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ADVANCES IN TRAFFIC DATA COLLECTION AND MANAGEMENT

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“Advances in Traffic Data Collection and Management”

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Introduction

Since the first known vehicle detector was introduced in 1928 at a signalized intersection, there have been hundreds of attempts to improve and create systems that monitor vehicle presence and passage at strategic locations on the nation’s streets and highways. Without accurate and reliable detectors, traffic management decisions based upon real-time or historical data are compromised. Many agencies use post processing for *Quality Assurance* as opposed to *Quality Control*. Quality Assurance attempts to “fix the data” or identify defective data rather than ensuring the accuracy and reliability of the equipment. Quality Control emphasizes good data by ensuring selection of the most accurate detector then optimizing detector system performance. This white paper identifies innovative approaches for improving data quality through Quality Control. It includes innovative contracting methods, standards, training for data collection, data sharing between agencies and states, and advanced traffic detection techniques.

Background

The first known installation of a vehicle detection device occurred at a Baltimore intersection, forming the first semi-actuated signal installation. The detector required drivers on the side street to sound their horn to activate the device, which consisted of a microphone mounted in a small box on a nearby utility pole. Another device introduced at about this same time was a pressure-sensitive pavement detector using two metal plates acting as electrical contacts forced together by the weight of a vehicle passing. This treadle-type detector proved more popular than the horn-activated detector, enjoying widespread use for over 30 years and becoming the primary means of vehicle detection at actuated signals *(1)*.

Ongoing problems with the contact plate detector led to the introduction of an electro-pneumatic detector. It was not a final solution either because of its cost to install. Also, it was only capable of passage or motion detection. Inductive loops were introduced as a vehicle detection system in the early 1960s and have become the most widespread detection system to date *(1)*. However, the well-documented problems with inductive loops have led to the introduction of numerous non-intrusive devices utilizing a variety of technologies to replace many of the failing inductive loops.

By the late 1980s, video imaging detection systems were marketed in the U.S. and elsewhere, generating sufficient interest to warrant research to determine their viability as an inductive loop replacement. In 1990, the California Polytechnic State University began testing 10 commercial or prototype video image processing systems that were available in the United States. Evaluation results indicated that most systems generated vehicle count and speed errors of less than 20 percent over a mix of low, moderate, and high traffic densities under ideal conditions. However, occlusion, transitional light conditions, and high-density, slow-moving traffic further reduced the accuracy of these new systems *(2)*.

Hughes Aircraft Company conducted an extensive test of non-intrusive sensors for the Federal Highway Administration (FHWA). The objectives of the study, *Detection Technology for IVHS (3)*, included determining traffic parameters and accuracy specifications, performing laboratory and field tests of non-intrusive detector technologies, and determining the needs and feasibility of establishing permanent vehicle detector test facilities. This research went beyond testing of video imaging systems, testing a total of nine detector technologies and including both freeway and surface street test sites in a variety of climatic and environmental conditions. Conclusions indicated that video imaging systems were not one of the better performers in inclement weather.

In another study sponsored by FHWA, the Jet Propulsion Laboratory (JPL) conducted research to identify the functional and technical requirements for traffic surveillance and detection systems in an Intelligent Transportation System (ITS) environment. The report entitled *Traffic Surveillance and Detection Technology Development, Sensor Development Final Report (4),* published in 1997, presented details on the development and performance capabilities for seven detection systems. JPL focused on video imaging, radar, and laser detection systems and utilized the work performed by Hughes *(3, 5)* to assess current technology capabilities.

The Minnesota DOT and SRF Consulting conducted a two-year test of non-intrusive traffic detection technologies. This test, initiated by FHWA, had a goal of evaluating non-intrusive detection technologies under a variety of conditions. The researchers tested 17 devices representing eight technologies. The test site was an urban freeway interchange in Minnesota that provided signalized intersection and freeway main lane test conditions. Inductive loops were used for baseline calibration. The test consisted of two phases, with Phase 1 running from November 1995 to January 1996 and Phase 2 running from February 1996 to January 1997 *(6, 7, 8)*. This paper provides more details on Phase 2 in another section.

A critical finding of this research was that mounting video detection devices is a more complex procedure than that required for other types of devices. Camera placement is crucial to the success and optimal performance of this detection device. Lighting variations were the most significant weather-related condition that impacted the video devices. Shadows from vehicles and other sources and transitions between day and night also impacted count accuracy *(8)*.

The Texas Transportation Institute (TTI) has been involved in detector research for more than 10 years, with early research addressing inductive loops and more recent research emphasizing non-intrusive detectors. Most of the research included field investigations, and some also included a state-of-the practice review to identify success stories. Even though installation and maintenance practice for inductive loops should be well established due to product maturity, performance and service life attributes were still deficient at the outset of this series of research activities. One of the early detector research projects developed a *Traffic Signal Detector Manual* primarily for inductive loop installers. The manual presents: 1) installation procedures that ensure reliable performance, and 2) suggested practices to reduce loop installation time and maintenance costs *(9)*. Other TTI research investigated the use of acoustic and active infrared detectors at traffic signals for reducing stops and delays to trucks, finding that inductive loops were still more reliable for these applications, and especially in inclement weather and in poor lighting conditions *(10, 11)*.

More recent TTI research projects investigated the accuracy, reliability, cost, and user-friendliness of various non-intrusive detectors in seeking viable replacements for inductive loops *(12, 13, 14)*. TTI tested the Autoscope Solo Pro video image detection system (VID), Iteris Vantage (VID), SAS-1 by SmarTek (acoustic), and RTMS by EIS (radar). TTI initially field-tested devices in low-volume conditions at one of its testbeds in College Station with subsequent more demanding tests at another testbed on I-35 in Austin. More information is available on results of the latest tests in the Advanced Traffic Detection Techniques section of this paper.

Innovative Contracting Methods

A few agencies around the country have already invested resources in developing new contracting methods as a means of ensuring data quality at its source. Performance criteria in contracts, while not common, are beginning to be considered by DOTs as a method to transfer some of the risk and maintenance requirements to contractors. The following text provides examples from Virginia and Ohio showing the potential that can be tapped though innovative contracting methods.

The Virginia Department of Transportation (VDOT) at the Hampton Roads Traffic Management Center uses contractors for support of its day-to-day operations. The TMC monitors 19 centerline miles (soon to be 50 centerline miles) of freeway and collects all the data in-house for its own use for freeway operations. The TMC accomplishes the necessary maintenance on the detection system through hiring contractor personnel who are supervised by VDOT personnel. The contractor staff answers to the TMC director and two other VDOT personnel to conduct field maintenance and operations and maintaining detection equipment. VDOT plans to continue using its own staff for maintaining some items like surveillance cameras. VDOT makes the determination of when maintenance is needed, using both a preventive maintenance program and a reactive maintenance program for detectors and related equipment *(15)*.

For the reactive maintenance mode, identification of problems occurs in various ways. A few problem notifications come from motorists, but the more common method of identifying problems is through an alarm system built into the TMC that calls attention to a problem. That alarm alerts “controllers” in the TMC that are monitoring the system health in real time. If a camera fails, for example, controllers notice it first. For the routine maintenance mode, VDOT goes through comprehensive diagnostic checks in the field when contractor personnel visit a site.

VDOT treats contractor personnel as an extension of its own staff, apparently giving the TMC director even more latitude to add or remove contractor personnel compared to VDOT staff. If contractor personnel are not performing to VDOT’s expectations, they can be removed immediately. By the same token, VDOT also recognizes above average contractor performance by acknowledging them, as they do VDOT employees, in their periodic newsletters. VDOT offers no cash incentives, however, for good performance *(15)*.

Training of contractor personnel is accomplished in different ways. For field maintenance, VDOT provides training to both its own and contractor personnel with no distinction. The contractor is also responsible to provide a staff that is technically competent. Sometimes the training provided by VDOT comes from the Virginia Transportation Research Council (VTRC) as workshops are made available or from other organizations such as FHWA that make training available in the local area. They also occasionally send people out-of-state for training. The TMC operation does not borrow from others within VDOT (e.g., traditional data collection) for maintenance needs *(15)*.

The second example in Virginia is the VDOT Mobility Management Section (traditional data collection), which leases its traffic counters and modems from Digital Traffic Systems (DTS). However, VDOT owns the sensors such as inductive loops and piezoelectric sensors. Since 1996, VDOT has contracted the data collection activity, and leased data collection equipment. The current maintenance agreement with DTS is carefully written to assign responsibilities and minimize "finger pointing." There are cases where difficulties might otherwise arise, such as with traffic counters that did not work due to faulty piezoelectric sensors. A state inspector checks the equipment once a year, but if there are substantial errors in the data, the contractor has to re-collect the data *(16)*.

VDOT has established performance based lease criteria for payment of data collection services. Contractor compensation is based on the amount of acceptable data being submitted by the contractor. Furthermore, VDOT requires a certain quantity of acceptable data from each site to be able to use that site for traffic factor creation. The list below summarizes some key elements of the agreement *(16)*.

- There will be full payment for all Automatic Traffic Recorders (ATRs) and modems at sites with 25 or more days of useable classification and volume data (for factor creation) during a calendar month.
- There will be 75 percent payment for 15 or more days and lesser payment for fewer days of acceptable data except that monthly payment will not be made for sites that have less than 15 days of volume data only available during a calendar month.
- For service calls for maintenance purposes, the contractor will not be reimbursed a separate charge (pay item) for the service calls related to ATR/modem equipment problems, telephone line problems, or failed sensors, as costs associated with the service calls are included in the price of the monthly lease charge.
- The contractor is given seven calendar days to investigate, make site visits, make repairs and respond back to VDOT after notification/receipt of a service call.

Another example of an innovative contracting method is with the Ohio Department of Transportation's Office of Technical Services, Traffic Monitoring Section. In the past, ODOT has used small personnel service contracts to maintain pavement sensors. Now, ODOT is in the process of executing a task order type contract for maintenance to have contractors on board for anticipated and unanticipated maintenance requirements of the traditional data collection equipment statewide. The contract is expected to begin in the summer of 2003 and will cover a time period of two years *(17)*.

Standards

Standards development is still at an early stage in the United States. The U.S. DOT ITS Standards Program is working toward the widespread use of standards to encourage the interoperability of ITS systems, including traffic data collection systems *(18)*. The National Transportation Communication for ITS Protocol (NTCIP) committee is the Standards Development Organization (SDO) for traffic data collection and sensor standards. NTCIP 1201 to NTCIP 1209 are standards documents that deal with roadside traffic data collection and traffic sensors. These standards are at various stages in the development process. More information on the NTCIP standards can be found at the NTCIP website *(19)*.

There is also a draft standard being developed by the American Society for Testing and Materials (ASTM), entitled "Standard Specification and Test Methods for Highway Traffic Monitoring Devices," which will be available soon *(20)*. In its current form, the standard includes, among other items, device classifications, performance requirements, user requirements for tests, and test methods. Devices are classified by the functions they perform and the data required to carry out those functions. The seven primary functions are 1) traffic counting, 2) traffic counting/classifying, 3) incident detection, 4) speed monitoring, 5) metering (ramp, mainline, or freeway-to-freeway), 6) signal control, and 7) enforcement.

Based on an FHWA Scan Tour of European countries *(21)*, standardization has occurred in Germany, the Netherlands, and France, where national standards for data collection equipment have been developed. All equipment purchased for national traffic data collection will utilize the same formats and protocols for communication purposes. The process has increased the quality and accuracy of the data collected, decreased the effort needed to transfer data between agencies or offices, and increased the reliability of field equipment. The down side is the increased initial cost of the equipment when compared to non-standard equipment.

Training for Data Collection

Training of personnel on the intricacies of the equipment is an essential part of ensuring data quality. With improvements in non-intrusive detector hardware and software occurring at a rapid pace, maintenance personnel must be computer literate and must maintain an awareness of the latest changes for a variety of detection systems. Initial training of new systems is often available through the vendor, but turnover in maintenance staff and new models require an ongoing training program.

If data sharing is to be effective, the training program must also encourage employees to develop positive relationships and a sharing attitude with agencies that need data and those serving as resources. The goal is to explain the synergism of sharing data with others, rather than simply looking at ones own needs. Familiarity with the equipment will be critical to achieving success. Troubleshooting techniques must include training on the right equipment along with ways of immediately identifying problems.

Advanced Traffic Detection Techniques

Quality Control emphasizes data quality by ensuring selection of the most accurate detector then optimizing detector system performance. Most evaluations of advanced or newer non-intrusive detectors compare with inductive loops because loops are a mature technology and, when properly installed, serve as an adequate benchmark for test purposes. In other words loops are being replaced in the U.S. due to factors other than their accuracy such as the high expense of traffic control, the danger in exposing installation crews to traffic, and excess motorist delay and fuel consumption. Several studies conducted in the 1980s found that most failures originate in the loop wire, but the wire itself is not necessarily the initiating cause of failure. Results from studies conducted in Minnesota, New York, Oregon, and Washington indicate that improper sealing, pavement deterioration, and foreign material in the saw slot were most prominent in explaining loop failure *(22)*.

Even though most U.S. jurisdictions are seeking non-inductive loop solutions to fill the traffic monitoring need, that is not true of European countries. According to findings of a scanning tour sponsored by the Federal Highway Administration, while each of the five countries visited is conducting research into new detection systems, none is seeking to replace inductive loops as the primary means of traffic data collection. The main reason is that inductive loops continue to adequately serve their needs *(21)*.

Now that decision-makers have a choice in detectors, they must know the performance, cost, and user interface characteristics of the alternatives in order to choose wisely. Many agencies purchase new and unfamiliar detectors based on limited knowledge of these factors because they lack resources for testing (sometimes relying on vendor claims) and/or an immediate need for detection at a critical location. Two recent research initiatives described below provide useful input for this process.

The most recent research into the performance attributes of advanced detection techniques has occurred at the Texas Transportation Institute *(14)* and in Phase II of the MinnDOT Non-Intrusive Tests *(23)*. As noted in the Background section of this paper, TTI tested the Autoscope Solo Pro, Iteris Vantage, SAS-1 by SmarTek, and RTMS by EIS. In its Phase II tests, MinnDOT evaluated the Autosense II by Swartz Electro-Optics (active infrared), 3M microloops (magnetic), ECM Loren (radar), SAS-1 by SmarTek (acoustic), IR 254 by ASIM (passive infrared (PIR)), DT 272 by ASIM (PIR/ultrasonic), TT 262 by ASIM (PIR/ultrasonic/radar), the Autoscope Solo by ISS (VID), and VIP by Traficon (VID). The text that follows summarizes findings, organized alphabetically by detector name.

ASIM IR 254

The IR 254 is a passive infrared sensor made by ASIM Technology Ltd of Switzerland. The sensor only monitors one lane, and it can be mounted either over the lane or slightly to the side of the roadway but it must face oncoming traffic. Its alignment needs cause problems in obtaining optimum performance, so installations should prefer overhead mounting. MinnDOT tests found that the IR 254 use was simple, straightforward, small and easy to mount. Detection accuracy was better during free-flow conditions, but it undercounted by 10 percent during heavy traffic. The device consistently underestimated speed by 10 percent on average *(23)*.

ASIM DT 272 Passive IR/Pulse Ultrasonic

This sensor incorporates two technologies: pulse ultrasonic and passive infrared. It is a single lane detector that can be installed either overhead or in sidefire, and is designed to detect vehicles at a short distance (no more than 39 ft). This requirement is met by installing it at 20 ft above the lane and 20 ft to the side. MinnDOT 24-hour test findings indicate that its absolute percent difference compared to loops was 8.7 percent for overhead mounting and 0.8 percent sidefire. It demonstrated unstable performance during parts of the sidefire testing. Test documents did not show speed comparisons *(23)*.

ASIM TT 262 PIR/Pulse Ultrasonic/Doppler Radar

This sensor incorporates three technologies: passive infrared, ultrasonic, and Doppler radar. For this test, MinnDOT mounted the detector overhead with its orientation downward and tilted 5 degrees toward oncoming traffic. The detector is not intended for sidefire orientation. The setup was straightforward, requiring only 30 minutes. The count results were good, showing an absolute percent difference between sensor and baseline of 2.8 percent at 21 ft and 4.9 percent at 17 ft height. For speed accuracy, its absolute average percent difference between sensor and loops was 4.4 percent at 21 ft and 3 percent at 17 ft mounting height. In summary, the triple technology detector showed excellent performance, and its installation and calibration were simple *(23)*.

Autoscope Solo

The Autoscope Solo is a video imaging system whose cameras can be mounted either overhead or to the side of the road. MinnDOT tests of the Autoscope 30 ft over the center of the lanes indicated excellent performance. The absolute percent volume difference between the sensor data and loop data were under 5 percent for all three lanes. The detector also performed well for speed detection. The absolute average percent difference was 7 percent in lane one, 3.1 percent in lane two, and 2.5 percent in lane three. For other mounting locations beside the roadway, the detector performed best when mounted high and closest to the roadway *(23)*.

Autoscope Solo Pro

The Autoscope Solo Pro is the latest version of the integrated camera and processor from ISS. TTI tested this detector both in College Station on S.H. 6 (all low- to moderate-volume free-flow conditions) and in Austin on I-35 (high-volume with some stop-and-go traffic). The results reported in this paper come from the I-35 testbed and are based on 5-minute samples of count and speed data. The I-35 site has five southbound lanes with lane 1 (the median lane) being farthest from the detector. Tests placed the Solo Pro on a pole 35 ft above the pavement and 6 ft from the nearest lane *(14)*.

The Autoscope Solo Pro count accuracy was within 5 to 10 percent of the baseline counts during free flow conditions, but it generally diminished in all lanes when 5-minute interval speeds dropped below 40 mph and especially during stop-and-go conditions. On all four of the monitored lanes, it overcounted during free flow, but almost always within 10 percent of baseline counts. During the peak periods, however, it undercounted. On lane 1, its error was always within 10 percent. On lane 2, its undercounts were about half within 10 percent and half between 10 and 20 percent. On lane 3 (closer to the camera), its undercounts were two-thirds within 10 percent and one-third from 10 to 20 percent of baseline counts. On lane 4, the Autoscope had 9 out of 10 within 10 percent and one out of 10 between 10 and 20 percent. Speed and occupancy of the Solo Pro were the best of any devices tested by TTI in these most recent evaluations. Speeds were almost always within 0 to 3 mph of the baseline system. Its 15-minute cumulative occupancy values differed from loops by as much as 3.9 percent, but during most intervals its difference was less than 1 percent *(14)*.

Autosense II

The Autosense II by SEO is an active infrared sensor that monitors a single lane and must be mounted over the lane at a height between 19.5 and 23 ft. The MinnDOT tests of volume indicated excellent agreement with the baseline inductive loop system. The absolute percent difference between sensor data and loop data averaged 0.7 percent, which is within the accuracy level of loops. The 24-hour tests indicated that its absolute percent difference of average speed between the sensor and the baseline system was 5.8 percent. The sensor consistently overestimated speed. The sensor performed consistently during the entire six months of continuous testing *(23)*.

ECM Loren

MinnDOT tests of the ECM Loren microwave detector indicated that it did not function properly. It is a relatively new detector and needs further development *(23)*.

Iteris Vantage

The Iteris Vantage had the highest standard deviation of differences in counts between baseline and test device during free flow of all devices tested recently by TTI, indicating that its counts were more erratic than other devices. Like the Autoscope, the Iteris undercounted during peak periods and overcounted during free flow. In lane 1, 95 percent its counts were within 12 percent of baseline counts. In lane 2, three-fourths of its counts were within 20 percent of baseline and one-fourth was between 20 and 40 percent of baseline. In lane 3, its count performance was better with 95 percent of the count intervals no more than 10 percent different from baseline counts. It was not monitored in lane 4. Free flow results were very similar to peak results. The standard deviation of speed differences between baseline and test device for the Iteris was among the lowest of the devices tested on all but one lane. The Iteris speed estimates were almost always within 5 mph during both peak and off-peak periods, with a few intervals erring as much as 15 mph on one lane. The higher errors were hypothesized to be a function of calibration. Of the three non-intrusive devices tested for occupancy output in lanes 3 and 4, the Iteris Vantage was the second most accurate. Its 15-minute cumulative occupancy values differed from loops by as much as 8.1 percent, but during most intervals the difference was less than 6 percent *(14)*.

Other considerations for the Iteris Vantage include its relative newness for freeway detection. This newness is a factor to consider, since most new devices need modifications following their release for public use. Therefore, it could be an even better detector as the manufacturer makes more refinements. One of the specific problems identified in this research is that it loses calibration after a short time *(14)*.

Peek ADR-6000

TTI tested the new Peek ADR-6000 vehicle classification system, partly because of its potential for simultaneously generating classification and speed output. The ADR-6000 uses inductive loop signatures for its classification algorithm, so its speed, count, and classification results were expected to exceed previous experience. TTI designed the test site architecture such that the Peek system contact closure output fed into a Local Control Unit (LCU) – a component of TxDOT's legacy freeway monitoring system – which in turn communicated with the Austin District Traffic Operations Center. The ADR stored classification data internally to be downloaded later to a site computer or to other computers via the Internet using FTP *(14)*.

The site selected for the test was the same I-35 testbed site noted earlier in downtown Austin that frequently experienced stop-and-go traffic. TTI developed and equipped a freeway testbed for this and future TxDOT sponsored research with equipment such as equipment cabinets, computers, baseline inductive loops, CCD cameras, Digital Subscriber Line (DSL) communication, and baseline inductive loops.

TTI findings indicated that the ADR-6000 was very accurate as a classifier, counter, and speed detection device and as a generator of simultaneous contact closure output. However, its recent introduction into the U.S. market and being adapted from a toll application are factors in its need for further refinement. Table 1 shows the classification result for a dataset of 1,923 vehicles, indicating only 21 errors and resulting in a classification accuracy of 99 percent (ignoring Class 2 and 3 discrepancies). This data sample occurred during the morning peak and included some stop-and-go traffic. For count accuracy, the Peek in this same dataset only missed one vehicle (it accurately accounts for vehicles changing lanes). Figure 1 shows the close agreement of the ADR with two other test systems using one-minute speeds from the Peek, an overhead Doppler radar system, and an Autoscope Solo Pro. The graphic indicates discrepancies only at slow speeds (below about 15 mph) where the Doppler radar is known to drop out and the Autoscope speed accuracy decreases slightly. Peek needs to continue refinements to the ADR-6000 to improve its stability in the harsh environment of a field equipment cabinet and to improve its user interface. Its unit cost for future applications is currently unknown but is expected to be under $10,000, depending on the number of units purchased *(14)*.

The future of the ADR-6000 in Texas and elsewhere in similar applications is expected to be a function of its cost, willingness of agencies to continue installing inductive loops, and multiple agencies being willing to develop agreements to share maintenance responsibilities. The fact that it can serve the dual role is expected to be a positive factor in its installation, especially at more demanding locations with extremely high volumes and where the traffic operations and traditional data needs can both be served.

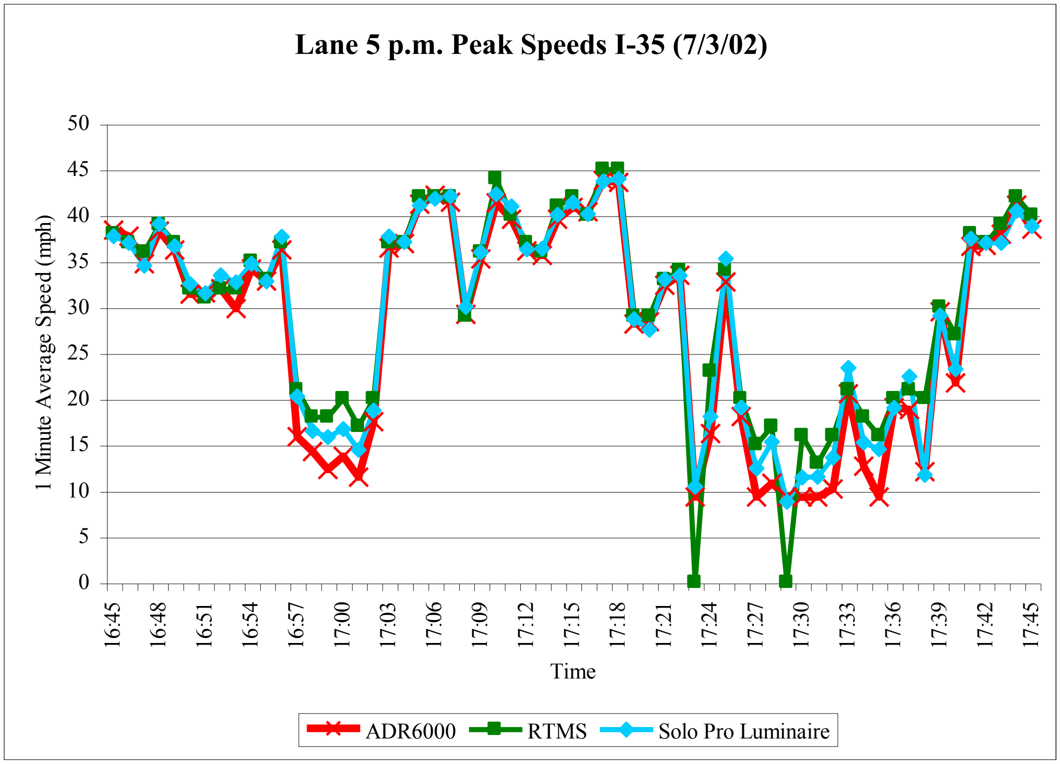
Table 1. Peek ADR-6000 Classification Accuracy Comparison

	Vehicle Classification													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**Total**	**Errors**
Lane 1 Count	0	330	118	1	9	0	0	2	15	0	1	0	476	
Errors	0	0	0	0	1	0	0	0	2	0	0	0		3
Lane 2 Count	0	299	84	0	16	3	1	11	23	0	1	0	438	
Errors	2	1		3	1				1					8
Lane 3 Count	2	306	96	1	11	3	0	7	6	0	0	0	432	
Errors		1			2	1			1					5
Lane 4 Count	0	312	88	1	14	1	0	4	2	0	0	0	422	
Errors			1	1	1	1								4
Lane 5 Count	0	106	36	0	5	3	0	0	5	0	0	0	155	
Errors		1												1
Totals	4	1356	423	7	60	12	1	24	55	0	2	0	1923	
Total Errors	2	3	1	4	5	2	0	0	4	0	0	0		21

Source: Reference *(14)*

RTMS by EIS

Results of TTI research indicate that the RTMS is much more accurate in both counts and speeds in the overhead position although it covers only one lane. The more popular application is in sidefire, so the following discussion focuses on its sidefire accuracy. In sidefire, the RTMS can generate speeds and counts for five or more lanes with reasonable accuracy. Its advantages also include ease of setup, being mounted only 17 ft above the roadway, and its good user interface. Its coverage and initial cost make the RTMS an economical means of monitoring several lanes. In fact, in previous research, TTI found it to have the lowest life cycle cost for freeway applications of those detectors included in that research *(13)*.



Source: Reference (14)

Figure 1. Speed Accuracy of the ADR-6000

TTI research findings indicate that it undercounted in all lanes during both peak and off-peak intervals. Its five-minute counts in lane 1 were all in the –10 to –25 percent range. Lane 2 was not evaluated. In lane 3, 95 percent of the time intervals were within 5 percent of baseline. In lane 4, 98 percent of the time intervals were within 15 percent of baseline counts. These findings indicate that distance from the detector and occlusion affected count accuracy. Lane 1 (farthest) was slightly worse than lane 3, and lane 4 was slightly worse than lane 3, suggesting either calibration differences or middle lanes naturally being better than either extreme. Speed estimates by the RTMS in sidefire differed from baseline speeds by as much as 15 mph during peak periods, but it was usually within 5 to 10 mph of baseline speeds during the off-peak. This research did not include occupancy tests on the RTMS *(14)*.

The RTMS is an even more accurate count device in the overhead position, but it only covers one lane. In TTI tests, the overhead RTMS generated excellent speeds until prevailing traffic speeds dropped below about 15 mph. It is a mature product and is not significantly affected by weather or lighting conditions *(14)*.

SAS-1 by SmarTek

The SAS-1 is a passive acoustic detector that monitors vehicular noise (primarily tire noise) as vehicles pass the detection area. The detector can monitor as many as five lanes and the SAS-1 must be oriented in a sidefire position. Precise alignment is not critical because the sensor can cover a wide area. Heights recommended by the vendor range from 25 ft to 40 ft, and the recommended offset range is 10 ft to 20 ft. Higher mounting positions can reduce the effects of occlusion in multiple lane applications. MinnDOT tests found that the absolute percent volume differences for lane two and three were under 8 percent at all test heights, and between 12 and 16 percent for lane one with heights less than 30 ft. It provided good results under free flow traffic, but undercounted during congested flow with slow speeds. For 15-minute intervals, its free flow absolute percent differences were between 0 percent and 5 percent during off-peak and between 10 percent and 50 percent during congested periods. For speed accuracy, the SAS-1 showed an absolute average percent difference under 8 percent for most mounting locations and between 12 percent and 16 percent for lane one with heights less than 30 ft. These tests concluded that the optimal installation position is to have equal distance for both vertical height and horizontal offset between the sensor and centerline of multiple lanes (45 degrees from horizontal) *(23)*.

TTI research found that the SAS-1 predominantly undercounted in both peak and off-peak conditions. In lane 1, all time intervals showed counts less than the baseline system from zero to 20 percent. In lane 2 during the peak period, two-thirds of its undercounts were between zero and 10 percent below baseline counts, and during the off-peak, 80 percent of its time intervals were undercounts and 20 percent were overcounts by as much as 30 percent over baseline counts. In lane 3 during the peaks, 80 percent of its time intervals represented undercounts (zero to –10 percent and 20 percent were overcounts (zero to 5 percent). During the off-peak on lane 3, 95 percent of its time intervals reflected under counts (zero to –25 percent) while 5 percent were overcounts (zero to 30 percent). Its counts in lane 4 were undercounts in both peak and off-peak periods – ranging from zero to –15 percent in both cases *(14)*.

The SAS-1 speed estimates were within 5 to 10 mph of baseline during some peak periods but as much as 20 to 25 mph different in others. Free-flow speed estimates were usually within 5 mph of baseline speeds. Of the three non-intrusive devices tested by TTI for occupancy output in lanes 3 and 4, the SAS-1 was the third most accurate. Its 15-minute cumulative occupancy values differed from loops by as much as 14.7 percent, but during most intervals its difference was less than 4 percent. Heavy rain caused significant reduction in the SAS-1 detection accuracy. In summary, the SAS-1 has undergone many improvements and performed well in free-flowing traffic, but its slow-speed accuracy and its degraded performance in rain need to be addressed *(14)*.

Traficon NV

MinnDOT tests mounted the Traficon video image detector directly over the lanes at heights of 21 ft and 30 ft facing downstream. The preferred orientation was facing oncoming vehicles, but site features precluded this orientation. At the 21-ft height, the absolute percent difference between the sensor data and loop volume data was under 5 percent for all three lanes. At the 30-ft height, its off-peak performance was similar but it undercounted during congested flow showing an absolute percent difference of some 15-minute intervals from 10 percent to as high as 50 percent. Reasons suspected for the reduced accuracy were snow flurries and sub-optimal calibration. Its speed accuracy at 21 ft indicated good performance. Its absolute average percent difference was 3 percent in lane one, 5.8 percent in lane two, and 7.2 percent in lane three. During the snowfall, its speed accuracy declined to a range of 8.9 percent to 13 percent *(23)*.

3M Microloops

The 3M system consisted of three components: Canoga Model 702 Non-Invasive microloop probes, Canoga C800 series vehicle detectors, and 3M ITS Link Suite application software. The microloop probes can monitor traffic from a three-inch non-metallic conduit 18 to 34 inches below the road surface or from underneath a bridge structure. Installers must use a magnetometer underneath bridges to determine proper placement of the probes; otherwise optimum performance requires trial-and-error. Probes installed in a “lead” and “lag” configuration under pavements or bridges can monitor speeds by creating speed traps in each lane. One of the requirements of this system is that the probes remain relatively vertical, so keeping the horizontal bores straight is critical. Probes placed in a non-vertical orientation can lead to speed errors. MinnDOT tests under pavement indicated excellent volume and speed results. The absolute percent volume difference between sensor and baseline was under 2.5 percent, which is within the accuracy capability of the baseline loop system. For speeds, the test system generated 24-hour test data with absolute percent difference of average speed between baseline and test system from 1.4 to 4.8 percent for all three lanes *(23)*.

At a relatively low to moderate volume site in College Station, Texas, TTI found that, for a six-day count period, 3M microloops were almost always within 5 percent of baseline counts. In the right lane, all except two 15-minute intervals out of the 330 total intervals were within 5 percent of baseline counts. The remaining two were within 10 percent of baseline counts. Therefore, microloop counts were within 5 percent of baseline counts 99.4 percent of the time in the right lane (dual probes). In the left lane (single probes), 94.5 percent of the 15-minute intervals were within 5 percent, 4.5 percent were between 5 and 10 percent, and 1.0 percent there was a more than 10 percent difference from baseline *(12)*.

Table 2 summarizes performance results of MinnDOT’s Phase II tests, while Table 3 represents a subset of the TTI data during off-peak, free-flow, daylight, and dry pavement conditions. TTI took a random single block of time from 10:00 a.m. to 2:00 p.m. using 5-minute data intervals to develop this summary. This analysis took the absolute value of percent differences for the selected 5-minute intervals, summed the 5-minute percent differences, and then divided by the total number of intervals. Table 4 summarizes costs of detectors based on MinnDOT research.

To supplement Table 3 and to demonstrate detector results under less than ideal conditions, Figures 2 and 3 show examples of data plotted from TTI research *(14)*, indicating the accuracy of non-intrusive devices as a function of prevailing freeway speeds. As 5-minute average speeds drop below about 40 mph, there is a noticeable difference in both count and speed accuracy for all devices. The Peek ADR-6000, using four inductive loops per lane, served as the baseline system in these tests. Two of its loops in each lane serve as axle detectors, one in each wheel path.

Table 2. Summary of MinnDOT Detector Test Results[1]

Sensor	Technology	Mount Location	Lane	Vol. Accuracy[2]	Speed Accuracy[2]
ASIM IR 254	PIR	OH	1	10.0%	10.8%
ASIM DT 272	PIR/Ultrasonic	OH	1	8.7%	N/A
		Sidefire	1	0.8%	N/A
ASIM TT 262	PIR/Ult/Radar	OH	1	2.8%	4.4%
ISS Autoscope Solo	VID	Sidefire	1	2.3%	5.7%
			2	2.7%	6.0%
			3	2.0%	7.4%
		OH	1	2.2%	7.0%
			2	1.5%	3.1%
			3	1.6%	2.5%
SEO Autosense II	Active Infrared	OH	1	0.7%	5.8%
SmarTek SAS-1	Acoustic	Sidefire	1	12.0%	5.4%
			2	6.7%	6.3%
			3	7.3%	4.8%
Traficon NV	VID	Sidefire	1	3.4%	7.7%
			2	1.9%	4.4%
			3	3.7%	2.3%
		OH	1	4.4%	3.3%
			2	2.7%	5.8%
			3	4.8%	7.2%
3M Microloop	Magnetic	Under Pvmt	1	2.4%	4.9%
			2	2.5%	2.2%
			3	2.3%	1.4%
		Under Bridge	1	1.2%	1.8%

Source: Reference *(23)*

[1] The results in this table represent a single test at an optimal mounting location for each sensor.

[2] Volume and speed accuracy are measured by the absolute percent difference between sensor data and baseline loop data in 15-minute intervals.

Data Sharing Between Agencies and States

Budget cuts are causing agencies to seek alternate means of meeting data quality needs, with one solution being to share data between agencies. The Hampton Roads TMC currently shares video with the city of Norfolk. There are also plans to share with other jurisdictions in this seven-city metropolitan area. Norfolk has a TMC and there is mutual benefit to sharing each other's data. Hampton Roads has interfaced with Norfolk and plans to share video, voice, and data with other six cities. Hampton Roads is investigating sharing traffic data now since it only has a video sharing agreement. That means that each has access to the other's camera feeds and to control of the cameras on a priority basis. If another organization has a higher priority, then they will have control of a camera *(9)*.

Table 3. Non-Intrusive Detector Test Results Based on a Selected TTI Dataset[1]

Sensor	Technology	Mount Location	Lane	Vol. Accuracy[2]	Speed Accuracy[2]
EIS RTMS	Radar	Sidefire	1	13.6%	5.9%
			2	N/A	3.4%
			3	2.4%	2.6%
			4	10.6%	4.7%
ISS Autoscope Solo Pro	VID	Sidefire	1	2.7%	0.8%
			2	2.8%	1.5%
			3	3.5%	1.8%
			4	2.1%	3.1%
			5	2.8%	2.1%
SmarTek SAS-1	Acoustic	Sidefire	1	6.7%	4.8%
			2	5.9%	3.8%
			3	6.8%	3.4%
			4	5.8%	3.9%
			5	4.0%	4.7%
Iteris Vantage Pro	VID	Sidefire	1	12.5%	5.4%
			2	5.1%	2.6%
			3	7.3%	1.2%

Source: Reference *(14)*

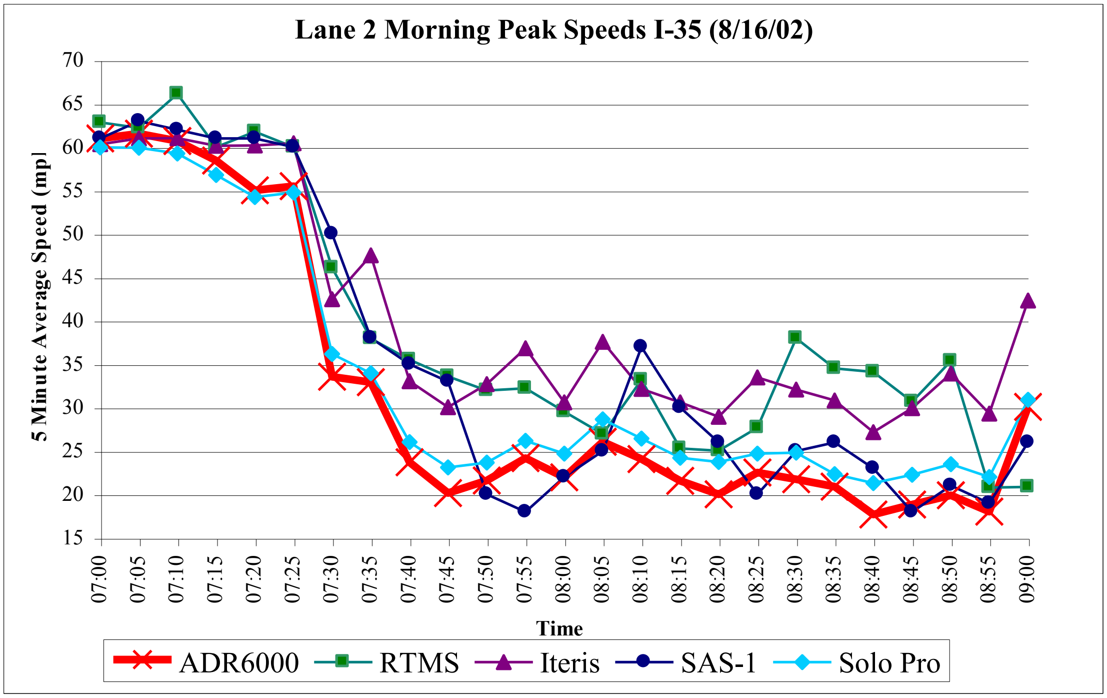
[1] The results in this table represent a single test at an optimal mounting location for each sensor.

[2] Volume and speed accuracy are measured by the absolute percent difference between sensor data and baseline loop data in 5-minute intervals.

Table 4. Detector Cost Summary

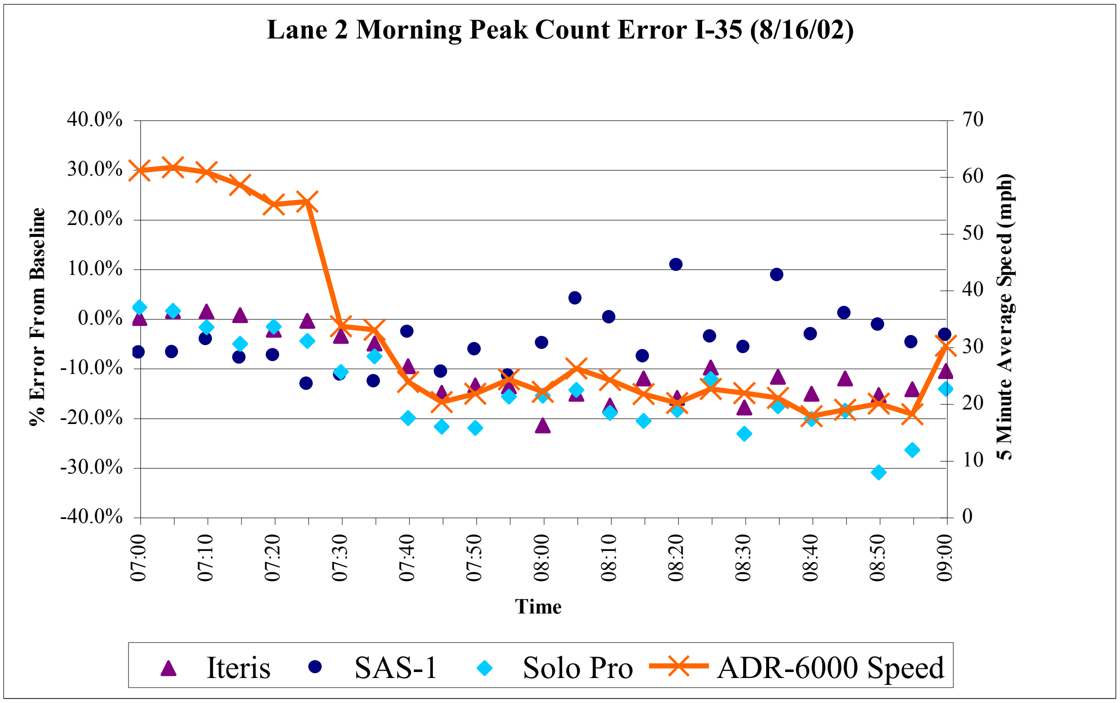
Vendor	Detector	Unit Cost	Note
ASIM Technologies Ltd	ASIM IR 254	$700	
	ASIM DT 272	$700	
	ASIM TT 262	$1,600	
ISS, Traffic Control Corp.	Autoscope Solo	$7,000 (Intersection Application)	Cost includes Solo unit, Minihub, interface panel and cable
	Autoscope Solo	$6,155 (Freeway Application)	Cost includes Solo unit, interface panel, and cable
Schwartz Electro-Optics, Inc.	Autosense II	$6,000 - $7,500	Depending on configuration/ functionality desired
SmarTek Systems, Inc.	SAS-1	$3,500	$3,080/unit in quantities over 10
Traficon NV	Traficon	Contact vendor	
3M NIM	Canoga Detector C822F (2 channel)	$546	Installation Kit $114 each; carriers (50/pkg) $354/pkg; C30003 Home-run cable $390/1000’ spool
	Canoga Detector C824F (4 channel)	$703.50	
	702 Microloop probe	$159.50/probe (+$0.39/ft for lead-in cable)	
	701 Microloop probe	$137.50/probe (+$0.39/ft for lead-in cable)	

Source: Reference *(23)*



Source: Reference *(14)*

Figure 2. Speed Performance as a Function of Freeway Speeds



Source: Reference *(14)*

Figure 3. Count Performance as a Function of Freeway Speeds

The New England states of Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont have cooperated to help each other and share transportation data. Applications are inventory, travel-monitoring data, and performance data used by states and reported to FHWA. By working together for many years, these states have improved data quality in a more efficient and cooperative environment *(24)*.

ARTIMIS supplies data to the following agencies: planning agencies within the Ohio DOT, the Kentucky Transportation Cabinet, and the FHWA Mobility Monitoring project. The agencies perform their own analysis of data quality. The data can be provided in several formats to suit the customer; the formats typically used are ASCII text file format, FHWA Type 3 and C records, and new record type formats developed by ODOT and KYTC (Types S, V, and L). ARTIMIS also shares data with the local MPO (Ohio-Kentucky-Indiana Regional Council of Governments), the City of Cincinnati Traffic Engineering office, and local FHWA contacts. The ARTIMIS staff makes the data available on an internal FTP site for their use. The ASCII text files and the Type 3, S, and V records contain some simple flags that indicate completeness of the data. There are currently no formal arrangements to share personnel or other resources to fix problems *(25)*.

Summary

This white paper identifies innovative approaches for improving data quality through *Quality Control*. It includes innovative contracting methods, standards, training for data collection, data sharing between agencies and states, and advanced traffic detection techniques.

The states of Virginia and Ohio are utilizing innovative contracting methods to improve data quality. VDOT at the Hampton Roads Traffic Management Center hires contractor personnel who are supervised by VDOT personnel. In another example of innovative contracting methods, VDOT has established performance based lease criteria for payment of data collection services for traditional data. Contractor compensation is based on the amount of acceptable data being submitted by the contractor. Ohio DOT is planning an innovative venture by executing a two-year statewide task order agreement for maintenance of traffic monitoring equipment for planning or historical data.

There are many reasons for adopting data and equipment standards, not the least of which is facilitating sharing of data across agencies. The U.S. DOT ITS Standards Program is encouraging development of standards to facilitate interoperability of ITS systems, including traffic data collection systems. In its current form, the forthcoming ASTM standard includes, among other items, device classifications, performance requirements, user requirements for tests, and test methods. In some European countries, all equipment purchased for national traffic data collection must utilize the same formats and protocols for communication purposes. The process has increased the quality and accuracy of the data collected, decreased the effort needed to transfer data between agencies or offices, and increased the reliability of field equipment, but the overall standardization effort has increased equipment costs.

Advanced traffic collection techniques includes the oldest technology, inductive loops. Results from studies conducted in Minnesota, New York, Oregon, and Washington indicate that improper sealing, pavement deterioration, and foreign material in the saw slot were most prominent in explaining loop failure.

Of the detectors recently tested by TTI and MinnDOT, the multi-lane detectors that are most competitive from a cost and accuracy standpoint are: Autoscope Solo Pro, Iteris Vantage, RTMS by EIS, SAS-1 by SmarTek, Traficon NV, and 3M Microloops. Based upon initial cost information, the SAS-1 and RTMS are less expensive than other units, but count and speed accuracies were inferior to other more expensive devices. Video imaging systems also provide an image of traffic, which is often useful in spot-checking traffic conditions. The initial cost of 3M microloops is relatively expensive (due largely to horizontal boring costs when installed under pavements), but their life-cycle costs should make them competitive with other technologies. Of the video imaging systems tested, the Iteris Vantage is the newest and has potential but needs further development. The count accuracy on all non-intrusive devices tested by TTI declined when 5-minute average speeds dropped below about 30 mph (possibly included some stop-and-go conditions). The Peek ADR-6000 is a high-end classifier that is extremely accurate, but its recent introduction into the U.S. market is a factor in its need for further refinement.

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