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TECHNICAL SUMMARY

Detection Technology for IVHS Volume I: Final Report and Volume II: Final Report Addendum

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IntelligentTransportationSystems

This technical summary announces the key findings of a Federal Highway Administration (FHWA) study that is fully documented in two separate reports: *Detection Technology for IVHS, Volume I: Final* Report (FHWA-RD-95-100) and *Volume II: Final Reporf Addendum* (FHWA-RD-96-109). See report-ordering information on the last page of this summary.

Project Objectives

The objectives of the FHWA-sponsored "Detection Technology for IVHS" project were to:

- Determine the traffic parameters and their corresponding accuracy specifications needed for future Intelligent Vehicle-Highway Systems (IVHS) applications.

- Perform laboratory and field tests with detectors that apply technologies compatible with above-the-road, surface, and subsurface mounting to determine the ability of state-of-the-art detectors to measure traffic parameters with acceptable accuracy, precision, and repeatability.

- Determine the need and feasibility of establishing permanent vehicle detector test facilities.

In performing the technology evaluations and in analyzing the data, focus was placed on the underlying technology upon which the detectors were based. It was not the purpose of the program to determine which specific detectors met a set of requirements, but rather whether the sensing technology they used had merit in measuring and reporting traffic data to the accuracy needed for present and future applications.

The project consisted of 12 major tasks:

Task A. Develop a working paper that defines IVHS traffic parameter specifications for the following application areas:

- Interconnected Intersection Control.
- Isolated Intersection Control.
- Freeway Incident Detection.
- Traffic Data Collection.
- Real-Time Traffic Adaptive Control.
- Vehicle-Roadway Communications.

Task B. Select sites for detector field tests. Test sites in three different regions of the country will be selected to provide a range of environmental and traffic conditions broad enough to ensure the utility of the test results on a nationwide basis.

Task C. Develop vehicle detector laboratory test specifications and a laboratory test plan.

Task D. Select and obtain vehicle detectors for testing.

Task E. Conduct laboratory detector tests and generate a report describing the results.

Task F. Develop vehicle detector field test specifications and field test plan.

Task G. Install vehicle detectors at field test sites and collect detection technology evaluation data.

Task H. Generate detection technology field test results.

Task I. Determine which of the currently available vehicle detectors meet the IVHS criteria of Task A.

Task J. Determine the need and feasibility of establishing permanent vehicle detector test facilities.

Task K. Prepare a draft final report.

Task L. Prepare the final report that incorporates comments received from FHWA and others.

Detector Technologies Evaluated

The detector technologies evaluated in the field tests were ultrasonic, microwave radar, infrared laser radar, nonimaging passive infrared, video image processing using visible spectrum and infrared imagery, passive acoustic array, high sampling rate inductive loop, conventional inductive loop, microloop, and magnetometer. The term passive denotes that energy is not transmitted by the detector as these devices sense energy or signals emitted by the vehicles and roadway. The theory of operation of each of the technologies has appeared in project reports and other papers. Weigh-in-motion types of detectors were not part of the study.

Vehicle Detector Field Test Sites

The cold winter environment evaluations of detector performance were conducted in Minnesota; summer thunderstorms, lightning, and humidity were experienced in Florida; and dry desert summer heat were experienced in Arizona. Testing in Minnesota occurred during winter 1993, in Florida during summer of 1993, and in Arizona during fall and winter of 1993 and summer of 1994.

Conclusions

Most Accurate Vehicle Count for Low Traffic Volume

Most of the detectors gave good results when used under light traffic conditions. Detectors with multiple outputs or detection zones give the appearance of better performance than do those with only one detection zone because only the most accurate of the outputs was displayed in the reported results. For example, if loop #1 showed better agreement with the ground truth value than loop #2 (for the same lane), then the loop #1 results were presented. Likewise, if a single traffic detector had multiple detection zones, the most favorable of the outputs was used in the plotted results. This affords a greater opportunity for these devices to appear in a favorable light, whereas a simple detector having a single relay output was represented solely on the basis of that single output.

The ultrasonic and infrared detectors exhibit count accuracies that make them suitable for a variety of applications, but they were typically not among the most accurate. The self-powered vehicle detector (SPVD) two axis magnetometer performed well in low-volume applications, as demonstrated by the 0-percent error over a 2-h run during snowfall conditions for one of the Minnesota surface-street runs.

Microwave detectors were also well suited to low-volume conditions. The presence-type microwave radar consistently provided better vehicle count results in forward-looking operation than in side-looking orientation. Forward-looking count accuracies to within 1 percent were not uncommon; however, these accuracies were typically provided by only a single detection zone due to the difficulty in confining the detector's elliptical beam footprint to a single lane of traffic. Because of this footprint geometry, only one detection zone tends to be optimally matched to the dimensions of the traffic lane, while the remainder of the zones tend to undercount (in the narrow parts of the beam where the detection zones are not as wide as the lane) or overcount (where the wide part of the beam tends to spill over into adjacent lanes of traffic).

Doppler-type microwave detectors fare well in low-to-moderate traffic volume conditions, where free-flowing traffic consistently provides a component of motion in the detector's viewing direction that is necessary for the operation of these units. However, there can conceivably be traffic management applications where a knowledge of decreasing speeds can be used to infer that stopped vehicles are present even though the Doppler detector does not give an output indication once the vehicle comes to a full stop. Again, care must be taken to ensure that the detector's beam footprint on the roadway is confined to the desired monitoring area.

Some video image processors exhibit counting characteristics similar to microwave detectors. The Autoscope 2003, for example, can be configured to have three separate detection zones per lane (two emulating a pair of inductive loops and a third configured as a speed trap). Data show that count results tend to be optimized for a given zone.

Inductive loops are among the most consistent performers, with count accuracies typically in the 99-percent range. Even so, problems with crosstalk and double- or triple-counting large trucks and tractor-trailer rigs have been seen when reviewing videotapes of the field tests.

Most Accurate Vehicle Count for High Traffic Volume

Many of the same observations made in the previous section apply here as well. However, the electronic hold time of a detector begins to become an important factor when intervehicle gap times decrease. The hold time is the period over which a detector remains in the active state after the initial detection of a vehicle.

For the field tests, the hold time of each device was always set to its minimum value. Increasing the hold time in heavy traffic conditions has a negative impact on count accuracy due to the detector's inability to determine when one vehicle departs the detection zone and another enters. With long hold times, a second vehicle enters the detection zone prior to the falling edge of the pulse created by the first vehicle. This can result in several closely spaced vehicles registering only a single count on a given detector. Although several detectors evaluated were designed with long hold times because of an initial traffic management requirement, devices of similar types can certainly be redesigned with shorter hold tunes as new applications arise.

Most Accurate Speed for Low Traffic Volume

Speed accuracy is a difficult parameter to assess due to the challenge of obtaining the true speeds against which to compare the detector speed outputs. Some detectors compute speeds based on average vehicle lengths. Such devices may yield acceptable accuracies for average vehicle speed over long time intervals, but not for applications that require speeds over short, tactical time intervals or speeds on a vehicle-by-vehicle basis. The latter requirement favors the implementation of detectors that make direct speed measurements, or pairs of detectors that can be used in a speed-trap configuration.

The simplest and most accurate way to measure speed is with a detector that provides it directly, such as a Doppler microwave detector. Doppler devices require a component of vehicle motion in the direction of travel monitored by the detector. Since free-flowing traffic is normally available in low-volume conditions, a Doppler device would seem a logical choice for such an application. Speed, as measured by Doppler microwave detectors, usually agreed within 3.2 to 4.8 km/h (2 to 3 mi/h) with readings from the speedometers of the probe vehicles. However, the imprecision associated with a human observer recording these values from an analog speedometer of unknown accuracy yields, at best, a reference value and not absolute truth.

Most Accurate Speed for High Traffic Volume

The main difference in requirements between low- and high-volume applications stems from the change in vehicle speeds. Vehicles in low-volume conditions are likely to be free-flowing and unconstrained in their movements, while vehicles in high-volume conditions, where the roadway is at or near its designed capacity, will be restricted in their speed. When the traffic demand exceeds the capacity of the roadway, speeds will obviously decrease. If the speeds slow significantly and bumper-to-bumper traffic conditions ensue, then Doppler detectors will not perform when the vehicle speed is below approximately 4.8 km/h (3 mi/h). In some applications, this may not be of concern as the necessity for zero speed measurement may decrease once the traffic flow falls below some fixed threshold.

Best Performance in Inclement Weather

The detectors that seemed the most impervious to inclement weather conditions were the microwave detectors. No appreciable change in performance was noted during conditions such as ram, snow, wind, and extreme heat or cold. The magnetometers performed well in the snow during the Minneapolis surface-street tests. The inductive loops, when properly installed, performed reliably through a broad spectrum of weather conditions.

The technologies with the greatest extreme weather limitations include the ultrasonic, infrared, acoustic, and video image processors. This is not due to any flaw in the design of these units, but rather to physical limitations caused by weather-related phenomena, such as gusty winds (greater than 25 m/s [greater than 56 mi/h] in the case of the Doppler ultrasound detector) or the presence of atmospheric obscurants. However, even these devices are relatively unaffected by inclement weather conditions when operating at the short ranges typically associated with their normal traffic management applications.

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Distribution-This technical summary is being distributed according to a standard distribution. Direct distribution is being made to the Regions and Divisions.

Availability-This is a two-volume publication that will be available in December 1996. Copies will be available from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22161. A limited number of copies will be available from the R&T Report Center, HRD-11, FHWA, 9701 Philadelphia Court, Unit Q, Lanham, Maryland 20706.

Key Words-Detection technology, detectors, sensors, ITS, microwave, infrared, video image processing, ultrasound, inductive loops, magnetometers, presence, speed, occupancy.