Traffic Parameter Measurement Technology Evaluation

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ABSTRACT

The three primary goals of this FHWA-sponsored program are to: (1) determine the types of traffic parameter data and the associated accuracies required for IVHS vehicle detection applications on surface streets and freeways, (2) conduct tests to determine the performance of current state-of-the-art detectors, and (3) determine the need for a national detector test facility. Detectors based on technologies such as microwave radar, passive and active infrared, ultrasound, video image processing, inductive loops, and magnetometers are being tested and evaluated in three states that exhibit widely divergent climates.

One freeway and one surface street arterial site were chosen in each state to test and evaluate the applications of the detector technologies. The states selected for the tests were Minnesota for its cold winter environment, Florida for its spring thunderstorms, lightning, and humidity, and Arizona for its dry desert summer heat. Testing in Minnesota began during the 1992-1993 winter and Florida in late spring of 1993. Arizona is scheduled for late summer and fall 1993.

INTRODUCTION

In recent years, continuing traffic growth and limited construction of new highways have combined to require the maximum utilization of the existing transportation network. This includes both the urban street system as well as freeway facilities. Traffic monitoring detectors supply data to real-time, adaptive signal control systems and incident detection and notification systems that are an integral part of nearly every modern traffic management system. Thus, there is a growing need to explore the use of newer detection technologies to obtain real-time data for area-wide surveillance and control of signalized intersections, freeways, and motorist information services.

Current vehicle detection is based predominantly on inductive loop detectors (ILDs). These ILD applications provide a baseline for evaluating more advanced detector systems. Alternative detector technologies are being developed with the potential to be installed and maintained without disrupting traffic flow. Some can directly measure a wider variety of parameters, such as density, travel time, and vehicle turning movements, in addition to the more common parameters of flow, speed, and occupancy. The less obtrusive buried detectors will continue to find applications in the future, as for example, where aesthetic concerns are dominant.

This paper summarizes the methods used to evaluate the detector technologies in the field tests and gives some of the early results. Desired IVHS traffic parameter and accuracy specifications [1], manufacturers detector specifications [2], detector laboratory test specifications and test plans [3], and laboratory test results [4] are described in detail in the project reports.

DETECTOR TECHNOLOGIES EVALUATED

The detector technologies evaluated in the field tests are ultrasonic, microwave radar, active and passive infrared, video image processing, inductive loop, and magnetometer as shown in Table 1. The theory of operation of each of the technologies has appeared in project reports and other papers [1, 5, 6]. Weigh-in-motion types of detectors are not part of the present study.

MEASURED TRAFFIC PARAMETERS

One set of monitored traffic parameters includes flow rate, speed, and density or its surrogate occupancy. These parameters are interrelated and together describe the quality of traffic flow on a highway [1]. To measure flow rate accurately, detectors need to discriminate between vehicles where there are spatial gaps on the order of one to two car lengths and average time headways of about 1.5 to 2 seconds, although headways of 0.5 second are not uncommon in congested areas. Speeds have been measured with speed traps composed of two closely spaced (ten to twenty feet apart) inductive loop detectors, or with microwave radar, laser radar, or ultrasonic detectors using the Doppler effect. Density (vehicles per mile per lane) is difficult to measure directly, except with some type of picture format such as video imaging or aerial photography. Consequently, lane occupancy (the percent of time the detection zone of a detector is occupied by a vehicle) has been used as a surrogate measure for density. To accurately measure occupancy, it is often required to discriminate between vehicles and gaps to within 1 to 5 percent of their true values [1].

Other traffic parameters include presence, queue length, travel time, intersection turning movements, and vehicle classification. Presence needs to be measured, even if the vehicle is

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stationary, for signal activation applications. Therefore, detectors which require motion to be activated, e.g., magnetic detectors and some overhead types, cannot perform this task.

Table 1. Detectors Used During Field Tests

Symbol	Technology	Manufacturer	Model
U-1	Ultrasonic Doppler	Sumitomo	SDU 200
U-2	Ultrasonic Presence	Sumitomo	SDU 300
U-3	Ultrasonic Presence	Microwave Sensors	TC-30C
M-1	Microwave Radar Motion Medium Beamwidth	Microwave Sensors	TC-20
M-2	Microwave Radar Doppler Medium Beamwidth	Microwave Sensors	TC-26
M-4	Microwave Radar Doppler Narrow Beamwidth	Whelen	TDN-30
M-5	Microwave Radar Doppler Wide Beamwidth	Whelen	TDW-10
M-6	Microwave Radar Doppler Narrow Beamwidth	Electronic Integrated Systems	RTMS
IR-1	Active IR Laser Radar	Schwartz Electro-Optics	780D1000
IR-2	Passive IR Presence Output for Stopped Vehicle Detection	Eltec	842 Operates with speeds < 45 mph
IR-3	Passive IR Pulse Output For Moving Vehicle Detection	Eltec	833 Operates with speeds up to 85 mph
VIP-1	Video Image Processor	Econolite	Autoscope 2003
VIP-2	Video Image Processor	Computer Recognition Systems	Traffic Analysis System
VIP-3	Video Image Processor§	Traficon (formerly Devlonics)	CCATS
MA-1	Magnetometer	Midian Electronics	Self Powered Vehicle Detector
ILD	Inductive Loop Detector	Various	Various

§ Scheduled for delivery at Florida field tests.

Queue length, as density, requires wide area detection to be measured directly. Point detectors that measure presence at specific distances from a stop line can be used to estimate queue length. Travel time is inversely proportional to average speed. However, for travel time to be measured directly, a network-wide interrogation system is needed. Thus, travel time could be a side benefit of instituting an automatic vehicle identification (AVI) system in which the vehicles act as "probes". However, AVI systems are beyond the scope of the field test portion of this project. Imaging systems, high resolution ranging systems such as active infrared and some ultrasonic systems, and ILDs coupled with special vehicle transmitters and receiver amplifiers also have vehicle classification ability.

TEST SITE DESCRIPTION

The I-394 at Penn Avenue freeway test site in Minneapolis is shown in Figure 1. The lanes instrumented with inductive loops and overhead detectors were the two permanent eastbound lanes into Minneapolis and one of the reversible high occupancy vehicle (HOV) lanes. The Olson Highway surface street site near I-94 contained three through westbound lanes and one left-turn and one right-turn pocket. Of these, the two left-most through lanes were instrumented with inductive loops, magnetometers (one lane only), and overhead arrays of detectors. Several side-mounted detectors were also mounted on a light pole approximately 25 feet east of the sign bridge that supported the overhead detectors. The Florida and Arizona test sites have similar features. Their descriptions are found in the Task B Report [7].

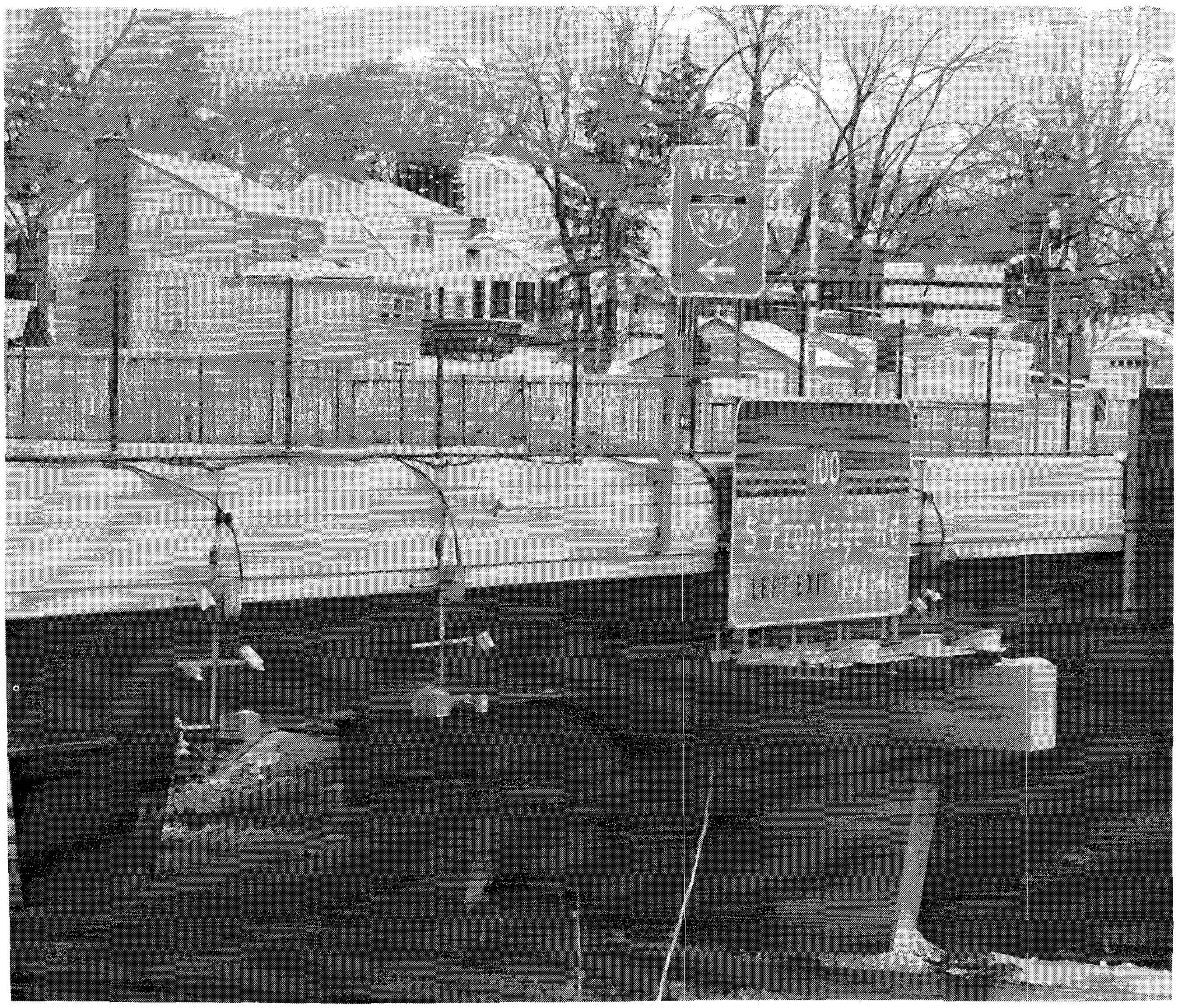

Figure 1. I-394 freeway test location showing detectors overlooking eastbound lanes and one HOV lane

DETECTOR INSTALLATION

Detectors representing the overhead technologies evaluated were mounted on a pipe tree constructed of 1-1/2-inch iron, which in turn was bolted to the overhead roadway bridge or sign bridge. Three pipe trees were used at the Minneapolis freeway site, as was shown in Figure 1, and two at the surface street site. The detectors attached to the nearest tree in Figure 1 are, from left to right and bottom to top, an ultrasonic SDU 200, microwave radar TDW-10, passive infrared 833, passive infrared 842, and microwave radar TC-20. Those on the middle tree are a microwave radar TDN-30, ultrasonic TC-30C, and microwave radar TC-26. The black and white video camera is mounted at the top of the middle tree. The third tree, over the reversible HOV lane, contains a microwave radar TDW-10, microwave radar TC-26, laser radar 780D1000, and microwave radar TC-20.

Pairs of inductive loop detectors, spaced approximately fifteen feet apart, were placed under the road surface in the monitored traffic lanes. Magnetometers were not installed at the Minneapolis freeway test site, but were at the surface street site, where they were placed at the centers of a pair of inductive loops. The onset and duration of the green phase signal was recorded at the surface street site to correlate with the traffic data. The detailed field test plan is contained in the Task F Report [5].

RECORDING OF TRAFFIC FLOW DATA

A data logger was designed and built to time tag, record, analyze, and overlay selected detector output data on the video imagery of the traffic flow. Typical recorded data consist of vehicle count, presence, speed, and classification based on vehicle length, depending on the detector. Some detectors output both discrete and serial (RS-232) traffic parameter data, while others output only discrete data using Form C relay closures or optically isolated outputs. As part of the data analysis, similar parameters from several detectors can be plotted as a function of time along with their mean values and standard deviations. Selected detector outputs or analysis results, such as detector technology type, traffic parameters (e.g., count and speed), and mean and standard deviation of the traffic data parameter, can be superimposed onto the video tape that was recorded during the data collection process. This visual presentation facilitates a qualitative comparison of the performance of the different detector technologies [6].

Up to sixteen serial detector outputs, forty optically isolated outputs, sixteen Form C relay closure outputs, and eight analog outputs that include environmental data (e.g., temperature, wind speed, wind direction) and analog detector outputs such as Doppler frequency can be recorded.

DATA ACQUISITION RUNS

The data acquisition runs include: (1) morning rush hours, (2) mid-day lower volume traffic, and (3) evening rush hours. The morning run included transitions from darkness to twilight to daylight and the evening run included transitions from daylight to twilight to darkness. Paint and traffic cone markings were placed on the roadside to calibrate distances. During each run, a tagged vehicle was driven through the field of detectors at a known speed to aid in the calibration of the detectors' speed outputs. When made available by the states, radar speed guns were used for calibration. Traffic parameter truth data (e.g., counts, presence, and vehicle type) were also obtained from the recorded video imagery.

DATA ANALYSIS

The data were analyzed by first converting the recorded detector output transitions or serial data into a format that was compatible with importation into a data base program. From here, selected files were tagged by detector technology, time of run, weather, or data type for further analysis in a program such as Mathcad.

RESULTS

Before evaluating the detectors in Minneapolis, the Los Angeles Department of Transportation conducted preliminary tests on their Exposition Avenue detector evaluation site. The vehicle count accuracy data gathered were expressed as the ratio of vehicle count from the detector-under-test to the count from a calibrated inductive loop detector over a fifteen minute interval. The accuracy of the inductive loop with respect to vehicle count was 99.4% according to data supplied by Los Angeles. The counts from most detectors were within 2% to 11% of those from the inductive loops. The detectors with lower accuracy ratios typically had long hold times built in by the manufacturer and, hence, may have missed counts when closely spaced, high speed traffic was present. The same effect was observed in data obtained at the Minneapolis freeway test site.

An example of vehicle count data from the Minneapolis freeway test is shown in Figure 2. The data were collected from 11:30 am to 1:30 pm when traffic flow was moderate to light. The counts from all the detectors appear to track well. The vehicle speed versus flow rate data in Figure 3 were collected from 6:30 am until 10:30 am, corresponding to before, during, and after the morning rush hours. The inverse relationship between speed (in mph) and flow (in vehicles per minute) can be seen.

CONCLUSIONS

The detector technologies to be evaluated have been identified and are represented by detectors that have been obtained from various manufacturers. The requirements for future detectors needed to support IVHS applications will be compared with the performance of the currently available detectors. Field tests in Minneapolis and Orlando have been completed. Early results from the Minneapolis tests show the response to light, moderate, and heavy traffic flows. Correlation of detector data with ground truth is still ongoing.

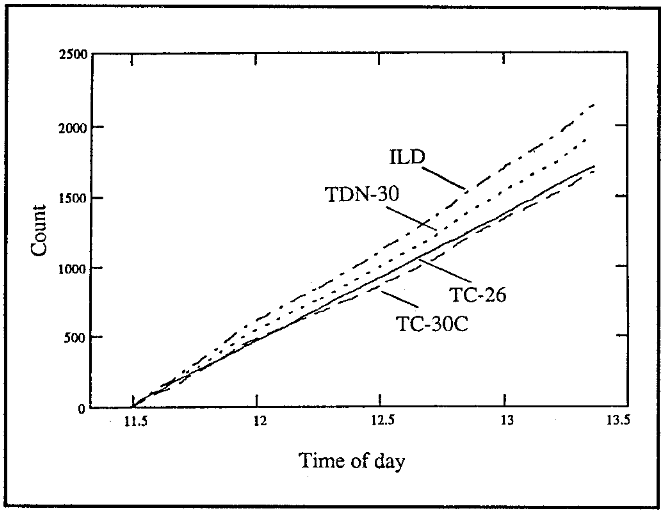

Figure 2. Vehicle count data obtained at Minneapolis freeway test site

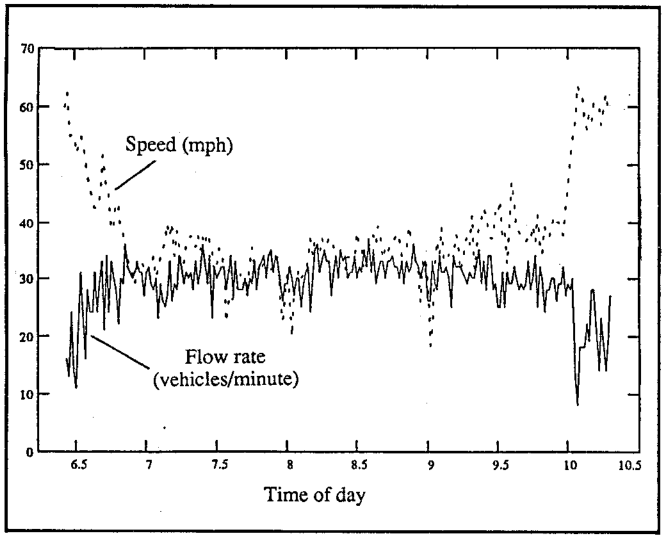

Figure 3. Inverse vehicle speed versus flow relationship obtained from Minneapolis freeway test site data

REFERENCES

[1] *Detection Technology for IVHS – Task A Report: Development of IVHS Traffic Parameter Specifications,* Federal Highway Administration Contract DTFH61-91-C-00076, U.S. Department of Transportation, Washington, D.C. (1993).

[2] *Detection Technology for IVHS – Task D Report: Detector Selection,* Federal Highway Administration Contract DTFH61-91-C-00076, U.S. Department of Transportation, Washington, D.C. (1992).

[3] *Detection Technology for IVHS – Task C Report: Vehicle Detector Laboratory Test Specifications and Test Plan,* Federal Highway Administration Contract DTFH61-91-C-00076, U.S. Department of Transportation, Washing-ton, D.C. (1993).

[4] *Detection Technology for IVHS – Task E Report, Parts I, II, and III: Vehicle Detector Laboratory Test Results,* Federal Highway Administration Contract DTFH61-91-C-00076, U.S. Department of Transportation, Washington, D.C. (1993).

[5] *Detection Technology for IVHS – Task F Report: Vehicle Detector Field Test Specifications and Field Test Plan,* Federal Highway Administration Contract DTFH61-91-C-00076, U.S. Department of Transportation, Washington, D.C. (1993).

[6] L.A. Klein, M.S. MacCalden, Jr., and M. Mills, *Detection Technology for IVHS*, in Proceedings of the IVHS AMERICA Third Annual Meeting, Washington, D.C. (April 1993).

[7] *Detection Technology for IVHS – Task B Report: Field Test Site Selection,* Federal Highway Administration Contract DTFH61-91-C-00076, U.S. Department of Transportation, Washington, D.C. (1993).