	$200	$595			
Detector amplifier - Cabinet	$200	$0	$0			
Detector Cost	$2,400	$2,400	$3,190	$5,430	$7,000	$7,900
Transmission						
Trenching (ft)	500					
Trenching unit cost (per ft)	$6.00					
Total trenching cost	$6,000.00					
Boring (ft)	50					
Est. boring unit cost (per ft)	$10.00					
Total boring cost	$1,000.00					
Wire length per approach (ft)	1000					
Wire cost (per ft)	$0.85					
Total wire cost	$3,400.00					
Pull boxes	3	2				
Cost of pull boxes	$180.00	$180.00				
Total cost of pull boxes	$1,080.00	$1,080.00				
CC radio cost - Cabinet		$1,935	$1,935			
CC radio cost - Pole		$2,735	$2,735			
Serial radio - Cabinet				$1,030	$0	$1,030
Serial radio - Pole				$1,030	$0	$1,030
Transmission Cost	$11,480	$8,485	$7,405	$3,090	$0	$3,090
Miscellaneous						
Solar power	$0	$1,950	$1,950	$1,950	$1,950	$1,950
Pole		$500	$500	$1,300	$1,300	$1,300
Miscellaneous cost	$0	$2,450	$2,450	$3,250	$3,250	$3,250
Est. total cost without solar power	$13,880	$14,045	$11,595	$11,120	$9,600	$13,590
Est. total cost with solar power	**$13,880**	**$17,945**	**$15,495**	**$15,020**	**$13,500**	**$17,490**

Table 6. Cost of Installing Detection Systems for a Four-Lane Highway.

	Baseline Inductive Loops with Lead-in Wire	Inductive Loops with CC Radio	Road Runners with CC Radio	Traficon - Video	SmarTek - Acoustic	Wavetronix - Radar
Detector						
# of detectors per lane	2	2	2	-	-	-
# of lanes per approach	2	2	2	-	-	-
# of units per approach	4	4	4	1	1	1
# of approaches	2	2	2	2	2	2
# of units per intersection	8	8	8	2	2	2
Detector unit cost	$500	$500	$500	$2,715	$3,500	$3,950
Detector amplifier - Pole	$0	$200	$595			
Detector amplifier - Cabinet	$200	$0	$0			
Detector Cost	$4,800	$4,800	$5,190	$5,430	$7,000	$7,900
Transmission						
Trenching (ft)	500					
Trenching unit cost (per ft)	$6.00					
Total trenching cost	$6,000.00					
Boring (ft)	50					
Est. boring unit cost (per ft)	$10.00					
Total boring cost	$1,000.00					
Wire length per approach (ft)	1000					
Wire cost (per ft)	$0.85					
Total wire cost	$6,800.00					
Pull boxes	3	2				
Cost of pull boxes	$180.00	$180.00				
Total cost of pull boxes	$1,080.00	$1,080.00				
CC radio cost - Cabinet		$1,935	$1,935			
CC radio cost - Pole		$2,735	$2,735			
Serial radio - Cabinet				$1,030	$0	$1,030
Serial radio - Pole				$1,030	$0	$1,030
Transmission Cost	$14,880	$8,485	$7,405	$3,090	$0	$3,090
Miscellaneous						
Solar power	$0	$1,950	$1,950	$1,950	$1,950	$1,950
Pole		$500	$500	$1,300	$1,300	$1,300
Miscellaneous cost	$0	$2,450	$2,450	$3,250	$3,250	$3,250
Est. total cost without solar power	$19,680	$16,445	$13,595	$11,120	$9,600	$13,590
Est. total cost with solar power	**$19,680**	**$20,345**	**$17,495**	**$15,020**	**$13,500**	**$17,490**

Selection of an advance detection system depends on numerous criteria. These include installation cost, functionality, and maintenance cost. It is very difficult to quantify the maintenance/life-cycle costs. These costs vary from one district to another and within the same district from one location to another. Good engineering judgment and past experience should be used to estimate the life-cycle cost of each technology. Based on the information currently available, a rating of the advance detection systems was generated and is illustrated in Table 7.

Table 7. Rating of the Detection Systems Evaluated.

				Total Cost	
	Counts	**Classification**	**Speed**	**Elect.**	**Solar**
Baseline – ILD	Excellent / Excellent	Excellent / Excellent	Excellent / Excellent	Bad	Below Average
ILD with CC Radio	Excellent / Excellent	Excellent / Excellent	Excellent / Excellent	Below Average	Bad
Road Runners	Bad / Bad	Bad / Bad	Bad / Bad	Average	Average
Traficon – Video	Excellent / Average	Excellent / Average	Excellent / Excellent	Good	Good
SAS-1 – Acoustic	Average / Average	Average / Average	Below Average / Below Average	Excellent	Excellent
SmartSensor – Radar	**N/A**	**N/A**	**N/A**	Average	Average

Excellent   Good   Average   Below Average   Bad