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Use of Los Angeles Freeway Service Patrol Vehicles as Probe Vehicles

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USE OF LOS ANGELES FREEWAY SERVICE PATROL TRUCKS AS PROBE VEHICLES

FINAL REPORT TO THE
PARTNERS OF ADVANCED TRANSIT AND HIGHWAYS
MOU 347, SUBSEQUENT TO MOU 282

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California Department of Transportation District 7
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1 INTRODUCTION

1.1 Problem Statement

The Los Angeles County Metropolitan Transportation Authority/California Department of Transportation/California Highway Patrol **Freeway Service Patrol (FSP)** program is the largest in the nation, operating 144 service vehicles on 40 beats covering 393 center-line freeway miles in Los Angeles County.

The Caltrans District 7 Transportation Management Center (TMC) exercises FSP fleet control via the California Highway Patrol Computer Aided Dispatch (CAD) system. Each freeway service patrol truck is equipped with a Mobile Data Terminal (MDT), polled by the Automatic Vehicle Location (AVL) system. The system includes a Transportation Management Solutions Incorporated (TMSI, now Orbital TMSI) Geo-Position System (GPS) that can identify transponder locations to within 100 feet. There is potential for using the GPS and/or the AVL information to determine FSP truck speeds automatically because field units are polled frequently, and GPS locations are sufficiently accurate.

This research assesses the feasibility of using existing FSP trucks as probe vehicles for measuring level of service on Los Angeles freeways. If the information FSP trucks provide in Los Angeles is of sufficient quality and quantity to measure level of service on the network, then FSP trucks (or other similarly-equipped fleets) would also be useful for measuring LOS in other Caltrans Districts, especially those with relatively fewer loop detectors than Caltrans District 7.

1.2 Research Objective

Data resources Caltrans District 7 currently uses to support the Freeway Service Patrol present new opportunities to assess the Los Angeles transportation network. This research evaluates one way Caltrans Transportation Management Center staff can use such information to better understand level of service on the network. The report also explores how new transportation management approaches might transfer to other locations.

This research produces and compares freeway traffic ambient speed empirical estimates from several sources. These include floating car studies, single-loop detectors, and data from mobile data terminals on FSP trucks. This MDT data is accessible in two ways: manually in pseudo (near) real-time format from the AVL terminal connected to the

CHP CAD console located in the Caltrans District 7 TMC; or automatically from a log file at the CAD station in the CHP Los Angeles Communications Center (LACC).

The project determines whether this sort of probe vehicle information can estimate level of service, the requirements for doing so, and the conditions required for generating this data reliably. Operational or institutional constraints that might limit use of the Los Angeles FSP fleet as probe vehicles are identified based on observation of both CAD operator and FSP truck driver tasks and a comprehensive review of all associated systems.

Specific research objectives include:

- Determining how to use the existing fleet of FSP trucks as probe vehicles for estimating traffic conditions, and determining the information the existing system can provide;
- Identifying operational or institutional constraints that limit the feasibility of using Los Angeles FSP trucks as probe vehicles;
- Possibly improving loop detector data by combining it with probe vehicle data, and determining how to combine the output of functioning loop detectors and probe vehicles to generate level of service information for the links in the network; and
- Identifying what new infrastructure requirements (if any) are required to process probe vehicle information on a large scale in the new District 7 interim TMC in downtown Los Angeles.

2 LITERATURE REVIEW

2.1 Freeway Service Patrol Evaluation (Skabardonis *et al.,* 1995)

This report presents the findings from an evaluation of the FSP program on a 9-mile section of I-880 in the City of Hayward (Alameda County) in the San Francisco Bay Area. A team associated with the California Partners for Advanced Transit and Highways conducted the study whose objective was to determine the savings in incident delay and other performance measures by comparing the 'before' and 'after' traffic conditions associated with FSP program implementation.

Three primary objectives of the study were to:

- Develop a comprehensive database of freeway incidents;
- Develop and apply an appropriate methodology for estimating incident delay; and
- Evaluate the effectiveness of the FSP program in the Bay Area.

Important findings of this study include:

- About 10 percent of the incidents were accidents;
- Only 4 percent of the incidents blocked traffic lanes;
- The proportion of tow truck-assisted incidents increased from 9 percent before FSP program implementation to 24 percent after;
- The FSP provided about 80 percent of assists;
- Response times for assists decreased significantly in the 'after' period compared to the 'before' period; and
- There was a statistically significant shortening of incident duration for FSP-assisted incidents compared to non-FSP assisted incidents.

The study estimated a benefit: cost ratio of 3.4:1 for the FSP program at the specific test site on the basis of observed incident delay savings, and reductions in fuel consumption and pollution emissions. The study also mentioned additional benefits from the FSP program such as time and cost savings for the assisted motorists, improved incident detection by FSP drivers, and reductions in time CHP officers spent on incidents. FSP program benefits are higher in locations with higher traffic volumes, mixed lanes, and narrow or no shoulders. Benefits are limited in locations with fewer incidents.

2.2 The I-880 Field Experiment: Analysis of Incident Data (Skabardonis *et al.*, 1996)

The I-880 field experiment that the same PATH research team conducted has produced one the largest databases of freeway traffic flow characteristics. This paper presents findings from an analysis of incident data collected during the I-880 study. The team collected field data through observations of probe vehicle drivers 'before' and 'after' implementing FSP service on a selected portion of the I-880 Freeway. The California Highway Patrol Computer Aided Dispatch Database and FSP and tow truck company logs provided supplementary data. Procedures included recording field data on incidents, conducting probe vehicle runs, and colleting speed-flow occupancy data from closely-spaced loop detectors.

The research shows:

- Most of the incidents or breakdowns were on the right shoulder;
- The estimated incident rate on the study section was 104 incidents per million vehicle miles;
- In-lane incidents accounted for 4.7% of the total;
- 59% of incidents in travel lanes were accidents;
- A much higher proportion of incidents block two or more lanes;
- Accidents accounted for 10% of the total incidents;
- On average, 3.8 accidents occurred during a 6-hour peak period;
- 49% of accidents involved at least two vehicles;
- Average incidents per shift doubled on rainy days;
- The number of assisted breakdowns increased 120% during the 'after' period;
- Average response time for all incidents declined by 36% (from 37.6 to 21.1 minutes);
- FSP assistance reduced average incident duration from 41.2 minutes to 28.6 minutes;
- Response times were less than 20 minutes for 80% and 40% of breakdowns during 'before' and 'after' periods respectively;
- The average duration of all incidents was 25 minutes, with 85% of incidents lasting up to 50 minutes;
- Average in-lane and right shoulder incident clearance times were 20 and 7 minutes respectively; and
- 51% of the recorded incidents could be matched with entries in the CHP's CAD database.

The paper concludes by recommending this database for recalibrating incident detection algorithms and simulation models. It also formulates improved guidelines for deploying and evaluating incident management programs.

2.3 The Optimal Placement of FSP Tow Trucks (Petty *et al.*, 1996)

This paper presents a methodology the authors developed using the I-880 database for determining FSP truck placement to maximize congestion reductions.

The FSP-patrolled freeway sections (or "beats") vary between 10 and 20 miles in length. FSP trucks rove along these beats continuously and assist disabled vehicles free of charge. The FSP reduces motorist delays by reducing incident clearance time. The external benefit associated with this foregone delay justifies the cost of FSP programs to transportation authorities.

The study develops an algorithm to determine the optimal placement of FSP tow trucks. The algorithm has an intuitive solution: the tow trucks are placed one-by-one on the beat with the largest marginal benefit until there are no more tow trucks. Under this circumstance, cost does not increase if one truck is moved from one beat to another.

The 'before' situation for numerical analysis included an I-880 test site without FSP trucks on the selected beat. In the 'after' scenario, two trucks roved on the same beat. For the 'before' situation, it was assumed that one FSP truck roved on the beat to acknowledge that tow trucks attended incidents in the absence of FSP trucks. The numerical analysis revealed that the marginal benefit: cost ratio decreased from 5.1 in the 'before' scenario to 1.1 in the 'after' scenario. Therefore, the high marginal benefit: cost ratio strongly supports deployment of an FSP truck on the selected beat. The 'after' ratio indicated that the benefit of adding another FSP truck was approximately equal to truck operating costs.

2.4 FSP Evaluation in Los Angeles (Skabardonis *et al.*, 1996, Bertini *et al.*, 1997)

This study describes the first stage of a recently-completed Los Angeles area FSP evaluation on a 7.8-mile I-10 freeway segment within FSP Beat 8. The basic study objective is evaluating the FSP program impact in the Los Angeles region on reducing delay, fuel consumption, and emissions. This evaluation is similar to the San Francisco Bay Area PATH study of the I-880 Freeway.

Preliminary data analysis shows that incident types vary significantly in the study area relative to both national and San Francisco Bay Area averages. In-lane incidents are much more frequent in Los Angeles than in the Bay Area, and the average number of FSP assists is much higher in the Los Angeles region than in the Bay Area. The study found differences in the distribution of incident types, even though FSP response and clearance times for a given type of incident were almost identical in both study areas.

2.5 The Los Angeles Freeway Service Patrol (FSP) Evaluation: Site Selection and Database Development (Bertini *et al.*, 1997)

This paper is the second phase of a Los Angeles FSP evaluation study focusing primarily on two issues: developing site selection criteria for defining data collection procedures, and developing a database. Staff of CHP, Caltrans District 7 and LACMTA prepared a list of potential sites using the following criteria:

- Active and reliable loop detectors must provide speed and occupancy data,
- Traffic volume should be close to or at capacity during peak hours but, potential bottleneck locations are not desirable,
- Incident frequency should be high,
- Traffic lanes at the site must be mixed non-HOV lanes with narrow or no shoulders, and
- Ongoing construction sites must be excluded.

The detailed test site evaluation procedure included:

- Collection of freeway section geometrics,
- Experimental tach runs in floating cars to determine freeway segment suitability,
- Reliability check of loop detector data available from the District 7 MODCOMP, and
- Video recording of traffic flow at test sites to determine loop detector data accuracy.

Analysis showed that Beat 8 on the I-10 Freeway matched proposed site-selection criteria well. This beat has a high loop density rating, high ADT, a high total number of FSP assists and many in-lane assists. Analysis of this site used loop detector and accident data from Caltrans Traffic Accident Surveillance and Analysis Selective (TASAS) Record Retrieval System.

Data collection and database development consisted of:

- Collecting six hours of peak period data for 32 weekdays from June 24 to Aug. 9, 1996;
- Collecting field logs for 1,560 incidents;
- Performing 3,619 tach runs at 5.7-minute headway;
- Collecting data from 240 loop detectors at 48 stations; and
- Compiling data from additional sources including FSP Scantrons, CHP CAD, tow company logs, video recordings, and Caltrans District 7.

2.6 The Los Angeles Freeway Service Patrol (FSP) Evaluation: Study Methodology and Preliminary Findings (Petty *et al.*, 1997)

This study describes a methodology for estimating the benefit: cost ratio of FSP tow truck service on a selected freeway section in Los Angeles. It is the third phase of an FSP service evaluation in the Los Angeles area.

Loop detectors and probe vehicles provided data for developing density plots of the study area. These plots identify the delay each incident caused and incident duration. Fitting the data into a queuing model determined incident capacity. The model accounted for over-sampling of FSP-assisted incidents. The study included data from three sources:

- Probe vehicles patrolling during specified measurement periods sampled traffic stream speed, incident duration and characteristics, and response and clearance times.
- Loop detectors at the test site measured lane-by-lane traffic flows and occupancies.
- Archived CHP CAD data provided incident response times and duration for a period before FSP service implementation.

The proposed methodology incorporates a combination of model assumptions supporting prediction of before-study incident delay. The paper presents a preliminary benefit: cost ratio only because analysis of CHP CAD log data was incomplete at publication. The cost of operating FSP service in Los Angeles was $118 per hour of FSP tow truck operation. The research team believes that the developed methodology will apply to any site within California.

2.7 An Evaluation Plan for the Los Angeles Freeway Service Patrol (Moore *et al.*, 1997)

This study prepared a plan for evaluating the Los Angeles FSP role in reducing freeway congestion, fuel consumption, vehicle emissions, and secondary traffic incidents. The study evaluated different incident detection and recording technologies such as loop detectors, tach or other probe vehicles, stand-alone rooftop cameras coupled with video recorders, and aerial video technology. The study recommended a pilot evaluation plan that includes: selecting sites; implementing the most suitable incident detection technology; collecting field data; post-processing videotape; and estimating effectiveness measures.

The report includes the following operations recommendations:

- Change FSP procedures and improve communication with dispatchers to increase level of service.
- Equip all field equipment with Mobile Data Terminals to significantly reduce communication problems.
- Update the Scantron survey form to identify problems preventing FSP drivers from dispatching swiftly.

2.8 Estimating Freeway Service Patrol Assists: An Analysis of the Los Angeles County Metro Freeway Service Patrol (Finnegan, 1992)

This study attempted to quantify the relationship between the number of FSP assists and factors such as accident rate, freeway geometry, average annual daily traffic (AADT), vehicle mix, and congestion level. The study developed a methodology for maximizing the number of FSP assists for a given level of resources. Caltrans Route Segment reports and the Metro FSP MicroCAD database provided most of the data used in this study.

The study presents a regression model for estimating FSP assists from three explanatory variables: accident rates, beat length (in miles), and AADT/lane. Together these variables explain 54 percent of the variation in the number of FSP assists. The summary results in the report do *not* support evaluation of the quality of the statistical analysis, however. General inferences from this analysis are tentative because the number of observations and the reported coefficient of determination are small.

2.9 Metro Freeway Service Patrol Evaluation (JHK and Associates, 1992)

The study is an initial attempt to evaluate FSP program performance one year after implementation in Los Angeles. The most significant conclusion, however, is that the data collected was not sufficient to evaluate the program. The report provides valuable information about the length of the data collection period that could support a program evaluation. The use of rooftop cameras for incident data collection is also notable in this study. Other highlights include:

- Collection of incident observation data at three FSP beat locations overlooking Freeways 10, 101, and 405 over a three-month period before and after FSP implementation.
- Observation of 1,484 incidents through rooftop cameras. Further analysis omitted 47% of these because they were self-clearing in less than five minutes.

- Of the remaining 53% of incidents, in the pre-FSP period 58.5% were stalled vehicles, 4.7 % accidents, and 36.8 % other, while 57.8% were stalled vehicles, 5.2% accidents, and 37.1% other in the post-FSP period.

The pre-FSP sample data covers a total of 57 days at three locations, or approximately 20 days at each location. During this period, only four in-lane accidents occurred. JHK and Associates found this data inadequate to compare conditions with and without FSP. The report suggests that an appropriate comparison would require data for at least 214 days at five locations, or about 44 days at each location.

The report noted an increase in delay following FSP program implementation. The report concluded, "The estimated delay caused by incidents within the FSP network before FSP implementation is 9.8 million vehicle hours. The corresponding estimated delay caused by incidents within the FSP network after FSP implementation is 10.8 million vehicle hours. This represents an increase of 1.1 million vehicle hour delay." However, JHK's overall conclusion is questionable since the reported data is statistically inadequate for a valid FSP program evaluation.

2.10 Management Analysis of the Metro Freeway Service Patrol (Ernst *et al.*, 1992)

This report describes an early management analysis of the Metro FSP program in Los Angeles. The consultants conducted interviews with FSP staff and tow truck operators, observed dispatch functions, reviewed documents, and conducted ride-along surveys.

This study covers issues including:

- Re-assignment of roles and responsibilities among participating agencies,
- Program evaluation and reporting,
- Computer and communication issues, and
- Budgetary controls for program monitoring.

Study objectives were mainly organizational – defining roles of the participating agencies, for example – although it also covered certain technology issues. Overall the report concludes that the FSP program was functioning well considering the short time it had existed. The study was not an evaluation of FSP program performance, and is of limited importance for the current study.

2.11 Guidelines for Establishing Freeway Service Patrols (Fenno *et al.*, 1996)

Traffic 'incidents' account for a majority of *non-recurrent* congestion, and FSP is effective for detecting and clearing such incidents. FSP objectives are locating incidents, minimizing incident duration, reducing risks of secondary incidents, and restoring full freeway capacity. This paper prescribes guidelines for establishing new FSP services.

Public agencies usually sponsor and operate existing service patrols. Funding sources for these FSPs are DOT maintenance budgets, gasoline taxes, local sales tax, DMV fees, ISTEA funds, and other public and private funds. In 1993, DOT exclusively funded operation of nearly half (15 of 32) of these FSP services. With the exception of one service, all patrols utilize roving vehicles to search for incidents. All patrols use two-way radios for communication.

In 1993, the Houston Motorist Assistance Patrol (MAP) recorded that 78% of all located incidents were on the right shoulder. This suggests that FSP trucks should use the right lane while roving to optimize their service. MAP encountered 28% of incidents during morning peak hours, and 40% during the evening peak. Therefore, a new FSP service should begin during peak hours, and increase hours of operation gradually.

The report explains that all service patrols provide special training programs that prepare operators for a variety of incidents. Operator training programs cover defensive and evasive driving, first aid and CPR, freeway operations and incident management, traffic management center operations, safety policies, radio procedures, public relations, and equipment and vehicle maintenance. Two and four-wheel drive pick-up trucks that are relatively inexpensive and easy to operate, are the preferred vehicles for FSP services.

The Guidelines report highlighted many FSP program benefits such as:

- Free assistance and increased safety for stranded motorists;
- Prompt incident removal, and reduced potential for secondary incidents;
- Reduced incident-related congestion, fuel consumption, emissions, and delay;
- Positive public relations for sponsoring agencies; and
- Savings in time enforcement agency officers spend on non-enforcement activities.

The paper uses six case studies – Chicago Minuteman, Minneapolis Highway Helper, Denver, Houston Motorist Assistance Patrol, and the Los Angeles FSP and Samaritan programs to develop recommended guidelines for establishing a new FSP service:

- Assess actual needs before implementing the program;
- Observe other programs in the field and study their operations;
- Formalize sponsoring agency responsibilities through memoranda of understanding;
- Begin with a small program and expand it gradually;
- Initiate the program as soon as possible to recover expenses quickly in both revenue and positive public response;
- Assign experienced supervisors and personnel to run the program;
- Avoid using the word 'tow' which implies FSP trucks merely relocate vehicles when they actually provide certain maintenance services; and
- Maintain a good relationship with the state patrol.

2.12 **Trip Data Collection with Probe Vehicles – A SANBAG Intelligent Vehicle – Highway System Project** (Titan Systems, 1993)

Probe vehicle experiments are the most efficient means of performing origin-destination studies; collecting additional travel behavior information, and accurate real-time traffic congestion data; and monitoring travel patterns. This Intelligent Vehicle – Highway System (IVHS) project used probe vehicles to demonstrate the feasibility of collecting real-time vehicle trip data. Volunteers drove probe vehicles from home to work (Caltrans District 8 Headquarters), and provided trip information including vehicle route and speed data. These vehicles, equipped with Automatic Vehicle Locator technology, transmitted real-time location information to a central computer. Travel data collection covered 30 workdays during morning and evening commute hours.

One of SANBAG's IVHS program goals was using a high-technology process to collect trip data. Data gathered during the demonstration period shows that probe vehicles are an excellent alternative to costly and time-consuming O-D surveys. The project demonstrated that probe vehicles can provide data on personal and fleet vehicle travel behavior. This technology offers up-to-date and accurate information for transportation and environmental planning uses. Probe data can be an effective input source for transportation, land use, congestion mitigation, and air quality planning models. The data can also have traffic engineering applications.

2.13 Integration of Probe Vehicle and Induction Loop Data – Estimation of Travel Times and Automatic Incident Detection (Westerman *et al.*, 1996)

This California PATH study examined how combining loop detector and probe vehicle data can enhance the quality of real-time traffic information. A second objective was determining how to use probe vehicle data to enhance the reliability and accuracy of travel time estimates. The study demonstrates the utility of probe vehicles for reducing non-recurrent delay.

This study assessed three approaches to obtaining data for Advanced Transportation Management Information Systems (ATMIS): infrastructure-based induction loop detectors, probe vehicles, and a combination of the two. An algorithm estimated real-time, travel time data using large – width loop detectors. A model called COMETT calibrated loop detector data. The calibration process produced reliable and accurate real-time, travel time data for both free flow and congested traffic conditions. The authors report that two detectors, spaced more than 5 kilometers apart, cannot reliably detect incidents using the existing Automatic Incident Detection (AID) algorithms.

The second approach used probe vehicles only to collect real-time traffic and speed data. The study shows that probe vehicles alone, especially only a few probe vehicles, cannot reliably obtain accurate real-time traffic flow and traffic density data.

The third approach integrated loop detector data with probe vehicle data using two methods: one for many loop detectors, and another for a few loop detectors. The former approach incorporates probe vehicle data into loop detector data. Travel time data from this method are more reliable and accurate than loop detector data alone. The second approach incorporates loop detector data into probe vehicle data. This method also provides more realistic and appropriate data than probe vehicles alone.

Overall, integrating loop detector and probe vehicle data enhances the reliability and accuracy of travel time estimates and incident detection. When integrated with loop detector data, probe vehicles can:

- Enhance the quality of loop detector data;
- Determine accurately the exact location of a disturbance in the traffic flow;
- Provide observations of traffic flow irregularities more quickly; and
- Provide updates to adjust loop detector measurement errors.

2.14 **A Working Freeway Service Patrol Program and its Role in Traffic Management** (Wei *et al.*, 1995)

This paper presents a working model of the Los Angeles County Metropolitan Freeway Service Patrol management system and its components. The model identifies seven subsystems (organization, planning, communication, tow truck, operations, management, and evaluation), and one data bank that comprise the FSP program.

The Organization subsystem is responsible for conducting and administering the program. The Planning subsystem ensures consistent operations within an allocated budget by implementing cost-effective strategies. The Communication subsystem provides efficient links for exchanging information between tow truck operators and the incident management center. The Tow Truck subsystem provides incident information, and the actual number of tow trucks in the field to assist motorists and disabled vehicles. This subsystem also selects tow truck contractors and the type of tow truck equipment needed.

The Operations subsystem ensures proper tow truck operation on the freeways, and monitors compliance with regulations and FSP policies. The Management subsystem helps contractors and tow truck drivers accomplish tasks, and implement orders and amendments to FSP policies. The evaluation subsystem provides information to FSP management including: tow truck service performance, system operations performance, program benefit: cost ratios, and program improvement strategies.

The report discusses the role and potential of FSP in traffic management. FSP trucks are the most effective tool in detecting and clearing incidents. FSP truck data such as incident information and average speed can feed into ATMIS. Incident information can predict incident occurrences and impacts. FSP data, when combined with other data sources such as loop detectors or closed circuit television, can improve traffic management center surveillance and monitoring capabilities.

3 LOS ANGELES FSP SYSTEM OVERVIEW

The Los Angeles FSP Communication and Automatic Vehicle Locator System enables FSP truck drivers, and dispatchers at the CHP Los Angeles Communication Center to communicate effectively with each other. The Los Angeles County Metropolitan Transportation Authority maintains this system. CHP controls FSP truck dispatch from its facility at LACC.

Caltrans District 7 monitors and evaluates FSP program effectiveness. Caltrans also collects statistical data on FSP assists. Dispatchers at CHP LACC use the AVL system, connected to the Computer Aided Dispatch system, to monitor and communicate with vehicles through Mobile Data Terminals and GPS antennas. An AVL terminal displays a full color map of Los Angeles County freeways clearly delineating each FSP beat, location, and vehicle status, as Figure 1 shows.

3.1 Tow Truck Driver Activities

Tow truck drivers circulate on assigned freeway beats, traversing the beat in loops. A driver can self-dispatch upon identifying an incident, otherwise dispatchers at the CHP LACC assign drivers to incidents on each driver's beat. FSP drivers use traditional voice radio communication or MDTs to communicate with dispatchers at the LACC. After servicing an incident, FSP drivers send a conformation message to dispatchers for clearance. Drivers continue on their beats once they receive clearance from dispatchers.

3.2 Dispatcher Activities

Dispatchers use LACC monitoring equipment consisting of the Level II CAD system and the AVL terminal. Monitors display real-time incident and status information so dispatchers can quickly respond by communicating with the appropriate FSP truck. Dispatchers append selected contents of theses communications to an historic log. MDTs relieve dispatchers of repetitive CAD inputs by automatically processing FSP system data without dispatcher intervention. Workstation maps also provide visual cues to the dispatcher describing drivers' activity. Dispatchers use the FSP system, rather than conventional voice communication, to assign trucks to incidents.

FIGURE 1. LOS ANGELES FSP COVERAGE AREA

3.3 Data Communication

MDTs and AVLs communicate with formatted and codified data. MDT systems are becoming prevalent because they are relatively interference-free and transmit, process and display status messages automatically. Communication takes a fraction of a second rather than minutes in the case of voice communication.

Voice communication supplements the MDTs when more specific details need to be communicated. Sixteen voice communication channels are also available to the FSP drivers or the dispatcher. Dispatchers and FSP drivers use voice communication extensively even though most communication between drivers and dispatchers is possible without it.

All MDT-equipped FSP trucks also have GPS receivers and antennas for linking to a public-access satellite system to determine a vehicle's location. Location data transmits over radio and updates automatically every 2 minutes; the system can also track the vehicle. A modem converts both GPS and MDT data into signals for transmission to LACC. The FSP system uses two repeater sites located at Mount Luken and Sierra Park for transmission between the trucks and LACC. The repeater stations can serve 150 trucks simultaneously and retransmit messages automatically until the recipient acknowledges them.

3.4 FSP Truck Operating Characteristics

FSP truck drivers are trained to follow the "Metro FSP Standard Operating Procedures (SOP)," including all FSP program rules, policies, and regulations. This section reviews how certain truck operations might conflict with operation as probe vehicles.

Contractors providing FSP service are responsible for reporting vehicle status, and each truck is equipped for this task. Since most FSP trucks are self-dispatched, the CAD system is vital in ensuring that contractors are executing work agreements, patrolling beats, and providing services to motorists. This process already involves extensive status checking of FSP trucks.

Given the nature of the work, drivers may easily announce their status when operating as probe vehicles. On the other hand, drivers may be reluctant to add to their responsibilities by performing probe vehicle services. Equally important, this sort of probe vehicle activity might require changing labor agreements.

3.4.1 FSP Vehicle Tracking Surveys

The research assistants conducted FSP truck tracking surveys by following FSP trucks on various freeway beats during different time periods to gather statistical data. These observations determine how truck speeds relate to ambient speeds, and what proportion of time trucks might act as probe vehicles. This determination requires completing floating car counts and driver activity inventories to determine: which lane trucks tend to operate in; the percentage of cars and light trucks the FSP vehicles pass; and the percentage of these vehicles that passed the roving FSP trucks. Project research assistants also completed a few preliminary ride-alongs with FSP truck drivers, largely for the purpose of designing data collection forms.

The tracking surveys reveal that current FSP truck operations would not support use as probe vehicles. FSP trucks do not necessarily travel at the same speed as ambient traffic, particularly when a driver is searching for or towing a disabled vehicle. Most trucks are not centrally dispatched because the FSP fleet is so large and incidents are so frequent; drivers usually identify disabled vehicles first and report the incident via the CAD system. This suggests that FSP drivers conduct considerable ongoing surveillance of the shoulders and guide ways. When level of service is high, the attention necessary to provide surveillance may limit FSP cruising speeds. If so, the probe information trucks provide may be misleading. This mismatch is less likely under congested conditions when traffic, rather than driver attention, constrains FSP truck vehicle speed.

An FSP Statistical Report contains information on FSP activities, for example, service areas, frequency, and duration. This information is necessary since FSP trucks cannot continue probe duty during service activities. The service activities data reveals the expected proportion of time FSP trucks can run as probe vehicles, and the spatial density of probe vehicle FSP trucks. Figure 2 illustrates the division of FSP truck activities during operating hours.

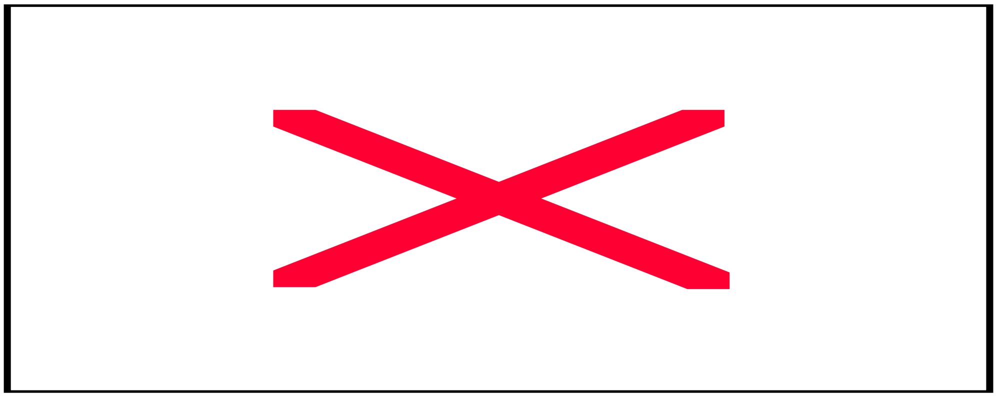


FIGURE 2. DIVISION OF FSP OPERATING HOURS

3.4.2 Time Limits on Using FSP Trucks as Probe Vehicles

The number of FSP truck in-service working hours is the time limit for using the trucks as probe vehicles. This section examines FSP truck activities from the 1996 FSP Statistical Report to determine the time available for FSP trucks to operate as probe vehicles.

In the second quarter of 1996, there were 140 FSP trucks patrolling 41 beats covering almost 400 center-line miles of Los Angeles County freeways. There are 40 peak hour FSP beats with two shifts per weekday; a morning shift and an afternoon shift (the mid-day Downtown beat is the only exception). Most of the morning shifts operate between 6:00 AM and 10:00 AM. Several shifts begin at 5:30, 5:45, or 6:30 and end at 9:00, 9:30, or 9:45 respectively. Most afternoon shifts are also 4 hours long. Thus, FSP trucks typically work for 8 hours on weekdays. Since the Standard Operating Procedure allows drivers a 15 minute break per shift, Net Working Hours per vehicle equals 7.5 hours. Net Patrol Hours (NPH) equals Net Working Hours (7.5) less service time and time needed to change direction:

$$\mathbf{NPH} = \mathbf{NWH} - (\mathbf{ADCT} + \mathbf{ATST}) \qquad (1.)$$

Where:

NPH = Net Patrol Hours

NWH = Net Working Hours

ADCT = Average Direction Change Time on Weekdays and

ATST = Average Total Service Time on Weekdays

The time needed to change direction (ADCT) varies from beat to beat depending on ramp and traffic conditions, and local signal systems unique to each beat. A sample of ADCT on beats in this study ranges from 1.2 minutes to 7.4 minutes, and averages 5.6 minutes per transition from one direction to another. Field observations show that the ADCT is a function of ambient traffic conditions, and the geometry of the path needed to change direction.

The FSP Statistical Report is a good reference for estimating Average Total Service Time. For example, the Statistical Report provides the following data for the second quarter of 1996:

$$\textbf{ASR} = 1.12 \text{ services/hour/truck} \quad (\textbf{2.})$$

$$\textbf{AST} = 0.1987 \text{ hours/service} \quad (\textbf{3.})$$

Where:

ASR = Average Service Rate per hour per truck and

AST = Average Service Hours per incident or service.

Therefore, Average Total Service Time, i.e., the time an FSP truck is attending to incidents, for an FSP truck during a weekday is:

$$\begin{aligned}\textbf{ATST} &= (\text{ASR} \times \text{AST}) \times 8 \text{ hours/weekday} \\ &= (1.12 \times 0.1987) \times 8 \\ &= 1.780 \text{ (hours/truck/weekday)} \quad (\textbf{4.})\end{aligned}$$

Equations (**1.**) and (**4.**) determine the Net Patrol Hours of the current FSP system. Using 5.6 minutes for ADCT, the calculation of NPH is as follows:

$$\textbf{NPH} = 7.5 - (5.6/60 + 1.78) = 5.6 \text{ (hours/truck/weekday)} \quad (\textbf{5.})$$

This estimation indicates that, on average, an FSP truck can operate as a probe vehicle for 70% of its weekday operation, or an average of 5.6 hours of 8 hour weekday operations.

3.4.3 FSP Truck Density

FSP trucks scattered throughout the service area are point speed estimators when operating as probe vehicles. It is important to estimate the average distance over which a probe vehicle can serve in this capacity. FSP truck density gives the approximate density of these point estimators on the freeway.

140 FSP trucks patrol almost 400 freeway center-line miles in Los Angeles County. The Average FSP Truck Density (ATD) in the service area is:

$$\textbf{ATD} = 140 \text{ trucks} / (2 \text{ directions} \times 400 \text{ centerline miles}) = 0.175 \text{ (trucks/mile)} \qquad \textbf{(6.)}$$

Or alternately:

$$\textbf{ATDH} = 800 \text{ miles} / 140 \text{ trucks} = 5.71 \text{ (miles/truck)} \qquad \textbf{(7.)}$$

Where:

ATD = Average Truck Density and

ATDH = Average Truck Distance Headway

These **ATD** and **ATDH** values are valid only when all FSP trucks are patrolling normally. For probe vehicle purposes, only densities and headways for FSP Trucks patrolling under normal conditions are relevant. The number of FSP trucks that can serve as probes (Effective Number of Probe Vehicles, **ENPV**) is:

$$\textbf{ENPV} = 140 \text{ trucks} \times$$

$$= 140 \text{ trucks} \times \quad = 104.5 \text{ (trucks)} \qquad \textbf{(8.)}$$

Where:

ENPV = Effective Number of Probe Vehicles in the Study Area

NPH = Net Patrol Hours and

NWH = Net working Hours

Therefore, the Average Probe Vehicle Density (**APVD**), the density of FSP trucks that can serve as probe vehicles in the study area, is:

APVD = [illegible] = 0.13 (probes/mile) **(9.)**

Or alternately:

APVDH = [illegible] = 7.7 (miles/probe) **(10.)**

Where:

APVDH = Average Probe Vehicle Distance Headway

The estimated APVD of 0.13 is only 10% of the average loop detector density on corresponding segments. Comparing the APVD or APVDH values with the density of the detectors on certain Interstate 5 segments in Los Angeles, found in Table 1, shows that FSP trucks operating as probe vehicles provide considerably less data than freeway segment loop detectors.

Table 1. Detector Density on Selected I-5 Segments in Los Angeles

Freeway	Segment	Length (miles)	No. of Detectors	Detector Density (detectors / mile)
I-5 NB	Artesia – Western 2	27.9	54	1.9
I-5 NB	Alameda 1 – Hungry Valley	26.7	33	1.2
I-5 SB	Hungry Valley – Broadway	58.3	56	1.0
I-5 SB	Marengo – Osmond	18.5	41	2.3
Total (Average)		131.4	184	(1.4)

4 SURVEY 1: FLOATING CAR AND SINGLE-LOOP DETECTOR SPEED ESTIMATES

Survey 1 compares floating car speed estimates with single-loop detector speed estimates. It would be ideal to collect data from single-loop detectors, FSP trucks operating as probe vehicles, and floating cars simultaneously. However, this is logistically difficult under the best circumstances, and was impossible in this case because the investigators' access to electronic CAD data was interrupted during the study. Limited data describing FSP truck speeds was available continuously from the AVL station in the Caltrans District 7 TMC, but this information must be extracted manually in near real-time. Automatic access to CAD log files is needed to obtain data in sufficient quantity to be useful. Lacking automatic CAD data access, it was necessary to compare loop detector data to floating car data in one survey, and loop detector data to CAD log data describing FSP truck speeds in a second survey.

4.1 Study Location

The location for both surveys is the section of Freeway I-10 between Vermont Avenue and Washington Boulevard (7.4 centerline miles) west of Downtown Los Angeles, as shown in Figure 3. This section of freeway meets the following selection requirements:

- Sufficient traffic volume representative of typical urban freeway traffic conditions during peak periods,
- Similar capacities of all lanes in either direction,
- Adequate number of working loop detectors,
- Ample number of Freeway Service Patrol trucks roving the freeway segment, and
- Convenient on/off ramps allowing the floating car to change travel direction easily.

Flow and speed conditions are similar for all lanes of the selected freeway segment allowing a single floating car to measure ambient speed accurately. The research team collected speed data during a field survey in November – December 1997, conducted 8:00 AM to 9:15 AM weekdays.

FIGURE 3. SELECTED FREEWAY SEGMENT (I –10 WEST OF DOWNTOWN LOS ANGELES)

4.2 Survey 1 Procedures

Survey 1 involved collecting and comparing speed data from three sources:

- Floating cars (a primary data source),
- Loop detector log files downloaded from the MODCOMP in the Caltrans District 7 TMC (a primary data source), and
- Data from the Automatic Vehicle Locator terminal attached to the CAD system in the Caltrans District 7 TMC (a secondary data source).

Members of the research team collected speed data simultaneously to synchronize data collection from these different sources. One investigator drove a floating car along the freeway segment to collect speed data. A second manually recorded near real-time FSP speed data from the AVL. In addition, immediately following each survey period, the team downloaded corresponding loop detector log data from the MODCOMP at District 7.

4.2.1 Floating Car Data

The floating car survey provides the best estimate of ambient traffic speed on the selected freeway segment. The floating car completed the maximum possible number of round trips on the segment during the 8:00 AM to 9:15 AM weekday survey periods. The floating car maintained a representative speed by passing as many vehicles as passed it. Due to relatively high traffic volumes, the overall freeway segment condition was forced flow. The driver of the floating car could easily maintain a floating condition because few vehicles pass each other under these conditions. The driver recorded start and end times for each trip. Since travel distances are known, the average speed for each trip equals the travel distance divided by travel time. The speed estimates the floating car provided represent the overall average speed of each one-way trip.

4.2.2 Loop Detector Log File Data

The second source of primary data for the first survey is loop detector data downloaded from the Caltrans District 7 MODCOMP computer, which reports loop detector locations by milepost. At the time of the study, the Los Angeles freeway system included three zones: Los Angeles North, Los Angeles South, and Orange County. Separate computer servers are dedicated to each zone. The Orange County Zone (also known as the 32-bit system) actually includes parts of Los Angeles County such as the I-10

Smart Corridor, i.e., I-10 west of Downtown Los Angeles. The I-10 segment used in this study is part of the Smart Corridor, and thus is in the Orange County Zone.

The MODCOMP is a mainframe computer generating loop detector data in hard copy format 24 hours a day, 7 days a week. During the study, it was possible to download electronic loop detector in formatted text files using PCPLUS software and a PC terminal attached to the mainframe. However, this electronic data was only available for 36 hours, after which Caltrans archived the data on 4-mm tapes and flushed it from memory. Since it was not possible to retrieve archived data in electronic format, a member of the research team downloaded relevant loop detector data immediately after each floating car survey.

The MODCOMP system can provide volume and occupancy counts for each individual loop detector and for each separate lane. The system provides data in thirty seconds, one, two, five, ten, fifteen and thirty minute intervals. This study uses one-minute interval data. The program also runs an algorithm converting volume and occupancy counts into speed information (see Appendix B2). These are spot speed estimates that must be aggregated to report the average speed across the freeway segment.

4.2.3 Freeway Service Patrol Truck Automatic Vehicle Location Data

The Automatic Vehicle Locator terminal at the Caltrans District 7 Transportation Management Center automatically polls in-service FSP trucks, providing a third, but secondary source of study data. The AVL generates FSP spatial information by overlaying trucks on a Los Angeles map showing major arterials and all highways and freeways. An MDT in each truck provides a two-way communication link allowing data exchange between FSP trucks and the central control system. If a particular truck's MDT is not functioning properly, the truck's icon will not appear on the screen and the truck cannot be polled. The AVL/MDT system records information such as truck status, location, speed, accuracy of speed, and direction of travel at four-minute intervals. Users may also poll manually any FSP truck visible on the screen at discrete intervals of two-minutes or more.

A research team member manually polled all FSP trucks roving the selected freeway segment at 2-minute intervals and recorded time, truck status, speed, accuracy, direction and location information for each vehicle. This data was subsequently reviewed to identify trucks roving free the freeway. The MDT status for these trucks is coded "1098." Only status 1098 trucks can represent ambient traffic speed. Unfortunately, filtering AVL-FSP data for status 1098 trucks and for trucks moving in the correct direction, i.e., on the same side of the FSP beat as the floating car, greatly reduced the sample size for this data.

4.3 Data Processing

4.3.1 Floating Car Speed Data

The floating car made 34 one-way speed observations –17 eastbound and 17 westbound trips. Each one-way observation includes the date, travel direction, trip start time, and trip end time. We assume floating car speed provides the best estimate of average speed on the freeway segment during the survey period. Equation (**11.**) shows the formula for average trip speed, and Table 2 summarizes the floating car speed data.

$$\text{Average Trip Speed (mph)} = \frac{\text{Distance (miles)}}{\text{Travel Time (minutes)}} \times \frac{60\text{ (minutes)}}{1\text{ (hour)}} \qquad \textbf{(11.)}$$

Prior to the field survey, we assumed that traffic flow would be consistent due to recurrent weekday traffic demand, and multiple sampling efforts at the same time of day in the same location. The results of the survey do not support this assumption. Eastbound traffic (towards Downtown Los Angeles) is faster than corresponding westbound traffic. The highest observed westbound traffic speed (28.8-mph) is approximately 2.5 times the lowest observed speed (11.7-mph). The eastbound sample shows similar but less extreme variation. The highest recorded speed (38.3-mph) is 1.8 times the lowest recorded speed (21.4-mph). Most observed traffic speeds for the survey period are well below 35-mph – the design criterion for Level of Service F for 65-mph freeways. Figure 4 indicates that traffic speeds along the freeway segment were neither stable nor consistent during the weekday peak period.

Table 2. Floating Car Speed Data

Date	Direction	Cruise Time (minutes)	Distance (miles)	Floating Car Average Speed (mph)
11/19/97 (Thu)	WB	18.33	4.2	13.7
	EB	8.75	4.2	28.8
11/24/97 (Tue)	WB	17.95	4.2	14.0
	EB	11.93	4.6	23.1
	WB	12.17	3.7	18.2
	EB	7.25	3.8	31.4
11/25/97 (Wed)	WB	9.60	4.2	26.3
	EB	7.72	4.2	32.6
	WB	8.75	4.2	28.8
	EB	6.58	4.2	38.3
12/1/97 (Tue)	WB	11.48	4.2	22.0
	EB	9.50	4.2	26.5
	WB	11.15	4.2	22.6
	EB	9.05	4.2	27.8
12/2/97 (Wed)	WB	21.50	4.2	11.7
	EB	11.17	4.2	22.6
	WB	19.42	4.2	13.0
	EB	8.00	4.2	31.5
12/3/97 (Thu)	WB	17.42	4.2	14.5
	EB	9.92	4.2	25.4
	WB	15.83	4.2	15.9
	EB	9.00	4.2	28.0
12/8/97 (Tue)	WB	17.75	4.2	14.2
	EB	9.67	4.2	26.1
	WB	17.58	4.2	14.3
	EB	10.00	4.2	25.2
12/9/97 (Wed)	WB	20.95	4.2	12.0
	EB	11.17	4.2	22.6
	WB	16.88	4.2	14.9
	EB	10.92	4.2	23.1
12/10/97 (Thu)	WB	18.25	4.2	13.8
	EB	11.75	4.2	21.4
	WB	15.42	4.2	16.3
	EB	8.67	4.2	29.1

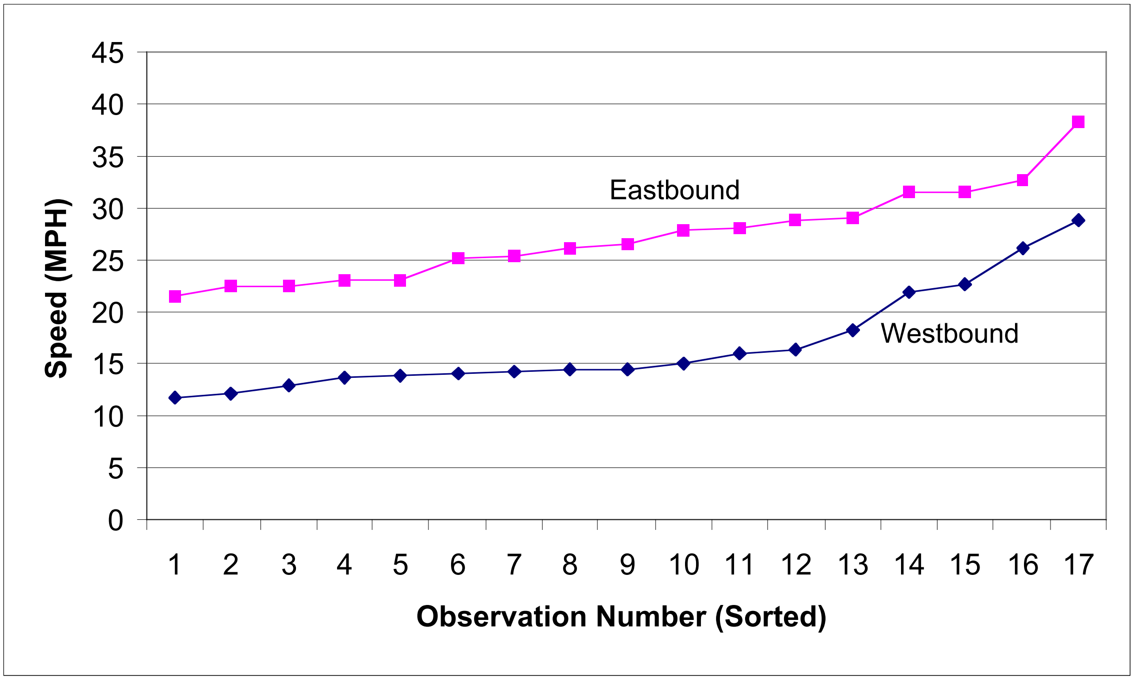


FIGURE 4. FLOATING CAR SPEED RANGES

4.3.2 Loop Detector Speed Data

The selected eastbound and westbound freeway segments include 15 and 16 loop detector locations respectively. At each detector location, there is one loop detector for each main lane in either direction. The MODCOMP uses an algorithm to convert loop volume and occupancy data to a single speed measure for each loop detector location, but it does not provide speed data for individual lanes.

Loop detector function was inconsistent during the study, varying throughout the survey period and over detector locations. For example, only three detectors were operational on the westbound freeway segment on November 19, 1998. On December 1, 1998, there were as many as six working loop detector locations on the same freeway segment. The research team observed numerous errors in the detector log, even though the MODCOMP system indicated that the detectors were functioning normally. In one instance, detectors reported unusually high volumes, several times greater than actual lane capacity. This analysis excludes such outliers.

Two properties of speed data in loop detector log files required special attention. First, since the MODCOMP software uses an algorithm to estimate speed indirectly, the loop detector speed estimate incorporates certain assumptions such as the average length of vehicles passing over detectors. Second, detector log speed entries are point speed estimates averaged over the reporting frequency (once per minute). Each individual speed value in a detector log file represents traffic speed at a specific location on the freeway at a particular point in time. Consequently, it is not possible to directly compare floating car speeds and loop detector log spot speeds. Rather, it is necessary to convert loop detector speeds to an aggregate measure comparable to average floating car speeds. Two methods for transforming loop detector spot speeds to average speeds are consistent with the spatial and temporal characteristics of floating car speeds. These methods produce:

- A simple average segment speed (SAS), and
- A travel time-based average speed (TTAS).

Computing SAS requires two steps:

Step 1. For time periods identical to those of the corresponding floating car survey, compute an average point speed (APS) for each loop detector location:

$$APS_i = \frac{\sum_{t=1}^{T} S_t^i}{T}, \qquad i = 1, 2, 3, \text{-----}, N \qquad \textbf{(12.)}$$

Where:

APS_I = average point speed at i^{th} working loop detector for T minutes

T = travel time of the corresponding probe vehicle (minutes)

i = i^{th} working loop detector in the survey segment

N = number of working loop detectors

S_t^i = speed at i^{th} working loop detector at time = t (t = 1, 2, -----, T)

Step 2. Compute the simple average segment speed (SAS) by averaging all APS_i over the entire freeway segment:

$$SAS = \frac{\sum_{i=1}^{N} APS_i}{N} \qquad \textbf{(13.)}$$

Equation (**13.**) is a simple, unweighted average of the speeds over all working detector locations. Unfortunately, when variance in spot speeds is large, SAS tends to under-estimate the impact of low speeds, and may bias travel time estimates downwards.

The second method for transforming loop detector spot speeds is the travel time-based average speed method. The TTAS method overcomes some of the bias in SAS values by better accounting for the impact of low-speed segments. The selected freeway segment is divided into sub-segments equal to the number of working loop detectors. Each loop detector is located at the midpoint of each sub-segment. Assuming the speed the loop detector records represents the speed of each sub-segment, speeds are weighted by sub-segment length. Total travel time for the segment is the sum of sub-segment travel times, so:

$$L = l_1 + l_2 + \text{-----} + l_N \qquad \textbf{(14.)}$$

$$T = \sum_{i=1}^{N} T_i \qquad \textbf{(15.)}$$

and

$$TTAS = \frac{L}{T} \qquad \textbf{(16.)}$$

Where:

l_i = length of i^{th} sub-segment

T_i = l_i / APS_i

APS_i = average point speed at i^{th} working loop detector from Equation (**12.**)

N = number of working loop detectors

Table 3 compares SAS and TTAS values computed for the loop detector log data. SAS values consistently exceeded TTAS values, and are more likely to exceed TTAS values when TTAS is less than 20-mph. As Figure 5 shows, TTAS and SAS values are similar for TTAS values greater than 20-mph.

Separating the data by direction, it is possible to further investigate the difference between TTAS and SAS values. Figures 6(a) and 6(b) compare SAS and TTAS for westbound and eastbound travel, respectively, and show that the difference between TTAS and SAS is related to travel direction.

Figures 7 and 8 reveal one possible explanation for differences between TTAS and SAS values. If spot speeds are constant for all loop detector locations along a freeway segment, then SAS and TTAS values should be equal. Figures 7 and 8 display spot speeds recorded at loop detector locations in either direction. The series of speed observations in

Figure 7 show significantly higher westbound traffic speeds at upstream locations such as Western and Arlington Avenues. Low downstream traffic speed and relatively high upstream speed define a speed transition boundary between the upstream and downstream locations. The floating car driver observed this transition point in the field.

Table 3. Estimated Speeds from Loop Detector Log File

Date	Direction	Simple Average Segment Speed (SAS in mph)	Travel Time-based Average Speed (TTAS in mph)
11/19/97 (Thu)	WB	16.00	14.42
	EB	26.19	23.62
11/24/97 (Tue)	WB	22.25	15.77
	EB	24.19	23.65
	WB	23.71	15.33
	EB	31.11	27.70
11/25/97 (Wed)	WB	29.81	24.25
	EB	36.12	31.38
	WB	36.48	28.80
	EB	41.33	36.68
12/1/97 (Tue)	WB	30.83	19.83
	EB	30.83	28.97
	WB	33.37	20.83
	EB	36.45	30.73
12/2/97 (Wed)	WB	20.93	12.60
	EB	24.99	23.80
	WB	18.43	12.97
	EB	32.86	31.62
12/3/97 (Thu)	WB	29.91	14.44
	EB	24.00	21.02
	WB	30.95	16.84
	EB	29.68	26.75
12/8/97 (Tue)	WB	27.19	13.57
	EB	23.94	22.56
	WB	23.55	15.77
	EB	25.48	24.90
12/9/97 (Wed)	WB	18.92	11.33
	EB	22.65	21.39
	WB	19.72	14.37
	EB	24.45	23.35
12/10/97 (Thu)	WB	17.62	11.93
	EB	23.10	20.88
	WB	19.54	13.64
	EB	30.38	28.83

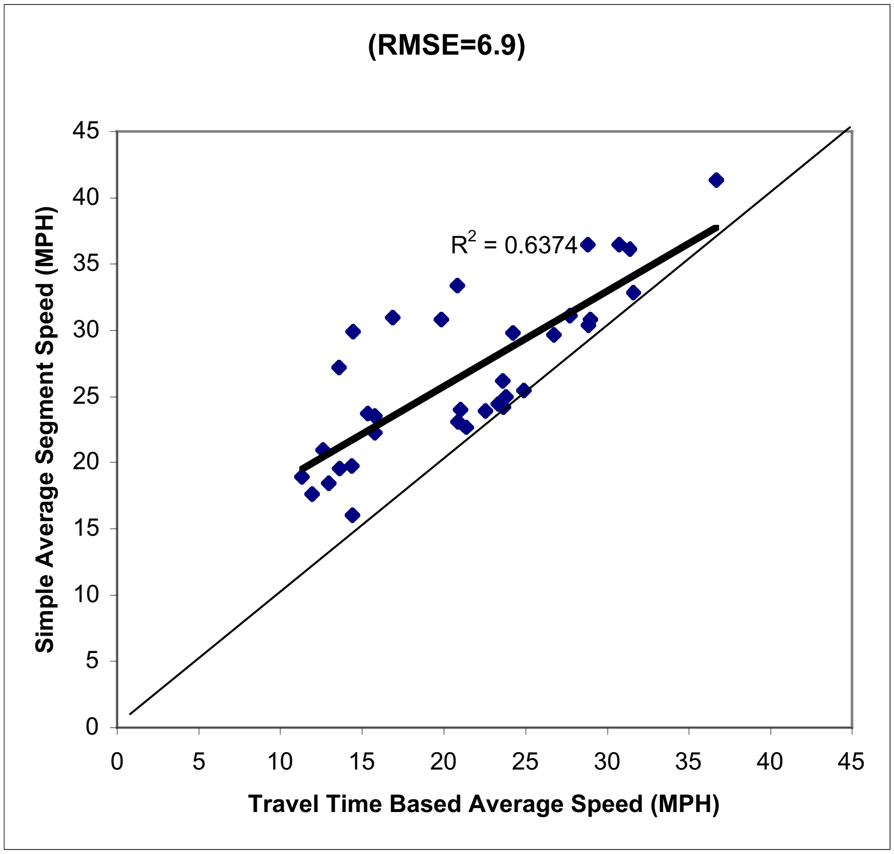
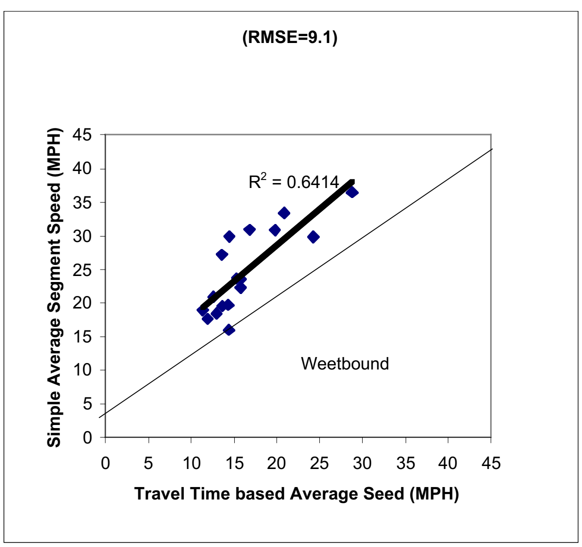
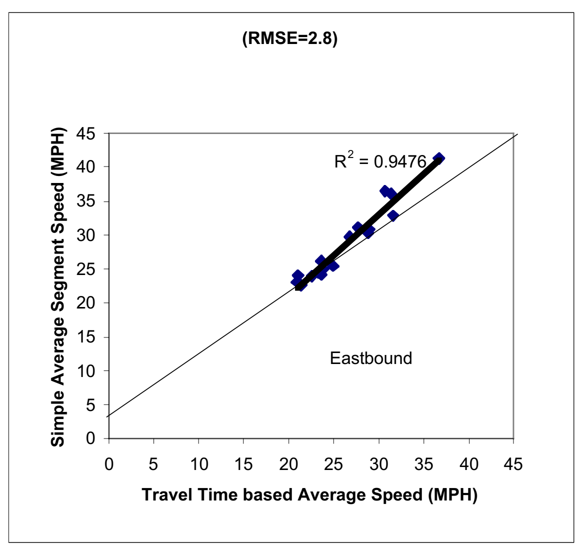


FIGURE 5. COMPARISON OF AVERAGE DETECTOR SPEEDS (TTAS VS. SAS)





(a) **(b)**

FIGURE 6. AVERAGE DETECTOR SPEEDS (TTAS VS. SAS) BY TRAVEL DIRECTION

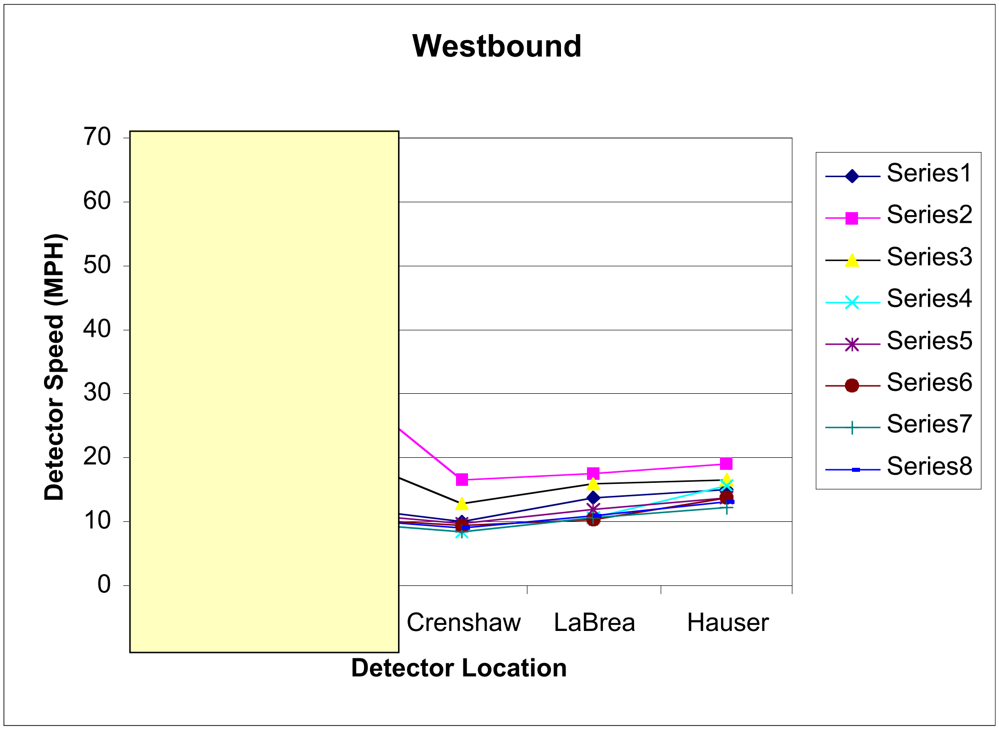


FIGURE 7. DETECTOR SPOT SPEED BY LOCATION (WESTBOUND)

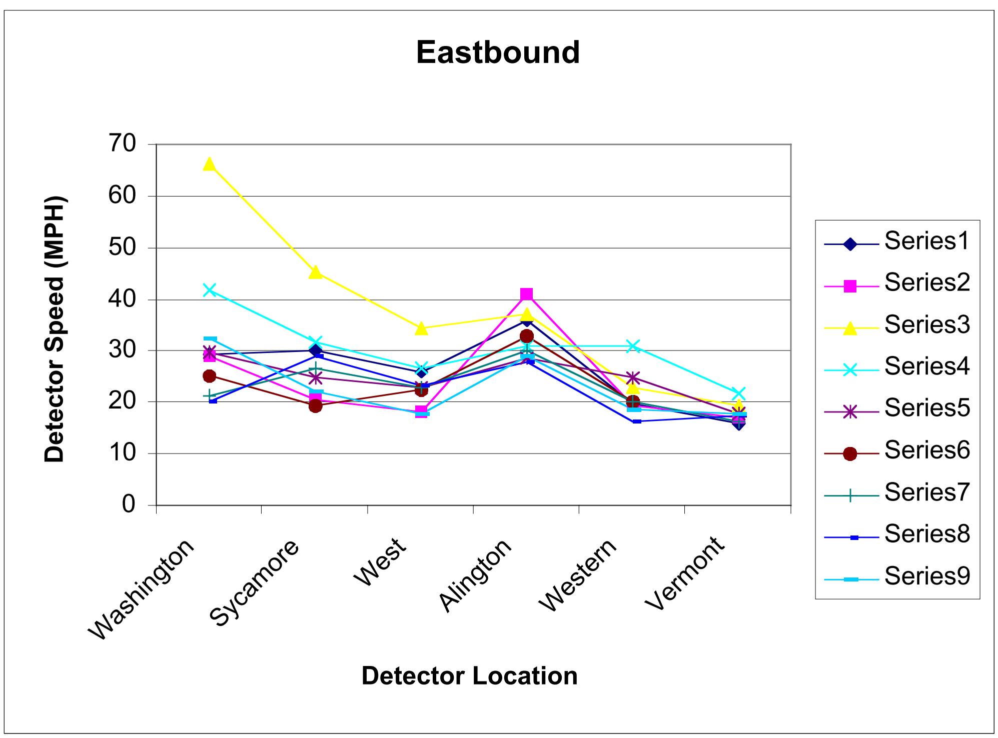


FIGURE 8. DETECTOR SPOT SPEED BY LOCATION (EASTBOUND)

SAS tends to overestimate average by overlooking the bottleneck effect of lower-speed segments. This is because SAS does not account for the impact of longer travel times on the low-speed sub-segments. Such wide variation in speeds (and delays) causes the simple average segment speed to bias estimated segment speed upward.

If spot speeds are constant for all loop detector locations along a freeway segment, then SAS and TTAS values should be equal. Figure 8 shows the spot speed recorded at eastbound loop detector locations. With one exception, eastbound spot speed observations vary much less than westbound observations.

4.3.3 FSP Truck Speed Automatic Vehicle Location Data

The FSP truck data manually extracted from the AVL during the floating car runs supports a preliminary analysis, but is too limited for a robust analysis. To be included in the analysis, the FSP truck data was selected according to two criteria: truck status is patrolling normally (Code 1098), and truck travel direction and time period are identical to those of the floating car. For example, if an FSP truck was attending to an incident, or the driver was on a break (both indicated by the truck status code), or was off the freeway for any reason (indicated on the spatial map of the AVL terminal), then the analysis excluded data for that truck. As a result, this data set does not include a majority of AVL terminal FSP truck data. Table 4 summarizes the filtered FSP truck speed data, while Figure 9 shows the range of speed observations for each truck.

Due to the small size of the truck speed sample, and the large range of values within this sample, the sample average FSP truck speed is likely to be an inaccurate speed estimate. For example, in Figure 9, the average FSP truck speed for observation 6 is 13.6-mph, while the minimum and maximum speeds are 0 (zero) mph and 47-mph, respectively.

Table 4. Average FSP Truck Speed During the Survey Period

Date	Direction	Average FSP Truck Speed (mph)	Date	Direction	Average FSP Truck Speed (mph)
11/19/97 (Thu)	WB	13.2	12/2/97 (Wed)	WB	15.7
	EB	17.3		EB	30.5
11/24/97 (Tue)	WB	39.0	12/3/97 (Thu)	WB	9.6
	EB	20.8		WB	12.0
	EB	25.0	12/8/97 (Tue)	WB	11.5
11/25/97 (Wed)	WB	18.0		WB	24.0
	EB	0.0		EB	19.5
	WB	24.5	12/9/97 (Wed)	WB	16.9
	EB	25.0		EB	14.3
12/1/97 (Tue)	EB	28.7		WB	20.1
	WB	16.7		EB	26.3
	EB	17.5	12/10/97 (Thu)	WB	6.0
12/2/97 (Wed)	WB	14.2		EB	34.0
	EB	11.0		WB	11.4

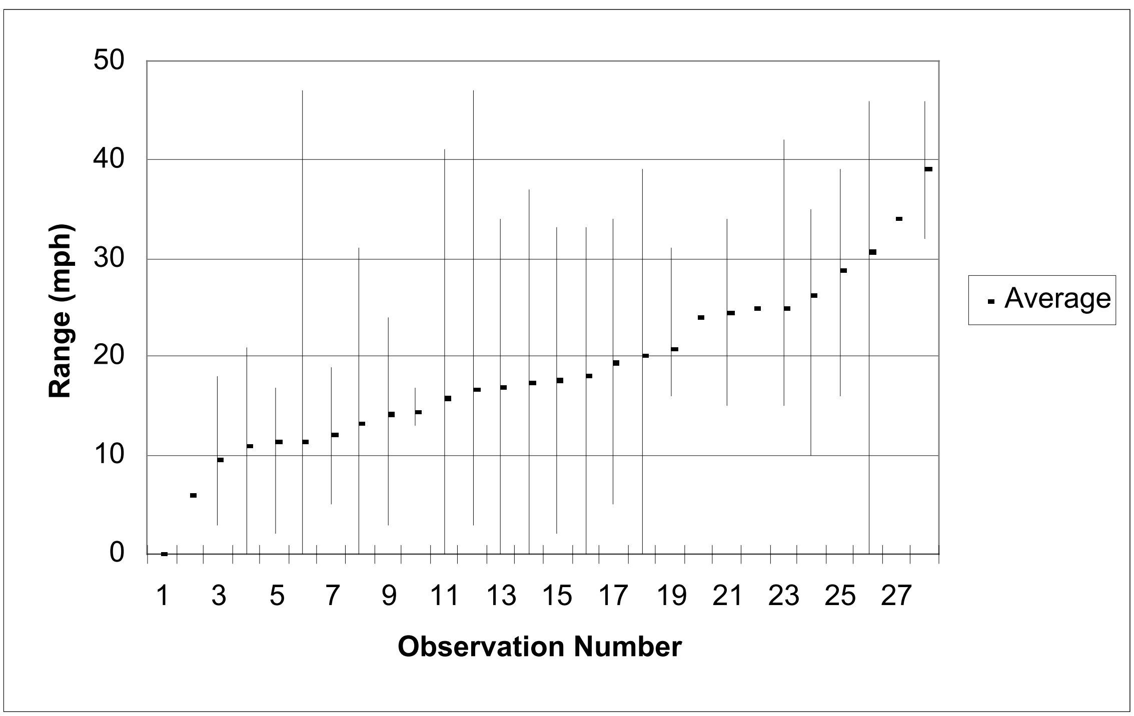


FIGURE 9. FSP TRUCK SPEED RANGES

4.4 Speed Estimate Comparisons

This section presents a comparison of speed data from the three survey sources. Speed comparisons show that average floating car speed best represents ambient average traffic speed. Floating car speed also provides a baseline for comparing the quality of other speed estimates.

4.4.1 Comparison of Floating Car Speeds and Single Loop Detector Speed Estimates

Figures 10 and 11 compare floating car speeds with corresponding loop data SAS and TTAS values. The vertical distance between each coordinate and the 45-degree line indicates the magnitude of the error term in each speed estimate. The root mean square error (RMSE) for SAS estimates is approximately three times that for TTAS values. The coefficient of determination (R^2) is also far smaller for SAS than TTAS, which is close to 1.0. This suggests that TTAS is a more accurate speed estimate than SAS under the (representative) peak conditions observed during the survey period.

4.4.2 Preliminary Comparison of Floating Car Speeds and FSP Truck Speeds

FSP truck spot speeds were averaged for the time period corresponding to each floating car survey. In some cases, truck speed coordinates in Figures 10 and 11 correspond to a single observation in the filtered AVL truck speed data. As Figure 12 shows, AVL terminal FSP truck speeds do not co-vary strongly with floating car speeds. Most observations are scattered widely about the 45-degree line. The line of best fit deviates significantly from 45-degrees. In one extreme case, FSP speed is zero-mph, while the corresponding floating car speed is 32.6-mph. The extremely low R^2 value for this comparison indicates that FSP truck speed does not represent ambient speed systematically.

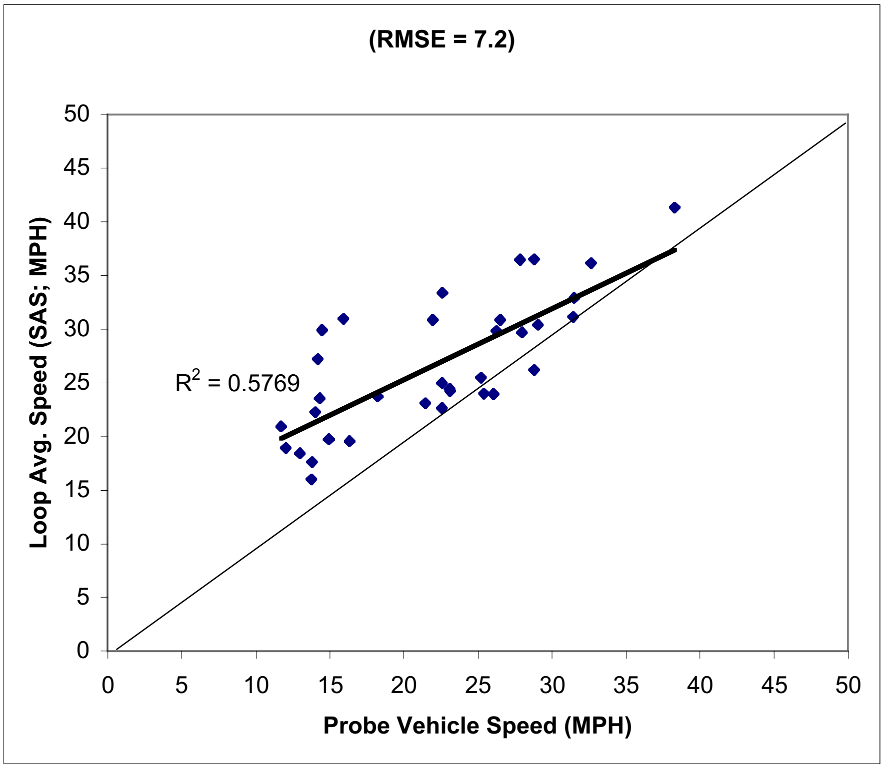


FIGURE 10. FLOATING CAR SPEED VS. SIMPLE AVERAGE SEGMENT SPEED (SAS)

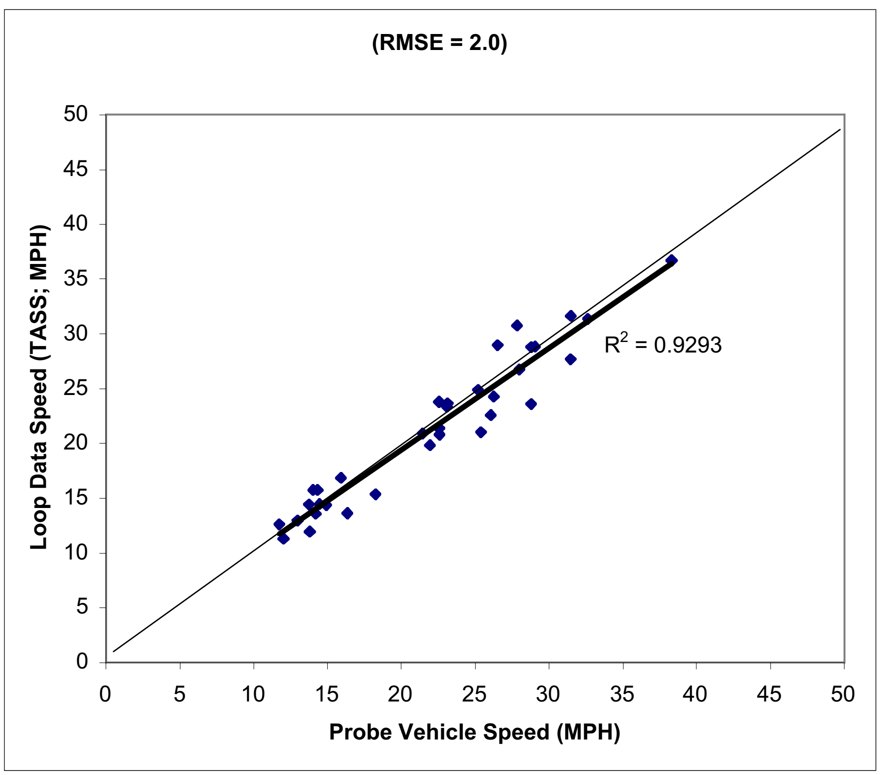


FIGURE 11. FLOATING CAR SPEED VS. TRAVEL TIME BASED AVERAGE SPEED (TTAS)

Comparing estimated errors from Figure 12 against the number of FSP truck speed observations for each coordinate illustrates the relative error in FSP observations (Figure 13). Coordinates representing more than two FSP truck speed observations per floating car run (right of the vertical line in Figure 13) have less error.

Figures 14 a and b illustrate the result of the data trimming; Figure 14a excludes the higher-error terms, and Figure 14b shows the result trimmed of farther outliers. This data analysis suggests that FSP truck speeds may provide reliable, reasonably accurate speed estimates. While there is a tendency for FSP truck speeds to underestimate ambient average speeds, a finding consistent with assumptions about how FSP trucks operate in the field, this FSP data set is too small for a conclusive analysis.

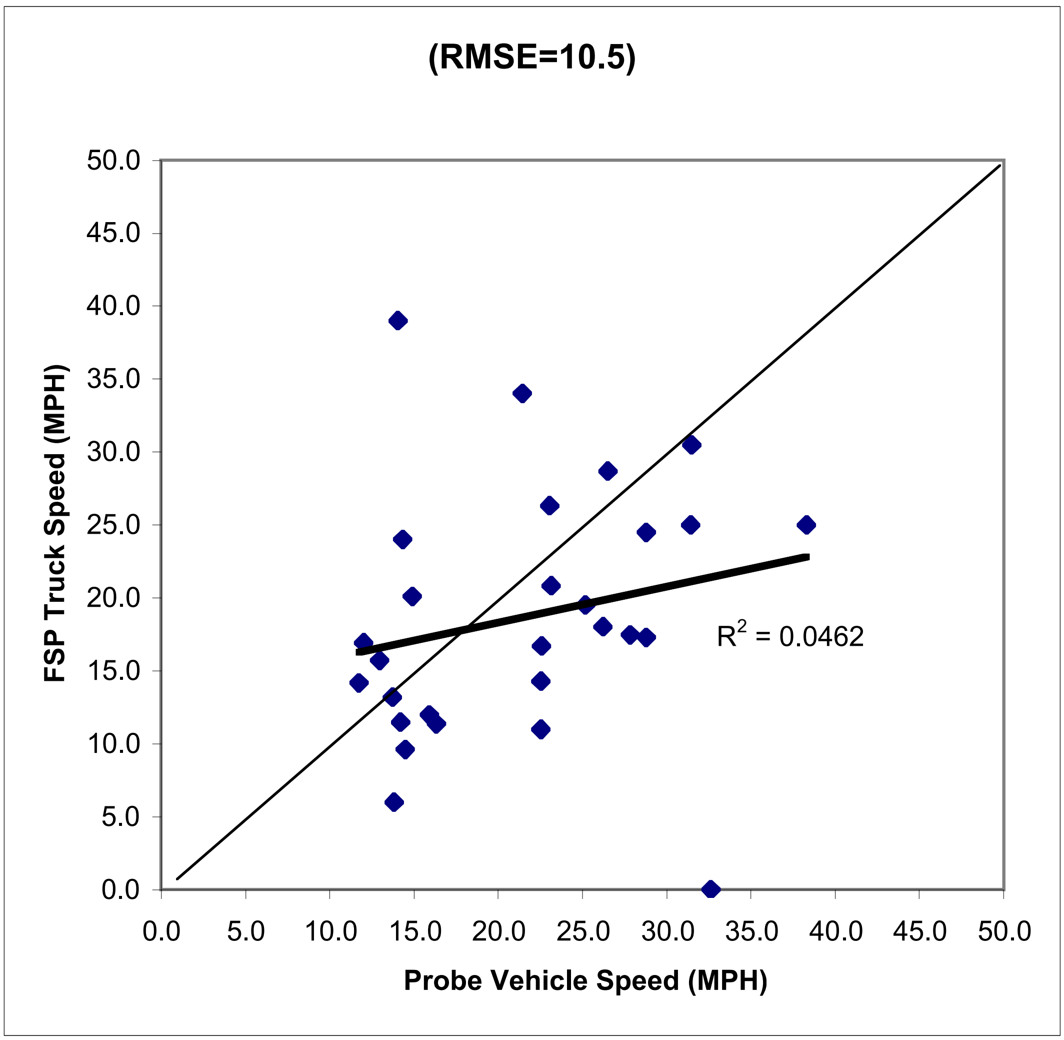


FIGURE 12. FLOATING CAR SPEED VS. FSP TRUCK SPEED (AVL DATA)

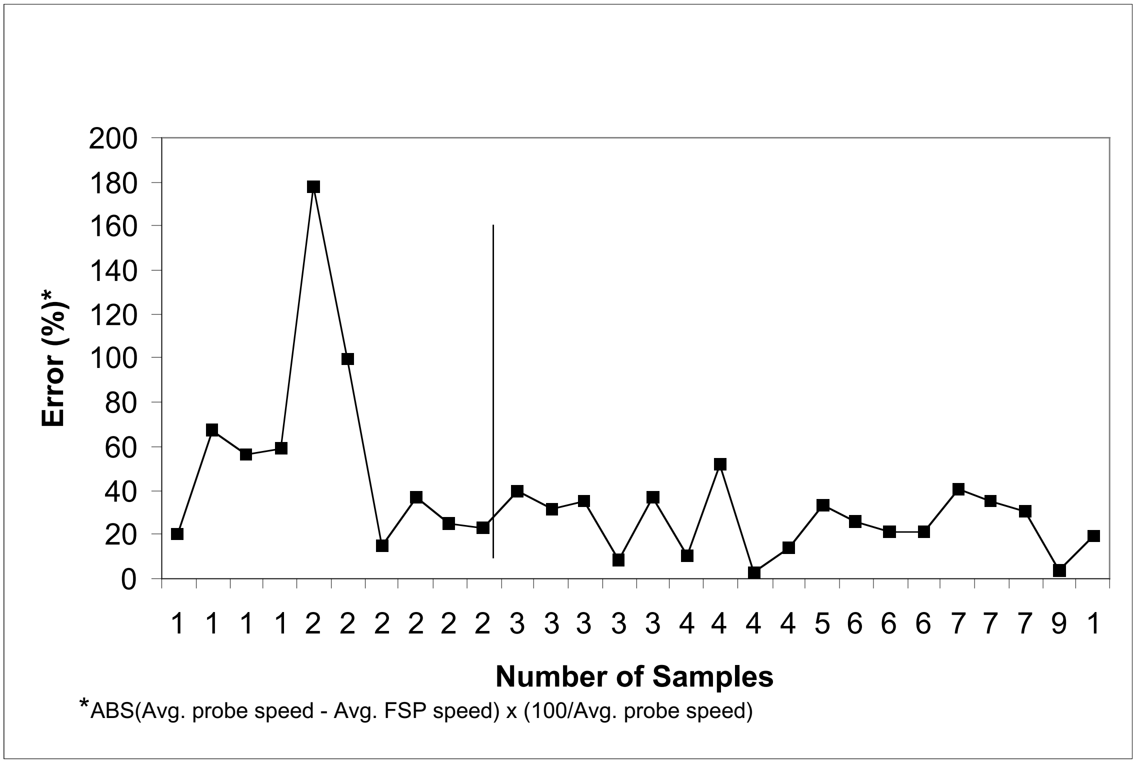


FIGURE 13. RELATIVE ERROR IN FSP TRUCK SPEED VS. NUMBER OF OBSERVATIONS

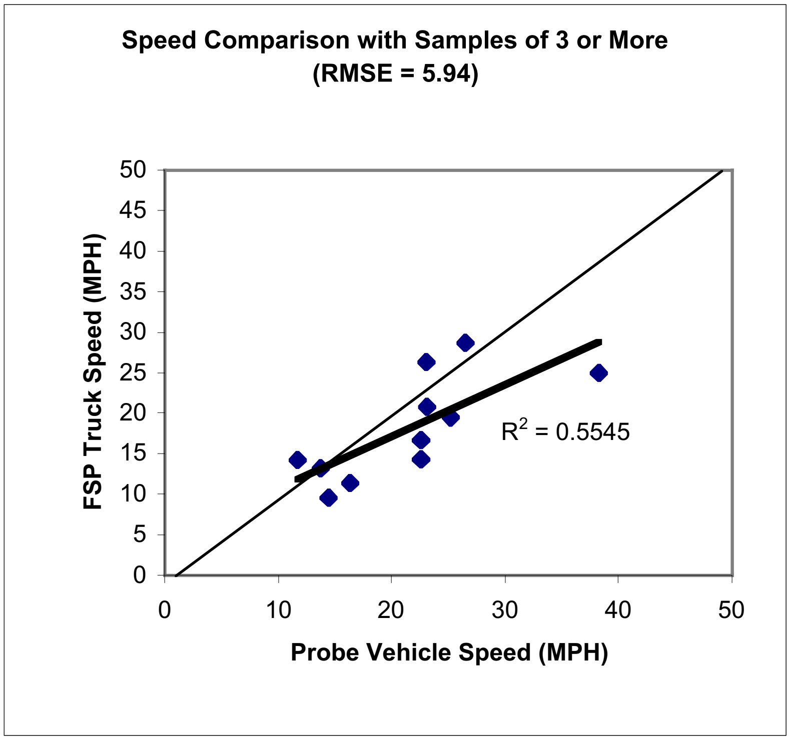


FIGURE 14A. FLOATING CAR SPEEDS VS. LOWER-ERROR FSP TRUCK SPEEDS (AVL DATA)

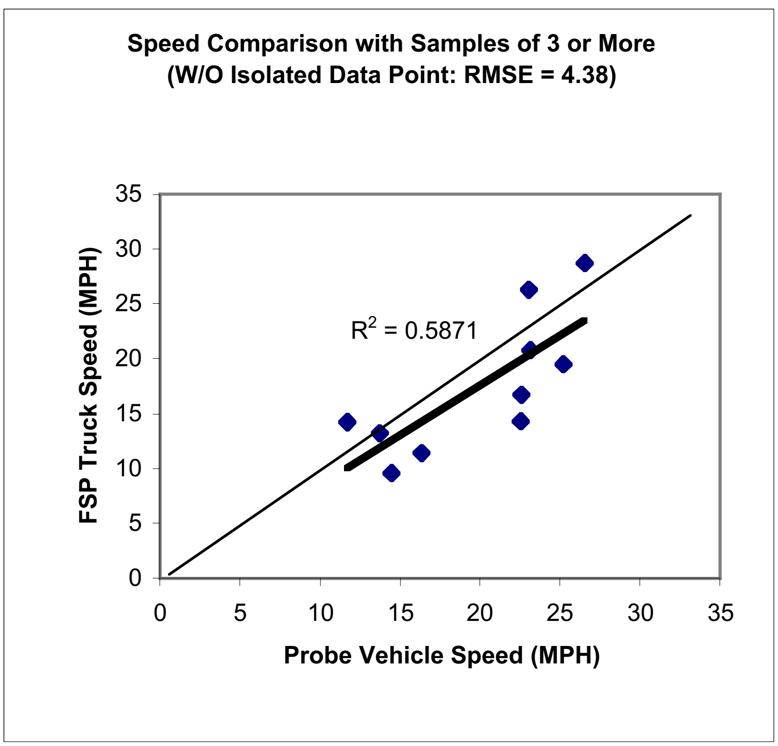


FIGURE 14B. FLOATING CAR SPEEDS VS. LOWER-ERROR FSP TRUCK SPEEDS TRIMMED OF OUTLIERS (AVL DATA)

5 SURVEY 2: FSP TRUCK/PROBE VEHICLE AND SINGLE LOOP DETECTOR SPEED ESTIMATES

5.1 Accessing CAD Historic Log Files

There is a temporary log file containing records of MDT responses to all automatic and manual system polls. Log entries are automatic whenever the AVL terminal attached to the CAD system in CHP's Los Angeles Communication Center polls an FSP truck. This log file accounts for all MDT-equipped FSP trucks in Los Angeles County, providing an automatic data source describing the status of these trucks over time.[1] A CHP CAD user with AVL terminal administrator privileges can retrieve these database files in space-delimited text format and download the contents to 4mm DAT tape.

CHP LACC personnel provided data for the last two weeks of April 1999, and the second half of September 1999. There are two master files for each day, one associated with the Mount Lukens transceiver and another with the Sierra Park transceiver. These are the two transceivers for two-way communications between CAD and the MDTs in FSP trucks. A master file for each transceiver consists of several files, one for each day, containing relevant space, time, and speed information for all FSP trucks. Together these transceiver master files provide daily data for the entire Los Angeles FSP system. These master files are large, including more than 120,000 lines each.

The LACC historic FSP data file does not include FSP truck *working status* details, unlike the near real-time AVL terminal FSP speed data. As a result, historic average speed data includes FSP trucks in working status (Code 1098), as well as trucks "approaching to attend an incident," and "towing a vehicle." Approaching or towing trucks are actually in working status Code 1097. Field observations show that FSP truck speeds are highest when trucks are cruising on the freeway. FSP truck speed is slower in any other working status. Consequently, historic FSP truck speed data tends to under-estimate ambient traffic speed, with greater variance than ambient speed data.

5.2 CAD Historic Log Speed Data

Historic log speed data for four weekdays in September 1999 were filtered to delete observations unlikely to reflect ambient speeds. The first step was discarding speed data for which truck working status is not coded 1098. Working status 1098 indicates that the FSP truck is roving. However, code 1098 does not necessarily mean that the FSP truck is running as a probe vehicle, rather that it is not servicing a vehicle, or dispatched to an incident.

For example, an FSP truck driver may take a break while on 1098 status. Per FSP operational requirements, drivers are required to change truck status during “long” breaks. However, the LACC log file shows that some trucks are stopped for several minutes while in status 1098. This is understandable, it is easy to imagine conditions – such as traffic congestion or a “short” break, requiring a driver to stop even while in roving status. As a result, it was necessary to filter and order the log data using two criteria.

1. ***Stopped FSP Trucks****:* If data indicate an FSP truck was stationary for two minutes or longer, the team determined the truck was not roving and omitted corresponding speed data from the analysis.
2. ***Direction of Movement****:* Direction of travel data indicate whether FSP truck movements were unusual, e.g., inconsistent with the roadway orientation. The analysis omits data describing trucks with unusual movements. Specifically, the azimuth component of movement should fall within a particular range for an FSP truck on a given beat. This reading depends on truck travel direction on the freeway.
    - FSP Beat 17 on I-10: Vehicle azimuth range is from 225 to 315 degrees westbound, and from 45 to 135 degrees eastbound.
    - FSP Beat 4 on I-5: Vehicle azimuth range is from 300 to 45 degrees northbound, and from 120 to 225 degrees southbound.

    FSP trucks with azimuth readings outside these ranges are likely executing maneuvers other than normal (code 1098) cruising.

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[1] While CAD AVL system documentation indicates there is a menu option for writing results of truck status queries to a file, Orbital TMSI personnel reported that this feature is was never implemented.

Table 5. Historic FSP Truck Speed Data

		Date and Time			
	FSP ID	9/16/99	9/20/99	9/22/99	9/23/99
I-10	814	07:00–10:00 14:30-19:00	17:00-17:10	07:30-10:00 14:30-19:00	
	974	15:40-19:00		17:00-19:00	16:00-19:00
	978	15:40-18:50			
I-5	100				18:00-19:00
	851			07:00-10:00 15:00-19:00	
	896				17:40-19:00

5.3 Loop Detector Log Speed Data

The Caltrans District 7 MODCOMP generated loop detector volume and speed data at one-minute intervals. The MODCOMP observations corresponded to the beats, dates, and time periods in the post-processed FSP historic log data set. In some cases, loop detector data was not available because loop detectors were not working. Table 6 shows the time periods and locations for which both loop detector log speed data and FSP historic log speed data are available.

Table 6. Time Periods and Locations of Available FSP Truck Speed and Loop Detector Data

	Date and Time		
Location	9/16/99	9/22/99	9/23/99
I-10	07:00-10:00 14:00-19:00	15:00-1900	16:30-18:45
I-5		07:00-10:00	18:00-19:00

5.4 Comparison of Single Loop Detector Speed Estimates and FSP Truck Speeds

Figure 15 shows comparisons of historic FSP truck speeds, and associated loop detector speed estimates for the I-10 Freeway. Covariance between these measures is weak. Floating car speeds are not available in this case for simultaneous comparison with loop detector and FSP truck speeds. However, evidence in Section 4 shows that floating car speeds and TTAS values co-vary closely. Using TTAS values as baselines, east and westbound RMSE values are significantly higher, and R^2 values are significantly lower, than corresponding values for comparisons of TTAS estimates and floating car speeds. In addition to the higher variance, historic FSP truck speeds tend to underestimate speed significantly compared with loop detector estimates.

Figure 16 repeats this comparison for the I-5 Freeway. Overall, FSP truck speeds tend to be much lower than TTAS values, and demonstrate much greater variance. TTAS values range from 35 to 47-mph, while corresponding FSP truck speeds vary from 8 to 53-mph. The RMSE for historic northbound FSP truck speeds is 17.2. Historic log data does not include any substantive information on ambient speeds in this case.

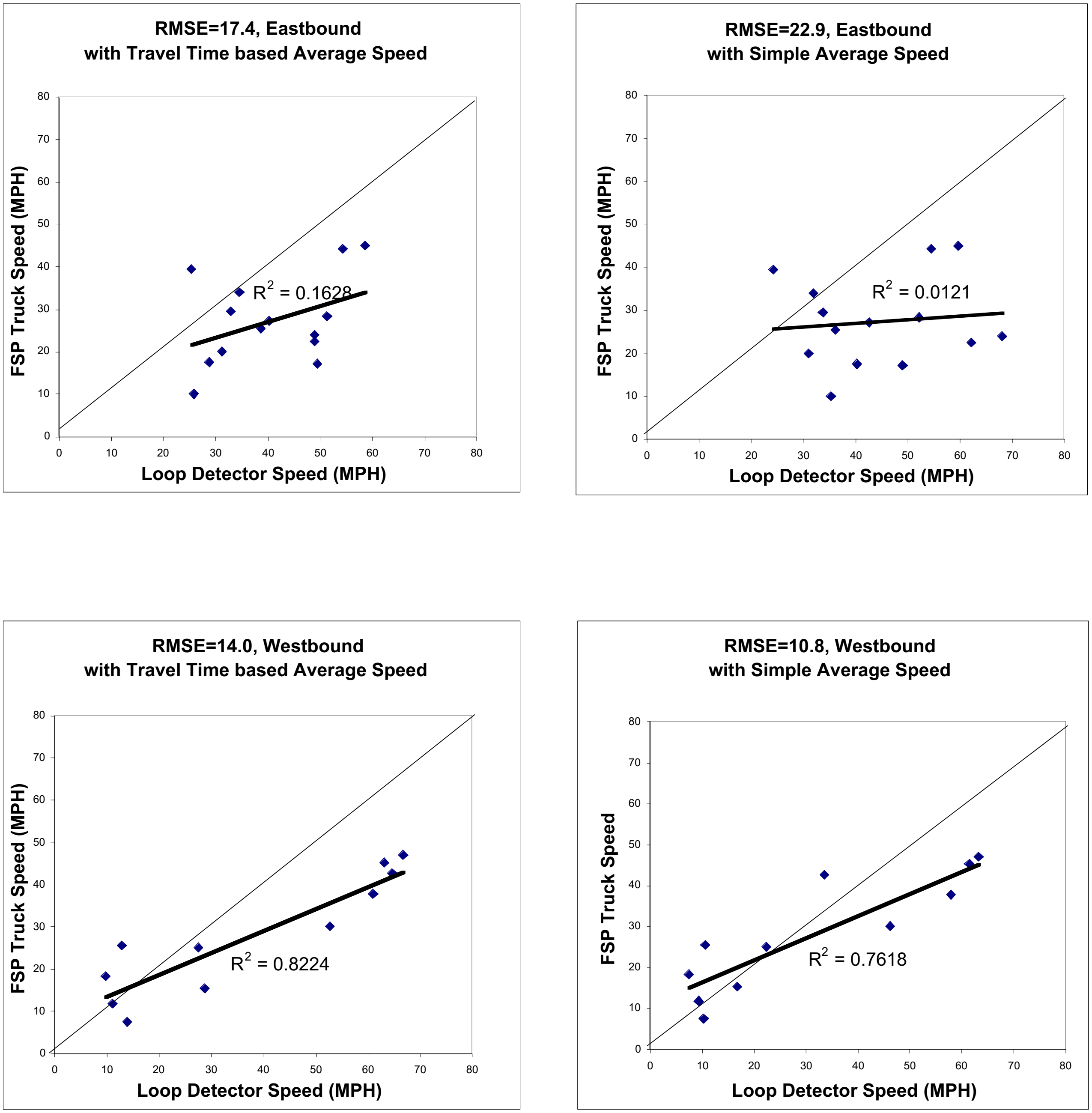

FIGURE 15. TRAVEL TIME-BASED AVERAGE SPEED (TTAS) VS. HISTORIC FSP TRUCK SPEED, I-10 FREEWAY)

FSP Truck Speed (MPH)

FSP Truck Speed (MPH)

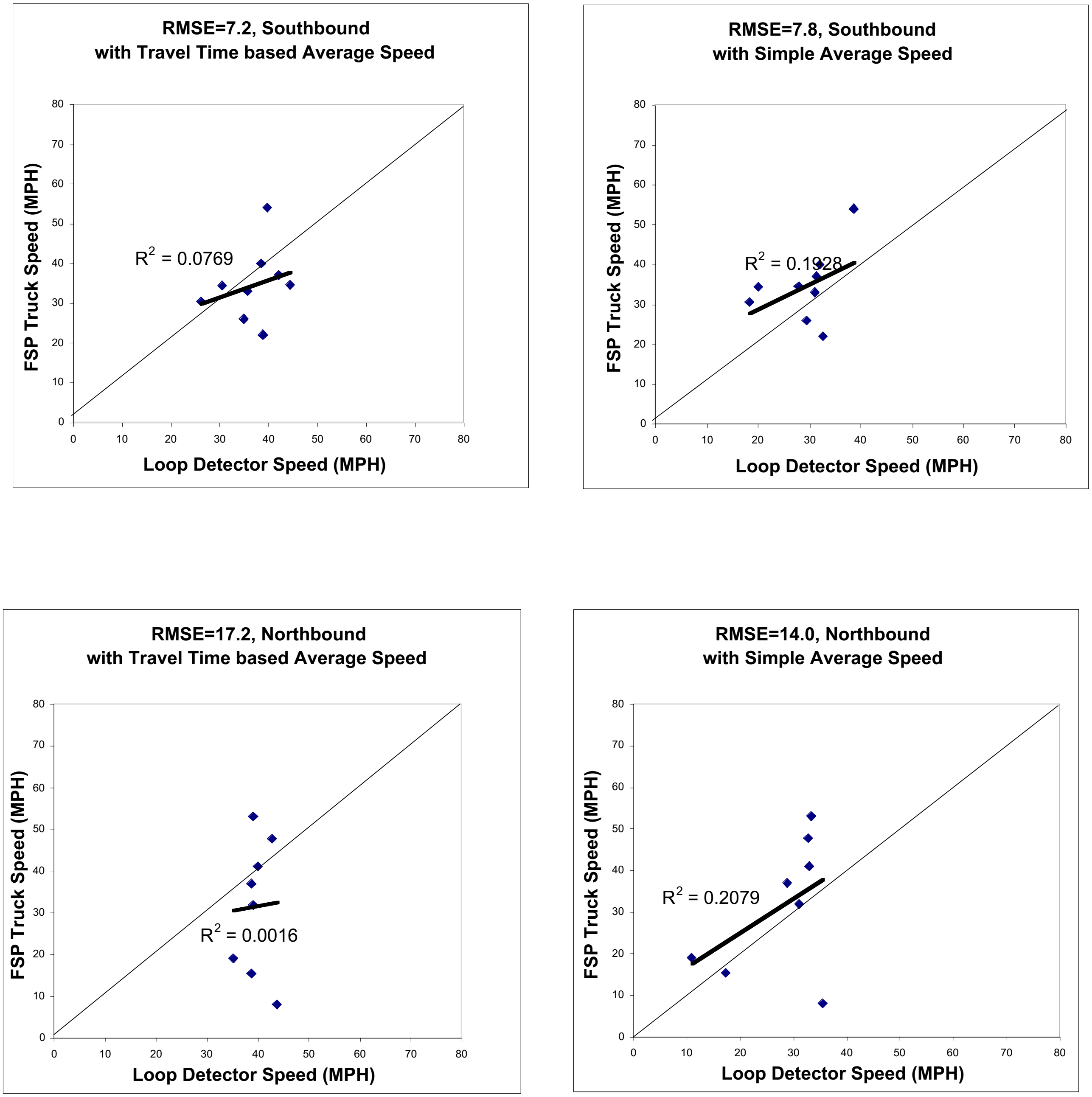

FIGURE 16. TRAVEL TIME-BASED AVERAGE SPEED (TTAS) VS. HISTORIC FSP TRUCK SPEED, I-5 FREEWAY)

FSP Truck Speed (MPH)

FSP Truck Speed (MPH)

Finally, Figure 17 shows the comparison between *all* historic FSP truck speeds and corresponding loop detector log speeds. These Figures show the general tendency for large error, high RMSE, and small R^2 values in the historic FSP truck speed samples studied.

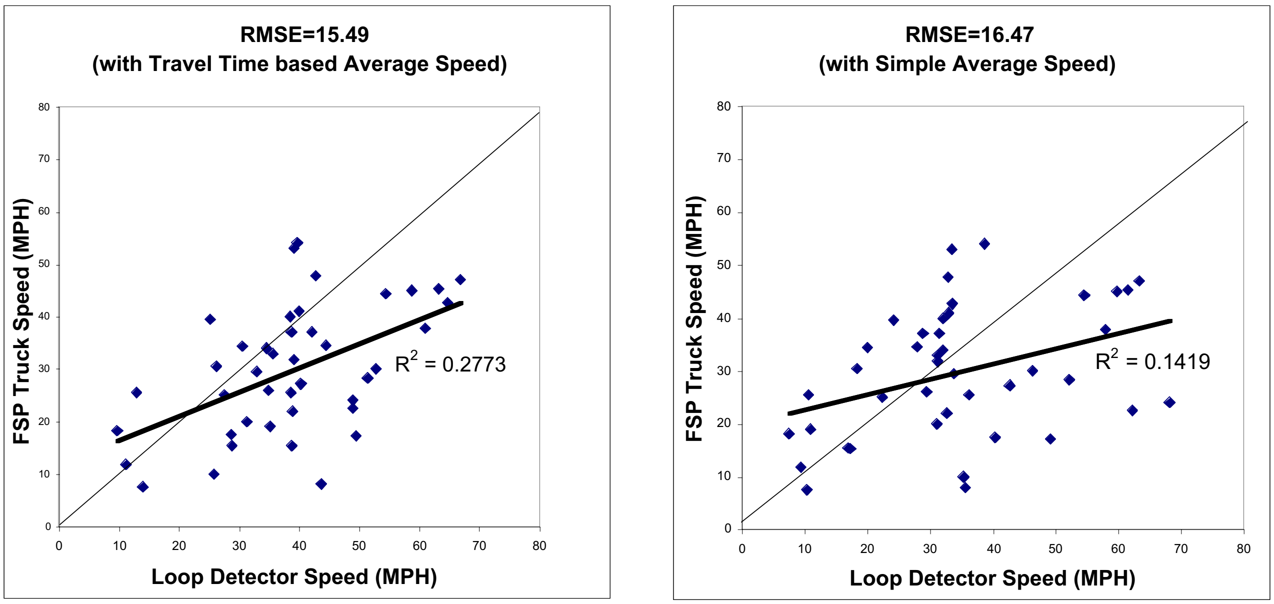

FIGURE 17. DETECTOR SPEED VS. ALL HISTORIC FSP TRUCK SPEEDS

Overall, TTAS is the best ambient speed estimator. Near real-time and historic FSP truck speeds are poor estimators of ambient speed, while SAS is an intermediate estimator. Combining FSP truck speeds with loop detector speeds to obtain ambient speed is not recommended since this approach does not improve the accuracy of detector speed estimates. The usefulness of FSP trucks operating as probe vehicles is limited, even when CAD log data is readily available.

6 DETERMINING MINIMUM FSP TRUCK DENSITY FOR ESTIMATING AMBIENT SPEED

Several factors account for errors in estimating ambient speeds from FSP operations. First, since FSP trucks operate in various modes (status), only a fraction of FSP truck operating time is suitable for probe vehicle activities, that is, time in normal working status 1098 . Second, since existing FSP truck operating status classifications do not accurately reflect actual operating conditions, estimated FSP truck speeds are low relative to ambient speeds.

The frequency of FSP truck speed reports is another factor limiting estimates of ambient speed. FSP truck speed averages based on less than three observations are poor ambient speed estimates. Three or more observations provide more accurate average speed estimates with less variance. Larger sample sizes and more accurate truck working status classifications are needed when deploying FSP trucks as probe vehicles.

The number of FSP trucks required to obtain an appropriate sample size is directly related to the length of an FSP truck beat, speed reporting frequency, and overall speed on the beat. Ideally, FSP truck speed reports should be evenly distributed spatially, and sufficiently frequent to measure overall beat speed (a space mean speed) from FSP truck speeds (point speeds). The following example shows how to estimate the number of FSP trucks needed for probe vehicle operations on a freeway beat not equipped with loop detectors:

Assuming that beat length is 7.4 center miles, overall beat speed is 40-mph, FSP trucks report speed at two minute intervals, and the minimum required sample size is three trips in either direction, one-way travel time is:

$$t = \frac{l}{v} \times 60 = 11.1 \text{ (minutes).}$$

During time period t, an FSP truck will report speed t/2 times, or once every two minutes.

The number of FSP trucks, X, needed to report speed information with a sample size of three is:

$$x \times \frac{t}{2} = 3 \text{ (observations).}$$

Therefore:

$$x = \frac{2}{11.1} \times 3 = 0.54 \text{ (probes/7.4 miles)}$$

$$= 1.08 \text{ (probes/beat).}$$

1.08 probe vehicles are required per beat to generate the minimum sample size for estimating ambient beat speeds. However, not all FSP trucks can operate as probe vehicles simultaneously because they do not rove continuously. The proportion of the net patrol hours (NPH) available from total working hours helps determine the total number of FSP trucks needed for adequate sample sizes. It follows that the total number of required FSP trucks X, is:

$$X = 1.08 \times \frac{8.0}{5.6} = 1.54 \text{ (trucks/beat)}$$

Where:

5.6 is net patrol hours, and

8.0 is total daily working hours for one FSP truck on the sample beat.

This sample computation shows that at least two FSP trucks are needed to generate the required minimum sample size of three speed observations on the subject beat. Two assumptions underlying this example are worth repeating: that speed reporting frequency is adequate, and working status classification is accurate. More specifically, FSP truck working status should include additional detail to distinguish between probe operations and all other operating modes.

7 CONCLUSION

This research assessed the feasibility of using trucks in an existing FSP fleet as probe vehicles to measure ambient speed on freeway segments with or without loop detectors. To be useful, FSP truck speeds should represent ambient speeds; if not, the difference between the two speed measures must be systematic in order to infer ambient speed through appropriate operations. Neither real-time nor historic FSP truck speeds satisfy this requirement. Therefore, FSP truck speed data presently available from the existing system is insufficient to estimate ambient speeds.

Floating cars deployed on the selected freeway segment measured average segment travel speed (real ambient speeds) while observers recorded FSP truck speeds on the same freeway segment. Loop detector-based segment speeds, and historic FSP truck speed data completed the analyzed dataset. Floating car speeds were the freeway segment reference speeds and the basis of comparison with other speed data.

This study compared two loop detector speed averaging methods: Simple Average Speed (SAS) and Travel Time-Based Average Speed (TTAS). When converting several loop detector point speeds into distance-based average speed, the averaging method affects the final result. Simple Average Speed is always greater than Travel Time-Based Average Speed. SAS overestimates tend to be higher when TTAS is slower than 20-mph, while SAS overestimates less when TTAS is faster than 20-mph.

Comparing SAS and TTAS with corresponding floating car speeds shows that TTAS is the most accurate, *and recommended* ambient speed estimate.

Preliminary comparisons of floating car and FSP truck speeds reveal that FSP truck speed is a poor measure of floating car (ambient) speed. FSP truck speeds underestimate floating car speeds overall, and covariance between the two is weak. Distribution patterns of differences between the two speed estimates do not appear systematic. FSP truck speeds can differ from ambient speeds for several reasons including driving characteristics, geographic location, etc. As a result, it is difficult or impossible to use FSP trucks to infer ambient speed.

Comparing detector-based TTAS and historic FSP truck speeds provides a similar result. Historic FSP truck speeds co-vary weakly with the detector-based TTAS. The unsystematic distribution of these speed differences makes it impossible to infer ambient speed from historic FSP truck speed data currently available from the CAD AVL system.

Based on the “FSP Statistical Report” and “Metro FSP Standard Operating Procedures,” a maximum of 70 percent of FSP truck operating hours are available for probe vehicle operations. This is the upper limit for using FSP trucks as probe vehicles.

Even when FSP trucks are patrolling normally (status 1098), truck speed rarely represents ambient speeds because of the superficial classification of “FSP truck working status.” Current status classifications do not differentiate various FSP truck driving modes sufficiently. Therefore, to improve ambient speed measurement, it is necessary to subdivide FSP truck working status codes to incorporate details for identifying and distinguishing probe-like truck driving modes.

This study finds that FSP truck speed sample size can affect the accuracy of ambient speed estimates. A sample with at least three FSP truck speeds tends to produce a closer estimate of ambient speeds than smaller samples. It is possible to increase sample size by increasing FSP truck speed reporting through more frequent polling. This could minimize the need to increase the number of FSP trucks to conduct probe vehicle operations.

These findings suggest the following recommendations:

- ✓ Identify the different driving conditions included in FSP Working Status Code 1098 and assign new status codes to these conditions. Once established, the new working status codes should represent FSP truck probe-like driving status more accurately. This will help determine when trucks are operating as probes.
- ✓ Modify the host computer at CHP LACC to automatically record and post-process FSP truck speed information. For system-wide reporting, the host computer should be able to poll all FSP trucks simultaneously, and process the data to provide near real-time speed information. A separate study is required to establish system requirements and hardware/software capabilities to achieve this.
- ✓ Perform an experiment using FSP trucks as probes to estimate variance between FSP truck and ambient speeds under ideal conditions.

- ✓ Consider using single-loop detectors as a speed information source in conjunction with FSP truck speeds. While neither single-loop detectors nor FSP trucks provide reliable ambient speed information alone, together they might complement each other and provide more reliable ambient speed estimates.
- ✓ Use FSP trucks to measure ambient speed in areas without loop detectors, or where they may be the only inexpensive source of reliable ambient speed information. The TRAVINFO project in the San Francisco Bay Area may benefit from such an approach.
- ✓ Provide additional training to FSP truck drivers on driving requirements while operating under a working status corresponding to probe vehicle-like operations. Revise operational and institutional components of FSP Operating Procedures accordingly.

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APPENDIX A1

Estimating Section Travel Time (Loop Detector Log Data)

Freeway:	I-10
Direction:	WB
Date:	11/19/98
Time:	8:01-8:18

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Western	O.K.	23.00	1.07	2.791304348	16.0866667	47.79417778
Arlington	O.K.	12.00	1.575	7.875	16.0866667	16.70084444
Hauser	O.K.	13.26	1.505	6.809954751	16.0866667	7.990044444
	sum	48.26	total travel time	17.4762591		72.49
	Simple Ave. Spd	16.09			Variance	36.24253333

Freeway:	I-10
Direction:	EB
Date:	11/19/98
Time:	8:21-8:30

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Washington	O.K.	29.54	0.395	0.802301963	26.1916667	11.21133611
Sycamore	O.K.	30.00	0.775	1.55	26.1916667	14.50340278
West	O.K.	25.92	0.965	2.233796296	26.1916667	0.073802778
Arlington	O.K.	36.16	0.945	1.568030973	26.1916667	99.36766944
Western	O.K.	19.75	0.86	2.612658228	26.1916667	41.49506944
Vermont	O.K.	15.78	0.5	1.901140684	26.1916667	108.4028028
	sum	157.15	total travel time	10.66792815		275.0540833
	Simple Ave. Spd	26.19			Variance	55.01081667

Freeway:	I-10
Direction:	WB
Date:	24-Nov
Time:	8:01-8:18

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Western	O.K.	60.11	1.07	1.068041923	22.254	1433.076736
Arlington	O.K.	12.41	0.71	3.432715552	22.254	96.904336
Crenshaw	O.K.	10.08	0.85	5.05952381	22.254	148.206276
LaBrea	O.K.	13.63	0.865	3.807776963	22.254	74.373376
Hauser	O.K.	15.04	0.655	2.613031915	22.254	52.041796
	sum	111.27	total travel time	15.98109016		1804.60
	Simple Ave. Spd	22.254				451.15063

Time: 8:45-8:57

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Western	O.K.	61.62	1.07	1.041869523	23.71	1437.1681
Arlington	O.K.	14.28	0.71	2.983193277	23.71	88.9249
Crenshaw	O.K.	11.20	0.85	4.553571429	23.71	156.5001
LaBrea	O.K.	14.43	0.865	3.596673597	23.71	86.1184
Hauser	O.K.	17.02	0.655	2.309048179	23.71	44.7561
	sum	118.55	total travel time	14.484356		1813.47
	Simple Ave. Spd	23.71			Variance	453.3669

Freeway: I-10
Direction: EB
Date: 11/24/98
Time: 8:29-8:41

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Washington	O.K.	28.95	0.395	0.81865285	24.1885714	22.67120204
Sycamore	O.K.	20.62	0.775	2.255092144	24.1885714	12.73470204
West	O.K.	17.97	0.965	3.222036728	24.1885714	38.67063061
Arlington	O.K.	41.03	0.945	1.381915671	24.1885714	283.6337163
Western	O.K.	19.26	0.65	2.024922118	24.1885714	24.29081633
Budlong	O.K.	24.34	0.5	1.23253903	24.1885714	0.022930612
Vermont	O.K.	17.15	0.21	0.734693878	24.1885714	49.54148776
	sum	169.32	total travel time	11.66985242		431.5654857
	Simple Ave. Spd	24.19			Variance	71.92758095

Time: 8:58-9:06

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Washington	O.K.	27.79	0.395	0.852824757	31.1128571	11.04137959
Sycamore	O.K.	32.73	0.775	1.42071494	31.1128571	2.61515102
West	O.K.	33.91	0.965	1.707460926	31.1128571	7.824008163
Arlington	O.K.	35.99	0.945	1.575437622	31.1128571	23.78652245
Western	O.K.	37.16	0.65	1.049515608	31.1128571	36.56793673
Budlong	O.K.	29.19	0.5	1.027749229	31.1128571	3.697379592
Vermont	O.K.	21.02	0.21	0.599429115	31.1128571	101.8657653
	sum	217.79	total travel time	8.233132198		187.3981429
	Simple Ave. Spd	31.11			Variance	31.23302381

Freeway: I-10
Direction: WB
Date: 11/25/98
Time: 8:06-8:15

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Western	O.K.	62.61	1.07	1.025395304	29.812	1075.708804
Arlington	O.K.	33.12	0.71	1.286231884	29.812	10.942864
Crenshaw	O.K.	16.62	0.85	3.068592058	29.812	174.028864
LaBrea	O.K.	17.57	0.865	2.953898691	29.812	149.866564
Hauser	O.K.	19.14	0.655	2.053291536	29.812	113.891584
	sum	149.06	total travel time	10.38740947		1524.44
	Simple Ave. Spd	29.81			Variance	381.10967

Time: 8:26-8:35

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Western	O.K.	57.20	1.07	1.122377622	36.484	429.152656
Arlington	O.K.	61.11	0.71	0.697103584	36.484	606.439876
Crenshaw	O.K.	19.40	0.85	2.628865979	36.484	291.863056
LaBrea	O.K.	18.56	0.865	2.796336207	36.484	321.269776
Hauser	O.K.	26.15	0.655	1.502868069	36.484	106.791556
	sum	182.42	total travel time	8.747551461		1755.52
	Simple Ave. Spd	36.48			Variance	438.87923

Freeway: I-10
Direction: EB
Date: 1125
Time: 817-824

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Washington	O.K.	66.15	0.395	0.358276644	36.1285714	901.2861735
Sycamore	O.K.	45.22	0.775	1.028306059	36.1285714	82.65407347
West	O.K.	34.28	0.965	1.689031505	36.1285714	3.417216327
Arlington	O.K.	37.06	0.945	1.52995143	36.1285714	0.867559184
Western	O.K.	22.88	0.65	1.704545455	36.1285714	175.5246449
Budlong	O.K.	27.98	0.499	1.070050036	36.1285714	66.39921633
Vermont	O.K.	19.33	0.209	0.64873254	36.1285714	282.192002
	sum	252.9	total travel time	8.028893669		1512.340886
	Simple Ave. Spd	36.13			Variance	252.0568143

Time: 8:38-8:44

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Washington	O.K.	67.83	0.395	0.349402919	41.3371429	701.8714796
Sycamore	O.K.	50.66	0.775	0.917883932	41.3371429	86.91566531
West	O.K.	33.14	0.965	1.747133374	41.3371429	67.19315102
Arlington	O.K.	39.06	0.945	1.451612903	41.3371429	5.185379592
Western	O.K.	47.40	0.65	0.82278481	41.3371429	36.75823673
Budlong	O.K.	30.55	0.499	0.980032733	41.3371429	116.362451
Vermont	O.K.	20.72	0.209	0.605212355	41.3371429	425.0665796
	sum	289.36	total travel time	6.874063027		1439.352943
	Simple Ave. Spd	41.34			Variance	239.8921571

Freeway: I-10
Direction: WB
Date: 12/1/98
Time: 8:07-8:18

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Budlong	O.K.	58.33	0.42	0.432024687	30.8283333	756.3416694
Western	O.K.	60.03	0.65	0.649675162	30.8283333	852.7373361
Arlington	O.K.	21.44	0.71	1.986940299	30.8283333	88.14080278
Crenshaw	O.K.	12.76	0.85	3.996865204	30.8283333	326.4646694
LaBrea	O.K.	15.76	0.865	3.293147208	30.8283333	227.0546694
Hauser	O.K.	16.65	0.655	2.36036036	30.8283333	201.0251361
	sum	184.97	total travel time	12.71901292		2451.764283
	Simple Ave. Spd	30.83			Variance	490.3528567

Time: 8:32-8:44

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Budlong	O.K.	61.71	0.42	0.408361692	33.3716667	803.0611361
Western	O.K.	62.58	0.65	0.623202301	33.3716667	853.1267361
Arlington	O.K.	28.30	0.71	1.505300353	33.3716667	25.72180278
Crenshaw	O.K.	12.73	0.85	4.006284368	33.3716667	426.0784028
LaBrea	O.K.	14.16	0.865	3.665254237	33.3716667	369.0881361
Hauser	O.K.	20.75	0.655	1.893975904	33.3716667	159.3064694
	sum	200.23	total travel time	12.10237885		2636.382683
	Simple Ave. Spd	33.37			Variance	527.2765367

Freeway: I-10
Direction: EB
Date: 12/1/98
Time: 8:20-8:30

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Washington	O.K.	41.60	0.395	0.569711538	30.825	116.100625
LaBrea	O.K.	32.20	0.38	0.708074534	30.825	1.890625
Sycamore	O.K.	31.79	0.51	0.962566845	30.825	0.931225
West	O.K.	26.68	0.38	0.854572714	30.825	17.181025
Arlington	O.K.	31.13	0.945	1.821394154	30.825	0.093025
Western	O.K.	21.55	1.36	3.786542923	30.825	86.025625
	sum	184.95	total travel time	8.702862708		222.22
	Simple Ave. Spd	30.83			Variance	44.44443

Time: 8:45-8:55

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Washington	O.K.	53.09	0.395	0.446411754	36.4416667	277.1670028
LaBrea	O.K.	38.38	0.38	0.594059406	36.4416667	3.757136111
Sycamore	O.K.	41.07	0.51	0.745069394	36.4416667	21.42146944
West	O.K.	35.11	0.38	0.649387639	36.4416667	1.773336111
Arlington	O.K.	29.94	0.945	1.893787575	36.4416667	42.27166944
Western	O.K.	21.06	1.36	3.874643875	36.4416667	236.5956694
	sum	218.65	total travel time	8.203359642		582.99
	Simple Ave. Spd	36.44			Variance	116.5972567

Freeway: I-10
Direction: WB
Date: 12/2/98
Time: 8:02-8:23

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Budlong	O.K.	59.97	0.42	0.420210105	20.925	1524.512025
Western	O.K.	21.05	0.65	1.852731591	20.925	0.015625
Arlington	O.K.	9.900	0.71	4.303030303	20.925	121.550625
Crenshaw	O.K.	8.540	0.85	5.971896956	20.925	153.388225
LaBrea	O.K.	10.54	0.865	4.924098672	20.925	107.848225
Hauser	O.K.	15.55	0.655	2.52733119	20.925	28.890625
	sum	125.55	total travel time	19.99929882		1936.21
	Simple Ave. Spd	20.93			Variance	387.24107

Time:	8:38-8:58					
Location	**Loop Status**	**Point Speed (Mile/Hr)**	**Coverage (Mile)**	**Travel time (Minute)**	**Simple Avg. Spd**	**(P. spd - SAS)^2**
Budlong	O.K.	48.02	0.42	0.524781341	18.3683333	879.2213361
Western	O.K.	14.56	0.65	2.678571429	18.3683333	14.50340278
Arlington	O.K.	11.05	0.71	3.85520362	18.3683333	53.55800278
Crenshaw	O.K.	9.640	0.85	5.290456432	18.3683333	76.18380278
LaBrea	O.K.	11.41	0.865	4.548641543	18.3683333	48.41840278
Hauser	O.K.	15.53	0.655	2.530585963	18.3683333	8.056136111
	sum	110.21	total travel time	19.42824033		1079.94
	Simple Ave. Spd	18.37			Variance	215.9882167

Freeway:	I-10					
Direction:	EB					
Date:	12/2/98					
Time:	8:25-8:36					
Location	**Loop Status**	**Point Speed (Mile/Hr)**	**Coverage (Mile)**	**Travel time (Minute)**	**Simple Avg. Spd**	**(P. spd - SAS)^2**
Washington	O.K.	29.57	0.395	0.801487995	24.9942857	20.93716122
Sycamore	O.K.	24.71	0.775	1.881829219	24.9942857	0.080818367
West	O.K.	23.01	0.965	2.516297262	24.9942857	3.937389796
Arlington	O.K.	28.72	0.945	1.974233983	24.9942857	13.88094694
Western	O.K.	24.78	0.65	1.573849879	24.9942857	0.045918367
Budlong	O.K.	26.62	0.499	1.124718257	24.9942857	2.642946939
Vermont	O.K.	17.55	0.209	0.714529915	24.9942857	55.4173898
	sum	174.96	total travel time	10.58694651		96.94257143
	Simple Ave. Spd	24.99			Variance	16.15709524

Time:	8:59-9:07					
Location	**Loop Status**	**Point Speed (Mile/Hr)**	**Coverage (Mile)**	**Travel time (Minute)**	**Simple Avg. Spd**	**(P. spd - SAS)^2**
Washington	O.K.	35.91	0.395	0.659983292	32.8642857	9.27637551
Sycamore	O.K.	33.72	0.775	1.379003559	32.8642857	0.732246939
West	O.K.	30.26	0.965	1.913417052	32.8642857	6.782304082
Arlington	O.K.	38.48	0.945	1.473492723	32.8642857	31.53624694
Western	O.K.	37.83	0.65	1.030927835	32.8642857	24.65831837
Budlong	O.K.	31.34	0.499	0.955328653	32.8642857	2.323446939
Vermont	O.K.	22.51	0.209	0.55708574	32.8642857	107.2112327
	sum	230.05	total travel time	7.969238854		182.5201714
	Simple Ave. Spd	32.86			Variance	30.42002857

Freeway:	I-10
Direction:	WB
Date:	12/3/98
Time:	8:01-8:17

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Budlong	O.K.	60.67	0.42	0.415361793	29.914	945.931536
Western	O.K.	53.89	0.65	0.723696419	29.914	574.848576
Arlington	O.K.	11.73	0.71	3.631713555	29.914	330.657856
Crenshaw	O.K.	9.56	1.215	7.625523013	29.914	414.285316
Hauser	O.K.	13.72	1.155	5.051020408	29.914	262.245636
	sum	149.57	total travel time	17.44731519		2527.97
	Simple Ave. Spd	29.91			Variance	631.99223

Time:	8:33-8:49

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Budlong	O.K.	59.41	0.42	0.424171015	30.946	810.199296
Western	O.K.	54.13	0.65	0.720487715	30.946	537.497856
Arlington	O.K.	14.48	0.71	2.94198895	30.946	271.129156
Crenshaw	O.K.	11.60	1.215	6.284482759	30.946	374.267716
Hauser	O.K.	15.11	1.155	4.586366645	30.946	250.778896
	sum	154.73	total travel time	14.95749708		2243.87
	Simple Ave. Spd	30.95			Variance	560.96823

Freeway:	I-10
Direction:	EB
Date:	12/3/98
Time:	8:20-8:30

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Sycamore	O.K.	19.36	1.17	3.626033058	23.998	21.511044
West	O.K.	22.34	0.965	2.591763653	23.998	2.748964
Arlington	O.K.	32.88	0.945	1.724452555	23.998	78.889924
Western	O.K.	20.17	1.36	4.045612295	23.998	14.653584
	sum	94.75	total travel time	11.98786156		117.80
	Simple Ave. Spd	23.69			Variance	29.450879

Time: 8:50-8:59

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Sycamore	O.K.	18.98	1.17	3.698630137	31.37	153.5121
West	O.K.	36.63	0.965	1.580671581	31.37	27.6676
Arlington	O.K.	39.88	0.945	1.421765296	31.37	72.4201
Western	O.K.	29.99	1.36	2.720906969	31.37	1.9044
	sum	125.48	total travel time	9.421973983		255.50
	Simple Ave. Spd	31.37			Variance	63.87605

Freeway: I-10
Direction: WB
Date: 12/8/98
Time: 8:03-8:21

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Budlong	O.K.	61.20	0.42	0.411764706	27.19	1156.6801
Western	O.K.	57.58	0.65	0.677318513	27.19	923.5521
Arlington	O.K.	10.69	0.71	3.985032741	27.19	272.25
Crenshaw	O.K.	9.400	0.965	6.159574468	27.19	316.4841
Sycamore	O.K.	10.36	0.865	5.00965251	27.19	283.2489
Hauser	O.K.	13.91	0.54	2.329259526	27.19	176.3584
	sum	163.14	total travel time	18.57260246		3128.57
	Simple Ave. Spd	27.19			Variance	625.71472

Time: 8:35-8:53

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Budlong	O.K.	60.68	0.42	0.415293342	23.5466667	1378.884444
Western	O.K.	27.31	0.65	1.428048334	23.5466667	14.16267778
Arlington	O.K.	14.01	0.71	3.040685225	23.5466667	90.94801111
Crenshaw	O.K.	12.34	0.965	4.692058347	23.5466667	125.5893778
Sycamore	O.K.	12.42	0.865	4.178743961	23.5466667	123.8027111
Hauser	O.K.	14.52	0.54	2.231404959	23.5466667	81.48071111
	sum	141.28	total travel time	15.98623417		1814.87
	Simple Ave. Spd	23.55			Variance	362.9735867

Freeway:	I-10
Direction:	EB
Date:	12/8/98
Time:	8:23-8:32

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Hauser	O.K.	21.29	0.54	1.52184124	23.96	7.1289
Sycamore	O.K.	26.75	0.63	1.413084112	23.96	7.7841
West	O.K.	23.01	0.965	2.516297262	23.96	0.9025
Arlington	O.K.	30.01	0.945	1.88937021	23.96	36.6025
Western	O.K.	20.13	0.65	1.937406855	23.96	14.6689
Budlong	O.K.	27.06	0.499	1.106430155	23.96	9.61
Vermont	O.K.	16.24	0.209	0.772167488	23.96	59.5984
	sum	164.49	total travel time	11.15659732		136.30
	Simple Ave. Spd	20.56125			Variance	19.47075714

Time:	8:54-9:04

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Hauser	O.K.	23.39	0.54	1.385207354	25.395	4.020025
Sycamore	O.K.	26.12	0.63	1.447166922	25.395	0.525625
West	O.K.	30.46	0.965	1.900853578	25.395	25.654225
Arlington	O.K.	34.68	0.945	1.634948097	25.395	86.211225
Western	O.K.	20.45	0.65	1.907090465	25.395	24.453025
Budlong	O.K.	27.04	0.499	1.107248521	25.395	2.706025
Vermont	O.K.	16.98	0.209	0.738515901	25.395	70.812225
	sum	179.12	total travel time	10.12103084		214.38
	Simple Ave. Spd	22.39			Variance	30.62605357

Freeway:	I-10
Direction:	WB
Date:	12/9/98
Time:	8:03-8:24

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Budlong	O.K.	59.27	0.42	0.425172937	18.925	1627.719025
Western	O.K.	13.43	0.65	2.903946389	18.925	30.195025
Arlington	O.K.	9.920	0.71	4.294354839	18.925	81.090025
Crenshaw	O.K.	8.250	0.965	7.018181818	18.925	113.955625
Sycamore	O.K.	10.54	0.865	4.924098672	18.925	70.308225
Hauser	O.K.	12.14	0.54	2.668863262	18.925	46.036225
	sum	113.55	total travel time	22.23461792		1969.30
	Simple Ave. Spd	18.93			Variance	393.86083

Time: 8:38-8:55

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Budlong	O.K.	48.20	0.42	0.522821577	19.7216667	811.0154694
Western	O.K.	13.92	0.65	2.801724138	19.7216667	33.65933611
Arlington	O.K.	13.14	0.71	3.242009132	19.7216667	43.31833611
Crenshaw	O.K.	10.02	0.965	5.778443114	19.7216667	94.12233611
Sycamore	O.K.	15.54	0.865	3.33976834	19.7216667	17.48633611
Hauser	O.K.	17.51	0.54	1.850371216	19.7216667	4.891469444
	sum	118.33	total travel time	17.53513752		1004.49
	Simple Ave. Spd	19.72			Variance	200.8986567

Freeway: I-10
Direction: EB
Date: 12/9/98
Time: 8:25-8:35

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Hauser	O.K.	20.00	0.54	1.62	22.6528571	7.03765102
West	O.K.	23.05	0.965	2.511930586	22.6528571	0.157722449
Sycamore	O.K.	29.06	0.63	1.300757054	22.6528571	41.05147959
Arlington	O.K.	27.96	0.945	2.027896996	22.6528571	28.16576531
Western	O.K.	16.28	0.65	2.395577396	22.6528571	40.61330816
Budlong	O.K.	24.72	0.499	1.211165049	22.6528571	4.273079592
Vermont	O.K.	17.50	0.209	0.716571429	22.6528571	26.55193673
	sum	158.57	total travel time	11.78389851		147.8509429
	Simple Ave. Spd	22.65			Variance	24.64182381

Time: 8:57-9:15

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Hauser	O.K.	25.65	0.54	1.263157895	24.4514286	1.436573469
West	O.K.	27.30	0.965	2.120879121	24.4514286	8.114359184
Sycamore	O.K.	29.28	0.63	1.290983607	24.4514286	23.31510204
Arlington	O.K.	30.75	0.945	1.843902439	24.4514286	39.67200204
Western	O.K.	18.92	0.65	2.061310782	24.4514286	30.59670204
Budlong	O.K.	18.76	0.499	1.595948827	24.4514286	32.39235918
Vermont	O.K.	20.50	0.209	0.611707317	24.4514286	15.61378776
	sum	171.16	total travel time	10.78788999		151.1408857
	Simple Ave. Spd	24.45			Variance	25.19014762

Freeway:	I-10
Direction:	WB
Date:	12/10/98
Time:	8:05-8:23

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Budlong	O.K.	49.9	0.42	0.50501002	17.615	1042.321225
Western	O.K.	12.14	0.65	3.212520593	17.615	29.975625
Arlington	O.K.	10.640	0.71	4.003759398	17.615	48.650625
Crenshaw	O.K.	9.080	0.85	5.616740088	17.615	72.846225
La Brea	O.K.	10.83	0.865	4.792243767	17.615	46.036225
Hauser	O.K.	13.10	0.655	3	17.615	20.385225
	sum	105.69	total travel time	21.13027387		1260.22
	Simple Ave. Spd	17.62				252.04303

Time:	8:38-8:53

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Budlong	O.K.	53.23	0.42	0.473417246	19.54	1135.0161
Western	O.K.	14.28	0.65	2.731092437	19.54	27.6676
Arlington	O.K.	13.51	0.71	3.153219837	19.54	36.3609
Crenshaw	O.K.	10.69	0.85	4.770813845	19.54	78.3225
La Brea	O.K.	11.33	0.865	4.580759047	19.54	67.4041
Hauser	O.K.	14.17	0.655	2.773465067	19.54	28.8369
	sum	117.21	total travel time	18.48276748		1373.61
	Simple Ave. Spd	19.54			Variance	274.72162

Freeway:	I-10
Direction:	EB
Date:	12/10/98
Time:	8:25-8:37

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Washington	O.K.	32.48	0.395	0.729679803	23.1014286	87.95760204
Sycamore	O.K.	22.22	0.775	2.092709271	23.1014286	0.776916327
Western	O.K.	17.86	0.965	3.241881299	23.1014286	27.47257347
Arlington	O.K.	28.89	0.945	1.962616822	23.1014286	33.50755918
Western	O.K.	18.79	0.65	2.075572113	23.1014286	18.58841633
Budlong	O.K.	23.73	0.499	1.261694058	23.1014286	0.395102041
Vermont	O.K.	17.74	0.209	0.706877114	23.1014286	28.74491633
	sum	161.71	total travel time	12.07103048		197.4430857
	Simple Ave. Spd	23.10				28.2061551

Time: 8:56-9:04

Location	Loop Status	Point Speed (Mile/Hr)	Coverage (Mile)	Travel time (Minute)	Simple Avg. Spd	(P. spd - SAS)^2
Washington	O.K.	33.19	0.395	0.714070503	30.3785714	7.904130612
Sycamore	O.K.	31.19	0.775	1.490862456	30.3785714	0.658416327
Western	O.K.	29.14	0.965	1.986959506	30.3785714	1.534059184
Arlington	O.K.	34.86	0.945	1.626506024	30.3785714	20.08320204
Western	O.K.	39.67	0.65	0.983110663	30.3785714	86.3306449
Budlong	O.K.	21.82	0.499	1.372135655	30.3785714	73.2491449
Vermont	O.K.	22.78	0.209	0.55048288	30.3785714	57.73828776
	sum	212.65	total travel time	8.724127687		247.4978857
	Simple Ave. Spd	30.38			Variance	35.35684082

APPENDIX A2

Probe Vehicle Speed Survey Data

Date	Direction	Start	End	Cruise Time (min)	Distance (miles)	Avg. Speed (mph)
11/19(Thu)	WB	8:00:20	8:18:20	18.33	4.2	13.7
	EB	8:21:20	8:30:05	8.75	4.2	28.8
11/24(Tue)	WB	8:00:15	8:18:12	17.95	4.2	14.0
	EB	8:29:25	8:41:21	11.93	4.6	23.1
	WB	8:45:00	8:57:10	12.17	3.7	18.2
	EB	8:58:25	9:05:40	7.25	3.8	31.4
11/25(Wed)	WB	8:05:36	8:15:12	9.60	4.2	26.3
	EB	8:16:27	8:24:10	7.72	4.2	32.6
	WB	8:26:10	8:34:55	8.75	4.2	28.8
	EB	8:37:35	8:44:10	6.58	4.2	38.3
12/1(Tue)	WB	8:06:31	8:18:00	11.48	4.2	22.0
	EB	8:20:08	8:29:30	9.50	4.2	26.5
	WB	8:32:22	8:43:31	11.15	4.2	22.6
	EB	8:45:22	8:54:25	9.05	4.2	27.8
12/2(Wed)	WB	8:01:00	8:22:30	21.50	4.2	11.7
	EB	8:24:35	8:35:45	11.17	4.2	22.6
	WB	8:38:20	8:57:45	19.42	4.2	13.0
	EB	8:58:30	9:06:30	8.00	4.2	31.5
12/3(Thu)	WB	8:00:00	8:17:25	17.42	4.2	14.5
	EB	8:20:15	8:30:10	9.92	4.2	25.4
	WB	8:32:40	8:48:30	15.83	4.2	15.9
	EB	8:49:30	8:58:30	9.00	4.2	28.0
12/8(Tue)	WB	8:03:15	8:21:00	17.75	4.2	14.2
	EB	8:22:30	8:32:10	9.67	4.2	26.1
	WB	8:35:10	9:52:45	17.58	4.2	14.3
	EB	8:54:15	9:04:15	10.00	4.2	25.2
12/9(Wed)	WB	8:03:03	8:24:00	20.95	4.2	12.0
	EB	8:25:15	8:35:25	11.17	4.2	22.6
	WB	8:38:22	8:55:15	16.88	4.2	14.9
	EB	8:57:20	9:08:15	10.92	4.2	23.1
12/10(Thu)	WB	8:03:15	8:21:30	18.25	4.2	13.8
	EB	8:24:45	8:36:30	11.70	4.2	21.4
	WB	8:38:00	8:53:25	15.46	4.2	16.3
	EB	8:55:35	9:04:15	8.66	4.2	29.1

APPENDIX A3

FSP Truck Speed Comparison with Probe Speed and Loop Speed

Date	Direction	Start	End	PROBE	LOOP (TT based)		FSP Truck Observation Speed(mph)					
				Avg. Speed (mph)	Avg. Speed (mph)	Average	Obs. 1	Obs. 2	Obs. 3	Obs. 4	Obs. 5	Obs. 6
11/19(Thu)	WB	8:00:20	8:18:20	13.7	14.4	13.2	16	31	13	10	13	10
	EB	8:21:20	8:30:05	28.8	23.6	17.3	37	0	15			
11/24(Tue)	WB	8:00:15	8:18:12	14.0	15.8	39.0	46	32				
	EB	8:29:25	8:41:21	23.1	23.7	20.8	31	28	8	16		
	WB	8:45:00	8:57:10	18.2	15.3	N/A						
	EB	8:58:25	9:05:40	31.4	27.7	25.0	25					
11/25(Wed)	WB	8:05:36	8:15:12	26.3	24.3	18.0	33	0	21			
	EB	8:16:27	8:24:10	32.6	31.4	0.0	0	0				
	WB	8:26:10	8:34:55	28.8	28.8	24.5	15	34				
	EB	8:37:35	8:44:10	38.3	36.7	25.0	42	18	15			
12/1(Tue)	WB	8:06:31	8:18:00	22.0	19.8	N/A						
	EB	8:20:08	8:29:30	26.5	29.0	28.7	39	31	16			
	WB	8:32:22	8:43:31	22.6	20.8	16.7	12	26	3	3	47	9
	EB	8:45:22	8:54:25	27.8	30.7	17.5	2	33				
12/2(Wed)	WB	8:01:00	8:22:30	11.7	12.6	14.2	16	15	13	3	14	24
	EB	8:24:35	8:35:45	22.6	23.8	11.0	0	10	21	13		
	WB	8:38:20	8:57:45	13.0	13.0	15.7	0	0	22	15	16	41
	EB	8:58:30	9:06:30	31.5	31.6	30.5	39	46	37	0		
12/3(Thu)	WB	8:00:00	8:17:25	14.5	14.4	9.6	10	9	3	8	18	
	EB	8:20:15	8:30:10	25.4	21.0	N/A						
	WB	8:32:40	8:48:30	15.9	16.8	12.0	5	19				
	EB	8:49:30	8:58:30	28.0	26.8	N/A						
12/8(Tue)	WB	8:03:15	8:21:00	14.2	13.6	11.5	47	24	11	7	8	9
	EB	8:22:30	8:32:10	26.1	22.6	N/A						
	WB	8:35:10	9:52:45	14.3	15.8	24.0	24					
	EB	8:54:15	9:04:15	25.2	24.9	19.5	5	34				
12/9(Wed)	WB	8:03:03	8:24:00	12.0	11.3	16.9	27	34	0	26	12	13
	EB	8:25:15	8:35:25	22.6	21.4	14.3	13	13	17			
	WB	8:38:22	8:55:15	14.9	14.4	20.1	20	39	19	24	32	7
	EB	8:57:20	9:08:15	23.1	23.4	26.3	10	35	33	27		
12/10(Thu)	WB	8:03:15	8:21:30	13.8	11.9	6.0	6					
	EB	8:24:45	8:36:30	21.4	20.9	34.0	34					
	WB	8:38:00	8:53:25	16.3	13.6	11.4	17	15	2	17	9	16
	EB	8:55:35	9:04:15	29.1	28.8	N/A						

APPENDIX A4

FSP Truck Historic Speed Data (9/16,20,21,22,23/1999)

1. Primary data filter condition: data non-conformance with ambient speed
   (Not moving for more than 2 minutes evident from unchanged location & zero speed)
2. Additional filter condition: Zero speed and clearly isolated direction.

9/16/99 I-10

Time	MDT ID	Latitude	Longitude	Speed (mph)	Direction(Degree)	Direction(Bound)
6:57:09	814	34.03207	-118.42236	48	270	w
7:01:29	814	34.02847	-118.44811	43	72	e
7:05:35	814	34.03178	-118.38882	48	54	e
7:09:42	814	34.03459	-118.34038	44	86	e
7:17:58	814	34.03733	-118.30336	15	272	w
7:26:33	814	34.03507	-118.33485	7	270	w
7:30:36	814	34.03491	-118.34849	15	266	w
7:34:40	814	34.03396	-118.35988	8	272	w
7:47:02	814	34.02917	-118.39449	14	259	w
7:57:29	814	34.03159	-118.38963	43	53	e
8:06:38	814	34.03505	-118.36967	36	103	e
8:10:41	814	34.03451	-118.35054	4	267	w
8:14:46	814	34.03416	-118.36403	7	283	w
8:18:54	814	34.03634	-118.37245	15	283	w
8:23:10	814	34.03352	-118.38746	38	238	w
8:54:37	814	34.02937	-118.39432	27	255	w
9:30:30	814	34.03022	-118.44061	48	79	e
9:34:34	814	34.03005	-118.39182	45	57	e
9:50:56	814	34.03708	-118.31304	40	91	e
14:38:29	814	34.03711	-118.30392	48	269	w
14:42:30	814	34.03397	-118.3594	45	268	w
14:56:24	814	34.03421	-118.38539	26	234	w
15:12:16	814	34.02982	-118.39147	18	200	w
15:39:06	814	34.03063	-118.4395	45	262	w
15:43:24	814	34.02899	-118.44614	14	68	e
15:47:33	814	34.02944	-118.40547	49	96	e
16:12:56	814	34.03477	-118.36311	22	100	e
16:21:18	814	34.03738	-118.30207	48	277	w
16:29:32	814	34.03429	-118.34589	44	268	w
16:33:34	814	34.02935	-118.39427	43	255	w
16:37:36	814	34.03031	-118.44045	46	262	w
16:41:43	814	34.0288	-118.44725	14	71	e
16:45:53	814	34.02998	-118.40639	36	96	e
16:58:18	814	34.03366	-118.35265	39	86	e
17:02:31	814	34.03561	-118.31942	34	85	e
17:06:48	814	34.03678	-118.29197	13	60	e

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Time	MDT ID	Latitude	Longitude	Speed (mph)	Direction(Degree)	Direction(Bound)
15:37:28	974	34.03676	-118.28424	17	84	e
15:37:29	974	34.03676	-118.28424	17	84	e
15:37:37	974	34.03683	-118.28341	20	83	e
15:37:47	974	34.03699	-118.28253	16	71	e
15:37:55	974	34.03709	-118.28219	15	71	e
16:05:28	974	34.03393	-118.33427	18	25	e
16:43:44	974	34.03109	-118.41131	47	295	w
16:47:54	974	34.01257	-118.41916	40	146	w
16:52:11	974	34.01132	-118.416	21	149	w
16:56:38	974	34.0234	-118.42726	43	328	w
17:08:38	974	34.03115	-118.41365	53	109	e
17:09:11	974	34.0299	-118.40947	19	99	e
17:13:14	974	34.0359	-118.37122	21	100	e
17:29:39	974	34.03528	-118.33118	25	87	e
17:38:02	974	34.03587	-118.32435	14	261	w
17:42:08	974	34.03533	-118.36933	46	286	w
18:21:17	974	34.03435	-118.36622	10	106	e
18:49:33	974	34.03521	-118.26858	37	309	w
18:53:42	974	34.03716	-118.2918	13	273	w

9/16/99 I-10

Time	MDT ID	Latitude	Longitude	Speed (mph)	Direction(Degree)	Direction(Bound)
15:38:30	978	34.03429	-118.34468	43	86	e
15:42:42	978	34.03649	-118.29187	2	92	e
15:50:55	978	34.03638	-118.38085	47	252	w
15:59:04	978	34.03597	-118.37186	24	101	e
16:31:45	978	34.03697	-118.30932	55	273	w
16:31:54	978	34.03687	-118.31318	48	267	w
16:40:25	978	34.03658	-118.31851	25	255	w

9/16/99 I-10

Time	MDT ID	Latitude	Longitude	Speed (mph)	Direction(Degree)	Direction(Bound)
18:21:18	978	34.03136	-118.41353	18	108	e
18:34:02	978	34.02902	-118.39883	15	99	e
18:42:19	978	34.02879	-118.39613	22	89	e
18:45:33	978	34.03405	-118.36757	15	102	e

9/20/99 I-10

Time	MDT ID	Latitude	Longitude	Speed (mph)	Direction(Degree)	Direction(Bound)
17:08:41	814	34.03498	-118.36753	34	285	w
17:08:48	814	34.03515	-118.36828	30	286	w

9/22/99 I-10

Time	MDT ID	Latitude	Longitude	Speed (mph)	Direction(Degree)	Direction(Bound)
7:24:13	814	34.03714	-118.30385	34	90	e
7:32:32	814	34.03708	-118.31209	15	270	w
7:36:44	814	34.0356	-118.32739	6	268	w
7:40:55	814	34.03488	-118.33865	4	262	w
7:45:02	814	34.0348	-118.34735	8	274	w
7:49:18	814	34.03443	-118.36538	6	281	w
7:53:25	814	34.03628	-118.37431	6	285	w
8:01:57	814	34.02997	-118.39127	19	52	e
8:06:01	814	34.034	-118.36426	42	102	e
8:10:11	814	34.03551	-118.3285	10	85	e
8:14:25	814	34.03691	-118.30101	9	93	e
8:18:32	814	34.03736	-118.29963	35	270	w
8:26:41	814	34.03558	-118.32621	14	262	w
8:35:04	814	34.03442	-118.34774	6	272	w
8:39:14	814	34.03329	-118.35992	11	263	w
8:43:44	814	34.036	-118.3725	11	289	w
8:52:23	814	34.03641	-118.37766	6	344	w
9:07:24	814	34.03833	-118.37612	4	21	e
9:12:14	814	34.03532	-118.33433	47	87	e
9:29:52	814	34.0337	-118.36262	32	278	w
14:42:27	814	34.03745	-118.30427	47	268	w
14:46:32	814	34.03453	-118.36544	52	284	w
15:26:01	814	34.03659	-118.37674	29	103	e
15:30:11	814	34.03464	-118.34528	32	86	e
15:34:22	814	34.03642	-118.29198	8	85	e
16:21:06	814	34.03411	-118.34381	42	86	e
16:33:47	814	34.03466	-118.35229	44	267	w
16:46:51	814	34.02937	-118.44461	17	71	e
16:51:07	814	34.03201	-118.42481	19	89	e
16:59:28	814	34.03	-118.44091	5	82	e
16:59:42	814	34.03	-118.44091	5	82	e
17:03:47	814	34.03099	-118.41189	34	112	e
17:12:37	814	34.03389	-118.35639	30	87	e
17:12:43	814	34.03389	-118.35639	30	87	e
17:16:47	814	34.03635	-118.31448	34	83	e
17:51:33	814	34.03064	-118.43536	14	82	e
18:33:13	814	34.02983	-118.39244	20	63	e
18:37:23	814	34.03443	-118.36639	25	104	e
18:41:31	814	34.03469	-118.33282	26	82	e
18:45:35	814	34.03663	-118.30609	29	88	e
18:49:58	814	34.03678	-118.29128	7	88	e
18:54:02	814	34.03667	-118.28639	28	92	e

9/22/99 I-5

Time	MDT ID	Latitude	Longitude	Speed (mph)	Direction(Degree)	Direction(Bound)
6:46:55	851	33.99949	-118.1481	54	142	s
6:48:28	851	33.98628	-118.13668	8	23	n
7:02:48	851	33.98759	-118.13691	22	134	s
7:07:02	851	34.01214	-118.16255	50	300	n
7:11:10	851	34.02055	-118.19048	28	270	n
7:15:24	851	34.04674	-118.21481	58	19	n
7:19:35	851	34.09163	-118.23948	55	324	n
7:23:46	851	34.08663	-118.23346	49	123	s
7:27:49	851	34.06025	-118.21524	43	164	s
7:32:14	851	34.03008	-118.21831	47	144	s
7:36:27	851	34.00932	-118.15933	53	143	s
7:40:39	851	33.98774	-118.13725	8	93	s
7:45:05	851	34.00892	-118.15793	50	321	n
7:49:15	851	34.02018	-118.18237	9	276	n
7:53:27	851	34.02962	-118.21484	52	300	n
7:57:33	851	34.06681	-118.21573	43	358	n
8:01:59	851	34.06578	-118.21574	51	359	n
8:06:03	851	34.09446	-118.24392	24	144	s
8:10:13	851	34.06709	-118.21644	50	175	s
8:14:24	851	34.03717	-118.21985	24	199	s
8:18:34	851	34.01565	-118.1724	50	113	s
8:22:39	851	33.98602	-118.13767	13	275	n
8:26:42	851	34.00434	-118.15284	41	317	n
8:31:08	851	34.02013	-118.1842	23	271	n
8:35:11	851	34.03205	-118.2192	52	320	n
8:39:21	851	34.08112	-118.22387	56	300	n
8:43:47	851	34.08983	-118.23838	16	133	s
8:48:19	851	34.05154	-118.21443	20	179	s
8:52:30	851	34.02828	-118.2136	45	112	s
8:57:03	851	34.00115	-118.14983	57	141	s
9:01:14	851	33.99338	-118.14252	42	323	n
9:05:22	851	34.01999	-118.18074	23	288	n
9:12:48	851	34.02053	-118.19065	19	269	n
9:12:52	851	34.02055	-118.19119	25	272	n
9:17:09	851	34.03088	-118.21686	50	299	n
9:26:11	851	34.04222	-118.21728	16	42	n
9:26:16	851	34.04244	-118.21709	11	39	n
9:31:04	851	34.09119	-118.23972	53	325	n
9:35:13	851	34.08695	-118.23375	46	126	s
9:39:20	851	34.05919	-118.21448	31	166	s
9:43:27	851	34.04643	-118.21521	12	205	s
14:41:13	851	34.01567	-118.20158	19	1	n
14:49:45	851	34.02057	-118.19204	13	10	n
14:54:25	851	34.03106	-118.21744	11	301	n
14:58:30	851	34.06328	-118.21558	40	348	n
15:03:00	851	34.08891	-118.23604	38	128	s
15:22:42	851	34.08638	-118.23242	24	300	n
15:27:45	851	34.07687	-118.22281	15	339	n
15:31:49	851	34.06566	-118.21657	51	178	s

9/22/99	**I-5**					
15:40:20	851	34.06324	-118.21544	50	348	n
16:12:38	851	34.04833	-118.21403	53	191	s
16:16:54	851	34.02019	-118.18456	47	89	s
16:21:08	851	33.99039	-118.14088	34	141	s
16:25:13	851	33.98663	-118.13507	24	132	s
16:29:40	851	34.02505	-118.1725	57	2	n
16:38:08	851	34.01994	-118.1889	55	270	n
16:42:32	851	34.03221	-118.21853	6	311	n
16:46:55	851	34.06496	-118.21656	34	357	n
16:51:09	851	34.09193	-118.23982	41	144	s
17:18:07	851	34.02954	-118.21862	50	143	s
17:22:59	851	34.00882	-118.15873	31	144	s
17:27:21	851	33.99072	-118.14114	26	139	s
17:36:05	851	34.01322	-118.16606	51	300	n
17:40:15	851	34.02886	-118.21231	14	304	n
17:44:19	851	34.03174	-118.21817	4	302	n
17:48:29	851	34.04805	-118.2141	34	10	n
17:53:11	851	34.08275	-118.22747	35	297	n
17:57:14	851	34.09427	-118.24307	17	60	s
18:01:23	851	34.05221	-118.21399	57	178	s
18:05:56	851	34.01961	-118.18207	52	98	s
18:10:05	851	33.99144	-118.14151	48	140	s
18:14:17	851	34.00121	-118.14944	49	321	n
18:18:35	851	34.02365	-118.20099	52	298	n
18:22:43	851	34.03344	-118.21976	6	340	n
18:26:50	851	34.06027	-118.21463	26	344	n
18:31:18	851	34.09234	-118.24007	37	145	s
18:35:32	851	34.05509	-118.21408	49	177	s
18:43:52	851	34.02648	-118.20921	49	117	s

9/22/99 I-10

Time	MDT ID	Latitude	Longitude	Speed (mph)	Direction(Degree)	Direction(Bound)
16:51:29	974	34.03431	-118.36438	24	101	e
17:04:08	974	34.03723	-118.31171	54	269	w
17:08:17	974	34.03615	-118.3719	54	286	w
17:12:50	974	34.03239	-118.43386	53	304	w
17:31:49	974	34.03643	-118.3803	15	71	e
17:36:23	974	34.03413	-118.34376	45	87	e
17:40:35	974	34.03674	-118.29308	33	92	e
17:55:01	974	34.03653	-118.29503	36	90	e
17:55:12	974	34.03647	-118.29311	39	90	e
17:59:19	974	34.03497	-118.26677	21	297	w
18:39:22	974	34.03706	-118.31782	17	260	w
18:43:45	974	34.03395	-118.35804	36	267	w
18:56:08	974	34.03	-118.39218	13	61	e

9/23/99 I-5

Time	MDT ID	Latitude	Longitude	Speed (mph)	Direction(Degree)	Direction(Bound)
17:59:19	100	34.02896	-118.2124	3	298	n
18:00:30	100	34.03106	-118.21705	24	297	n
18:14:49	100	34.02826	-118.21802	19	26	n
18:18:56	100	34.01921	-118.17874	42	117	s
18:23:01	100	34.00179	-118.15048	38	142	s
18:46:35	100	34.03104	-118.21776	19	216	s

9/23/99 I-5

Time	MDT ID	Latitude	Longitude	Speed (mph)	Direction(Degree)	Direction(Bound)
18:16:26	896	34.11315	-118.24403	19	320	n
18:20:56	896	34.08339	-118.22813	45	119	s
18:25:00	896	34.06039	-118.21535	49	164	s
18:45:19	896	34.01977	-118.18945	12	129	s
18:45:23	896	34.01953	-118.18935	17	177	s
18:58:09	896	34.01541	-118.20053	7	183	s

9/23/99 I-10

Time	MDT ID	Latitude	Longitude	Speed (mph)	Direction(Degree)	Direction(Bound)
16:34:38	974	34.03664	-118.30388	44	266	w
16:53:54	974	34.03118	-118.43243	14	84	e
17:02:31	974	34.02987	-118.39245	31	60	e
17:06:45	974	34.03557	-118.37174	12	105	e
17:11:06	974	34.03434	-118.34237	40	85	e
17:53:29	974	34.03072	-118.43992	16	85	e
18:01:51	974	34.02917	-118.4027	7	93	e
18:06:54	974	34.036	-118.3806	10	73	e
18:15:12	974	34.02898	-118.39848	21	94	e
18:19:29	974	34.03605	-118.38205	15	55	e
18:34:39	974	34.03374	-118.3628	10	103	e
18:38:46	974	34.03474	-118.3358	19	87	e
18:39:25	974	34.03483	-118.33207	15	90	e
18:43:06	974	34.03708	-118.30798	25	89	e

APPENDIX A5

Loop Detector Speed Corresponding to Historic FSP Truck Speed

I-10	WEST					
Time	**BUDLONG**	**WESTERN2**	**ARLINGTO1**	**CRENSHAW2**	**LA BREA 2**	**HAUSER**
717:00:00	21.93	16.33	24.89	9.45	17.77	23.49
726:00:00	7.47	13.92	4.64	11.50	10.87	7.96
730:00:00	23.64	5.53	7.24	6.76	4.56	13.02
734:00:00	8.31	10.24	11.65	3.53	8.27	6.30
747:00:00	8.67	5.97	7.83	8.59	14.77	9.23
AVERAGE	**14.00**	**10.40**	**11.25**	**7.97**	**11.25**	**12.00**
810:00:00	8.59	9.52	11.16	10.41	9.96	5.25
814:00:00	18.00	10.02	4.79	6.00	9.50	5.13
818:00:00	13.61	5.98	5.65	4.48	10.00	4.69
823:00:00	22.94	13.49	6.37	3.90	5.48	19.09
854:00:00	22.27	12.01	13.41	6.48	9.64	4.49
AVERAGE	**17.08**	**10.21**	**8.28**	**6.26**	**8.92**	**7.73**
1438:00:00	72.02	52.37	61.90	63.99	64.90	
1442:00:00	73.88	62.43	62.76	56.58	56.90	
1456:00:00	77.61	66.30	61.10	63.14	55.21	
1512:00:00	78.55	66.54	64.36	64.82	64.18	
AVERAGE	**75.51**	**61.91**	**62.53**	**62.13**	**60.30**	
1539:00:00	82.30	60.50	63.42	64.09	66.26	
AVERAGE	**82.30**	**60.50**	**63.42**	**64.09**	**66.26**	
1621:00:00	71.82	62.28	59.22	60.32	61.72	
1629:00:00	74.27	63.78	57.00	59.96	63.66	
1633:00:00	73.32	63.73	62.91	54.89	62.17	
1637:00:00	72.54	63.37	62.51	61.02	53.83	
AVERAGE	**72.99**	**63.29**	**60.41**	**59.05**	**60.34**	
1643:00:00	79.97	61.95	63.89	48.30	55.57	
1647:00:00	75.28	64.91	62.75	52.91	58.00	
1652:00:00	71.22	60.12	55.76	38.37	58.23	
1656:00:00	74.52	65.24	53.95	62.45	58.26	
AVERAGE	**75.25**	**63.06**	**59.09**	**50.51**	**57.51**	
1738:00:00	72.76	60.33	32.59	38.73	56.98	
1742:00:00	73.06	25.25	47.99	28.86	91.05	

I-10	WEST					
Time	BUDLONG	WESTERN2	ARLINGTO1	CRENSHAW2	LA BREA 2	HAUSER
AVERAGE	**72.91**	**42.79**	**40.29**	**33.79**	**74.02**	
1849:00:00	45.17	24.62	25.38	21.46	29.95	
1853:00:00	34.01	5.71	17.91	33.82	37.56	
AVERAGE	**39.59**	**15.16**	**21.64**	**27.64**	**33.75**	
1550:00:00	77.61	66.13	65.69	65.75	59.08	
AVERAGE	**77.61**	**66.13**	**65.69**	**65.75**	**59.08**	
1631:00:00	76.07	63.55	60.75	64.52	62.03	
1640:00:00	74.67	64.39	60.02	57.27	64.21	
AVERAGE	**75.37**	**63.97**	**60.38**	**60.90**	**63.12**	

I-10	East			
Time	BUDLONG	WESTERN2	ARLINGTO1	LA BREA 2
701:00:00	51.09	58.90	65.24	62.55
705:00:00	52.94	58.55	62.72	60.99
709:00:00	54.50	54.09	62.29	60.60
AVERAGE	**52.84**	**57.18**	**63.42**	**61.38**
757:00:00	25.72	23.28	27.14	18.74
806:00:00	29.85	26.83	19.85	30.88
AVERAGE	**27.79**	**25.06**	**23.49**	**24.81**
930:00:00	34.44	55.37	63.13	53.81
934:00:00	33.36	60.57	66.17	56.75
950:00:00	49.42	54.44	63.72	62.04
AVERAGE	**39.07**	**56.79**	**64.34**	**57.53**
1543:00:00	43.04	56.60	57.40	38.83
1547:00:00		53.26	52.82	48.15
1612:00:00	56.81	57.85	57.53	43.96
AVERAGE	**49.92**	**55.90**	**55.92**	**43.65**
1641:00:00	41.04	45.71	49.74	47.66
1645:00:00		54.91	49.20	47.31
1658:00:00	31.34	24.57	49.40	43.90
1702:00:00	28.81	22.09	57.79	33.87
1706:00:00	28.16	21.01	56.63	40.19
AVERAGE	**32.34**	**33.66**	**52.55**	**42.59**

I-10	East			
Time	**BUDLONG**	**WESTERN2**	**ARLINGTO1**	**LA BREA 2**
1537:00:00	32.52	55.71	56.56	49.47
1605:00:00	37.76	57.28	54.51	51.96
AVERAGE	**35.14**	**56.50**	**55.53**	**50.72**
1708:00:00	18.98	24.52	52.83	36.49
1709:00:00	28.73	22.37	47.66	38.77
1713:00:00	28.98	16.53	44.34	37.01
1729:00:00	34.18	15.45		32.06
AVERAGE	**27.72**	**19.72**	**48.28**	**36.08**
1821:00:00	23.74	11.72	21.75	46.24
AVERAGE	**23.74**	**11.72**	**21.75**	**46.24**
1538:00:00	31.90	52.57	56.63	48.76
1542:00:00	41.90	57.54	57.81	45.08
AVERAGE	**36.90**	**55.05**	**57.22**	**46.92**
1559:00:00	44.58	53.93	47.21	50.29
AVERAGE	**44.58**	**53.93**	**47.21**	**50.29**
1821:00:00	23.74	11.72	21.75	46.24
1834:00:00	26.76	15.39	27.76	34.08
1842:00:00	36.99	22.73	21.73	32.89
1845:00:00	40.27	33.92	30.93	32.94
AVERAGE	**31.94**	**20.94**	**25.54**	**36.54**

I-5	SOUTH		
Time	**BROADWAY**	**EIGHTH**	**GARFIELD**
1818:00:00	45.34	39.95	19.10
1823:00:00	24.74	34.76	31.29
1846:00:00	61.09	44.28	20.90
AVERAGE	**43.73**	**39.66**	**23.76**
1820:00:00	25.62	36.09	21.38
1825:00:00	27.85	39.69	24.92
1845:00:00	58.36	45.83	9.16
1858:00:00	55.29	45.62	29.35
AVERAGE	**41.78**	**41.81**	**21.20**

I-5	NORTH				
Time	**GARFIELD**	**FERRIS**	**CONCORD**	**PASADENA**	**DORRIS**
1814:00:00	60.56	32.04	8.40	54.10	38.78
1816:00:00	53.82	32.94	4.71	49.26	35.18

APPENDIX A6

Speed Estimation from Detector Data without Speed Information

1. Sample Data with Speed Information.

1-MINUTE MAIN LANE OCCUPANCY AND VOLUME REPORT FROM 09/13/99 AT 1430:00 TO 09/13/99 AT 1500:00 RUN TIME: 14:45

FREEWAY LOCATION: L- 10-E 12.95 (WESTERN 2)

-------------- ADJUSTED ---------------

	MAIN		MAIN		MAIN		MAIN		MAIN				LOCATION		5MIN	15MIN	60MIN	ESTMD
	LANE #1		LANE #2		LANE #3		LANE #4		LANE #5		LANE #6		AVE	TOT	VOLUME	VOLUME	VOLUME	SPEED
TIME	OCC	VOL	OCC	VOL	OCC	VOL	OCC	VOL	OCC	VOL	OCC	VOL	OCC	VOL	TOTALS	TOTALS	TOTALS	(2.38)
1432:00	13.28	31	12.17	29	9.50	23	15.83	27	7.72	14	-1.00	-1	11.70	124				53.94
1433:00	15.00	36	15.00	35	15.11	34	11.33	23	5.56	10	-1.00	-1	12.40	138				56.61
1434:00	13.11	32	13.67	32	11.06	24	15.39	26	11.06	18	-1.00	-1	12.86	132				52.27

$$L = \frac{S \times t_{occ}}{0.6818 \times V}$$

Where:
L = Vehicle length + detector length (ft)
S = Speed (mph)
Occ = Occupancy (%)
t_{occ} = detector occupancy (sec; Occ x 60 x number of lanes)
V = Volume, and
0.6818 = constant to convert from ft/sec to mph

From the example samples:

L_1 = 22.39 (ft)
L_2 = 22.38 (ft), and
L_3 = 22.40 (ft)

2. Speed Estimation from Sample without Speed Information.

1-MINUTE MAIN LANE OCCUPANCY AND VOLUME REPORT FROM 09/23/99 AT 1800:00 TO 09/23/99 AT 1900:00 RUN TIME: 12:08
FREEWAY LOCATION: L- 5-S 19.45 (BROADWAY)
-------------- ADJUSTED ---------------

TIME	MAIN LANE,#1 OCC	VOL	LANE,#2 OCC	VOL	LANE,#3 OCC	VOL	LANE,#4 OCC	VOL	LANE,#5 OCC	VOL	LANE,#6 OCC	VOL	LOCATION AVE OCC	TOT VOL	5MIN VOLUME TOTALS	15MIN VOLUME TOTALS	60MIN VOLUME TOTALS	ESTMD SPEED (2.38)
1801:00	25.44	22	52.28	21	64.78	11	57.17	15	-1.00	-1	-1.00	-1	-1.00	-1	-1.00			
1802:00	21.39	22	41.94	23	41.56	17	39.89	22	-1.00	-1	-1.00	-1	-1.00	-1	-1.00			
1803:00	19.06	24	49.11	19	49.28	17	50.94	14	-1.00	-1	-1.00	-1	-1.00	-1	-1.00			

Occ = (25.44+52.28+64.78+57.17)/ 4 = 49.9175 (%)
t_{Occ} = 0.499175 x 60 (sec) x 4 (lanes) = 119 (sec)

V = 22+21+11+15 = 69 (veh/min)

Assuming L = 22.40 ft, from:

$$S = \frac{0.6818 \times V \times L}{t_{occ}}$$

Then:

S = 8.85 (mph).

APPENDIX B2

Sample MODCOMP Loop Detector Data


```
$JOB  12:02:34  /USR004/MOMLD
$ASS 1 TRM
$ASS 2 TRM
$ASS 3 PRI
$EXEC MLD000,LMT_#__'_,_)_B_01S_x4_
_)_="4MAIN LANE DATA (MLD) DATE REQUEST_='6DATA DATE (MM/DD/YY):  [_(  _)/_(  _)/_(  _)]_=.6ENTER DATA
OR X TO EXIT AND [SEND]__"_&_(__)_'_=" TIME-12:02_="bDATE-
09/22/99_&_(_)_'_&_(_+__)_'_#__'_,_)_B_01S_x4_
_=)9ENTER G-FACTOR [_(_)._(  _)]__"_&_(__)_'_=" TIME-12:02_="bDATE-
09/22/99_&_(_)_'_&__(_)_'_&_(238_&_'_&__'_#__'_,_)_B_01S_x4_
_)_=$ALOCATION_=(:COUNTY:_=(F[_(_)]_=):ROUTE:_=)F[_(   _)]_=*:DIRECTION:  [_(_)]_=+;POSTMILE:  [_(
_)] [_(  _)._(  _)]_=,7OR  X-STREET:  [_(           _)]__"_&_(__)_'_="@REAL-TIME DATA_&_(_)_'_=" TIME-
12:02_="bDATE-09/22/99_&_(_)_'_&_(_+__)_'_#__'_,_)_B_01S_x4_
_=$?TIME RANGE_='/STARTING TIME_=)2HOUR/MINUTE/SECOND: [_(  _):_(  _):_(  _)]_=-/ENDING
TIME_=/2HOUR/MINUTE/SECOND: [_(  _):_(  _):_(  _)]__"_&_(__)_'_="=TIME RANGE REQUESTED_&_(_)_'_=" TIME-
12:02_="bDATE-09/22/99_&_(_)_'_&_(_+__)_'_#__'_,_)_B_01S_x4_
_="1SELECT ONE OPTION FOR MAIN LANE DATA_=$<DATA INTERVAL_=(:1.  30-SECOND_=*:2.   1-MINUTE_=,:3.   5-
MINUTE_=.:4.  15-MINUTE_=0:X.  EXIT_=55ENTER SELECTION [1-4 OR X]: [_(_)]__"_&_(__)_'_=" TIME-
12:03_="bDATE-09/22/99_&_(_)_'_&_(_+__)_'_[=3l_&_(_)_'_#__'_,_)_B_01S_x4_
_="<OUTPUT FORMAT_=&41. 132-COLUMN CRT_=(42. 132-CHAR LINE PRINTER_=*4X. EXIT_=.4ENTER SELECTION (1-2
OR X): [_(_)]__"_&_(__)_'_=" TIME-12:03_="bDATE-09/22/99_&_(_)_'_&_(_+__)_'_=
_*_+_&_(_)_'_C_'_(__y_=+<_)REPORT BEING PROCESSED_&_(_)_'_=.APLEASE WAIT_&_(_`
```

```
CALIFORNIA, DEPARTMENT OF TRANSPORTATION - CALTRANS DISTRICT 7  -  SEMI AUTOMATED TRAFFIC MANAGEMENT SYSTEM (SATMS)    PAGE:  1
RUN DATE: 09/22/99          1-MINUTE  MAIN LANE OCCUPANCY AND VOLUME REPORT FROM  09/21/99 AT 0630:00 TO 09/21/99 AT 1000:00
RUN TIME: 12:03                    FREEWAY LOCATION:  L-110-S      14.29    (IMPERIAL2 )
--------------  ADJUSTED  ---------------                 MAIN        MAIN        MAIN        MAIN        MAIN        MAIN
LOCATION        5MIN  15MIN  60MIN   ESTMD                LANE #1     LANE #2     LANE #3     LANE #4     LANE #5     LANE #6      AVE
TOT     VOLUME VOLUME VOLUME   SPEED TIME        OCC  VOL     OCC  VOL     OCC  VOL     OCC  VOL     OCC  VOL     OCC  VOL     OCC   VOL
TOTALS TOTALS TOTALS   (2.38)  0631:00    8.78   24   7.17   20   7.06   16   7.61   15   9.89   16  5.17   12  7.61   103
57.36 0632:00  10.72   28   7.28   20   9.50   22  10.72   22  12.17   23   4.33   12   9.12   127
59.01 0633:00  11.44   16   9.11   13   9.78   11  12.44   15  10.78   11   8.33    9  10.31A  150A
61.60 0634:00   9.06   25  11.22   31  10.11   24  13.22   27  17.39   26  10.00  223  11.83   156
55.89 0635:00  10.17   29  10.11   28   8.50   21   6.22   16   5.67   10   4.50   10   7.53   114        639A
64.13 0636:00   9.67   12   9.56   13   8.00    8   7.78   11   6.78    7   4.44    4   7.70A  110A
60.50 0637:00  10.50   28   7.17   19   6.50   15  10.67   25  11.89   20   3.78    9   8.42   116
58.41 0638:00  13.89   38  10.61   29  12.06   22   6.22   15  15.22   23   5.56   13  10.59   140
56.03 0639:00   *** NO DATA *** 0640:00  12.11   34  12.94   35   9.50   22   6.89   17  11.89   19   5.94   15   9.88   142
647A                60.89 0641:00  14.44   41  12.44   33  11.72   27   8.61   20  15.11   18   4.72   11  11.18   150
56.89 0642:00  11.83   34  11.39   30  11.50   27  14.56   33  15.33   26   7.67   18  12.05   168
59.10 0643:00  15.56   38  14.33   38  11.39   23  12.83   30  11.28   24   6.28   17  11.94   170
60.30 0644:00  10.78   29  14.56   33   9.89   16  13.44   29   9.28   18   4.78   13  10.45   138
55.97 0645:00  13.56   36  11.67   33  10.89   23  10.67   26   6.61   13   2.28    6   9.28   137        763   2049A
62.54 0646:00  18.56   25  15.00   19  11.89   14  13.44   16  13.11   12   4.33    5  12.72A  182A
60.61 0647:00  13.83   39  14.78   37  10.06   25  10.00   25  12.17   24   6.00   12  11.14   162
61.61 0648:00  13.72   37  11.61   32  10.50   25   9.78   22  14.67   25   7.11   16  11.23   157
59.23 0649:00  12.33   34  11.22   31  12.17   23  10.61   25  10.28   18   4.11   10  10.12   141
59.04 0650:00  13.50   38  11.61   32   8.00   20  11.44   27  10.22   17   6.56   16  10.22   150        779A
62.16 0651:00  10.17   31  12.17   32   8.78   25  11.00   28  10.17   18   4.00    9   9.38   143
64.56 0652:00  11.06   31  12.89   37   9.33   19   8.83   23   9.39   18   6.28   16   9.63   144
63.33 0653:00  10.89   15   8.78   12  10.78    9  12.44   14  16.89   16   8.44   10  11.37A  152A
56.67 0654:00  15.22   40  12.89   38  11.67   27  11.22   24  12.22   21   6.50   16  11.62   166
60.52 0655:00  13.56   37  12.50   36   9.56   22  12.00   27   8.61   14   7.33   17  10.59   153        758A
61.19 0656:00  12.67   17  12.44   17  10.78   13   8.44   11  13.44   12   6.78    7  10.76A  154A
60.64 0657:00  12.11   35  12.33   35  10.33   24   9.72   24  13.06   21   3.89   10  10.24   149
61.63 0658:00   8.72   28  10.67   30  10.89   21   8.28   20  10.28   20   4.56   11   8.90   130
61.89 0659:00   9.89   26   8.94   24   8.67   22   9.56   23  10.67   17   6.11   15   8.97   127
59.97 0700:00  10.72   32   8.39   21   7.39   19  10.28   26   9.83   19   4.78   12   8.56   129        680A  2217A
63.78 0701:00  11.22   32  10.50   26  14.61   24  10.56   21  10.39   20   4.28   10  10.26   133
54.97 0702:00   9.11   25   8.33   22   8.94   18   5.61   15  13.56   22   4.39   11   8.32   113
57.54 0703:00  12.56   18   9.78   14  11.56   13  15.22   15  16.11   15   5.78    6  11.83A  162A
58.02 0704:00  13.06   33   9.00   24  10.22   22  10.39   25  11.61   21   9.61   18  10.65   143
56.93 0705:00  11.78   31  11.67   29  10.39   26   9.67   20  11.78   20   4.56   11   9.97   137        674A
58.22 0706:00  10.94   29   8.33   24  10.50   25   7.67   20  13.94   23   7.72   17   9.85   138
59.36 0707:00  11.11   15  10.11   15  12.44   12   8.6   10  18.67   15   6.44    7  11.22A  148A
55.91 0708:00   7.33   21   8.89   24   6.89   16   8.61   23  11.06   18   3.06    7   7.64   109
60.45 0709:00  12.17   36   9.61   27   7.17   18   5.00   14  10.72   18   5.83   10   8.42   123
61.90 0710:00  11.56   16  11.67   17  10.78   12   8.11   11   9.67    9   2.89    3   9.11A  136A        640A
63.22 0711:00  10.67   28   9.28   23   7.39   19  12.72   29  11.33   22   3.56    8   9.16   129
59.69 0712:00  11.17   33  10.50   27   6.00   14   6.89   18  10.00   16   3.94    9   8.08   117
61.32 0713:00   *** NO DATA *** 0714:00  12.44   16  10.00   13   2.78    4   7.00    8   8.22    7   4.56    5   7.50A  106A
59.88 0715:00  15.56   17  18.11   18  12.56   14  19.67   18  21.67   16   7.44    7  15.83A  180A        648A  1963A
48.27
```

```
                                                                    * = SUSPECT/MALFUNCTION DATA
A = ADJUSTED DATA / -1 = NO DATA                                                                                  ALL VALUES ARE
SUSPECT UNTIL VERIFIED BY ENGINEER

_a_)_'_C_'_(__y
$WEOF 3 _`
_a
$TAG STOP
$END  momld
$
momld NO PROCEDURE
$
$ass jc ajc $
momld
```