Current State of Radar in Traffic Data Collection and Its Place Among Competing Technologies

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Currently, the most popular traffic data detection systems are significantly intrusive in that they disrupt traffic during installation and maintenance and put road crews in danger. High maintenance costs as well as expectations on road agencies for better safety and lower traffic disruption have created significant demand for non intrusive data collection systems such as radar. Studies have shown that the accuracy of currently available radar solutions is on par with currently used intrusive systems such as inductive loops when used to detect volume and speed, but unacceptable when used for vehicle classification. Interested transportation engineers should continue to follow studies on evolving radar technologies, as they will surely replace many intrusive systems in both permanent and temporary installations in the future.

BACKGROUND

When collecting data used in highway safety analysis such as traffic volume, speed, and classification, there are many different technologies that can be used. It is difficult to determine which technologies are most efficient or effective, as factors including deployment, quality, and cost of sensors vary greatly. Additionally, different

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technologies have different strengths and weaknesses, and may be better in permanent installations rather than temporary ones (1). Currently, many technologies being used are "intrusive" detectors. They require a sensor to be placed on or in the surface of a road.

However, these intrusive technologies have significant disadvantages. First, road staff must work in significantly hazardous situations and must disrupt the flow of traffic to install detectors. Second, in some situations road agencies may not allow counts to be taken, either they are unwilling to disrupt the flow of traffic or temporary installments are not expected to stay in place for their required duration (1). Because of this, "...several non-intrusive detection systems are becoming more prominent, being viewed as cost-effective replacements" (2). Many new non-intrusive technologies are being used and evaluated, such as video cameras and acoustic detection. However, due to their current technological shortcomings, radar has become a much more tested and used non-intrusive detection method and is the focus of this paper.

POPULAR INTRUSIVE TECHNOLOGIES AND THEIR FAILURES

One of the most popular permanent intrusive detectors in use today is the Inductive Loop. It is a loop of conductive wire placed on or in the road that allows a small current of electricity to flow through it and to a control box that constantly monitors the inductance of the wire. A large presence of metal (such as a vehicle) can be detected above the loop because of the change in inductance (1). If installed and maintained correctly, loops can be of service for a long time and can very accurately measure volume, speed, and even classification data. For this reason, inductive loops are commonly used as a baseline for evaluating other technologies and methods of counting volume and speed data (3).

A more portable solution commonly used in the United States is the pneumatic tube, mostly deployed for counts over a shorter duration such as 24 or 48 hour traffic volume counts. The pneumatic tube is laid across the entire road and attached to an air switch that can count axles for all lanes. Data are stored and then converted later using an "axle correction factor" to determine a vehicle volume estimate for the duration of the data collection (1). Vehicle classification data can also be collected by using a second tube.

Failures

These popular solutions for traffic survey are not without their drawbacks. Inductive loops, for example, are tedious to install, and when installed poorly can be easily damaged by freeze-thaw cycles, water infiltration due to sub par sealants, chemical spills, and road cleanup and snow removal crews (1). Barbara Katherine Ostrom, Principal Engineer at MACTEC Engineering and Consulting, Inc. was quoted as saying, "One agency estimated that in any given month, half their loop counters were producing no or bad data" (4). Additionally, the cost and traffic disruption associated with replacing, fixing, and maintaining these loops is as high or higher than the original installation, and safety conditions for road crews are just as hazardous.

Also, inductive loops do not accurately detect vehicles with little metal such as motorcycles, and when turning the sensitivity up enough to do so, they commonly count vehicles in neighboring lanes (1).

Pneumatic tubes are plagued with their own set of problems. The tubes are highly vulnerable to dislocation due to their high profile and limited surface attachment (1). When installing a second tube to determine classification, there is a high margin of human error in making the tubes the exact same length. Also, rubber tubes are considered to be "slow sensors" because the rubber needs time to recover its deformities before a second axle can provide a second air pulse to the switch. The more lanes counted and the faster the vehicles are traveling, the more the system will under count axles (1).

RADAR: A PROMISING NON-INTRUSIVE ALTERNATIVE

What is Radar?

Both Doppler and microwave radar systems transmit a low-energy radiation and determine the time delay between the transmission and the reflection to calculate the distance to a vehicle. They are capable of measuring presence and speed but are not generally capable of classification (1).

Many radar systems, such as the SmartSensor developed by Wavetronix, are capable of working in either mode: microwave or Doppler. They can be placed overhead where they generally only observe one lane at a time, or can be setup on the side of the road in side-firing position to monitor multiple lanes. While side-firing is generally regarded as slightly less accurate due to occlusion problems, the overhead method is more expensive, generally requiring a unit for each lane.

Studies

In *Investigation of Vehicle Detector Performance and ATMS Interface*, different non-intrusive solutions available at the time were studied and compared to inductive loops. The objective of the study was to investigate the accuracy of these new and promising detectors; since the their performance continues to improve at a rapid pace, the detectors present an alternative to current methods such as inductive loops and pneumatic tubes (2).

The graph in Figure 1 shows a percent of error on count accuracy from the baseline data. The SmartSensor, a radar unit manufactured by Wavetronix and capable of both microwave and Doppler radar, is represented by the triangle. It is closest to the 0% error for the duration of the data shown in the graph. In Figure 2, speed accuracy is shown as fifteen-minute average speeds plotted at fifteen-minute intervals. The SmartSensor, once again shown as the triangle, very closely follows the baseline speed data.

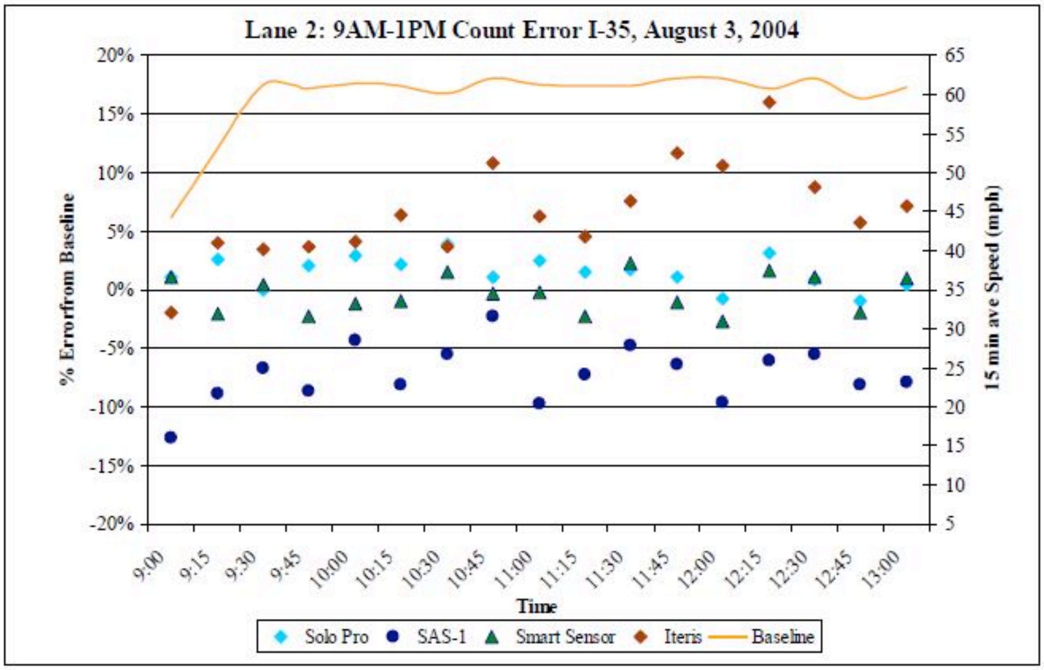

Figure 1: Detector count accuracy I-35 9am-1pm August 3, 2004. Source: Reference (2)

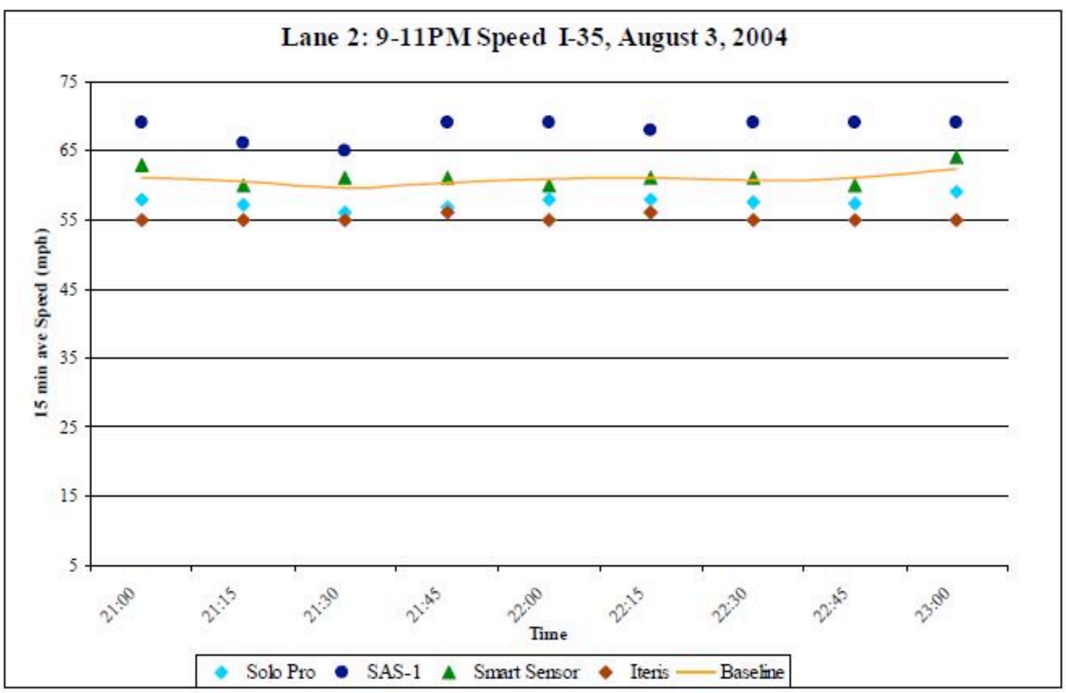

Figure 2: Detector speed accuracy I-35 9pm-11pm August 3, 2004. Source: Reference (2)

Middleton et. al. conclude that, since count accuracies of the Wavetronix SmartSensor were within 5% of the baseline data if installed correctly and properly maintained, and speed accuracies were within 2-5mph, both side-fired and overhead Doppler methods are suitable for freeway use and should be considered as replacements for inductive loops for the surveying of volume and speed data collection. In addition, the overhead Doppler method was even better, though testing on it was limited (2). However, since overhead units can only survey one lane at a time, higher costs are incurred to acquire a unit for each lane, when side-fired units can cover five lanes of traffic. This study also found that the SmartSensor tracked volume and occupancy "more closely than other non-intrusive devices" (3).

While this study looked at mostly stationary radar units, another study entitled *Evaluation of Microwave Radar Trailers for Nonintrusive Traffic Measurements* provides more insight into one of the larger advantages of nonintrusive detectors: portability. Zwahlen et. al. find that the Wavetronix SmartSensor units installed on a newly designed trailer provided promising count and speed results that measured traffic with "reasonable accuracy" (5). When compared to traffic that was independently measured by video, the radar system counted more than 95% of all vehicles and measured vehicle speeds to within 3 mph.

However, vehicle classification was very unreliable because the system uses running average speed to determine the length of a vehicle (5). This causes trucks to be severely over counted or under counted, leading the researchers to conclude that much more work needs to be done to accurately classify vehicles at an acceptable level.

Furthermore, an additional study by Yu et. al. entitled *Evaluation of Autoscope, SmartSensor HD, and Infra-Red Traffic Logger for Vehicle Classification* found that the SmartSensor HD by Wavetronix "provided inadequate vehicle classification accuracy for freeways," (6) further cementing the idea that current radar solutions can not adequately detect vehicle classification.

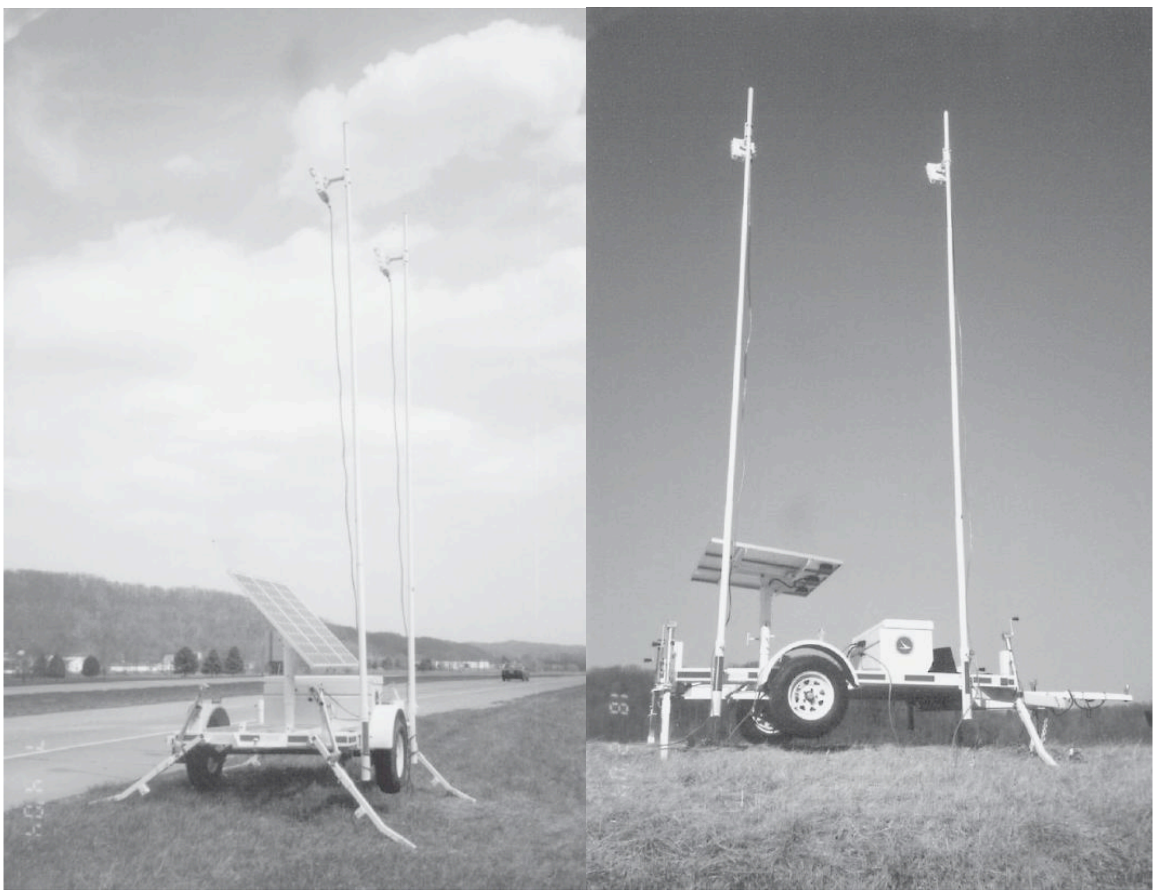

Figure 3: Microwave radar trailer set up to collect data at test site on US-50 east of Athens, Ohio. Source: Reference (5).

Successes and Failures of Radar

An immediately recognizable benefit to using radar as a non intrusive system is that it is minimally affected by lighting conditions and weather, if at all. The adaptability of many models allows the same unit to be used in overhead systems or side-firing systems for varying degrees of permanence or portability. Another large benefit of radar is that, as the technology has continued to evolve over time, its ease and speed of use have improved as well. The Wavetronix SmartSensor required 15 to 20 minutes total to setup in the study by Middleton et. al. (2).

However, current radar units are not without faults. In the presence of very heavy traffic, the detectors can miss entire vehicles or create fake counts. These occlusion and "phantom vehicle" problems were more prevalent in lanes further away from the center of the roadway and in the presence of large trailers (2). Additionally, current radar technologies cannot accurately survey vehicle classification as well as other technologies (5).

CONCLUSIONS

It is clear and understandable that road agencies are demanding more traffic data collection technologies and solutions that are less invasive than many currently used methods. Radar technology manufacturers have made huge strides in creating systems that are practical, feasible, adaptable, portable, and accurately record both traffic volume and speed. According to numerous studies, the volume and speed data that they record are on par with currently used technologies such as inductive loops and pneumatic tubes but without their invasive drawbacks and their high maintenance costs.

The technology can further its success by adding classification to its repertoire. Currently, the quality of classification data from radar units is lacking and inadequate for use by most data collectors. However, the technology makes great strides at being a perfectly capable replacement for volume and speed data collection, both in permanent and temporary use cases, and as the systems continue to evolve and become more cost effective, more traditionally invasive systems will be replaced with radar.

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