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ABSTRACT

Portable automated traffic data collection systems were evaluated by means of a series of field demonstrations. Systems demonstrated included (*a*) temporarily mounted microwave radar sensors intended to provide volume, speed, and/or length classification data for traffic census or various traffic studies; (*b*) similar sensors mounted on a semi-permanent basis and intended to serve as substitutes for loop detectors in traffic surveillance systems; and (*c*) low-mounted infrared sensors used for axle counting. The field demonstrations focused on the issues of sensor accuracy for all systems and the reliability of wireless transmission systems for semi-permanent installations. Microwave radar sensors tested included the Wavetronix SS-105 and Wavetronix SS-125 (HD) models. A planned demonstration of the EIS RTMS sensor had to be cancelled because of inability to download per-vehicle data required for evaluation. Performance of the Wavetronix SS-105 sensor was satisfactory. Performance of the SS-125 sensor was acceptable but not as good as the SS-105 sensor in non-congested traffic and marginal in congested traffic. In all cases, a majority of the errors were in the lanes farthest from the sensor. Performance of the communications system used in the semi-permanent installation demonstration varied greatly depending on circumstances. Possible problems included bandwidth limitations in the Caltrans statewide computer network, cellular telephone system maintenance activities, problems with the interface between the modem and the cellular telephone system, and sensor failure. The low-mounted infrared sensor system demonstrated provided accurate axle-classification counts under low-volume traffic conditions but was seriously inaccurate under high-volume conditions. Although portable automated data collection systems are practical and potentially cost-effective for the data collection tasks investigated, problems with sensor accuracy and the reliability of wireless communications for semi-permanent systems have not yet been fully resolved.

Keywords: traffic data collection, traffic census, non-intrusive traffic sensors, microwave radar sensors, infrared sensors, wireless communications

EXECUTIVE SUMMARY

This report documents results of a research project entitled "Evaluation of Portable Automated Data Collection Technologies." This project evaluated use of portable side-mounted non-intrusive sensors as substitutes for conventional traffic data collection technologies (e. g., manual counts, induction loops, or road tubes). Data collection tasks investigated included traffic census, collection of lane-specific volume and speed data for planning or operational studies, and use of portable sensors as temporary substitutes for loop detectors in traffic surveillance systems. The overall goals of the project were to (*a*) identify potential uses and system requirements and to identify candidate systems; (*b*) demonstrate these in the field under realistic conditions; and (*c*) evaluate them in terms of their accuracy, reliability, practicality, and cost. An interim report documented results of the early stages of the project, which included a literature survey, a survey of potential users, and the identification and preliminary evaluation of candidate systems. This report focuses on the field demonstrations and system evaluations.

Three types are portable data collection systems are of primary interest. The first consists of temporarily-mounted microwave radar sensors used to collect volume, speed, or vehicle-length classification data for relatively short periods of time (two weeks or less) for purposes of traffic census or various traffic studies. The second consists of similar sensors mounted semi-permanently and used as substitutes for loop detectors in traffic surveillance systems. These two systems differ primarily in terms of their power supplies and data transmission requirements. The third type of system is low-mounted infrared sensors that can be used for axle counting.

The systems demonstrated consist of a sensor, mounting system, power supply, and data-transfer system. Issues related to mounting systems, power supplies, and field data transfer have largely been resolved. Most current-model sensors are designed to be compatible with portable power sources such as storage batteries but also come equipped with transformers so that they can also be operated with AC current. Most also are designed to allow for local data transfer in the field (for instance, to laptop computers) using software supplied by the manufacturer. Meanwhile, a number of temporary mounting systems exist. The simplest is an attachable pole system in which the sensor is fixed to a metal pole that can in turn be attached to an existing object in the right-of-way such as a sign post. Such attachable pole systems can be quickly installed by a single person. Other (more expensive) mounting systems include telescoping pneumatic poles mounted on portable tripod bases or trailers.

Issues that have not been fully resolved include sensor accuracy and the reliability of wireless communications systems for transmitting data from portable sensors to remote data collection points. Because of the uncertainty surrounding these two issues, the field demonstrations were focused on them. Three types of field demonstrations were undertaken. The first was intended to provide for evaluation of the accuracy of sensors for lane-specific traffic counts and involved temporary installation of microwave radar sensors using an attachable pole mounting system. The second was a test of wireless data transmission from a microwave radar sensor installed on a semi-permanent basis to a

remote data collection point. The third consisted of observation and evaluation of a manufacturer's demonstration of a low-mounted infrared sensor used for axle-classification counts.

It had originally been intended to test three types of microwave radar sensors: the Wavetronix SS-105, Wavetronix SS-125 (HD), and EIS RTMS. The RTMS test had to be cancelled because the evaluations required availability of per-vehicle data (time and duration of each detection), and EIS did not furnish instructions for downloading this type of data in a timely fashion. The two Wavetronix sensor models were tested for count accuracy in both congested and non-congested traffic.

Evaluations were conducted using VideoSync software furnished by Caltrans Division of Research and Innovation. A pan-tilt-zoom (PTZ) video camera was mounted on the pole with the sensor and aligned so that the detection zone was in the field of view. The VideoSync software allowed the resulting video clip to be synchronized with a file giving the beginning and ending times of each individual vehicle detection, as recorded by the sensor. By comparing the sensor file with the video clip, it was possible to distinguish genuine vehicle detections from false detections and missed detections. Because experience showed that large vehicles in the lanes nearest the pole could block the view of the other lanes, the later demonstrations also included use of a video shot from a camcorder mounted on the ground, slightly above and at an angle to the roadway. Using this second video clip, it was usually possible to tell whether hidden vehicles were present in the detection zone.

The Wavetronix SS-105 sensor was demonstrated in non-congested flow at a site on westbound I-8 in San Diego on March 29, 2007 and in both non-congested and congested flow at a site on southbound I-15 on April 26, 2007. Data were collected for periods of 10 to 15 minutes; detections recorded over individual 5 minute intervals were compared with the video clip to assess count accuracy. Overall performance of this sensor was quite good in both non-congested and congested flow. Overall detection accuracy was better than 98 percent in non-congested flow and 99 percent or better in congested flow. Most detection errors were in the lanes farthest from the sensor (that is, the leftmost two or three lanes in the direction of travel). It should be noted, however, that missed detections may have been understated in this evaluation, since only one video clip (that shot from the PTZ camera on the pole) was available.

The newer (and allegedly superior) Wavetronix SS-125 (HD) sensor was initially demonstrated in congested traffic at a site on southbound I-805 on June 21, 2007 and in non-congested traffic on July 23, 2007. Sensor performance was unsatisfactory in both of these demonstrations. Wavetronix representatives updated the sensor's firmware, and another demonstration, this time involving both non-congested and congested flow, was held at the same site on October 4, 2007. In this demonstration, the overall detection rate in non-congested flow was about 97 percent – considered satisfactory, but not better than the SS-105; however, the sensor's performance in congested flow was still unsatisfactory. A final demonstration in congested flow was conducted on February 26, 2007; for this demonstration, Wavetronix representatives supplied a new sensor unit. Sensor performance was improved, but still marginal. In this case the overall detection accuracy was 94 percent, but the detection rate in lane 2 (numbering from the median) was 88 only percent, and was as low as 84 percent for one 5 minute interval.

The communications test for the semi-permanent installation was conducted beginning February 21, 2008 and ending May 7. A Wavetronix SS-125 sensor was mounted on a pre-existing wooden pole in the interchange of I-5 and I-805 north of San Diego. Power supply consisted of AC current that was already available at the site. Data from the sensor were transmitted via an InfoTech Wizard serving as a cellular modem through the cellular telephone system to a laptop computer running Ramp Meter Information System (RMIS) software. Initially the server was located at Caltrans District 11 headquarters and was connected to the Caltrans computer network. Because it proved impossible to access the data from off-site, however, the server was moved to the office of AstArt Synergistics (developer of RMIS) on March 6. On March 30, there was a power failure at the site; power was not restored until April 16. Following the restoration of power, it proved impossible to restore satisfactory communications, and the demonstration was terminated on May 7.

Communication system performance was evaluated by determining a daily failed-transmission rate that was calculated by dividing the number of failed transmissions by the total number of data collection periods. System performance varied greatly depending on circumstances. During the period between February 21 and March 6, while the sensor was connected to the Caltrans network, daily transmission-failure rates varied from 35 to 52 percent. When the sensor was moved to AstArt's facility, failed-transmission rates dropped to between zero and 3 percent for a two week period. During the following week, failed-transmission rates remained generally low, except that there were three days for which there were by continuous transmission failures for periods lasting about 2.5 hours each. Following the restoration of power on April 16, failed-transmission rates were never less than about 80 percent, and there were apparent errors in the data.

The poor performance during the period the server was located at District 11 headquarters appears to have been a result of lack of bandwidth in the statewide Caltrans network. Signals were transmitted via a public cellular line and then through the statewide network, where delays due to limited bandwidth resulted in transmissions timing out. The sporadic failures while the server was at the AstArt facility are not definitely explained, but may have been due to shutdowns of the local cellular telephone network for maintenance. The failure to reestablish satisfactory communications following restoration of power is also not definitely explained. Possibilities include sensor failure and problems with the interface between the modem and the cellular telephone system.

The third type of demonstration involved Low-mounted infrared sensors. At least two types are available. The first of these, The Infrared Traffic Logging (TIRTL) system, is an interrupted-beam system which requires sensors to be installed on both sides of the roadway. The other, the Quixote (formerly Peek) AxleLight sensor, is a reflected-beam system that requires an automatic data recorder and two sensors mounted side-by-side for axle-counting applications. Both of these systems can also be used for vehicle counts, but because of their prices are cost-effective only for tasks that cannot be accomplished with microwave radar.

It had originally been planned to observe a demonstration of the TIRTL system that was planned for the Los Angeles area. This demonstration was never took place, however. Instead, the manufacturer of the AxleLight system provided a demonstration at a site on northbound US-101 in Los Angeles on September 25-27, 2007, portions of which were observed by a representative of this project. Results of this demonstration were summarized in a brief report by Steve Malkson of Caltrans District 7.

Data produced by the AxleLight system were compared with data from a nearby ADR6000 station connected to induction loop detectors. There were serious discrepancies in the vehicle-classification counts produced by the two systems, with undercounting of 2-axle trucks by AxleLight and over counting of other trucks, particularly 3- and 4-axle trucks. Comparison of results for different times of day showed that counts produced by the two systems were virtually identical during periods of very light traffic, but diverged significantly during periods of heavy traffic. From this, it appears that under heavy volume conditions, AxleLight may be mistaking closely-following two-axle vehicles for multi-axle trucks.

The overall conclusion of the study is that although portable automated data collection systems are practical and potentially cost-effective for the data collection tasks investigated, problems with sensor accuracy and the reliability of wireless communications for semi-permanent systems have not been fully resolved. On the basis of these results it is recommended that Caltrans (*a*) consider routine use of temporarily-mounted microwave radar units as an alternative to current methods of data collection for volume counts, speeds, and vehicle-length classification for sites with narrow roadways (two or three lanes) and/or non-congested traffic, but exercise caution in deploying such systems elsewhere; (*b*) maintain a continuous program for verifying the performance of new types and models of sensors and encourage manufacturers of side-mounted non-intrusive sensors to continue efforts to overcome problems related to occlusion and inability to distinguish vehicles in the lanes farthest from the sensors; (*c*) continue efforts to develop reliable wireless communications systems for semi-permanent data-collection installations as part of the overall effort to develop wireless data communications capability; (*d*) not attempt installation of systems requiring wireless communication without the involvement of personnel with extensive wireless communication experience; (*e*) use private, rather than public, cellular links to access servers connected to the Caltrans computer network; (*f*) carefully consider the location of nearby cell towers in selection of sites for installations requiring cellular data transmission; and (*g*) continue to investigate the suitability of low-mounted infrared sensor systems for axle classification counts.

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1. INTRODUCTION

Agencies such as the California Department of Transportation (Caltrans) have a variety of uses for traffic data collected over periods of time ranging from less than an hour to several months. In most such cases, the duration of data collection is too short to warrant the installation of loop detectors; meanwhile, manual data collection is tedious and expensive and the use of road tubes (where otherwise feasible) poses safety issues. In recent years, the availability of various types of non-intrusive traffic sensors has created the possibility of developing portable automated traffic data collection systems. Such systems combine a non-intrusive sensor with some sort of mounting system (usually a portable pole), a power supply, and a data delivery system. This goal of this project was to identify, demonstrate, and evaluate portable automated data collection systems that can be readily assembled from existing components. The overall project included a literature review, surveys of potential users and vendors, identification of candidate systems, field demonstrations, and the documentation and evaluation of the candidate systems. The literature review, surveys of potential users and vendors, and identification of candidate systems have been described previously in a working paper (Banks 2006); results of these tasks will be briefly summarized in this report, the focus of which will be on the field demonstrations and evaluation of the candidate systems.

2. PORTABLE DATA COLLECTION INFORMATION SOURCES

The literature review identified a number of sources of information about portable automated data collection systems. Perhaps the most pertinent reference is Kotzenmacher (2005), which reports on a similar project carried out by Minnesota Guidestar. Other sources of information include reports describing and evaluating various types of sensors (Vehicle Detector Clearinghouse no date; Mimbela and Klein 2003; Minnesota Department of Transportation 1997, 2002; Middleton and Parker 2002; Wald 2004a, 2004b; Martin 2003; Skszek 2001) and studies related to automated collection of data for specific data collection tasks, particularly turning movement counts (Hauer 1981, Virkler and Kumar 1998, Tian 2004). Because sensor technology continues to evolve rapidly, however, many of the published sources relating to sensors are already out of date.

3. POTENTIAL USES AND SYSTEM REQUIREMENTS

Potential users of portable automated data collection systems (including Caltrans personnel and personnel of other state departments of transportation and the Federal Highway Administration) were surveyed to determine potential uses of such systems and desired system characteristics. Results of these surveys are discussed in detail in Banks (2006); this section summarizes some of the more important points.

Potential uses include data collection for planning studies, traffic operations, and traffic census, and use of temporarily-mounted non-intrusive sensors as substitutes for loop detectors in various traffic surveillance roles. In most of these applications, sensors would be used to collect traffic counts, turning movement counts, vehicle-classification counts, or speeds. Most such uses would require sensors to be in place for only a few days at a time. Subsequent investigation suggested that collection of turning movement counts with side-mounted sensors might not be practical in many cases because it would not be possible to provide the necessary setbacks from the travel lanes; consequently there was no attempt to demonstrate this use.

Portable automated data collection systems might substitute for loop detectors as replacements for malfunctioning loops. In addition, they might be used for temporary data collection at locations where permanent detectors have not yet been installed or for data collection for construction zones, seasonal routes, or special events. Most of these uses imply some sort of "semi-permanent" installation in which units would be deployed for as much as several years.

System requirements include installation with minimum traffic disruption and safety risk; "plug-and-play" features providing for field installation with a minimum of effort and expertise; ability to upload settings and download data through wireless, IP-addressable communications systems; capability to provide data in a variety of formats to be specified by the user; and capability of being powered flexibly by either batteries, solar collectors, or AC current. Where intended for relatively long-term use as substitutes for loop detectors, systems should provide for seamless interface into existing data collection systems without need for an external server.

The systems demonstrated provide most of these features. They involve non-intrusive sensors with mountings that may be attached to objects on the roadside without disruption of traffic. Current models of the sensors themselves provide for installation with a minimum of field adjustment and for flexible data formats. Also, one system that was demonstrated utilized wireless communications technology currently under development for Caltrans to deliver data to a remote location; as this system is intended for use with the existing data collection system, it should be possible to use it to integrate data from semi-permanent sensors into existing traffic databases.

4. CANDIDATE SYSTEMS

Three basic types of portable data collection systems were tested. These were (*a*) temporarily-mounted systems intended for short-term use (deployed for less than two weeks), (*b*) semi-permanent systems installed in construction zones or similar situations and intended to provide traffic counts over a period of several months, and (*c*) systems intended to provide axle counts on a portable basis. The first two types of systems incorporated side-mounted microwave radar detectors and differed from one another primarily in terms of their power supplies and data transmission systems. The third type of system consisted of low-mounted infrared detector systems.

4.1 Temporarily-Mounted Systems

In the case of the temporarily-mounted systems, the major issue was the relative capabilities of different sensor models. Demonstration of these systems was scheduled first so that the most appropriate sensor could be selected for the demonstration of the semi-permanent system, where the major issue was the feasibility of data transmission from remote locations. All of the temporarily-mounted systems involved similar power-supply, data-download, and mounting systems. Power supply was provided by 12-volt storage batteries. Data were downloaded directly to a laptop computer located at the data collection site, using software provided by the sensor manufacturers. In order to provide a basis for evaluation of the performance of the sensors, event files (i. e., files recording the time and other characteristics of each vehicle detection) were downloaded during the demonstrations; in normal use, traffic counts aggregated over appropriate time intervals would be downloaded instead. Sensors were mounted by attaching them to metal poles that could then be clamped to sign posts, light standards, or other fixed objects on the roadside. Because the demonstrations included verification of the performance of the sensors, the equipment set-up also included a pan-tilt-zoom (PTZ) internet video camera attached to the sensor. This video camera was used to provide a visual record of the traffic flow.

A number of attachable pole-mounted systems similar to those used in these demonstrations have been developed by various state departments of transportation (Kotzenmacher, 2005). The initial system used in the demonstrations was developed independently by Caltrans District 11 personnel and consists of a single 10-foot long steel pole. This is attached to a sign post, light standard, or other fixed object by hose clamps, and is mounted so that the bottom of the pole is about 5 or 6 feet above the ground and the sensor about 15 to 16 feet above the ground. Two people are required to install the system. System installation includes attaching the pole, connecting all wiring, and initializing the sensor, and can normally be accomplished in about thirty minutes. Figure 1 shows the overall system after it was mounted.

In the course of the demonstrations, it was decided to experiment with higher mounting heights, requiring two 10-foot poles to be attached to one another. In order to reduce the weight of the poles, it was decided to substitute aluminum poles for the steel poles used originally. The later demonstrations used the aluminum poles in both single-pole and two-pole configurations. Also, District 11 personnel devised a way for one person to set up and tear down the aluminum pole versions. This method involves use of a ratcheting tie down to fasten the pole to the sign post or lamp standard initially. Once the pole is slid up into position and both hose clamps affixed, the tie down is removed (see Appendix A).

As originally planned, temporarily-mounted systems were to have incorporated three different types of sensor: Wavetronix SS-105, Wavetronix SS-125 (the so-called “HD” model), and EIS RTMS; however, the RTMS demonstration was cancelled because the manufacturer did not provide instructions for downloading event-file data. Both remaining types of sensors were evaluated for their ability to provide accurate counts in both non-congested and congested flow; in addition, the Wavetronix SS-125 sensor was evaluated for its ability to provide accurate vehicle length classification counts. The vehicle-length classification capabilities of the SS-105 were not evaluated because earlier research by Wald (2004a) had concluded that it did not provide sufficiently-accurate measurement of lane occupancy. This finding implies that the event durations for the detections are not accurate, and since vehicle length estimates for this sensor are derived

Figure 1 Attachable Pole Mounted Wavetronix SS-125 Sensor

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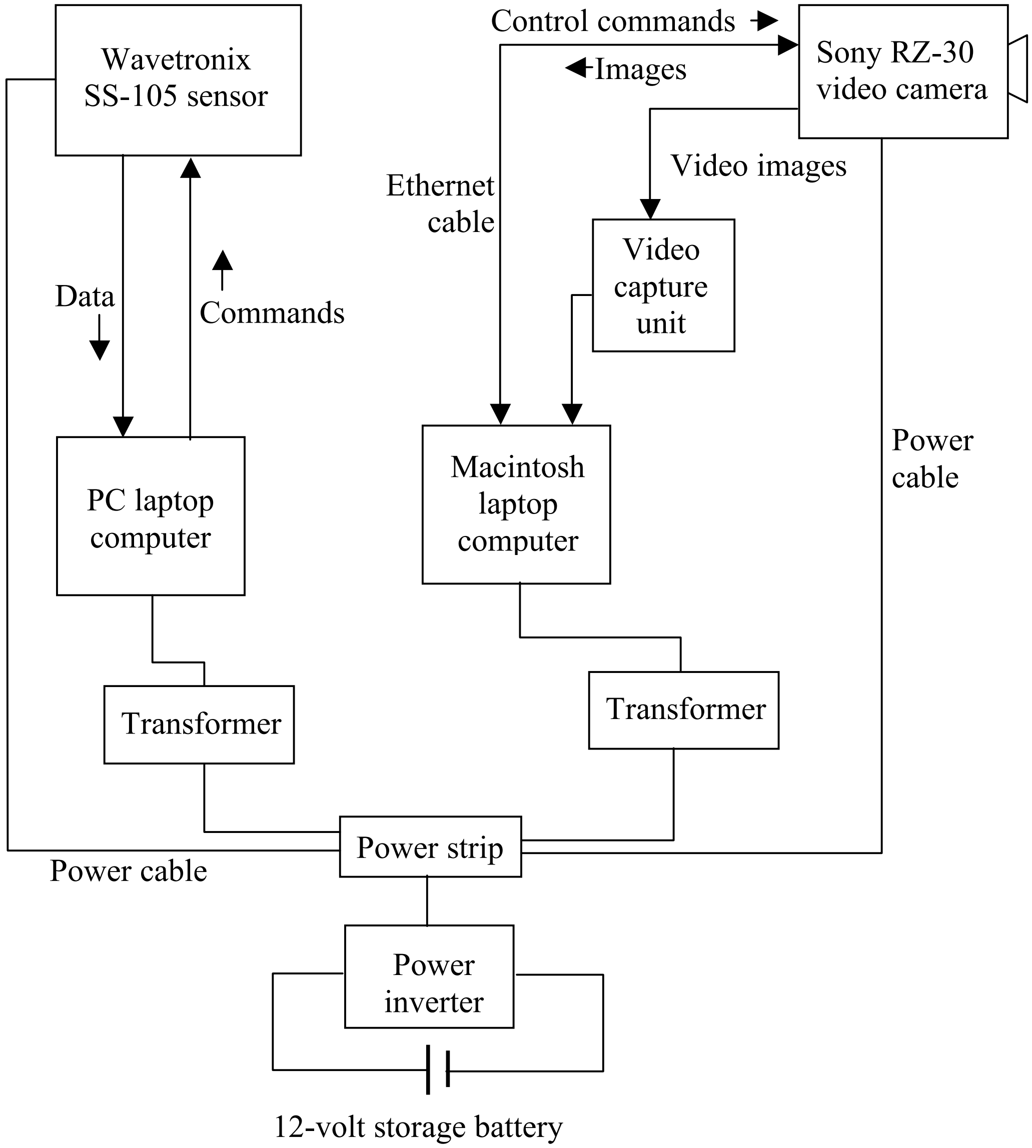
by multiplying the event duration by the estimated speed of the vehicle, the estimated vehicle lengths are not expected to be accurate either.

Figures 2 and 3 are schematic diagrams showing the wiring connections for both types of sensors used in the demonstration of temporarily-mounted systems. These diagrams include the PTZ video camera used to provide a visual record of the traffic flow.

4.2 Semi-Permanent System

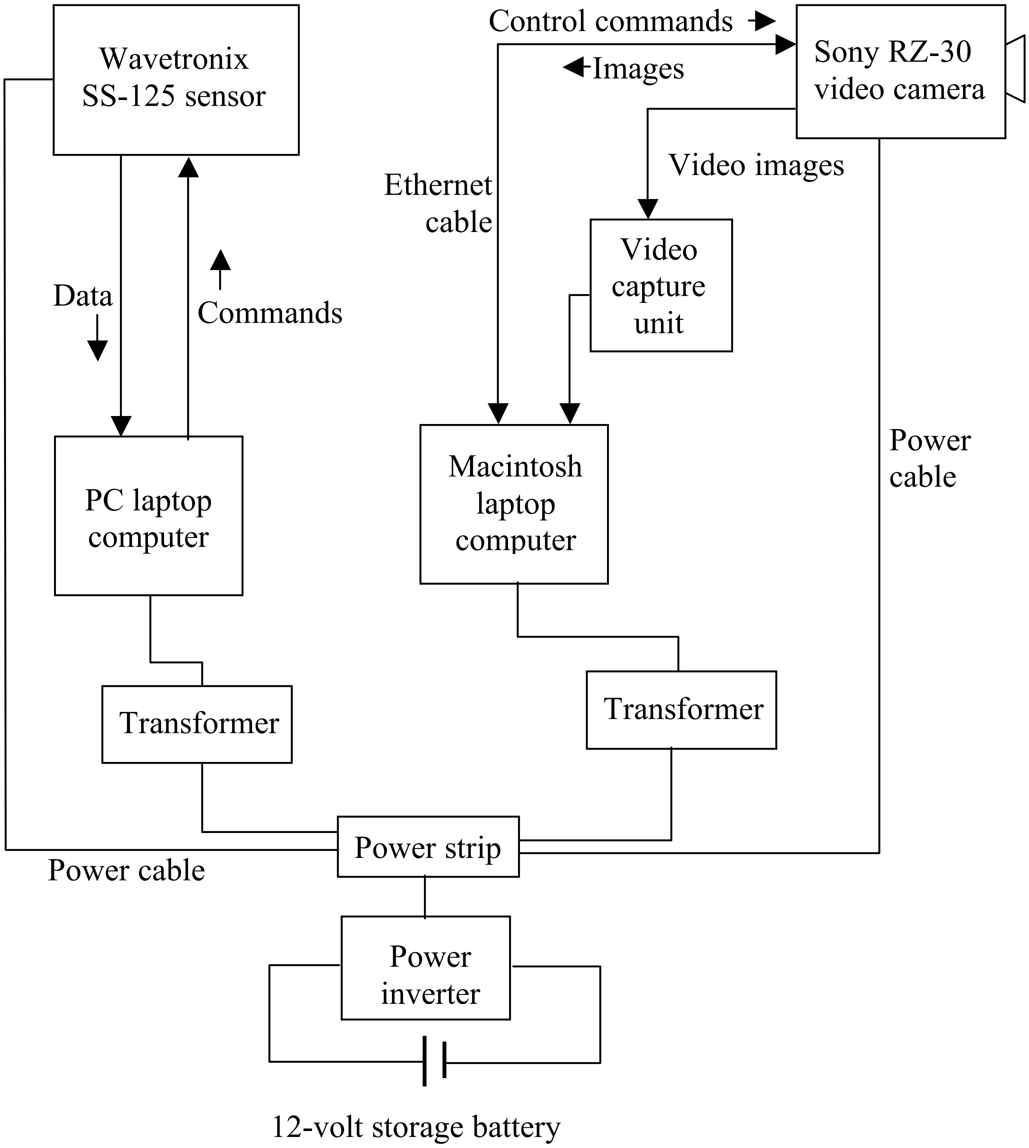
The major issues involved in the demonstration of the semi-permanent system were data transmission, accessibility of data via the internet, and compatibility of data with the formats of existing data bases. This demonstration made use of software developed by AstArt Synergistics for Caltrans for wireless transmission of traffic data. The AstArt software was primarily intended for use with permanent counter locations but was readily

Figure 2 Schematic Diagram of Wiring Connections for Wavetronix SS-105 Sensor Setup



adaptable for use with semi-permanent installations because the sensors and communications system are identical. The field portion of the test site incorporated a permanent traffic census installation. This installation included a wooden pole, two Wavetronix SS-125 sensors (only one of which was used for the demonstration), a permanent AC power supply, and an InfoTech Wizard provided by CommTech Services that served as a cellular modem. Although an AC power supply was used in this case, such systems may also be powered by storage batteries and solar collectors.

Figure 3 Schematic Diagram of Wiring Connections for Wavetronix SS-125 Sensor Setup



The semi-permanent system also required data transmission via the cellular telephone system and a server running Ramp Meter Information System (RMIS) software developed by AstArt Synergistics. For purposes of the demonstration, the server was a Dell Latitude D820 laptop computer; however, any computer with a Pentium 4 processor operating at 3 gigahertz or better, at least 1 gigabyte of RAM, and 40 gigabytes or more of hard drive could have been used. Figures 4 through 7 show the field installation and server; Figure 8 is a schematic diagram showing the wiring and wireless transmission links for the semi-permanent system.

Figure 4 Overall View of Semi-Permanent System Field Installation

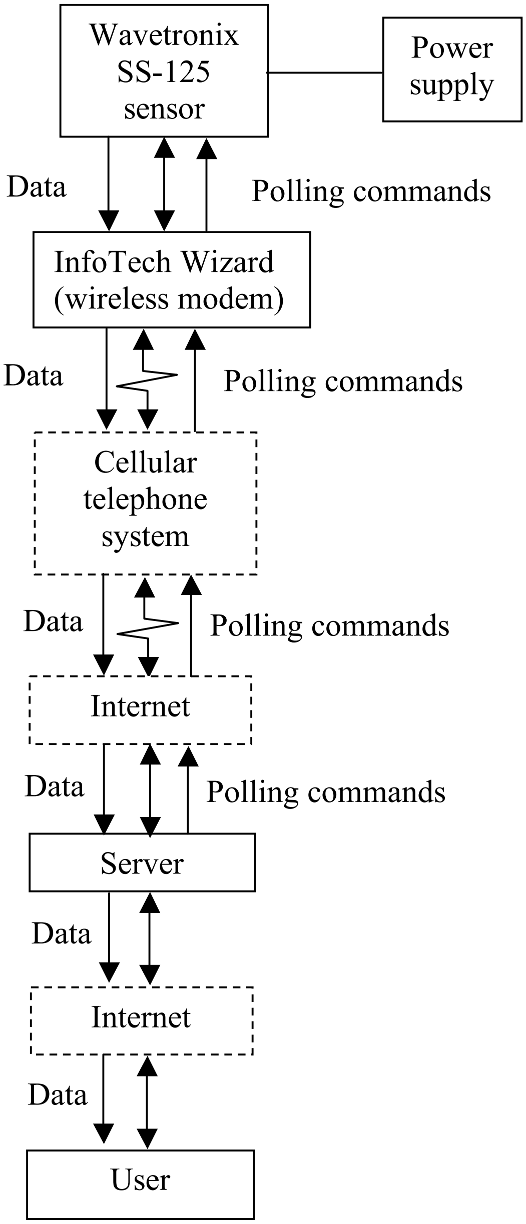
Figure 5 Sensor Used for Semi-Permanent System

Figure 6 Power Supply and Cabinet Used for Semi-Permanent System

Figure 7 Server for Semi-Permanent System

The initial data-collection site was District 11 Headquarters; however, the study team was unable to access the data from outside the Caltrans network because access was blocked by the Caltrans network's firewall system. Consequently, the sensor and wizard were moved to AstArt's offices for the rest of the test.

Figure 8 Schematic Diagram of Semi-Permanent System



4.3 Axle-Counting Systems

There are least two low-mounted infrared sensors on the market that feature axle-counting capabilities. The first of these is a device known as The Infra-Red Traffic Logger (TIRTL). TIRTL is an interrupted beam system; consequently it requires installation of separate transmitter and receiver units on opposite sides of the roadway. The Minnesota Department of Transportation and Caltrans District 7 have both conducted tests of this system. Minnesota found it generally satisfactory, but District 7 noted problems with a look-up table used for vehicle classification. District 7 planned an additional demonstration of TIRTL once this problem was resolved, with a representative of the study team present to observe. To date, however, this demonstration has not been scheduled.

The other axle-counting system considered is the Quixote Corporation (formerly Peek Traffic) AxleLight. AxleLight is a reflected-beam infrared system. It is possible to count vehicles with a single unit, but axle counts require two units mounted about 8.5' apart. The sensors are placed on the ground and their metal bases are strapped to guardrail posts. The sensors require a 12-volt battery as a power source and an automatic data recorder (ADR) to log the data. Figure 9 shows the setup used for classification counts. Quixote representatives conducted a demonstration of the AxleLight system in Los Angeles from September 25 through 27, 2007; a representative of the study team for this project was present to observe the initial setup of the system on September 25.

Figure 9 Dual AxleLight Units Set Up to Perform Vehicle Classification Counts

5. FIELD DEMONSTRATIONS

Field demonstrations were intended to evaluate the practicality of the candidate systems and the performance of the sensors used in them. Demonstrations were held at a number of sites in the San Diego and Los Angeles areas. Sites 1 – 3 were used for temporarily-mounted microwave radar sensor installations, site 4 was used for a semi-permanent microwave radar installation, and site 5 (in Los Angeles) was used for a demonstration of an axle-counting infrared sensor. The locations and characteristics of these sites are documented in Table 1. These sites were chosen to provide a safe working environment (including off-shoulder parking), the necessary objects for mounting the portable data collection devices, and a variety of traffic conditions. Site 1 was chosen primarily for its convenience, since it is close to Caltrans District 11 Headquarters; sites 2 and 3 were chosen because they experience congested traffic. In addition, site 3 includes a cut slope just north of the site that could be used as a vantage point for a camcorder that was used to provide a second video clip of the traffic. Since this was shot from slightly above the roadway and at an angle to it, it could be used to determine whether vehicles were hidden behind trucks in the primary video clip. Site 4 was a pre-existing traffic census site chosen by Caltrans District 11 staff and Site 5 was chosen by the Caltrans District 7 staff involved in setting up that demonstration; its primary advantage was that it is the site of a permanent axle-counting station utilizing an ADR6000 recorder attached to induction loop detectors.

Table 1 Demonstration Sites

Site	Location	Lanes	Mounting object
1	I-8 WB, Rosecrans Ave. on-ramp	2 ramp + 3 main	Sign post
2	I-15 SB, between Balboa Ave. and Aero Dr.	4 main + 1 Auxiliary	Sign post
3	I-805 SB, just south of Nobel Dr. on-ramp junction	4 main + 1 Auxiliary	Lamp standard
4	I-5 NB, just south of junction with I-805	4 main	Wooden pole
5	U.S. 101 NB, just south of Echo Park Avenue	4 main	Guardrail

Table 2 summarizes all planned field demonstrations. This table gives the status of all tests, including the dates and locations of those actually accomplished. Note that three of the demonstrations were cancelled. Reasons for these cancellations are discussed in Sections 5.1 and 5.3.

5.1 Temporarily-Mounted Systems

As originally planned, demonstrations of temporarily-mounted systems were to have included evaluation of attachable pole-mounted systems incorporating three different types of sensors: Wavetronix SS-105, Wavetronix SS-125, and EIS RTMS. Demonstrations of the two Wavetronix sensors are described below. The demonstration

Table 2 Summary of Field Demonstrations

Type	Test	Date	Location
Temporarily-mounted	Wavetronix SS-105		
	Non-congested flow	3/29/07	Site 1
		4/26/07	Site 2
	Congested flow	4/26/07	Site 2
	Wavetronix SS-125		
	Non-congested flow	7/23/07	Site 3
		10/4/07	Site 3
	Congested flow	6/21/07	Site 3
		10/4/07	Site 3
		2/26/08	Site 3
	Vehicle classification	7/23/07	Site 3
		10/4/07	Site 3
	EIS RTMS		
	Non-congested flow	Canceled	Canceled
	Congested flow	Canceled	Canceled
Semi-permanent	Wavetronix SS-125	2/21/08-5/7/08	Site 4
Axle-counting	TIRTL	Canceled	Canceled
	Peek AxleLight	9/25/07-9/27/07	Site 5

of the RTMS sensor was eventually cancelled because the study team was unable to download the individual vehicle data needed to evaluate the sensor's performance.

According to documentation supplied by EIS, the RTMS will produce such data, but there were no instructions for downloading it. The demonstration was finally cancelled after repeated requests to EIS representatives failed to resolve this problem.

Demonstrations of temporarily-mounted systems were intended to evaluate the accuracy of the sensors, as set up and adjusted by Caltrans personnel, and to document and evaluate the process of setting up and tearing down the installations. In all cases, sensor evaluation was carried out by using VideoSync software supplied by Caltrans Division of Research and Innovation (DRI) to match vehicle records from the sensor's event file with vehicle images from the video clip.

5.1.1 Wavetronix SS-105 Sensor, Non-congested Traffic

This demonstration involved using a Wavetronix SS-105 sensor to count non-congested traffic. The sensor, along with a PTZ video camera, was mounted on a portable pole that was clamped to a sign post. Two field installations were involved, one on March 29, 2007 at site 1 and a second (also involving congested flow) on April 26 at site 2. Data were reduced for two 5-minute periods on March 29 and two 5-minute periods on April 26. Results are summarized in Table 3. These results indicate that under non-congested conditions, the SS-105 sensor performed with accuracy that is comparable to that previously observed by Wald (2004a) at permanent installations. It should be noted, however, that for this demonstration the only video available was that from the camera mounted on the pole with the sensor; consequently, there may have been some missed detections that were not counted because the vehicles were hidden behind large vehicles, and conversely, some of the false detections recorded may have actually been successful detections of vehicles not visible on the video. If either were the case, the tendency for the sensors to undercount may be slightly greater than that shown in Table 3.

Table 3 Wavetronix SS-105 Sensor Verification in Non-Congested Traffic

Date	Period	Successful detections	Missed detections	False detections	Sensor count/ video count
3/29/07	36:57-41:57	349	8	8	1.000
3/29/07	41:57-46:57	348	6	5	0.997
4/26/07	00:00-05:00	640	14	9	0.992
4/26/07	05:00-10:00	678	24	13	0.984

5.1.2 Wavetronix SS-105 Sensor, Congested Traffic

This demonstration involved using a Wavetronix SS-105 sensor to count congested traffic. This field demonstration was held in conjunction with the second half of the non-congested-flow demonstration described in Section 5.1.1 on April 26, 2007 at site 2. Data were reduced for three 5-minute periods. Results are summarized in Table 4. Sensor accuracy for this demonstration was comparable to that for non-congested flow, indicating that there was no apparent deterioration in sensor accuracy in congested traffic. As in the case of non-congested flow demonstration, the only video available was that shot from the camera on the pole, so that there may have been more missed vehicles and fewer false detections than recorded. It should also be noted that no recalibration of the sensor was required: the unit was set up prior to the beginning of congested flow, the data for non-congested flow were collected, and then the sensor was turned off and turned back on at the beginning of congested flow.

5.1.3 Wavetronix SS-125 Sensor, Non-congested Traffic

This demonstration was held on July 23, 2007 at site 3 and involved use of a Wavetronix SS-125 (HD) sensor to count non-congested traffic. The original plan had been to conduct this demonstration in conjunction with the congested-flow test on June 21, 2007.

Table 4 Wavetronix SS-105 Sensor Verification in Congested Traffic

Date	Period	Successful detections	Missed detections	False detections	Sensor count/ video count
4/26/07	00:00-05:00	661	11	14	1.005
4/26/07	05:00-10:00	534	19	12	0.987
4/26/07	10:00-15:00	618	12	12	1.000

Because of delays in getting the equipment set up, however, traffic was already congested by the time the sensors were turned on. The results of the June 21 demonstration showed that the sensor was missing detections when vehicles in the inner three lanes were positioned side-by-side as they passed the sensor. Because the Caltrans personnel involved in the demonstrations suspected that this might be the result of too low a mounting height, the sensor and the PTZ video camera were mounted on a 20’ portable pole (as opposed to the 10’ pole used previously) clamped to a lamp standard. This raised the height of the sensor from the 15’ to 16’ level used in the previous tests to a little less than 20’. For this demonstration two videos were used: the one produced by the PTZ camera mounted on the pole with the sensor and a second video shot with a camcorder at an angle to the roadway. This second video was used to identify vehicles that were hidden behind large vehicles in the primary video. Data were reduced for two 5-minute periods.

Results are summarized in Table 5. Results in Table 5 indicate that the SS-125 sensor performed significantly worse in non-congested traffic than the older-model SS-105 sensor; also performance of this sensor at the higher mounting height was significantly worse than it had been when counting congested traffic in demonstration 4. Detection rates were between 50% and 60%, and the rate of detection was similar in all lanes, in contrast to experience in demonstration 4. Also, it was noted that the missed detections seemed to come in waves: almost all vehicles would be detected for a period of a few seconds, followed by a period in which almost all vehicles were missed.

Table 5 Wavetronix SS-125 Sensor Verification in Non-Congested Traffic, Initial Test

Date	Period	Successful detections	Missed detections	False detections	Sensor count/ video count
7/23/07	00:00-05:00	271	203	4	0.580
7/23/07	05:00-10:00	301	270	6	0.538

There was concern that the unsatisfactory performance of the SS-125 sensor in the initial test might have been the result of a bad sensor unit. To address this concern, tests of this sensor for non-congested flow, congested flow, and vehicle classification were repeated on October 4, 2007. Prior to this test, Wavetronix updated the firmware for the sensor; also, Wavetronix representatives were present at the test to verify that the sensor was properly installed.

These tests were held at site 3. The sensor was mounted on the 10’ pole, so that its height was approximately 15’ to 16’. As in the previous tests at site 3, a second video was shot at an angle to the roadway to provide limited visibility of areas hidden behind vehicles in the primary video.

For this test, data were reduced for a single period of more than 18 minutes. Results are summarized in Table 6. In this test, the sensor performed much better than in the previous one, with overall accuracy similar to that of the SS-105 sensor. Accuracy was similar for all lanes, with sensor-count-to-video-count ratios ranging from 0.95 to 0.98.

Table 6 Wavetronix SS-125 Sensor Verification in Non-Congested traffic, Second Test, October 4, 2007

Date	Period	Successful detections	Missed detections	False detections	Sensor count/ video count
10/4/07	00:00-18:34	1902	82	24	0.971

5.1.4 Wavetronix SS-125 Sensor, Congested Traffic

The initial test for this demonstration, which involved using a Wavetronix SS-125 (HD) sensor to count congested traffic, was held on June 21, 2007 at site 3. In this test, the sensor, along with the PTZ video camera, was mounted on a portable pole at a height of about 15’ to 16’. As in other tests at site 3, a second video, shot an angle to the roadway, was used to identify vehicles that were hidden behind large vehicles in the primary video. Data were reduced for two 5-minute periods.

Results are summarized in Table 7. These results indicate that the SS-125 sensor performed significantly worse in congested traffic than did the older SS-105 model. In particular, the manufacturer’s claims that it is better at detecting occluded vehicles do not appear to be accurate. The site in question consists of four main lanes plus an auxiliary lane connecting an on-ramp to an off-ramp, for a total of 5 lanes. Most of the missed detections were in the three inner lanes (that is, those farthest from the sensor). In numerous cases it was observed that the sensor failed to detect vehicles that were traveling side-by-side in these lanes, even when both vehicles were clearly visible in the video shot by the camera mounted with the sensor. In addition, there were a number of vehicles visible in the secondary video that were hidden behind large vehicles in the primary video; a few of these were successfully detected, but most were not. Finally, it was observed that in some cases the times of detection of large vehicles lagged the times these vehicles appeared in the video, and that in some cases, this led to a failure to detect vehicles immediately behind the large vehicle.

As in the case of the non-congested flow demonstration, this test was repeated on October 4, 2007 at site 3 with new sensor firmware and Wavetronix representatives present to verify that the sensor was properly installed. As in the previous case, the sensor was mounted at a height of approximately 15’ – 16’, and a secondary video was shot at an

Table 7 Wavetronix SS-125 Sensor Verification in Congested Traffic, Initial Test

Date	Period	Successful detections	Missed detections	False detections	Sensor count/ video count
6/21/07	00:00-05:00	596	69	5	0.903
6/21/07	05:00-10:00	560	81	10	0.887

angle to the road to provide limited visibility for areas hidden by vehicles in the primary video.

As had been the case in the previous test, data were reduced for two five minute periods. Results are given in Table 8. As the Table 8 shows, results were roughly the same as in the previous test, and still significantly worse than those for the SS-105 sensor. As in the previous SS-125 test, results were worst in the lanes farthest from the sensor, and the same specific problems were observed (particularly the occasional failure to detect vehicles traveling side-by-side).

Table 8 Wavetronix SS-125 Sensor Verification in Congested Traffic, Second Test, October 4, 2007

Date	Period	Successful detections	Missed detections	False detections	Sensor count/ video count
10/4/07	03:40-08:40	619	81	4	0.890
10/4/07	08:40-13:40	641	75	18	0.920

Wavetronix representatives requested that a third test be held, stating that they believed that they could improve the sensor’s performance in congested traffic by adjusting some of the settings. The third test was held at site 3 on February 26, 2008. For this test, Wavetronix provided a different unit and had representatives present to help set up the sensor. For this test the sensor was mounted at a height of approximately 18’.

As in the previous test, data were reduced for two 5-minute periods. Results are summarized in Table 9. Comparison of Table 8 with Table 9 shows that the missed detection rate was lower in the February 26 test than in the October 4 test but the false detection rate was considerably higher. Because the missed detections and false detections tended to cancel one another out, the overall accuracy was somewhat better. Missed detections tended to occur under the same conditions as before (when vehicles were traveling side-by-side, particularly in the lanes farthest from the sensor), but seemed to be more concentrated in periods of extreme congestion, especially at times when some vehicles were actually stopped. One type of false detection was much more commonly observed in this test than in the previous ones. This occurs when the detection of a single vehicle is dropped briefly and then resumed, thus registering as two vehicles.

Table 10 shows a breakdown of results by lane and time period. Note that in this table lanes are numbered from left to right in the direction of travel, so that lane 1 is the lane

Table 9 Wavetronix SS-125 Sensor Verification in Congested Traffic, Third Test, February 26, 2008

Date	Period	Successful detections	Missed detections	False detections	Sensor count/ video count
2/26/08	00:00-05:00	610	39	24	0.977
2/26/08	05:00-10:00	622	62	24	0.944

nearest the median and farthest from the sensor. Table 10 shows that the Caltrans standard of 90 percent accuracy in all lanes is met in all but one case (lane 2 during time period 2) but that in several cases the standard is met only because the missed detections and false detections cancel out. Also, if the two time periods are combined, the ratio of sensor count to video count for lane 2 is only 0.875, which does not meet the standard. On the basis of these results, the performance of the SS-125 sensor is at best marginally acceptable and is still considerably worse than that of the older SS-105 sensor.

Table 10 Results for Individual Lanes, February 26, 2008 test

Period	Lane	Successful detections	Missed detections	False detections	Missed/ total count	False/ total count	Sensor count/ video count
00:00-05:00	1	133	16	10	0.107	0.067	0.959
	2	135	13	3	0.086	0.020	0.914
	3	117	5	6	0.041	0.049	1.008
	4	154	5	2	0.031	0.013	0.981
	5	63	0	0	0.000	0.000	1.000
05:00-10:00	1	145	18	18	0.110	0.110	1.000
	2	136	26	0	0.160	0.000	0.839
	3	131	9	4	0.064	0.029	0.964
	4	141	5	1	0.034	0.006	0.973
	5	69	4	1	0.055	0.013	0.959

5.1.5 Wavetronix SS-125 Sensor Used for Vehicle Classification

The initial test for this demonstration was conducted in conjunction with the initial test of the Wavetronix SS-125 in congested flow on July 23, 2007. Vehicle lengths recorded in the sensor event log were compared with vehicle lengths measured from the primary video clip using the VideoSync software. A Caltrans vehicle was run through the section in two different lanes to establish a scale for converting pixels in the video image into distance. VideoSync was then used to measure the lengths of 100 consecutive vehicles in lane 3. Table 11 summarizes the detailed results and Table 12 compares the vehicle length distributions as determined by the two methods. Table 12 shows that of the 60 vehicles measured by both methods, 49 (82 percent) were classified correctly, and that all of the incorrect classifications resulted from vehicles being estimated to be longer in the sensor measurement than in the measurements from the video. In general, there appear to be three types of error in the measurements: 1) Random errors, which may apply to both methods; 2) bias between the two methods, in which vehicle lengths as determined from the video were on the average shorter than those determined by the sensor; these errors

Table 11 Results of Vehicle Length Comparisons, Wavetronix SS-125 Sensor vs. Measurements from Video, July 23, 2007 Test

	Video							
Sensor	0’ – 20’	20’ – 40’	40’ – 60’	>60’	Not measured	False detection	Total	Pct.
0’ – 20’	41	0	0	0	0	1	42	41.6
20’ – 40’	8	4	0	0	1	0	13	12.9
40’ – 60’	0	1	0	0	0	0	1	1.0
> 60’	0	0	2	4	0	0	6	5.9
Not detected	29	5	0	3	2	0	39	38.6
Total	78	10	2	7	3	1	101	100.0
Pct.	77.2	9.9	2.0	6.9	3.0	1.0	100.0	

Table 12 Comparison of Vehicle Length Distributions, Wavetronix SS-125 Sensor vs. Measurements from Video, July 23, 2007 Test

Length class	Pct., from video	Pct., from sensor
0 – 20’	81.2	67.7
20’ – 40’	10.4	21.0
40’ – 60’	2.1	1.6
> 60’	7.3	9.7

could be due to the calibration of the sensor or errors in establishing the scale for the video measurements, or both; and 3) errors due to missed detections and vehicles whose length could not be measured from the video because they were only partially visible; since the rate of missed detections was quite high in this demonstration, most of this type of error was probably due to the sensor’s failure to detect all the vehicles.

The vehicle classification functions of the Wavetronix SS-125 sensor were tested a second time on October 4, 2007 at site 3. This test was conducted in conjunction with the repetition of the sensor accuracy tests for that are described in Sections 5.1.3 and 5.1.4. Procedures were similar to those for the initial test, except that in this case it was possible to evaluate vehicle length classification for both congested and non-congested flow; also, in this case, the samples of 100 vehicles involved 25 consecutive vehicles from each of lanes 1 – 4, counting from the freeway median.

Tables 13 and 14 summarize the results for non-congested flow and congested flow respectively. Tables 15 and 16 compare the vehicle length distributions. Note that

Table 13 Results of Vehicle Length Comparisons, Wavetronix SS-125 Sensor vs. Measurements from Video, October 4, 2007 Test, Non-Congested Flow

	Video							
Sensor	0’ – 20’	20’ – 40’	40’ – 60’	>60’	Not measured	False detection	Total	Pct.
0’ – 20’	85	0	0	0	3	3	91	81.3
20’ – 40’	6	6	0	0	2	1	15	13.4
40’ – 60’	0	0	0	0	0	0	0	0.0
> 60’	0	0	0	3	0	0	3	2.7
Not detected	0	0	0	1	2	0	3	2.7
Total	91	6	0	4	10	4	112	100.0
Pct.	81.3	5.4	0.0	3.6	8.8	3.6	100.0	

Table 14 Results of Vehicle Length Comparisons, Wavetronix SS-125 Sensor vs. Measurements from Video, October 4, 2007 Test, Congested Flow

	Video							
Sensor	0’ – 20’	20’ – 40’	40’ – 60’	>60’	Not measured	False detection	Total	Pct.
0’ – 20’	71	0	0	0	7	0	78	69.0
20’ – 40’	22	3	0	0	3	0	28	24.8
40’ – 60’	2	1	0	0	0	0	3	2.7
> 60’	1	0	0	0	0	0	1	0.9
Not detected	1	0	0	0	2	0	3	2.7
Total	97	4	0	0	12	0	101	100.0
Pct.	85.5	3.5	0.0	0.0	10.6	0.0	100.0	

Table 15 Comparison of Vehicle Length Distributions, Wavetronix SS-125 Sensor vs. Measurements from Video, October 4, 2007 Test, Non-Congested Flow

Length class	Pct., from video	Pct., from sensor
0 – 20’	90.1	83.5
20’ – 40’	5.9	13.0
40’ – 60’	0.0	0.0
> 60’	4.0	2.8

Table 16 Comparison of Vehicle Length Distributions, Wavetronix SS-125 Sensor vs. Measurements from Video, October 4, 2007 Test, Congested Flow

Length class	Pct., from video	Pct., from sensor
0 – 20’	96.0	70.9
20’ – 40’	4.0	25.5
40’ – 60’	0.0	2.7
> 60’	0.0	0.9

because the four leftmost lanes were included, as opposed to lane 3 only, the percentage of vehicles less than 20’ in length was much higher than in the July 23 test. In non-congested flow, the results were slightly better than those of the July 23 test, especially in that the rate of missed detections was much lower. Of the 100 vehicles classified by both methods in the October 4 test, 94 percent were classified correctly; this compares with 82 percent classified correctly in the previous test. As in the previous test, most discrepancies resulted from vehicles being estimated to be longer in the sensor measurement than in the measurements from the video.

In congested flow, the accuracy of the classifications was considerably lower. Of the 100 vehicles classified by both methods, only 74 percent were classified correctly. Once again, there was a tendency for the sensor to overestimate vehicle length. The majority of such cases involved vehicles being placed in class 1 (0’ – 20’) on the basis of the video measurements but in class 2 (20’ – 40’) on the basis of the sensor measurement; however, in a few cases the discrepancy was much greater. Most of the cases with large discrepancies were observed to occur when there were vehicles in different lanes than were close to each other; in these cases, the sensor sometimes failed to drop one of the detections when the vehicle passed, and consequently overestimated the length of that vehicle.

Vehicle length classification was not considered directly in the second retest of the Wavetronix SS-125 sensor held on February 26, 2008. However, the tendency to sometimes hold detections too long (thus distorting the vehicle length determination) was observed to persist in this test.

5.2 Semi-Permanent Installation

Equipment involved in the semi-permanent installation demonstration included a Wavetronix SS-125 sensor and an InfoTech Wizard wireless modem installed in the field and a Dell laptop computer that was used as a server. This equipment was activated on February 21, 2008. Initially, the server was located at Caltrans District 11 headquarters and was connected to the cellular telephone service through the Caltrans network. Because it was not possible to access the data from off-site due to firewall issues with the Caltrans network, the server was moved on March 6 to the offices of AstArt Technologies, which had developed the polling software being used and was cooperating in the demonstration. On March 30, the power to the sensor failed. This was not discovered until April 11. Upon investigation by Caltrans staff, it was discovered that the main circuit breaker for the sensor site was tripped. Power was restored on April 16, and transmissions resumed. Inspection of the data revealed that there were comparatively few successful transmissions, that there were many duplicate data transmissions and that the timestamps being transmitted by the sensor did not match the times of transmission recorded by the server. On April 23 and 24, Caltrans staff attempted to reset the sensor clock and increase the baud rate; however, this resulted in protocol errors on almost all transmission attempts and did not correct the timestamp problem. Further investigation, including bench testing of the various components, was carried out in an attempt to determine the source of the failure; possible candidates included the sensor, the modem, and the interaction between the modem and the cellular telephone system. These investigations ultimately proved to be inconclusive and the test was terminated on May 7 when the CommTech representative removed the modem and terminated support of the test.

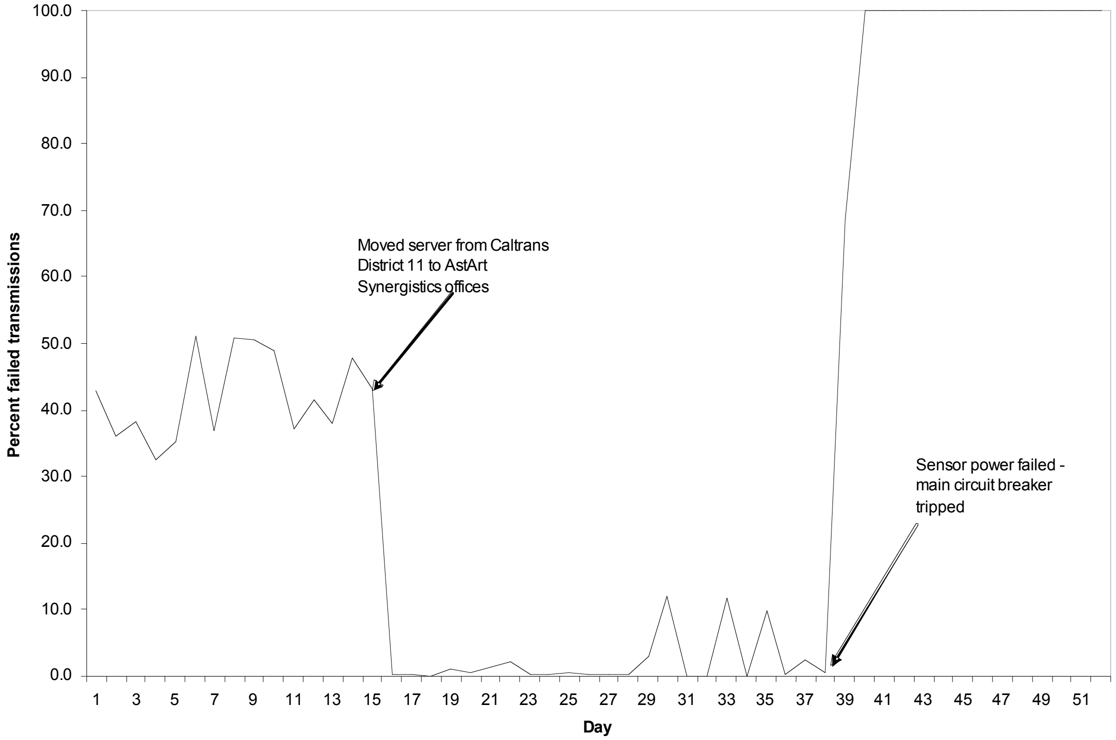
Table 17 summarizes the daily failed transmission rates for the period February 21 through April 12. Figure 10 presents the same data in graphical form. As may be seen, there was a high rate of failed transmissions from the beginning of the test until the server was moved to AstArt’s offices on March 6. During this period daily transmission failure rates ranged from about 35 to 52 percent. These failures formed no clear time-of-day pattern, although they were perhaps a little less frequent at night in most cases. Although their cause is not known with certainty, it appears to be related to the characteristics of the Caltrans network, since they ceased as soon as the server was transferred to AstArt’s network. One conjecture is that because a public cellular connection was being used, the transmissions were being routed through Caltrans’ statewide network and were failing due to a lack of sufficient bandwidth.

Table 17 Transmission Failure Rates for Semi-Permanent Installation

Date	Total polling intervals	Failed transmissions	Transmission failure rate	Date	Total polling intervals	Failed transmissions	Transmission failure rate
2/21/08	1554	666	42.9	3/18/08	2880	5	0.2
2/22/08	2880	1035	35.9	3/19/08	2880	4	0.1
2/23/08	2880	1102	38.3	3/20/08	2880	85	3.0
2/24/08	2880	935	32.5	3/21/08	2880	346	12.0
2/25/08	2880	1017	35.3	3/22/08	2880	2	0.1
2/26/08	2880	1469	51.0	3/23/08	2880	2	0.1
2/27/08	2880	1060	36.8	3/24/08	2880	339	11.8
2/28/08	2880	1462	50.8	3/25/08	2880	1	0.0
2/29/08	2880	1455	50.5	3/26/08	2880	284	9.9
3/1/08	2880	1406	48.8	3/27/08	2880	5	0.2
3/2/08	2880	1072	37.2	3/28/08	2880	72	2.5
3/3/08	2880	1196	41.5	3/29/08	2880	12	0.4
3/4/08	2880	1096	38.1	3/30/08	2880	1977	68.6
3/5/08	2880	1377	47.8	3/31/08	2880	2880	100.0
3/6/08	2132	920	43.2	4/1/08	2880	2880	100.0
3/7/08	2880	5	0.2	4/2/08	2880	2880	100.0
3/8/08	2880	6	0.2	4/3/08	2880	2880	100.0
3/9/08	2880	2	0.1	4/4/08	2880	2880	100.0
3/10/08	2880	27	0.9	4/5/08	2880	2880	100.0
3/11/08	2880	11	0.4	4/6/08	2880	2880	100.0
3/12/08	2880	34	1.2	4/7/08	2880	2880	100.0
3/13/08	2880	64	2.2	4/8/08	2880	2880	100.0
3/14/08	2880	8	0.3	4/9/08	2880	2880	100.0
3/15/08	2880	3	0.1	4/10/08	2880	2880	100.0
3/16/08	2880	14	0.5	4/11/08	2880	2880	100.0
3/17/08	2880	7	0.2	4/12/08	2880	2880	100.0

In any event, the performance of the system improved markedly once the server was moved to the AstArt network. For the first two weeks following the move, rates of failed transmissions were between zero and 3 percent, which is roughly comparable to the performance of land-line telephone systems. During the next week, however, there were three cases in which daily transmission failure rates were on the order of 10 percent. Investigation of the time-of-day patterns of failures on these days showed that most of them occurred in concentrated blocks of approximately 2.5 hours each. Once again, the cause of these failures is not known with certainty; however, the time pattern suggests that they may have resulted from maintenance activity related to the cellular telephone system. This period of relatively good performance ended with the power failure at approximately 7:30 a.m. on March 30. Following this, there were no successful transmissions until power was restored on April 16. Once power was restored, transmissions were sporadic (failure rates on the order of 80 percent) and the data were of questionable accuracy. This unsatisfactory performance persisted until the test was terminated on May 7.

Figure 10 Trend in Transmission Failure Rates, Semi-Permanent Installation



5.3 Axle-Counting System

As originally planned, field demonstrations of axle-counting systems were to have consisted of a demonstration of The Infra-Red Traffic Logger (TIRTL). Caltrans District 7 had conducted prior tests of this system and had noted problems with a look-up table used for vehicle classification. An additional demonstration was to be held once this problem was resolved, with a representative of the study team present to observe. Because this follow-up demonstration was never held, the TIRTL demonstration was deleted from this project.

In early 2007, Quixote Corporation (formerly Peek Traffic) announced the availability of its AxleLight system. A representative of Quixote's Southern California vendor was contacted in an attempt to schedule a demonstration in the San Diego area. Although it proved impossible to set up a demonstration in San Diego, one was held in Los Angeles for Caltrans District 7 on September 25-27, 2007; a representative from this project was able to observe the portion that took place on September 25. A report describing the demonstration and its results was prepared by Steve Malkson of District 7; this report is the source of part of the information reported here.

As described in Section 4.3, two AxleLight units are required for vehicle classification. On September 25, representatives of Quixote set up two units at site 5, intending to demonstrate both vehicle-counting and axle-counting capabilities; however, because one of the batteries failed only one unit could be operated. Consequently, on the first day vehicle counting only was demonstrated. A new battery was obtained and the second unit was activated of September 26 to demonstrate axle-counting. The units were removed on September 27. This resulted in 21 hours of volume-only data and an additional 23 hours of volume and classification data.

The site for this demonstration was chosen in part because there is a nearby ADR6000 station connected to induction loop detectors that can provide vehicle counts and vehicle classification data for purposes of comparison. Tables 18 through 20 present comparisons of the AxleLight and ADR6000 results for vehicle counts and vehicle classification.

Table 18 shows that the AxleLight sensor performed well for traffic counting. AxleLight counts vary about the ADR6000 counts; the maximum discrepancies in hourly counts across all lanes are about 10% and, overall, the AxleLight counts are approximately 2% less than the ADR6000 counts. This level of accuracy is comparable to the best-performing microwave radar sensors (e. g., the Wavetronix SS-105).

Tables 19 and 20, on the other hand, show that there are serious discrepancies in the vehicle classification counts, with 2-axle trucks undercounted by AxleLight, 5-or-more-axle trucks over counted, and 3- and 4-axle trucks seriously over counted. Figure 11 shows how the ADR6000 and AxleLight counts vary over time; from this figure it is readily apparent that the results for the two sensors are virtually identical during late night and early morning hours when traffic volumes are light, but diverge significantly during periods when there is heavy traffic. From this, it appears that under heavy volume conditions, AxleLight may be mistaking closely-following two-axle vehicles for multi-axle trucks.

6. EVALUATION OF CANDIDATE SYSTEMS

Candidate systems were evaluated in terms of their accuracy, practicality, and cost. Detailed cost estimates (including the assumptions used in cost calculations) may be found in Appendix B. Results are as follows.

6.1 Temporarily-Mounted Systems

6.1.1 Accuracy

Temporarily-mounted systems incorporating the Wavetronix SS-105 and SS-125 sensors were demonstrated. The accuracy of the older SS-105 sensor was satisfactory; however, that of the newer SS-125 sensor was at best marginal when deployed at sites with wide roadways, especially during periods of congestion. In all cases, the majority of the counting errors were for the lanes farthest from the sensor. This suggests that temporarily-mounted systems involving side-mounted microwave radar sensors may be most appropriate for roadways of one or two lanes, such as freeway ramps. In the case of wider roadways, accuracy may be satisfactory, but it would probably be wise to verify accuracy in the field. Where counts are expected to include periods of congestion, it is especially important that sensor accuracy be verified under congested conditions. Other

Table 18 Comparison of ADR6000 and AxleLight Counts

Date	Hour	ADR6000	AxleLight	AxleLight/ADR6000
9/25/07	13:00	7,215	6,776	0.939
	14:00	7,299	6,848	0.938
	15:00	6,240	6,549	1.050
	16:00	6,043	6,624	1.096
	17:00	5,741	6,290	1.096
	18:00	6,668	6,866	1.030
	19:00	6,324	6,671	1.055
	20:00	6,666	6,001	0.900
	21:00	6,000	5,350	0.892
	22:00	5,305	4,757	0.897
	23:00	3,206	2,924	0.912
	00:00	1,968	1,883	0.957
9/26/07	01:00	1,356	1,328	0.979
	02:00	1,198	1,185	0.989
	03:00	1,356	1,186	1.107
	04:00	1,756	1,867	1.063
	05:00	5,033	5,099	1.013
	06:00	7,198	7,143	0.992
	07:00	7,140	7,716	1.081
	08:00	7,260	7,451	1.026
	09:00	6,986	6,726	0.963
	10:00			
	11:00	6,869	6,598	0.957
	12:00	7,062	6,855	0.971
	13:00	6,926	6,686	0.965
	14:00	6,795	6,613	0.973
	15:00	7,369	7,048	0.956
	16:00	7,333	7,068	0.964
	17:00	6,720	6,425	0.956
	18:00	6,662	6,330	0.950
	19:00	6,623	5,994	0.905
	20:00	6,733	6,520	0.968
	21:00	6,188	6,012	0.972
	22:00	5,812	5,681	0.977
	23:00	3,296	3,655	1.109
	00:00	2,181	2,185	1.002
9/27/07	01:00	1,417	1,420	1.002
	02:00	1,205	1,212	1.006
	03:00	1,135	1,153	1.016
	04:00	1,778	1,777	0.999
	05:00	4,970	4,862	0.978
	06:00	7,285	7,020	0.964
	07:00	7,600	7,151	0.941
	08:00	6,938	6,750	0.973
	09:00	7,155	6,891	0.963
	Total	233,752	229,146	0.980

Table 19 Comparison of ADR6000 and AxleLight Vehicle Classification Counts

Vehicle Class	ADR6000	AxleLight	AxleLight/ADR6000
1	568	2,804	4.937
2	104,636	99,146	0.948
3	14,405	11,066	0.768
4	260	952	3.662
5	3,486	2,105	0.604
6	424	1,513	3.568
7	14	228	16.286
8	585	1,527	2.610
9	1,532	1,760	1.149
10	19	247	13.000
11	108	69	0.639
12	10	32	3.200
13	0	177	
14	0	0	
15	32	280	8.750
Total	126,079	121,900	0.967

Table 20 Comparison of ADR6000 and AxleLight Truck Classification Counts

Truck type	ADR6000	AxleLight	AxleLight/ADR6000
2-Axle	3,746	3,057	0.816
3-Axle	717	2,277	3.177
4-Axle	307	992	3.235
5+-Axle	1,669	2,285	1.337
Total trucks	6,438	8,610	1.383

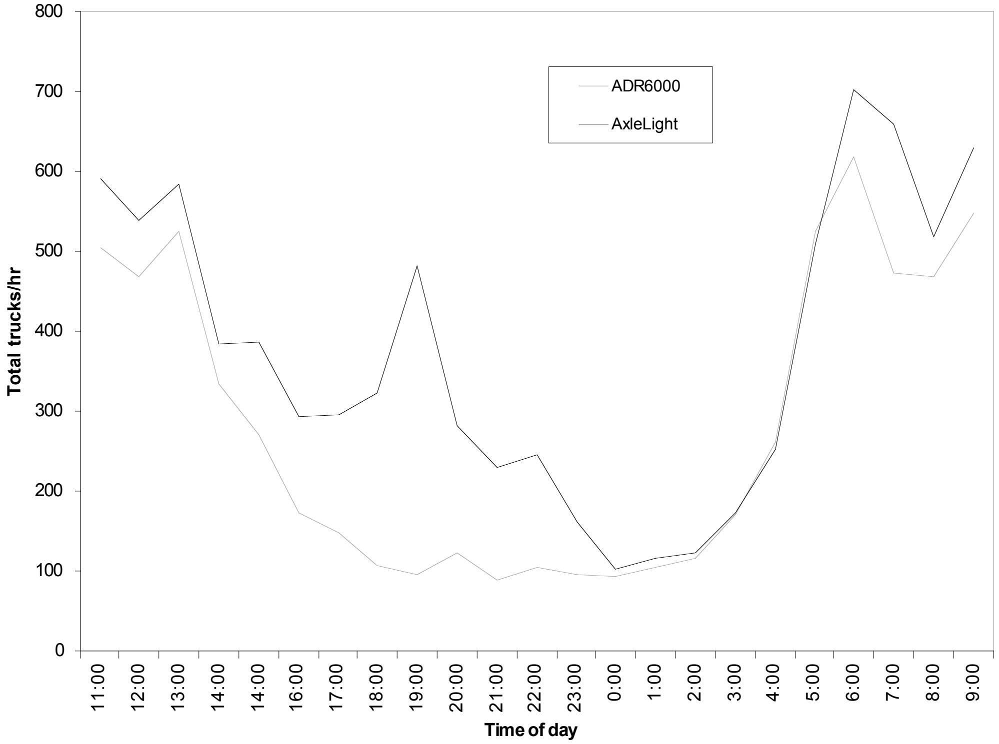
types of sensors, such as the EIS RTMS sensor, were not tested; consequently, their accuracy cannot be evaluated.

6.1.2 Practicality

Installation of temporarily-mounted systems is feasible under a wide variety of conditions. Issues related to the practicality of such systems include mounting systems, power supply, and provisions for downloading data.

Several different mounting systems are available. The simplest of these is the attachable pole-mounted system used in the demonstrations. This system can be used at any location where there are suitable objects such as sign posts of lamp posts to which the poles can be attached. The entire installation process can be accomplished by one person if necessary (see Appendix A for detailed instructions for one- and two-person installation processes) and normally takes about 30 minutes. It is probably prudent, however, to allow at least an hour for the setup process to provide for resolution of any unexpected

Figure 11 Variation in ADR6000 and AxleLight Truck Counts with Time of Day



difficulties. In the case of the demonstrations, the most uncertain part of the process was establishing connectivity for all the necessary components. This was especially true with regard to the video camera that was being used for count verification; where such cameras are not included, there should be less variation in the time required for installation. Tear-down and stowing of equipment can normally be accomplished in about 15 minutes.

Other mounting systems include pneumatic poles attached to either trailers or portable bases. The advantage of these systems is that they can be mounted where there are no suitable objects for attaching poles. Their major disadvantage is that they are more expensive. Also, it should be noted that an important limitation applying to any type of temporarily-mounted system is the need for safe and otherwise suitable areas for parking and work activities during installation. In many cases this may prove to be a more important restriction on the location of temporarily-mounted systems than is the availability of objects for attaching poles. Finally, there is some question about whether temporarily-mounted systems may violate clear-zone requirements if located in such areas. In the case of attachable poles, the breakaway or yield features of object to which the poles are attached are not altered, but the presence of the pole and sensor does alter the mass and center of gravity of the object; also, other objects commonly present, such as battery boxes, may constitute hazards (Kotzenmacher 2005).

Power supply for temporarily-mounted systems normally consists of 12-volt storage batteries. Because a range of amp-hour capacities is available, batteries exist that will allow systems to be operated without battery recharge for any period that would normally be considered "temporary."

Data from temporarily-mounted systems are usually downloaded directly to laptop computers in the field. Sensors allow for data to be stored for varying periods of time, so that it will normally be possible to collect all the data with a single download just prior to removing the system.

6.1.3 Cost

Costs of temporarily-mounted systems are largely dependent on the type of mounting system used and whether video count verification capability is included in the equipment package. The cost of attachable pole mounted systems is quite modest. Basic equipment for a single unit costs about $5,500 if video is not included and $7,200 if it is included. If equipment costs are amortized over 3 years assuming a 5 percent interest rate, a system that is deployed 20 times per year will cost about $190 per deployment if video is not included and $315 per deployment if it is. These costs include the cost of the labor required to deploy the system but do not include the costs of travel to the site. Acquisition costs for systems using pneumatic poles with portable bases are roughly 1.7 times those of attachable pole-mounted systems; however, because the cost of labor is similar for both systems, the cost per deployment for a system pneumatic pole system deployed 20 times per year is 1.4 times as great that of an attachable pole system if video is not included and only 1.3 times as great if video is included. Trailer-mounted systems cost 6 to 8 times as much as attachable pole mounted systems, and cost per deployment (again, assuming 20 deployments per year) is about 3 to 4 times as great.

6.2 Semi-Permanent Systems

6.2.1 Accuracy

Sensors used in semi-permanent systems are similar to those used in temporarily-mounted systems, and hence provide similar levels of accuracy. As in the case of temporarily-mounted systems, accuracy will normally be greatest for relatively narrow roadways and periods of non-congested flow.

6.2.2 Practicality

The demonstration showed that it is possible to provide satisfactory wireless transmission for data from semi-permanent installations under the proper conditions. It also showed, however, that there are can be problems with the reliability of such installations when conditions are not ideal. As a result, successful use of semi-permanent installations will require careful planning and involvement of personnel with extensive experience in wireless communications.

Reliability problems encountered in the demonstration included suspected network bandwidth problems, power supply problems, suspected problems with the interface between the modem and the cellular telephone system, and a possible sensor failure. In addition, it is reported that other projects involving wireless transmission of traffic data have encountered problems with the durability of system components.

One practical issue revealed by the demonstration is the importance of having relatively direct access to the server from the cellular telephone system. This may be provided by having a direct private cellular line as opposed to the public connection used in the demonstration. The demonstration showed that data transmission will not be reliable where public cellular connections are used in conjunction with Caltrans networks, presumably because of bandwidth limitations in the statewide Caltrans network.

A second practical issue revealed by the demonstration is that power supplies for semi-permanent traffic sensor installations are not always reliable even when they consist of AC current from the power grid; consequently, the performance of the system needs to be monitored frequently. In the case of the demonstration, the primary means of monitoring the system was by periodically downloading data from files that were posted to a web site several days after the actual data collection. This level of monitoring was inadequate and led to a delay of almost two weeks in the discovery that there had been a power failure.

A third practical issue illustrated by the demonstration was that interfaces between cellular modems and the cellular telephone network are not necessarily reliable and that location of the data-collection site relative to the nearest cell towers may be important. In the case of the demonstration, this failure of the modem-cellular system interface was only suspected, since it is also possible that the inability to restore communications following the power failure resulted from a sensor failure. Nevertheless, investigation did show that the cellular modem functioned properly when bench-tested at AstArt headquarters but not in the field. One possible explanation is that the location of the test site relative to the nearest cell towers was inappropriate. AstArt personnel reported that the site appeared to be equidistant to several cell towers and that this can lead to poor reception because the assignment of the signal to a tower can become unstable. At other sites, blockage of the signal by the terrain can be a problem. Consequently, feasible locations for semi-permanent installations may be limited by the location of cell towers.

A final practical issue related to semi-permanent installations has to do with the durability of components such as cellular modems, connectors, and antennas. Not all such components meet Caltrans’ Transportation Electrical Equipment Specifications (TEES). In configuring and setting up semi-permanent systems it is also important to note whether particular components merely meet the specifications for installation in a cabinet or are properly hardened for installation in the environment.

6.2.3 Cost

Costs of semi-permanent systems depend on the type of power supply (AC current or solar collectors) and whether or not a dedicated server is required to compile the traffic database. Because the usual motivation for installing a semi-permanent microwave radar system is to substitute for a loop detector station that is part of a traffic surveillance system, it will often be desirable to direct data transmissions to an existing server rather than providing a dedicated server for the semi-permanent installation. Where a dedicated server is not required, the initial cost of equipment for a system mounted on a wooden pole is about $7,400 if AC power is used and about $350 more if solar power is used. A computer meeting the minimum requirements for the server (see Section 4.2) can be purchased for $1,000 or less. Assuming a 3 year life for equipment, a 5 percent interest rate, and the ability to utilize all equipment continuously over its life, a semi-permanent system can be installed and operated for around $290 per month if a dedicated server is not required or about $320 per month if one is.

6.3 Axle-Counting Systems

6.3.1 Accuracy

The project included observation of a demonstration an axle-counting system consisting of a pair of Quixote (Peek) AxleLight low-mount infrared detectors. Results showed that vehicle classification based on this system was reasonably accurate for low-to-moderate traffic volumes but seriously inaccurate for heavy volumes. Consequently, it is not suitable for use at high-volume locations in its present state of development.

6.3.2 Practicality

The axle-counting system demonstrated is relatively easy to install, but its use is limited to locations where there is guardrail. Because of this feature, it may be difficult to find safe places to park vehicles during installation. In the case of the demonstration, this problem was avoided by accessing the site from outside the freeway right-of-way, but it is unlikely that this will be possible at all potential sites. Installation involves leveling the ground under the guardrail, installing and adjusting the height and direction of the detector units, connecting the detectors to the ADR, and connecting the detectors and the ADR to the power source. Judging from the demonstration, the basic setup process appears to require about 20 minutes; however, it was difficult to tell because there was a battery failure that necessitated considerable troubleshooting. The overall process of setting up the system and diagnosing the problem required nearly two hours.

6.3.3 Cost

Systems based on low-mounted infrared detector systems are about five to seven times more expensive than those based on microwave radar sensors. The TIRTL system costs about $25,000 per unit, and a Quixote (Peek) AxleLight system set up for axle counting (two AxleLight sensors plus a ADR1000 automatic data recorder) costs about $35,000.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

Demonstrations conducted as part of this project focused on three types of portable traffic data collection systems: temporarily-mounted microwave radar installations, semi-permanent microwave radar installations intended to serve as substitutes for loop detectors for periods of several months, and low-mounted infrared sensors intended to provide axle counts on a portable basis. The major conclusion is that although portable microwave radar systems are practical and potentially cost-effective for a number of traffic-data-collection tasks, problems with sensor accuracy and the reliability of wireless communications systems for semi-permanent systems are not fully resolved. Costs of such systems are modest, and there are practical off-the-shelf solutions to the issues of mounting, power supply, and data transfer. Major difficulties remain, however, in the areas of sensor accuracy (especially on wide roadways and/or in congested traffic) and communications reliability for semi-permanent systems. Meanwhile, axle-counting utilizing low-mounted infrared sensors appears to be feasible, at least under favorable conditions, but the technology involved is expensive and does not yet appear to be mature. A major concern is that side-mounted sensors (including both microwave radar and low-mounted infrared sensors) continue to have significant difficulty in distinguishing vehicles in the lanes farthest from the sensor, particularly under congested conditions.

More specific conclusions include the following:

7.1.1 Temporarily-Mounted Installations

1. Temporarily-mounted systems consisting of side-mounted microwave radar sensors may be easily assembled from readily-available components and are currently in use in a number of states. Mounting options for such systems include poles attached to existing roadside objects (sign posts, etc.) and portable pneumatic poles mounted on portable bases or trailers. Power supply is typically provided by storage batteries. Data are typically downloaded directly to laptop computers in the field.

2. Attachable pole mounted systems are significantly cheaper than are systems using pneumatic poles. Free-standing poles may offer more flexible sensor location, but the most important restriction on sensor location is the availability of safe areas to park and set them up; this restriction applies to both types of mounting. Trailer-mounted poles are much more expensive than the other options and appear to offer no real advantages.

3. Temporarily-mounted systems are practical and cost-effective for tasks involving count and speed data for individual lanes. They can also provide useful vehicle-length classification data where sensor accuracy is adequate. Such systems are normally not suitable for tasks such as turning-movement counts.

4. Sensor reliability remains a concern for side-mounted microwave radar sensors. Of the sensors tested, the Wavetronix SS-105 performed satisfactorily, but the performance of the newer Wavetronix SS-125 sensor was marginal at best for congested traffic and in the lanes farthest from the sensor.

5. Temporarily-mounted systems are most likely to provide accurate data for relatively narrow roadways (no more than two or three lanes) and non-congested flow.

7.1.2 Semi-Permanent Systems

1. Semi-permanent installations consisting of side-mounted microwave radar sensors, cellular communications systems, and power supply based on AC current or solar collectors are feasible. Indeed, most features of such systems (other than the details of the mounting system) resemble those of permanent radar sensor installations that are integrated into the wireless data communications system currently under development by Caltrans.

2. The accuracy of semi-permanent microwave radar units is similar to that of temporarily-mounted systems (since the same sensors are used). As in the former case, data are most likely to be accurate for relatively narrow roadways and under non-congested conditions.

3. Reliability of communications and power supply is a major concern for semi-permanent systems. Specific areas of concern related to reliability of communications include the interface between the cellular modem and the cellular telephone system and the routing of data from the cellular telephone system through computer networks. At present, the Caltrans statewide network does not appear to have adequate bandwidth to provide for reliable data transmission from public cellular links to traffic database servers connected to the network.

4. Location of semi-permanent installations may be limited by the geographical configuration of the cellular telephone system. The location of the traffic sensor installation relative to the nearest cell towers is of particular concern.

5. Because of the difficulty of providing reliable communications, the planning and installation of semi-permanent installations requires considerable expertise in wireless communications.

7.1.3 Axle-Counting Systems

1. Low-mounted infrared sensors may be useful for conducting axle-classification counts on a temporary basis. Prototypical systems are available and are currently being field tested.

2. Like other side-mounted systems, low-mounted infrared sensors are most accurate when used on relatively narrow roadways and under congested conditions.

Performance of Quixote (Peek) AxleLight sensors configured for axle counting was satisfactory under light traffic conditions, but seriously inaccurate under heavy volume conditions.

3. Low-mounted infrared sensors are not cost-effective for tasks other than axle-counting. Their accuracy and ease of deployment are roughly similar to those of attachable-pole-mounted microwave radar systems, but they are roughly five to seven times more expensive.

7.2 Recommendations

On the basis of the evaluations of portable data collection systems conducted as part of this project and other experience gained in the demonstrations of these systems, it is recommended that Caltrans:

1. Consider routine use of temporarily-mounted microwave radar sensors as an alternative to current methods of data-collection for lane volume counts, speeds, and vehicle length classification for sites with relatively narrow roadways (no more than two or three lanes) and/or non-congested traffic, but exercise caution in deploying such systems elsewhere.

2. Maintain a continuous program for verifying the performance of new types and models of sensors and encourage manufacturers of side-mounted non-intrusive sensors to continue efforts to overcome problems related to occlusion and inability to distinguish vehicles in the lanes farthest from the sensor on multilane roadways.

3. Continue efforts develop reliable wireless communication systems for semi-permanent data collection installations part of the overall Caltrans effort to develop wireless data communications capability.

4. Use private, rather than public, cellular links to transmit data from semi-permanent data collection sites to servers connected to the Caltrans computer network.

5. Carefully consider the location of nearby cell towers in the selection of sites for semi-permanent installations utilizing cellular data communications. Sites outside cellular coverage or approximately halfway between adjacent cell towers should be avoided.

6. Not attempt installation of systems requiring wireless communications without involvement of personnel with extensive experience in wireless communications.

7. Continue to investigate the suitability of low-mounted infrared sensors for axle classification counts. In the absence of major reductions in their price, such sensors should not be considered for collection of other types of traffic data.

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APPENDIX A

SETUP/TEARDOWN PROCEDURES FOR ATTACHABLE POLE-MOUNTED SYSTEMS

Two-person Setup/Teardown for One-Pole Assembly

Setup

1. Slide sensor assembly onto top of pole and tighten clamps (Figure 12)

Figure 12 Two-Person Setup, Step 1: Attaching Sensor Assembly

2. Place ladder so that one person can climb high enough to position top clamp

3. Raise pole with sensor attached and position top clamp (Figure 13). With bottom of pole still on the ground, person on ladder tightens top clamp part way (tight enough to support unit but loose enough so that the pole can slide within the clamp)

4. Person on ground raises bottom of pole to desired height (Figure 14). Person on ladder tightens top clamp (Figure 15).

Figure 13 Two-person Setup, Step 3: Positioning Top Pole Clamp

Figure 14 Two Person Setup, Step 4: Sliding Pole Up

Figure 15 Two-Person Setup, Step 4: Tightening Top Pole Clamp

5. Person on ground positions bottom clamp and tightens it (Figure 16)
6. Rotate pole to adjust angle of sensor to roadway
7. Plug sensor power cable into power strip attached to storage battery
8. Plug laptop computer re-charger unit into power strip and turn on computer
9. Attach sensor data cable to laptop computer
10. Initialize/calibrate sensor according to manufacturer's instructions and select data download options
11. Begin recording data

If PTZ video camera is part of the assembly:

1. Plug video camera power supply cable into power strip
2. Plug laptop computer re-charger unit into power strip and turn on computer

Figure 16 Two-Person Setup, Step 5: Tightening Bottom Pole Clamp

3. Connect Ethernet cable to laptop computer

4. Connect video output cable to video capture unit and connect video capture unit to laptop computer

5. Open video control software; pan camera so as to point in the same direction as the sensor (i.e., perpendicular to the roadway), tilt it so as to cover all lanes, and zoom out as far as possible

6. Open video capture software and set up file for recording video clip

7. Begin recording video

Teardown

1. Turn sensor off. If recording video, stop recording and exit video capture software. Turn off camera and exit camera control software

2. Turn off laptop computer(s)

3. Unplug sensor power supply and data cables. If camera is attached, unplug power supply, Ethernet cable, and video capture unit. Unplug video cable from video capture unit.

4. Remove bottom clamp

5. Loosen top clamp and slide pole down

6. Remove top clamp and lower unit

7. Loosen clamps and remove sensor assembly from pole

<u>One-person Setup/Teardown for Two-Pole Assembly</u>

Setup

1. Slide sensor assembly onto top of pole and tighten clamps (Figure 17)

Figure 17 One-Person Setup, Step 1: Attaching Sensor

2. Connect the two poles together, using pipe wrenches to tighten the connection (Figure 18)

3. Carefully position the bottom of the pole against the object it will be attached to so that it will not slip

Figure 18 One_Person Setup, Step 2: Connecting Poles

4. Raise the pole and hold it against the object to which it will be attached (Figure 19)

5. Position the cargo strap about chest high so that it will hold the pole to the object and tighten the ratcheting tie down (Figure 20)

6. Position the ladder. Climb the ladder and attach and tighten the top clamp (Figure 21)

7. Attach and tighten the bottom clamp (Figure 22)

8. Remove the ratcheting tie down

9. Using a pipe wrench, rotate pole to adjust angle of sensor to roadway (Figure 23)

10. Plug sensor power cable into power strip attached to storage battery

11. Plug laptop computer re-charger unit into power strip and turn on computer

12. Attach sensor data cable to laptop computer

13. Initialize/calibrate sensor according to manufacturer's instructions and select data download options

14. Begin recording data

Figure 19 One-Person Setup, Step 4: Raising the Pole

Figure 20 One-Person Setup, Step 5: Attaching Ratcheting Tie Down

Figure 21 One-Person Setup, Step 6: Tightening Top Clamp

Figure 22 One-Person Setup, Step 7: Tightening Bottom Clamp

Figure 23 One-Person Setup, Step 9: Rotating Pole

Teardown

1. Turn sensor off. If recording video, stop recording and exit video capture software. Turn off camera and exit camera control software
2. Turn off laptop computer(s)
3. Unplug sensor power supply and data cables. If camera is attached, unplug power supply, Ethernet cable, and video capture unit. Unplug video cable from video capture unit.
4. Attach and tighten ratcheting tie down
5. Position ladder. Climb ladder and remove top clamp (Figure 24)
6. Remove bottom clamp (Figure 25)
7. Remove ratcheting tie down, holding pole to mounting object
8. Lower pole (Figure 26)

Figure 24 One-Person Teardown, Step 5: Removing Top Clamp

Figure 25 One-Person Teardown, Step 6: Removing Bottom Clamp

Figure 26 One-Person Teardown, Step 8: Lowering Pole

APPENDIX B

COST ESTIMATES

The type of cost estimate provided varies with the type of system. An estimate of the initial and equivalent annual costs of dedicated equipment is provided for each type of system. Dedicated equipment includes items that will be used exclusively by the system for the duration of its deployment or that would normally have no other use. Such items include sensors, poles, cables, fasteners, etc. In addition, for temporarily-mounted systems, there is an estimate of the cost per deployment as a function of the number of deployments per year, and for semi-permanent systems, there is an estimate of the monthly cost of data collection.

For temporarily-mounted systems, basic equipment costs vary depending on the type of mounting and whether video-based data verification capability is included. For semi-permanent systems, they vary depending on the type of power supply (AC versus solar) and whether a separate server is required for recording and archiving data. In addition to the cost of the basic equipment, deployment of temporarily-mounted systems requires labor and temporary use of equipment including laptop computers and transformers needed to power them from the storage batteries used in the field. In the case of this equipment, an equivalent hourly rental fee is applied. This rental fee is based on the assumption that the equipment in question would normally be available for use for about 1600 hours per year. Monthly costs for semi-permanent systems include the basic equipment cost, the cost of cellular telephone service required for data transmission, and (where applicable) the cost of AC power used to operate the sensor and modem in the field.

Where possible, unit costs are based on recent Caltrans experience. Equivalent annual costs are based on the assumption of a 5 percent interest rate and a useful life of 3 years for items of equipment other than batteries, which are assumed to have a 5-year life.

Temporarily mounted systems

Basic equipment package, exclusive of mounting and setup equipment

Component	Quantity	Price	Extension	Life	Annual cost	Remarks
Sensor and accessories						
Sensor (including sensor cable)	1	$4,635	$4,635	3 yr.	$1,702	Wavetronix SS-125
Battery box	1	$200	$200	3 yr.	$73	NEMA enclosure. Price varies with size
12V Storage battery	2	$180	$360	5 yr.	$83	90 amp-hr. Price varies with amp-hr.
Surge proctector	1	$216	$216	3 yr.	$79	Wavetronix Click 200
PRN converter software for Peek database	1	$0	$0	3 yr.	$0	Wavetronix only. Requirements vary with sensor type
TOTAL			$5,411		$1,938	
Video-based count verification system						
PTZ Video camera	1	$1,511	$1,511	3 yr.	$555	Sony SNCRZ30
50' Crossover ethernet cable	1	$27	$27	3 yr.	$10	
50' RCA cable	1	$10	$10	3 yr.	$4	
Video capture device	1	$159	$159	3 yr.	$58	
TOTAL			$1,707		$627	

Mounting Equipment

Component	Quantity	Price	Extension	Life	Annual cost	Remarks
Attachable pole						
10'-Aluminum poles (1-1/2 " conduit)	2	$33	$66	3 yr.	$24	
Hose clamps	4	$12	$48	3 yr.	$18	
Racheting tie down for setup	1	$16	$16	3 yr.	$6	
TOTAL			$130		$48	
Pneumatic pole, portable base						
10 m Pneumatic pole	1	$3,000	$3,000	3 yr.	$1,102	Clark Masts Model SQT10/HP
Portable base for pneumatic pole	1	$1,500	$1,500	3 yr.	$551	
TOTAL			$4,500		$1,652	
Trailer mounted pole						
Trailer mounted pneumatic pole	1	35000	$35,000	3 yr.	$12,852	Clark Masts Model 802/30
TOTAL			$35,000		$12,852	

Setup equipment

Component	Quantity	Price	Extension	Life	Hourly "rental"	Remarks
Sensor only						
Laptop Computer (PC)	1	$1,000	$1,000	3 yr.	$0.23	
Transformer (DC to AC, for laptops)	1	$90	$90	3 yr.	$0.02	
TOTAL			$1,090		$0.25	
Video						
Laptop computer (Apple-running Windows/OSX)	1	$3,175	$3,175	3 yr.	$0.73	
TOTAL			$3,175		$0.73	

Setup cost per deployment

Item	Hours	Rate/hr	Extension
Without video			
Labor	2	$45.63	$91
Laptop computer (PC)	2	$0.23	$0
Transformer (DC to AC, for laptops)	2	$0.02	$0
TOTAL			$92
With video			
Labor	4	$45.63	$183
Laptop computer (PC)	2	$0.23	$0
Laptop computer (Apple-running Windows/OSX)	4	$0.73	$3
Transformer (DC to AC, for laptops)	2	$0.02	$0
TOTAL			$186

Equipment Package Costs

Package	Initial Cost	Annual cost
Without video		
Attachable pole	$5,541	$1,986
Pneumatic pole, portable base	$9,911	$3,590
Trailer mounted pole	$40,411	$14,790
With video		
Attachable pole	$7,248	$2,612
Pneumatic pole, portable base	$11,618	$4,217
Trailer mounted pole	$42,118	$15,417

Cost per deployment

	Deployments/year		
System	10	20	40
Without video			
Attachable pole	$290	$191	$141
Pneumatic pole, portable base	$451	$271	$182
Trailer mounted pole	$1,571	$831	$462
With video			
Attachable pole	$447	$317	$251
Pneumatic pole, portable base	$608	$397	$291
Trailer mounted pole	$1,728	$957	$571

Semi-permanent systems

Basic equipment package, exclusive of power supply and server

Component	Quantity	Price	Extension	Life	Annual cost	Remarks
Sensor (including sensor cable)	1	$4,635	$4,635	3 yr.	$1,702	Wavetronix SS-125
Hose clamps	3	$12	$36	3 yr.	$13	
Cellular modem	1	$1,000	$1,000	3 yr.	$367	InfoTech Wizard
Cabinet for modem	1	$150	$150	3 yr.	$55	NEMA enclosure. Price varies with size
Wooden pole, installed	1	$800	$800	3 yr.	$294	Part of 10-pole installation. Price depends on number installed
Click 172, 2 channel input card, for ADR connection	1	$277	$277	3 yr.	$102	Quantity depends on number of lanes
TOTAL			$6,898		$2,533	

Power supply options

Component	Quantity	Price	Extension	Life	Annual cost	Remarks
AC Current						
Transformer (AC to 12V DC)	1	$169	$169	3 yr.	$62	Wavetronix Click 202
Power supply cabinet	1	$100	$100	3 yr.	$37	NEMA enclosure. Price varies with size
Power cable (from service point)	1	$2	$2	3 yr.	$1	Price varies with length
Surge proctector	1	$216	$216	3 yr.	$79	Wavetronix Click 200
TOTAL			$487		$179	
Solar Collector and Storage Battery						
Solar panel	1	$250	$250	3 yr.	$92	
Battery box or cabinet	1	$200	$200	3 yr.	$73	
Battery	2	$180	$360	3 yr.	$132	
Extention cord for setup	1	$20	$20	3 yr.	$7	
Serial cable	1	$10	$10	3 yr.	$4	
TOTAL			$840		$308	

Server

Component	Quantity	Price	Extension	Life	Annual cost	Remarks
Server running RMIS (laptop computer)	1	$1,000	$1,000	3 yr.	$367	
TOTAL			$1,000		$367	

Communications service

Item	Quantity	Price/mo.
Private line cellular telephone service	1	$60
TOTAL		$60

AC power (if required)

Item	Quantity	Price/mo.
AC Power for sensor and modem	1	$10
TOTAL		$10

Equipment package cost

Package	Initial Cost	Annual cost
AC power, server required	$8,385	$3,079
AC power, server not required	$7,385	$2,712
Solar power, server required	$8,738	$3,209
Solar power, server not required	$7,738	$2,841

Cost per month for data collection

Package	Cost/mo.
AC power, server required	$327
AC power, server not required	$296
Solar power, server required	$327
Solar power, server not required	$297

Low-mounted infrared sensors

Component	Quantity	Price	Extension	Life	Annual cost
Quixote (Peek) AxleLight					
2 AxleLight sensors + ADR1000	1	$35,000	$35,000	3 yr.	$12,852
Battery box	2	$200	$400	3 yr.	$147
Battery	2	$180	$360	3 yr.	$132
TOTAL			$35,760		$13,131
TIRTL					
TIRTL sensor and mounting	1	$25,000	$25,000	3 yr.	$9,180
TOTAL			$25,000		$9,180