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ABSTRACT

The objectives of the study described in this report were to evaluate the effectiveness of the freeway service patrols on a 7.8 mile section of I-10 freeway (Beat 8) in Los Angeles. An evaluation methodology was developed to estimate incident delays based on field data from loop detectors and probe vehicles, and derive estimates of savings in performance measures in the absence of data for before FSP conditions. Field data were collected to develop a comprehensive database which completely describes the traffic conditions along Beat 8 for 32 weekdays, for a total of six hours each day. This 192-hour database includes detailed descriptions for 1,560 incidents, tach vehicle travel time traces for 3,619 runs (at 5.7 minute headways), and data from 240 loop detectors. Additional data include the electronic CHP/CAD logs and FSP logs for the entire study period.

The estimated benefit/cost ratios based on delay and fuel savings for a range of typical reductions in incident durations, indicate that FSP produces significant benefits at the test site. For reduction in duration due to FSP in the order of 15 minutes, the B/C ratio is greater than 5: 1. Additional benefits include reductions in air pollutant emissions, secondary accidents, CHP time used on non-enforcement activities, as well as increased safety to assisted motorists, and more efficient operation of the freeway system.

Keywords:
Freeways, Freeway Service Patrol, Evaluation Techniques, Incident Management, Traffic Delay, Traffic Flow

EXECUTIVE SUMMARY

Objectives and Methodology

Freeway Service Patrol (FSP) is an incident management measure designed to assist disabled vehicles along congested freeway segments and relieve peak period non-recurrent congestion through quick detection, verification and removal of freeway incidents. The program is jointly administered by the California Department of Transportation (Caltrans), the California Highway Patrol (CHP) and the local Metropolitan Planning Organizations (MPOs), and has been implemented on many freeway sites (beats) across the state. This report presents the findings of a comprehensive evaluation of the FSP program on a specific freeway section in Los Angeles.

The Los Angeles County Metro FSP is a partnership program jointly implemented by Caltrans, the Los Angeles County Metropolitan Transportation Authority (MTA), CHP and 20 private towing contractors. As of 1997, the Los Angeles program was comprised of 149 tow trucks patrolling 43 beats covering more than 400 freeway centerline miles in Los Angeles County Historically there have been approximately 1,000 assists per day performed by FSP tow truck operators. The continuously patrolling tow trucks provide complimentary services such as: changing a flat tire, refilling a radiator, providing one gallon of gasoline, and removing stalled vehicles from the freeway when they cannot be restarted.

A test site was selected for the FSP evaluation based on geometric characteristics, number of in-lane FSP assists, average daily traffic, congestion levels, and the density of functional loop detectors using both historical data and new data collected by the study team. The site selected was FSP Beat 8, which is located on Interstate Route 10, between Eastern Avenue and Santa Anita Avenue.

Field data on average travel speeds and incident characteristics were collected using seven specially instrumented probe vehicles traveling at an average of 5.7 minute headways, six hours per day, for 32 days. In addition freeway loop detector data was collected for the same time periods. Subsequent to data collection, a detailed, comprehensive, computerized database was developed. This database completely describes the trafIic conditions along Beat 8 for the 32 weekdays. The database includes detailed descriptions of 1,560 observed incidents, probe vehicle travel time traces for 3,619 runs, and 192 hours of loop detector data (30-second flow and occupancy) from 240 loop detectors.

Findings

An average of 41 incidents/day were observed during the peak periods were observed in the study area (excluding CHP-related events). The estimated incident rate was about 93 incidents per million vehicle miles of travel, and there were about 0.4 incidents per freeway mile per hour. Accidents accounted for 6.5 % of all the incidents and approximately 10 % of all incidents were blocking travel lanes. The average duration of all incidents was 20 minutes. Incident type, severity and the type of assistance provided were the major factors affecting incident durations. Assisted incidents lasted 24 minutes on the average, and non-assisted incidents 14 minutes.

FSP assisted 1,035 incidents during the field study (1.44 assists/truck&-), mostly vehicles with mechanical or electrical problems, flat tires and those that had run out of gas. About 21 percent of the assists were for accidents. The average response time of FSP tow trucks was 10.8 minutes. Analysis of the CHP/CAD data and field observations of incidents by other agencies indicate that the incident response times (and durations) without FSP are longer by about 7 to 20 minutes on average.

The estimation of incident specific delay, fuel consumption and emissions for assessing the FSP effectiveness was based on the difference in average travel speeds under normal and incident conditions using probe vehicle speeds and volume data from the loop detectors. Next, the average delay savings per incident were determined by modeling each incident with different duration values. The estimated reduction in average incident delay and fuel savings for a range of typical reductions in incident durations indicate that FSP produces significant benefits. The estimated benefit/cost ratio indicates that the FSP is cost effective. For reduction in duration due to FSP in the order of 15 minutes, the benefit/cost ratio is greater than 5:1 In addition, daily reductions in air pollutant emissions include a total of 60 Kg of hydrocarbons, 472 Kg of carbon monoxide and 122 kg of oxides of nitrogen.

Additional benefits of FSP that were not included in the calculation of the benefit/cost ratio include time and direct cost savings for the assisted motorists. Also, the FSP service results in fewer incidents attended, and reduction in the time spent on vehicle breakdowns by CHP officers, and serves as an incident detection and verification mechanism. Motorist feedback from surveys indicate that the FSP service receives excellent ratings. Furthermore, the presence of FSP provides a sense of security on the freeway, and the quicker removal of incidents could reduce secondary accidents.

Recommendations

The results of this study confirm that FSP is a successful, cost-effective operational program. Efforts should be directed to optimally deploying the FSP service on existing or new freeway beats. This requires developing a simple yet robust evaluation procedure to estimate the benefits along an existing or proposed beat based on data commonly available to partner agencies. Also, it is important to deploy the optimal number of required FSP trucks to obtain the maximum net benefit from the service

A number of issues related to the operation and impacts of FSP need further investigation. There is a need to quantify the safety benefits of the FSP service because of the reduction of secondary accidents. Also, the utilization of FSP as a mobile data source for incidents and freeway operating conditions is an important area of future study.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background

Incidents are accidents, vehicle breakdowns, spilled loads or any other random events that reduce the capacity of the road and cause congestion if the traffic demand exceeds the reduced capacity at the incident location.. The most often cited FHWA study (Lindley 1986) reports that incidents account for 61 percent of all the congestion delay in the US, and it is estimated that by the year 2005, over 70 percent of the total delay in urban areas would be incident related causing excess travel costs of $35 billion. The California Department of Transportation (Caltrans) also estimates that 50 percent of motorist delays on freeways are incident related (Hicomp 1992.) Furthermore, incidents may cause accidents because of the stop-and-go traffic conditions and the hazards of vehicles and pedestrians stalled in the roadway.

In response to the growing adverse impacts of incidents on travel conditions, incident management programs have been initiated in several metropolitan areas, with the cities of Chicago and Los Angeles having the most comprehensive programs. The goal of such programs is to restore the freeway to full capacity after the incident occurs and to provide information to motorists until the incident is cleared. Incident management programs require the cooperative and coordinated actions of several operating agencies and include freeway surveillance systems, incident response teams, law enforcement officers, motorist assistance patrols and other means to detect, respond to and clear incidents (Roper, 1990). Any reduction in detection, response, and clearance time reduces the total incident duration, which in turn reduces the congestion delay. Also, information to motorists is provided via changeable message signs (CMS), Highway Advisory radio (HAR) and other means to alert drivers, suggest alternate routes or direct traffic in case of total closures.

Incident response teams and freeway service (or motorist assistance) patrols (FSP) are one approach of facilitating the quick removal of incidents through fast response and clearance times. FSP consist of teams of tow truck drivers who continually patrol certain freeway segments ("beats") during commute hours, and provide assistance to disabled vehicles. They are able to handle a large number of minor incidents (stalls, flat tires, out of gas, and minor accidents) that constitute the largest portion of all freeway incidents. FSP serve also as a detection and verification mechanism for major incidents by providing information to transportation management centers. Benefits of FSP include reduction in incident related delay, fuel consumption and emissions. They also benefit law enforcement agencies by reducing the amount of time officers spend on non-enforcement activities.

Freeway service patrols have been operating on tunnels and bridges and other facilities without shoulders where traffic flow obstructions have a large effect on the quality of flow. Starting with the Chicago's "Minutemen program" in 1961 (McDermott 1975, 1991) FSPs have operated in several metropolitan areas on isolated freeway segments ranging from 6 to 10 miles to entire freeway systems (Morris 1994.) Most of the freeway service patrols involve tow trucks equipped to handle minor vehicle repairs. Communication with the dispatch/operation center is provided through two-way radio and/or cellular phones. The FSP in the San Francisco Bay Area and Los

Angeles are equipped with automatic vehicle location (AVL) systems and mobile data terminals Wm.

In California, the FSP program is jointly administered by Caltrans, the California Highway Patrol (CHP) and local transportation planning agencies (e.g., the Metropolitan Transportation Commission Service Authority for Freeways and Expressways (MTC SAFE) in the San Francisco Bay Area and the Metropolitan Transportation Authority (MTA) in Los Angeles County.) The service is provided by private tow truck companies selected through the competitive bid process, under contract to the local transportation planning agencies. Sources of funding include state funds approved by the legislature that require local contributions, federal ISTEA funds Transportation Management Plan (TMP) funds on reconstruction projects, funds from the Congestion Mitigation and Air Quality Programs (CMAQ), and other local funds. Criteria for finding allocations have been based on population, urban freeway lane miles, and vehicle hours of congestion delay.

FSP drivers provide in-the-field assistance to disabled vehicles free of charge (e.g., jump start of cars, provide a gallon of gas, refill radiators and change flat tires or other minor repairs). If the FSP driver cannot get the vehicle running in about 10 minutes, then the vehicle is towed to a designated drop location off the freeway. FSP drivers may be also dispatched to assist in clearing of vehicles involved in collisions and removing debris from the roadway. FSP drivers do not have peace officer powers. They explain the program to the assisted motorists and request that motorists complete a motorist assist form. All assists and responses are recorded in a daily log. Responses to motorist surveys, questionnaires and assist forms indicate that over 93 percent of the motorists rate the service as excellent and a worthwhile expenditure of public funds.

A study conducted by the University of California at Berkeley, sponsored by Caltrans through the PATH Program evaluated the effectiveness of FSP on a section of the I-880 freeway, Bay Area Beat 3 (Skabardonis et al, 1995). Extensive data on incidents and traffic characteristics were collected “before” and “after” the implementation of FSP, using specially instrumented probe vehicles and information from loop detectors in the roadway. The data were processed, verified and integrated into a computerized database. This database is perhaps the largest database on freeway operations created to date. A methodology was developed to estimate the incident-specific delays. The evaluation of the benefits based on delay savings, fuel consumption and air pollution reduction indicated that the FSP is a cost-effective measure at the specific test site.

The results of the I-880 study on the FSP effectiveness would apply to locations with similar characteristics as the specific beat which was studied. There is a need, however, to have performance estimates from other beats in the state to permit a thorough evaluation of the FSP program in California, and to develop a method for Statewide evaluation of FSP based on data commonly available to Caltrans operations staff.

1.2 The Los Angeles FSP Program

The Los Angeles County Metro FSP is a partnership program jointly implemented by Caltrans, LAMTA and CHP. As of April 1, 1996, the Los Angeles program was comprised of 149 tow trucks from 20 towing contractors patrolling 40 beats covering 404 centerline miles of freeway in Los Angeles County with an annual budget of approximately $24 million

The Los Angeles FSP program essentially began in 1978, when Caltrans began operating a service patrol for the 42-mile Downtown freeway loop (formed by the Santa Monica, San Diego and Harbor Freeways) as a component of the Los Angeles Area Freeway Surveillance and Control Project (LAAFSCP). In November of 1990, Los Angeles County voters approved Proposition C, a half-cent sales tax for transportation improvements, now administered by the LAMTA. Revenues from Proposition C are used for a variety of transportation programs, including incident management programs such as FSP. The Los Angeles FSP service was initiated in July, 1991. In 1992, Assembly Bill 3346 (Katz) authorized funding for the initiation of FSP statewide.

The Los Angeles FSP beat locations is shown in Figure 1.1. The number of FSP assists per month from 199 1 through 1996 are shown in Table 1.1. In 1995 there were a total of 257,463 responses on the 43 Los Angeles beats (21,455 assists per month, or about 1,000 assists/day). The average beat length is 9.8 centerline miles, with an average of 3.6 trucks per beat. The average number of service hours per beat is 7.8, and the average cost per hour per beat is $146.25 ($40.63 per truck/hour).

As an example of some typical statistics, FSP tow truck logs from the second quarter of 1995 used below to present characteristics of the FSP service. This data is recorded on ***Scantron*** forms filled out by each FSP driver after each assist. The majority of FSP assists involved mechanical problems (24%), followed by flat tires (20%), and out of gas (12%). Approximately 24% of the vehicles were towed off the freeway. About 85% of the assisted incidents were located by the FSP driver, and 13% were identified by the CHP dispatcher. Most disabled vehicles were located on the right shoulder (78%) at the time the FSP arrived, while 10% were located in the freeway lane. Most drivers (72%) reported that they waited less than five minutes, and 18% of drivers reported that they have waited between six and ten minutes. Only 10% of drivers reported that they waited more than 11 minutes for FSP service.

A detailed analysis of the Los Angeles County Metro FSP was conducted in 1992 (Finnegan, 1992). Caltrans also evaluated the FSP service in 1992 and found that the program reduced incident response times by 15 minutes (Caltrans, 1992). The program's effectiveness was then calculated based on total delay savings, using historical data and assumptions on incident characteristics, demand levels and capacity reduction. The present study is an effort to build upon past evaluation efforts based on empirical data and a minimum of assumptions.

FIGURE 1.1 LOS ANGELES FSP BEAT MAP

TABLE 1.1 LOS ANGELES FSP SUMMARY OF ASSISTS

Month	1991	1992	1993	1994	1995	1996
January		13163	17295	19383	18789	21498
February		13488	19387	18476	17933	25154
March		16294	28009	22327	22693	24888
April		13849	25586	20676	18537	28050
May		14469	24045	21543	21714	
June		16433	27066	23271	26239	
July	4872	17929	22547	19367	24988	
August	10231	16841	23873	24633	27156	
September	12651	16729	23077	21693	22425	
October	14477	15733	22276	20080	22175	
November	12882	15216	22517	18413	19398	
December	11020	14888	17551	15982	15416	
TOTAL	66133	185032	273229	245844	257463	99590

1.3 Objectives of the Study

The objective of this study is to evaluate the benefits and costs of the Freeway Service Patrol (FSP) at a specific freeway section in Los Angeles.

- Develop a comprehensive database on freeway incidents and operational characteristics
- Develop an improved evaluation methodology
- Evaluate the effectiveness of FSP at the selected freeway section

This study was conducted by the Institute of Transportation Studies (ITS) UC Berkeley as part of the Partners for Advanced Transit and Highways (PATH) program (MOU-172 and MOU-264). Wiltec Associates served as a subcontractor for field data collection. The work consisted of the following major tasks:

- **Development of Evaluation Methodology:** Develop an evaluation methodology to account for the lack of data "before" the FSP service. Because all of the potential freeway sites in Los Angeles currently have FSP service, the service cannot be temporarily suspended for collecting "before" data due to liability concerns. Also, a freeway beat with temporarily suspended FSP service is not exactly the same as a beat without service, because in the former case stranded drivers would expect the FSP to assist them and may not immediately call for other service. Also, procedures were developed to calculate incident delay from probe vehicle travel speeds.

- **Test Site Selection:** Select a test site for the field experiment. A rigorous test site selection process has been undertaken, which has included site ranking, site visits, travel time runs and detailed analysis of loop detector data.

- **Develop Database:** Field data collection to develop a comprehensive database on incidents and freeway operating conditions at the selected test site. This database will be fully computerized and integrated similar to the I-880 database

- **Analysis and Evaluation:** Data analysis and evaluation of the effectiveness of the FSP service at the test site. Analysis of the field collected data and data from other sources, incident modeling, calculation of performance measures, and the benefit/cost ratio.

1.4 Organization of the Report

This is the final report for the study and describes in detail the work performed and presents the project findings. Chapter 2 describes the research approach, including the design of the experiment and the procedures of estimating the selected measures of effectiveness. The study area and the procedures for data collection and processing are described in Chapter 3. Chapter 4 presents the findings from the analysis of the field data. Chapter 5 presents the evaluation of the FSP at the selected test site, and Chapter 6 summarizes the study findings along with suggestions for future research.

Appendix A documents the site selection process. Appendix B describes in detail the study methodology. Sample data from probe vehicles and incident reports are included in Appendix C. Appendix D documents the Los Angeles FSP Program costs as provided by MTA.

CHAPTER 2

METHODOLOGY

The effectiveness of FSP as an incident management tools depends on several factors including incident frequency and characteristics, freeway operational characteristics and FSP implementation. The FSP benefits would be significant on freeway segments with narrow (or no) shoulders operating near or at capacity, and with a high number of vehicle disablements. FSP effectiveness would be limited on a site with few major accidents and other incidents that require police investigation and specialized equipment to be cleared, and on uncongested freeways with wide shoulders. Also, the benefits of FSP depend on the number of tow trucks involved, hours of operation, and dispatching strategy.

Several approaches have been used to evaluate the effectiveness of FSP. Most of the approaches todate use historical data on incident characteristics and use analytical techniques or simulation models to determine the impacts of FSP based on certain assumptions on freeway demand and capacity. The I-880 FSP evaluation was the first major study that placed major emphasis in field measurements to measure all the variables that are likely to affect incident impacts on traffic operations and quantitatively evaluate the effectiveness of FSP through a "before" and "after" study.

The evaluation methodology adopted in this study is based on the same approach as the I-880 evaluation. Incident data are collected on a Los Angeles FSP beat supplemented by detailed information on operational characteristics (volumes, travel times). Models were then developed to calculate the measures of effectiveness based on the field data and to estimate the benefits from the FSP service. The important differences in the methodology adopted in this study, compared to the I-880 evaluation, are a) the development of procedures for estimating delay based on probe vehicle speeds, and b) development of models to account for the lack of data "before" FSP service at the test site. Detailed description of the study methodology is included in Appendix B.

2.1 Design of the Experiment

The design of the experiment for the FSP evaluation in this study consisted of the following steps:

Selection of the test site(s) for the field experiment
Selection of the measures of effectiveness
Development of a test plan for data collection/analysis

2.1.1 Selection of the Test Site

The selection of the test site(s) for the field experiment was based on the following criteria:

- ***Functional surveillance system:*** closely spaced loop detectors in place that provide accurate data on traffic volumes. Speeds and occupancy data are also needed, but their accuracy is limited by the existing surveillance system in Caltrans District 7.

- *Geometries:* Narrow (or no) shoulders; mixed lanes if possible (no HOV lanes)
- *Incident frequency:* high number of accidents and other incidents
- *Congestion levels:* traffic volumes close to (or at) capacity during the peak periods. Avoid congested freeway segments because of bottlenecks outside the study area.
- *Avoidance of reconstruction activities:* to differentiate the reduction in capacity and delays due to work zones and incidents, and avoid construction caused incidents.

Ten FSP beats in the Los Angeles County with existing or proposed FSP service were proposed to the ITS research team by Caltrans District 7, CHP and MTA for evaluating the effectiveness of FSP. A rigorous test site selection process was undertaken which included site visits, analysis of historical data on accidents and congestion patterns, sample travel time nms, video recording and analysis of sample loop detector data. Beat 8, a 12.5 km (7.8 miles) section along the I-10 freeway located in the cities of El Monte and Alhambra was selected as the test site. The test site characteristics are described in Chapter 3. Detailed documentation on the test site selection is included in Appendix A.

2.1.2 Measures of Effectiveness (MOEs)

Several performance measures have been proposed and applied to evaluate the FSP service in other studies. These include incident delay, average freeway travel speeds, freeway throughput, fuel consumption, air pollutant emissions, incident response and clearance times, number of secondary accidents, and public perception (Finnegan, 1992, Morris, 1994.) The effectiveness of the FSP is determined by translating the benefits in the MOEs into monetary values, and calculating the benefit/cost ratio.

The primary measure of effectiveness selected in this study for the FSP evaluation is savings in delay. Other MOEs include savings in fuel consumption and air pollutant emissions, and benefits to the freeway systems operators (improved incident detection, response and clearance times.)

2.1.3 Test Plan

A detailed test plan was developed for the collection and processing of the field data. The field data on incidents and traffic flow characteristics were collected for a period of about one month. The duration of the data collection period was selected to provide a sufficient sample for analyzing incident patterns at the test site, within the time and budget constraints of the project.

The times of the data collection were the morning (6:30-9:30) and afternoon (3:30-6:30) peak periods, to correspond with the times of the day that the FSP is operating on the test site. FSP operates from 6:00-10:00 AM and 3:00 to 7:00 PM on weekdays. The process of study design, preparation for fieldwork, and data collection and processing is described in detail in Chapter 3.

2.2 Estimation of Measures of Effectiveness

2.2.1 Estimation of Incident Delay

The estimation of incident delay was based on the procedure developed in the I-880 study, with only one important difference. Since the loop detectors in the Los Angeles area are single trap loop detectors it is not possible to accurately measure vehicle speeds. Therefore, the delay calculations'would have to be based on volumes from loop detectors and probe vehicle speeds. Therefore, the first step is to determine if (and how) it is possible to obtain accurate delay estimates from those data sources.

The incident delay is calculated as the difference in travel times on a freeway segment under normal and incident conditions (Figure 2.1). The freeway section upstream of the incident location is divided into k segments of approximate equal length *Lk*. The speeds and volumes on each segment are assumed to be constant and equal to the values provided by the loops within the segment. The delay for each time slice ***i*** and each segment *k* upstream of the incident is:

$$D_{ki} = L_k \frac{\Delta T}{60} Q_{ki} \left(\frac{1}{V_{ki}} - \frac{1}{V_{kif}} \right) \qquad for \quad 0 < V_{ki} < V_{kif} \tag{2-1}$$

$$D_{ki} = Q_{ki} \left(\frac{\Delta T}{60} \right)^2 \qquad for \; V_{ki} = 0 \tag{2-2}$$

where:

D_{ki} : incident delay on segment *k* during time-slice ***i*** (veh-hr)
Q_{ki} : traffic volume on segment *k* during time slice ***i*** (veh/h)
T : length of the time slice (min)
L_k : length of the freeway segment (miles)
V_{ki} :average travel speed on segment *k* during time-slice ***i*** (mph)
V_{kif}: average travel speed under prevailing incident free traffic conditions (mph)

The total incident delay then is:

$$D = \sum_{k=1}^{n} \sum_{i=1}^{m} D_{ki} \tag{2-3}$$

where ***n*** is the number of the freeway segments upstream affected by the incident (i.e., the end of the queue because of the incident,) and ***m*** is the number of congested time slices (i.e., the incident duration plus the time it takes for the queue to clear.) These n and m values represent the spatial and temporal effects of the incident and are determined from the density plots based on loop detector data. The application of the method in this study is described in detail in Chapter 5 (Evaluation.)

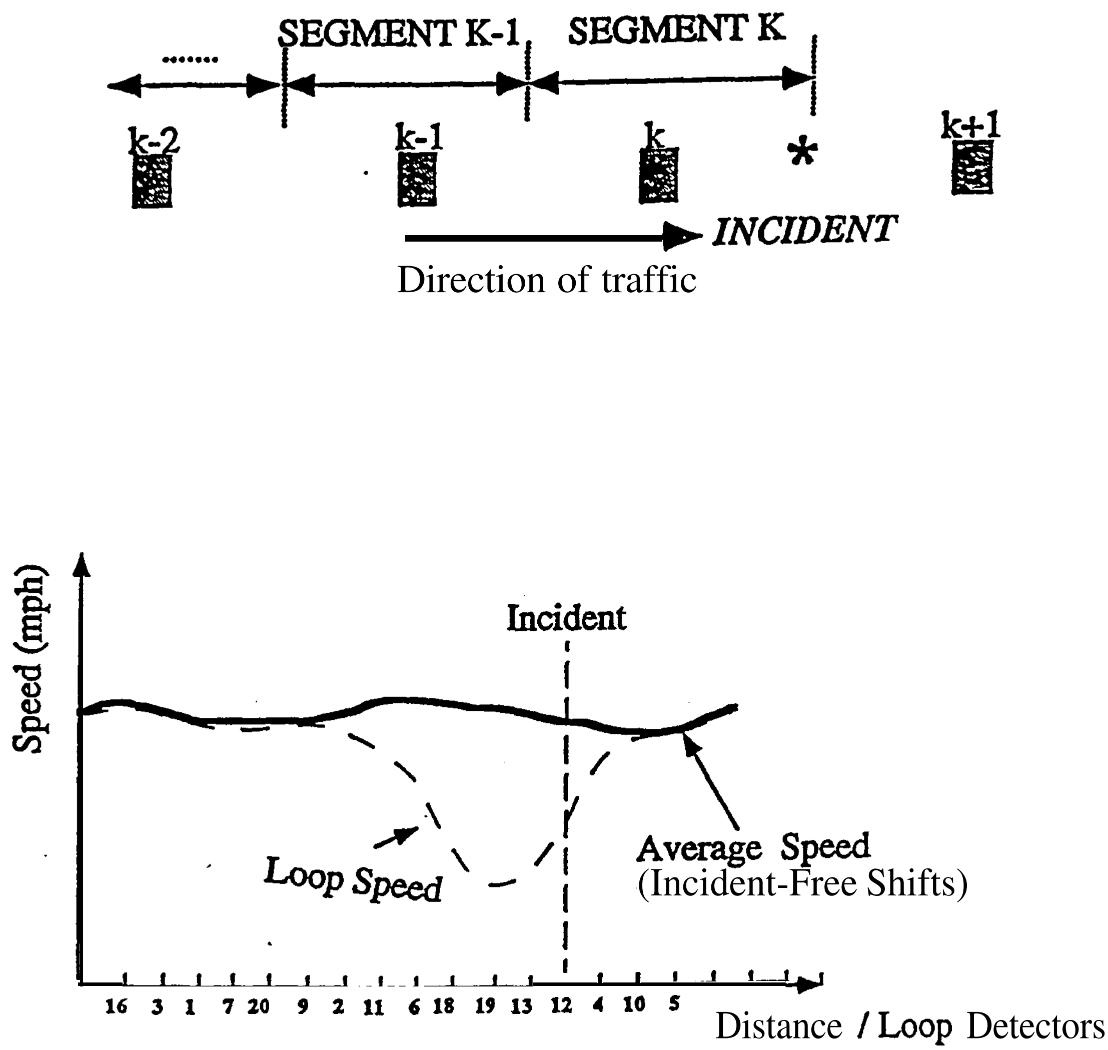


Figure 2.1 Estimation of Incident Delay

This procedure requires accurate data on speeds and flows from closely spaced loop detectors. If there is no reliable speed data from the loop detectors (single trap loops), then the average speeds can be obtained from the speed-distance (time) profiles of instrumented probe vehicles. In this case, to calculate this delay we substitute in the probe vehicle speeds $V_{kiprobe}$ instead of the loop speeds V_{ki} in Equation (2-1).

The accuracy of the delay estimated from probe vehicle speeds depends on the density of probe vehicles in the traffic stream; anything that perturbs the uniform density of the probe vehicles will also perturb the uniform sampling of the speed surface. Hence, whenever there is an incident and the probe vehicle is stuck in the queue the picture of the density of the freeway is warped. This is in contrast to the loop based speeds which are oblivious to traffic queues. Figure 2.2 shows the error between the double loop trap based speed surface (which is assumed to be the best), the single loop based speed surface, and the speed surfaces generated from probe vehicles. Note that for four probe vehicles the density of probes in the traffic stream is approximately 0.13%, and the average speed is the same as from single loops. Therefore, to have accurate probe vehicle speeds the number of probe vehicles should be higher (seven probe vehicles were used in the study).

The delay calculation in Equation (2-1) requires a speed value for every loop detector and for every output period (usually every 30 seconds). Thus *we have to interpolate* between the times when the probe vehicles cross a loop detector. The process is illustrated in Figure 2.3. The left side of Figure 2.3 is the plot of probe vehicle trajectories. The dotted lines mark out the "regions of attraction" for each loop and time period. The dot in the middle of the region represents the average of all the speed points inside the region. In this example, no probe vehicle trajectory fell in the time period-loop detector pair of *(J-1, J)*, so we interpolate from the known speed values to obtain the speed in this region. This is indicated by the empty circle at the grid coordinates *(J-1, J)* on the right side of Figure 2.3. If the probe vehicles are far apart, the estimate would be inaccurate (as indicated on the plot by the true speed line).

Figure 2.4 shows that the using probe vehicle speeds and the loop detector flows to calculate the density of traffic, and hence delay, is quite accurate. The top of the Figure is a contour plot of the density of vehicles on the freeway based on loop detector data. The plot on the bottom was calculated with the probe vehicle speeds and the loop detector flows. Hence we feel that with a high enough density of probe vehicles, the two measures of delay will be equivalent. The table below shows incident delay calculations using the I-880 database. The results indicate that the two methods produced similar results for a range of incident types.

All incidents	Loop based delay	Probe based delay	% difference
Accidents	46.81	42.67	8.8%
Breakdowns	12.01	10.78	10.2%
Assisted incidents			
Accidents	70.87	64.79	8.6%
Breakdowns	12.85	11.59	9.8%
Non-Assisted incidents			
Accidents	22.75	20.55	9.7%
Breakdowns	11.26	10.04	10.8%

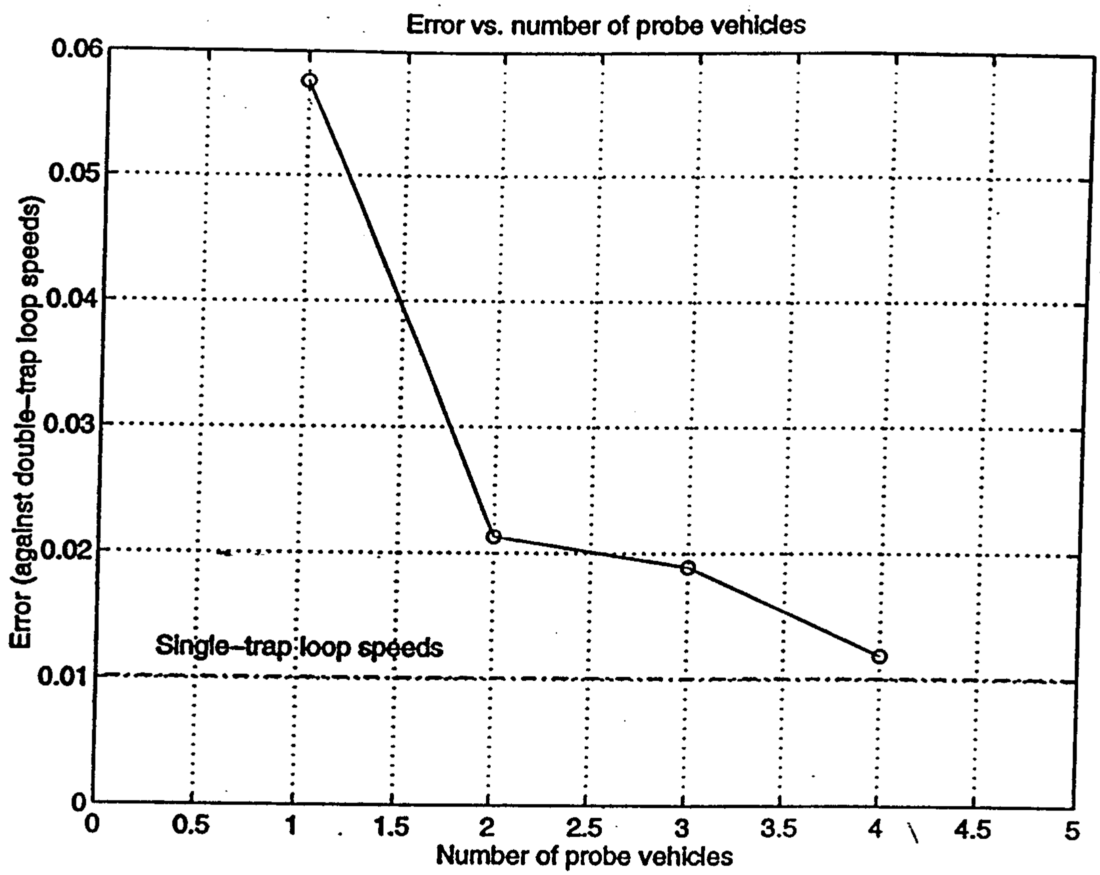


Figure 2.2 Speed Error vs. Number of Probe Vehicles

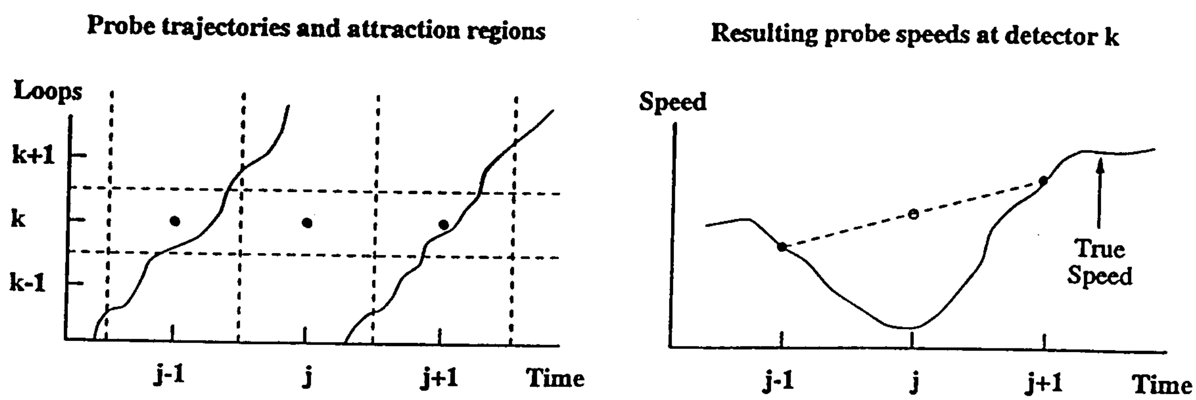


Figure 2.3 Interpolation of Probe Vehicle Speeds

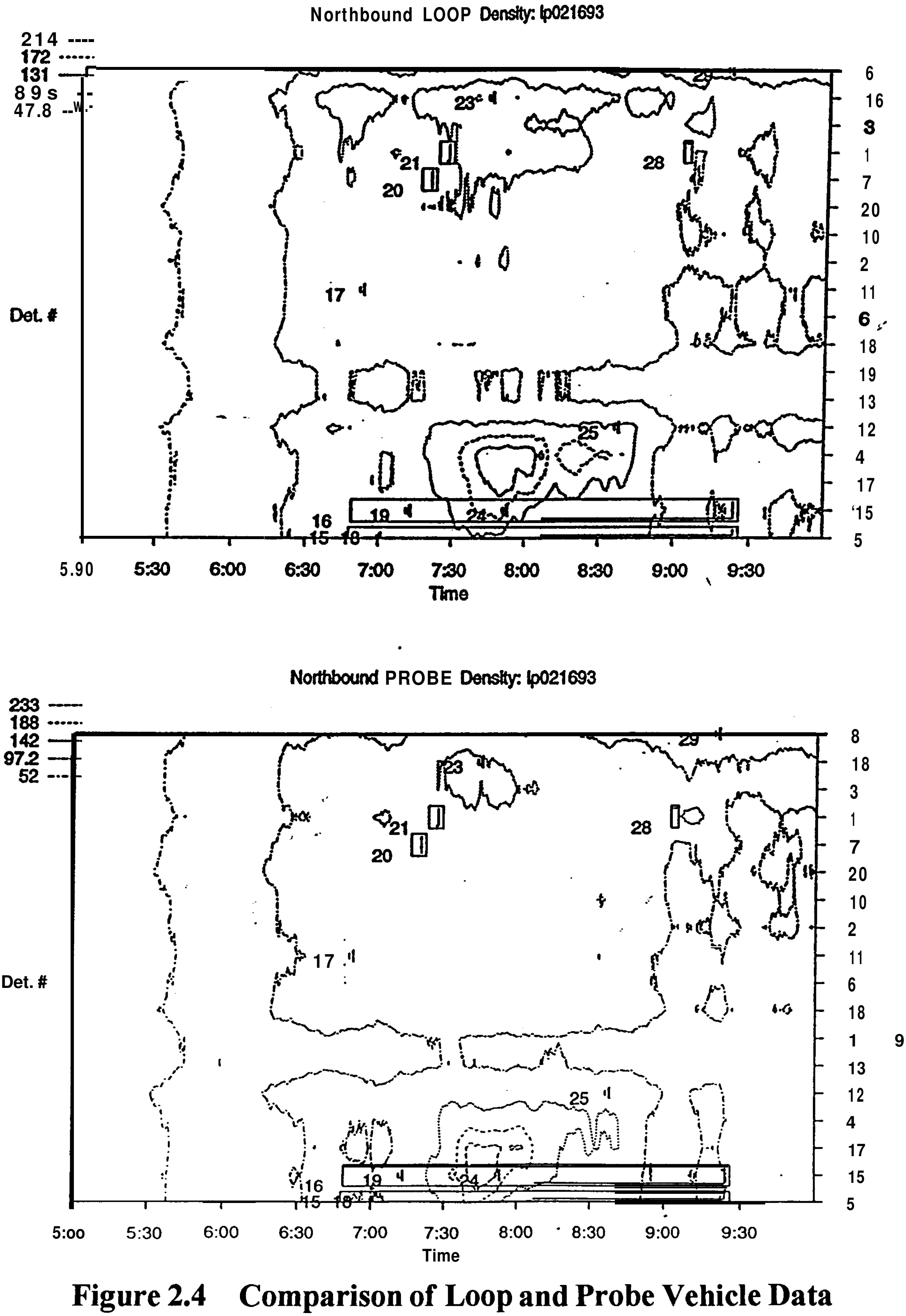


Figure 2.4 Comparison of Loop and Probe Vehicle Data Density Contours

2.2.2 Estimation of Fuel Consumption and Emissions

The amount of fuel consumption on each freeway segment affected by an incident was calculated based on a method derived by Lindley (Lindley 1988):

$$F_{LT} = L\frac{\Delta T}{60}Q_{LT}\ (\ 0.00657/1000\ +\ 0.20319/1000V_{LT}) \qquad (2\text{-}5)$$

where:
F_{LT}: fuel consumption on freeway section of length L during time period T (gal)

The amount of carbon monoxide CO, hydrocarbons HC and oxides of nitrogen NO_X air pollutant emissions from motor vehicles is calculated as follows:

$$E_{LTn} = L\frac{T}{60}Q_{LT}\ e_{VLTn} \qquad (2\text{-}6)$$

where:
n: air pollutant (1 :HC, 2:CO, 3:NO_x)
E_n: amount of emissions on the section L during time T for pollutant n (grams)
e_{VLTn} emission factor for average speed V_{LT} for pollutant n (grams/mile)

The emission factors used were based on the EMFAC7 factors developed by the California Air Resources Board (ARB) for California conditions.

The calculation of fuel and emissions consider the average speeds of vehicles and not explicitly the time spent in each driving mode (cruising, acceleration, deceleration and idling.) The amount of fuel consumption and emissions would be higher than the values estimated based on the above shown relationships especially for congested freeway segments with significant portion of the time spent under stop-and-go traffic conditions.

2.3 Modeling the Effects of FSP

The FSP tow trucks reduce the duration of incidents and incident related delay because of their faster response times. However, in this study, we do not have field measurements on incidents and traffic conditions "before" FSP to directly measure the savings in delay (and other MOEs) due to FSP. Therefore, we have to develop a model to estimate the FSP impacts based on the field data available at the site with FSP in operation.

2.3.1 Incident Delay Modeling

We model each incident by a standard queuing diagram (Figure 2.5). The queuing diagram originally discussed in the freeway operations context by Moskowitz (Moskowitz 1963), has been extended to consider various situations under incident conditions (Urbanek and Rodgers 1978) and it has been applied in numerous studies. Figure 2.5a shows cumulative vehicle arrivals and departures during an incident versus time. The line represented by V is the cumulative number of vehicles that want to pass down the freeway. The slope of this line V is the traffic demand on the freeway. When the incident occurs, the freeway capacity is reduced to C_I for the duration of the incident, t. Once the incident has cleared, after t minutes, the built-up queue will discharge at the capacity of the freeway, C, until the queue is dissipated. The delay (in veh-hrs) caused by this incident is the shaded area in Figure 2.5a:

$$D = t^2 \frac{(V - Ci)(C - Ci)}{2(C - V)} \qquad (2\text{-}4)$$

We can get demand V, capacity C and duration t from the field measurements. We calculate the delay from the measured loop volumes and probe vehicle speeds as described in Section 2.2.1. Since we know all of the other terms in Equation (2-4), we can simply solve for ***Ci*** the capacity reduction for each particular incident (a function of the incident characteristics and the freeway section under study).

We next use the queuing diagram with the known ***Ci*** value to calculate the delay assuming different values of duration for the particular incident. The difference between the delay with the observed duration and the delay with the new duration represents the incident delay savings (Figure 2.5b) We carried out the calculations for a range of incident durations per incident (expressed as an increase over the measured durations with the FSP service).

In reality, the value of ***Ci*** is not a constant, but changes throughout the incident duration (a vehicle initially blocks one lane, the vehicle is moved to the side of the road, the tow truck and a CHP officer show up, the vehicle is towed away, the CHP officer leaves). Every one of these possible stages would have a different effect, in terms of capacity reduction, on the traffic stream. Also, we measure incident durations with the probe vehicles, i.e., we are only sampling the start and end times by the probe headway (5 to 7 minutes) and we are always under estimating the incident duration.

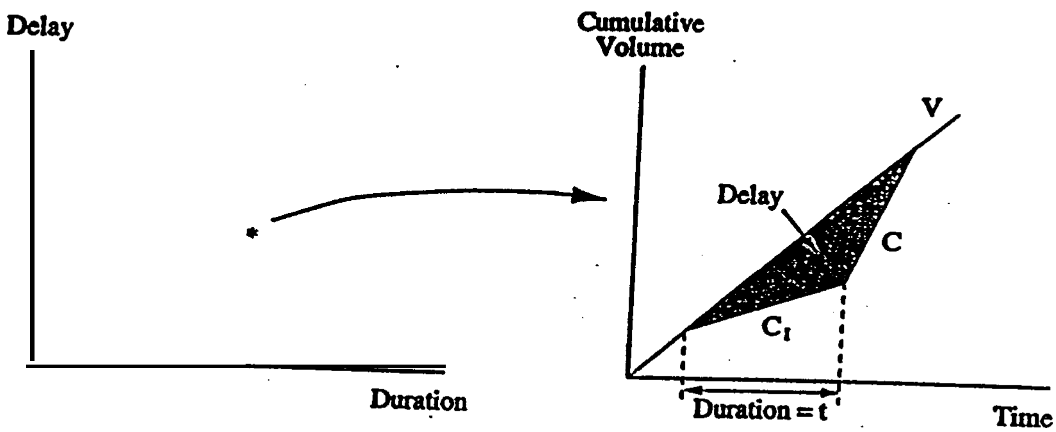


Figure 2.5a Modeling a Single Incident

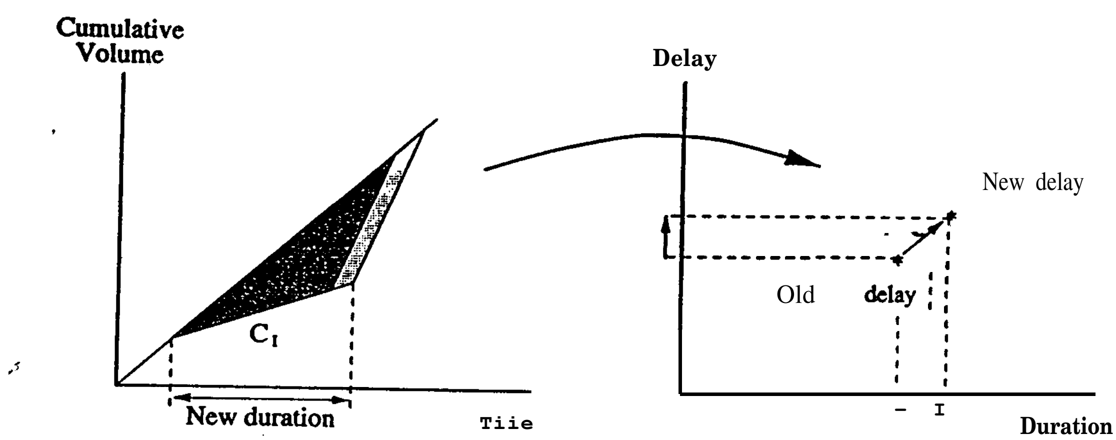


Figure 2.5b Estimating Delay for Different Durations

2.3.2 Incident Durations Before FSP

The incident durations before the FSP service could be obtained from historical data at the site, such as the CHP/CAD logs, rotational tow truck logs and other data. The average reduction in duration could then be obtained from the field data with FSP and the historical data. We may however, need to account for the "oversampling" of short duration incidents by the FSP tow trucks. The oversampling phenomenon and procedures to account for it are described below.

In the I-880 freeway section, the duration of assisted breakdowns was cut by 16.5 minutes from 37.6 "before" to 21.1 minutes "after" the implementation of FSP. As expected, the duration of non-assisted incidents remained unchanged (22.6 minutes.) However, the fraction of assisted incidents increased from 18% "before" to 41.2% "after". This implies that the FSP tow trucks helped several events that otherwise wouldn't have needed help (e.g., people stopping to check maps). These short duration assists reduce the average duration of the assisted breakdowns "afler". This phenomenon can be viewed as an oversampling of the short duration assists by the FSP.

Figure 2.6 shows Venn diagrams of the breakdowns "before" and "after". The assumption is that FSP not only assisted all of the incidents that would normally have needed assistance, but they also assisted a significant fraction of the incidents that would not normally need assistance. Hence, in the "after" Venn diagram, the assisted breakdown pool has grown to include some of the normally non-assisted incidents. This is also shown in the density plots on the bottom of Figure 2.6. Non-assisted breakdowns by nature have a shorter duration than the assisted breakdowns, hence their densities are concentrated at a lower duration than the assisted breakdowns as shown in the "before" density plots. But in the after study the distributions are almost identical, which indicates that the distribution of assisted breakdowns is incorrect. Therefore, we need to subtract the incidents that would not normally need assistance from the pool of assisted breakdowns to account for the oversampling bias that is being introduced by the nature of the FSP service.

First we determine the amount that the short incidents were oversampled by examining the fraction of assisted incidents for each duration. On the left side of Figure 2.7 is a plot of the fraction of assisted breakdowns per duration "before" and "after". The fraction of assisted breakdowns "after" is higher for shorter duration incidents. The difference between these two curves can be viewed as the fraction of incidents that are oversampled by the FSP (referred to as the oversampling density). Multiplying the oversampling density by the density of the non-assisted breakdowns we can obtain the density of non-assisted breakdowns that were oversampled. This process is shown in Figure 2.8. The upper left plot is the density of the non-assisted breakdowns, the middle plot is the oversampling density and the plot on the lower left is the product of the two. This is the over-sampled non-assisted breakdown density. This is what is added to the "true" assisted breakdown density to get what we have observed. So to account for the oversampling bias, we simply need to subtract off the density given in the lower left-hand plot of Figure 2.8.

Next, we determine the amount of reduction in duration due to the oversampling. We assume that the fraction of incidents in need of assistance is constant, i.e., it is unlikely that FSP would cause an increase in the breakdowns that would require assistance. Hence we should subtract the over-sampled non-assisted breakdown density until the fraction of FSP assisted breakdowns is the same as the fraction of assists without FSP (Figure 2.9). The resulting density distribution will be the correct distribution of assisted breakdowns. Therefore the true effect of FSP on the assisted breakdowns would be the difference between the average of this new distribution and the average of the assisted breakdowns "before" FSP.

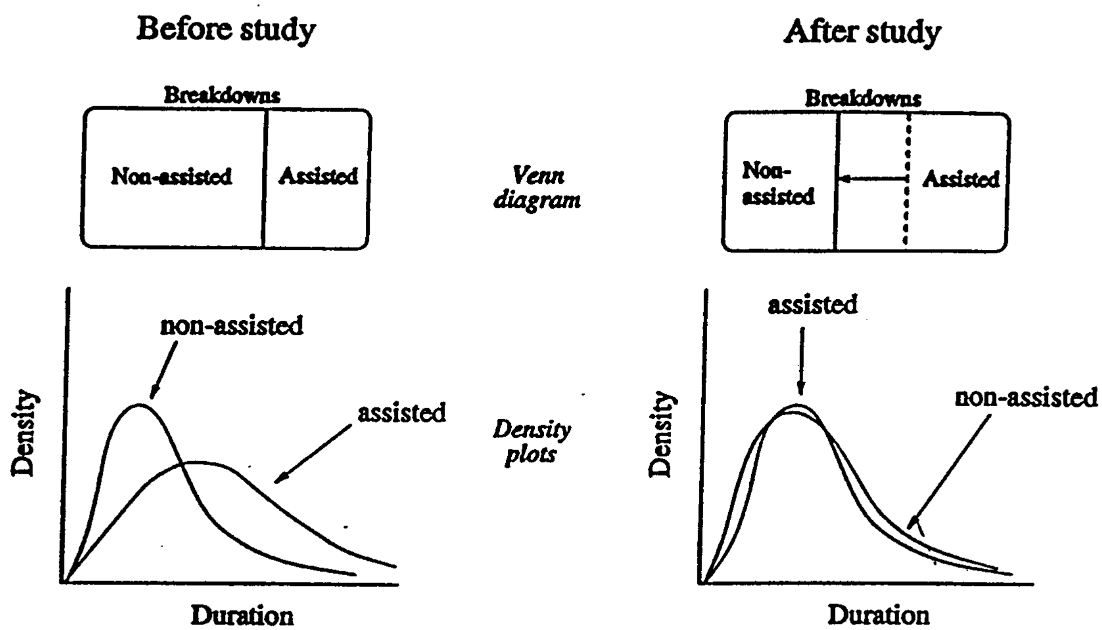


Figure 2.6 Density Distributions--Assisted Incidents

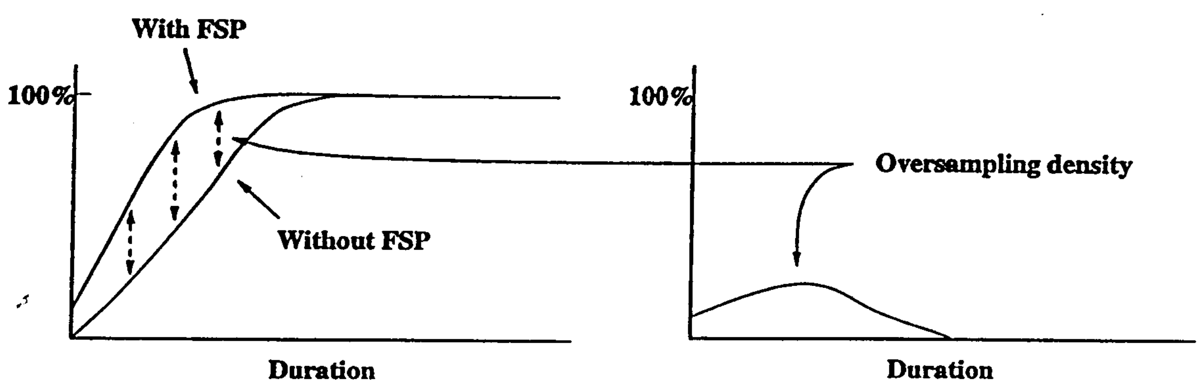


Figure 2.7 Fraction of Assisted Incidents/Density of Oversampling

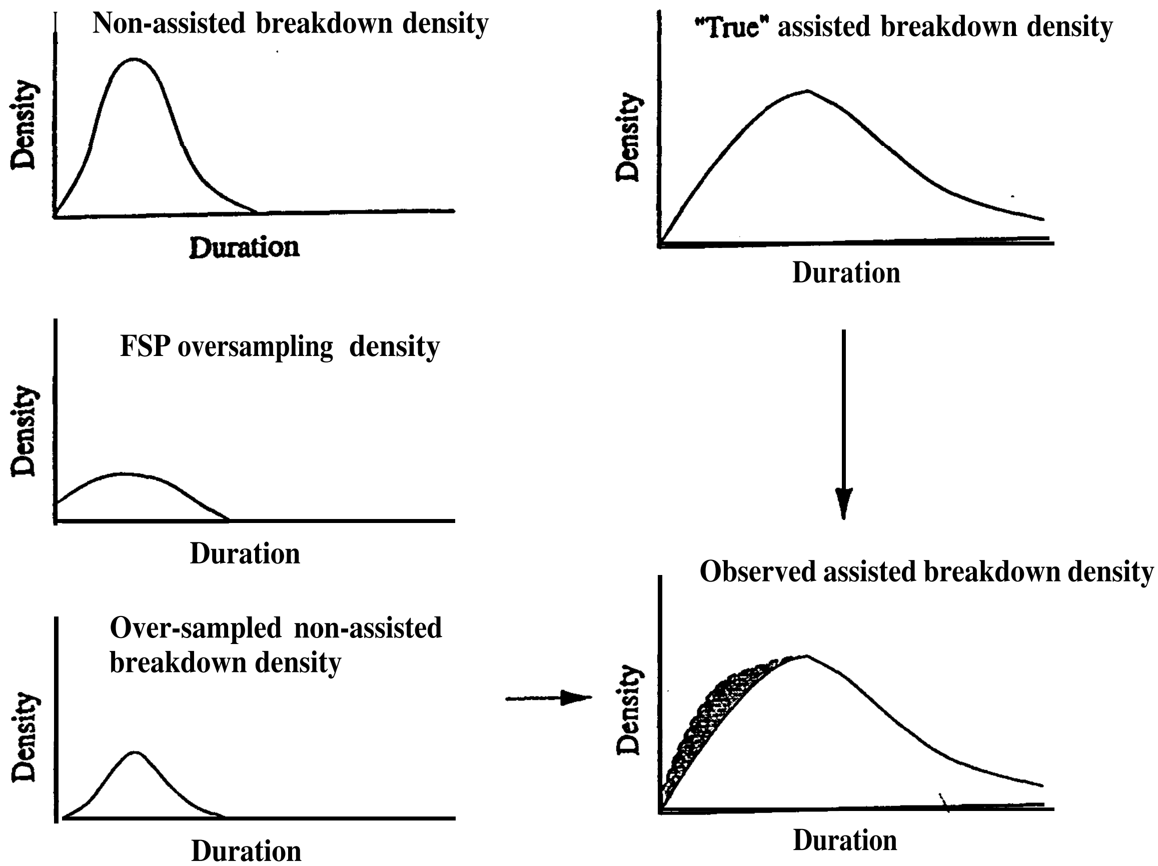


Figure 2.8 The Process of Oversampling

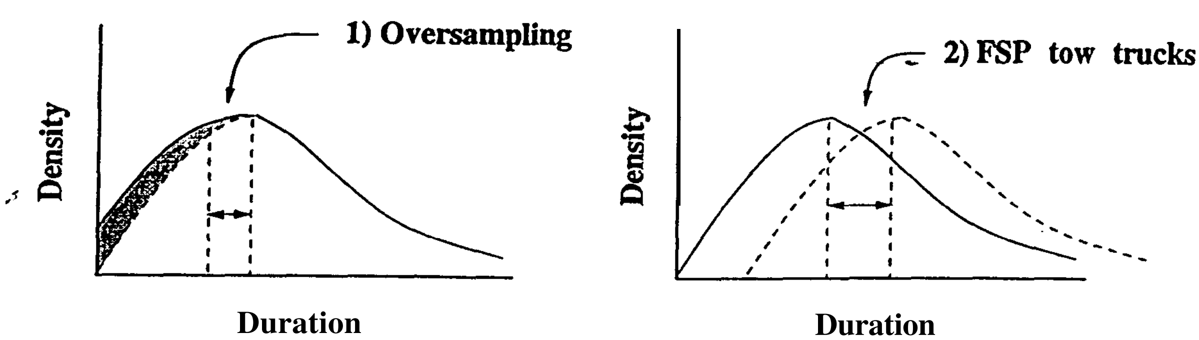


Figure 2.9 Effect of FSP on Assisted Breakdowns

CHAPTER 3

DATA COLLECTION AND PROCESSING

This chapter describes the data collection procedures, and summarizes the methods used for incorporating the various data into one comprehensive, computerized database. The data were collected over a five-week period, in order to develop a database consisting of a minimum 25 days. The data collection effort began on June 24, 1996 and continued through August 9, 1996. This provided 32 weekdays of data. On each day, data were collected between 6:30 and 9:30 a.m. and between 3:30 and 6:30 p.m. Figure 3.1 shows an overview of the data collection and processing effort. Incident report data from the 32 analysis days (64 shifts between June 26 and August 9, not including the days surrounding the July 4th holiday weekend) have also been analyzed.

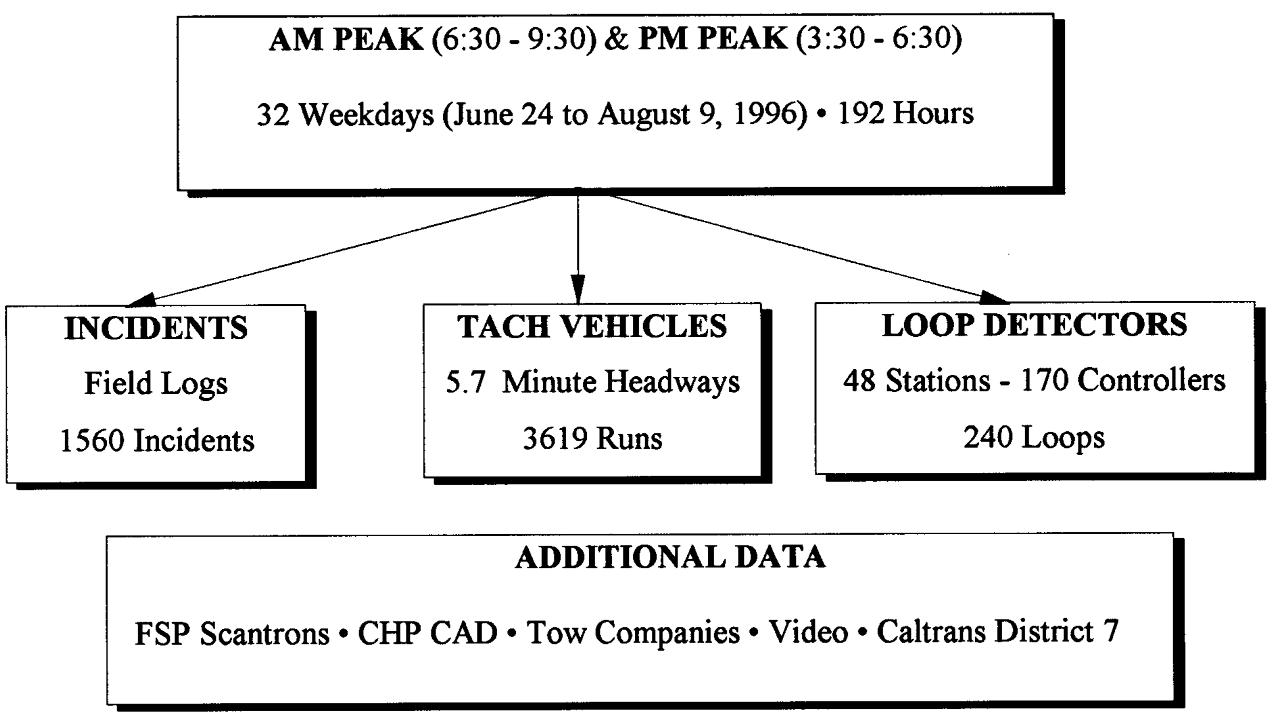


Figure 3.1 Data Collection Overview

3.1 Test Site Characteristics

The selected test site (FSP Beat 8) is a 12.5 km (7.8mile) segment of I-10, the San Bernardino Freeway, between Eastern Avenue and Santa Anita Avenue, in the cities of El Monte and Alhambra, in Los Angeles County. A schematic of the geometries on this beat are shown in Figure 3.2. The study section has four travel lanes per direction, and an HOV lane separated from the mixed-lanes by a continuous striped "divide" (Figure 3.3).

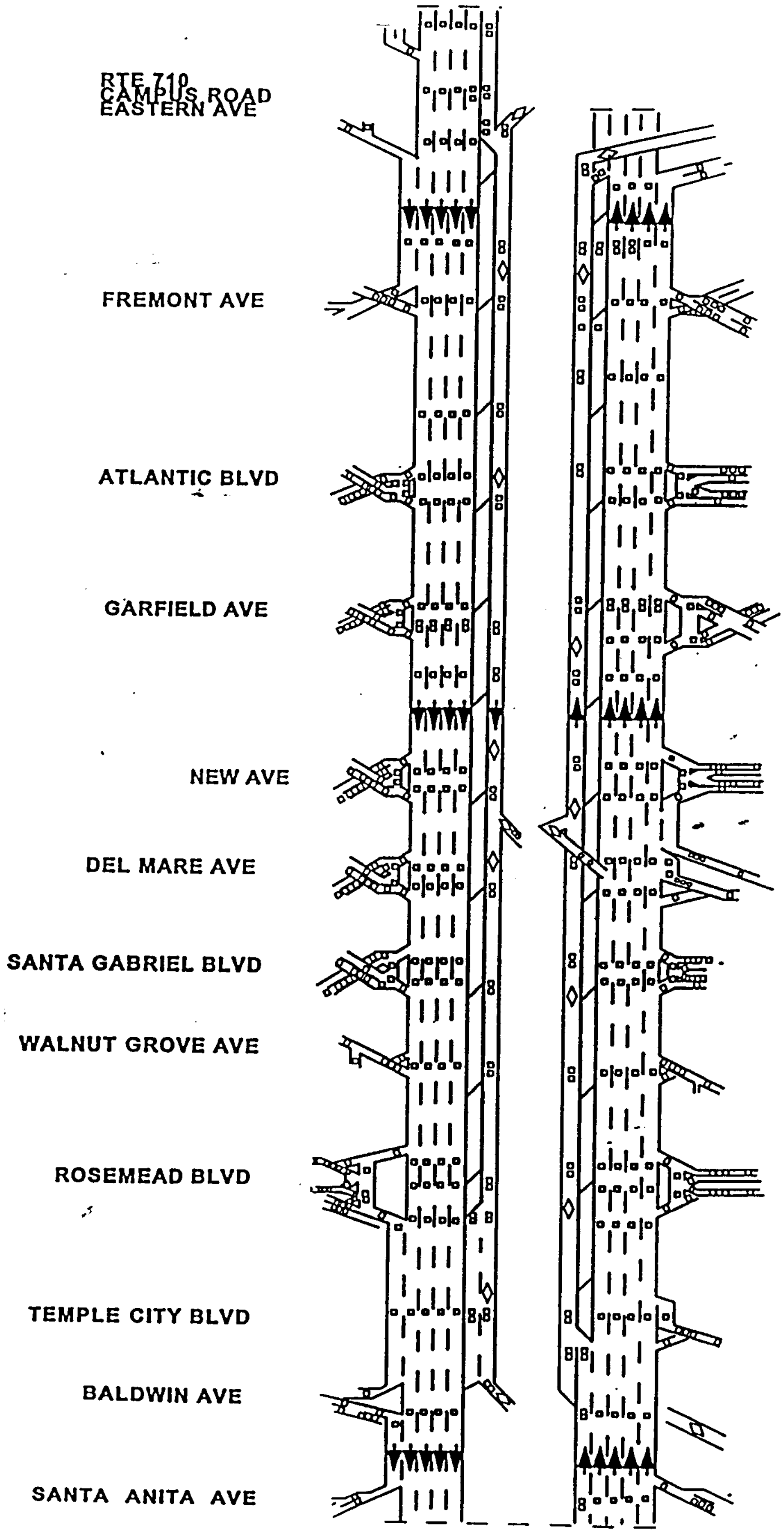
The AADT on Beat 8 is 249,000 vpd. There are 49 loop detector stations equipped with Type 170 controllers, with a total of 203 single loop detectors, of which approximately 179 (88%) are working. This translates into one active loop station every 0.57 km (0.34 mile). The controllers collect flow and occupancy data every 30 seconds, and then feed these data via telephone lines to the Modcomp computer at the Caltrans District 7 TMC.). The data are used to provide real time information on traffic conditions disseminated via local cable television and over the Internet WWW (http://www.scubed.com/caltrans/transnet.html/).

Accident data for Beat 8 were retrieved from the Caltrans Traffic Accident Surveillance and Analysis Selective (TASAS) Record Retrieval system and analyzed over a ten-year period (Figure 3.4). The number of property damage only (PDO) accidents has steadily increased over the last ten years (from 450 to 850 per year), while the number of injury accidents has decreased (from 350 to 250 per year). Accident analysis also shows that approximately 50% of the accidents occur during the 8 peak hours of the day. To the extent that the numbers of property damage only (PDO) accidents have steadily increased, it may be the case that PDO reporting has improved with the introduction of the FSP service

3.2 Preparation for Data Collection

The procedures developed for the I-880 study have served as the basic guide for the field data collection and analysis. However, it was recognized early that procedures used in the I-880 study would not be directly transferable to the Los Angeles study. Therefore, Caltrans District 4 provided a tach vehicle, laptop computer, and data collection hardware and software. ITS and Wiltec staff performed trial runs on I-80 in Berkeley to confirm that the software and hardware configurations would be appropriate for the Los Angeles study. The software and hardware arrangements appeared to be satisfactory and provided the team with sample data for analysis and practice.

Seven vehicles were used for the floating car runs, with one additional vehicle serving as back-up. The test cars (1995 Ford Escorts) were selected based on experience and suggestions of the Caltrans Transportation Laboratory to maximize the use of existing resources and minimize the possibility of equipment failures. The test vehicles were rented and subsequently instrumented with commercially available speedometer transducers. Caltrans provided custom-made wiring harnesses which were fed from the transducer, through the vehicle firewall, and into the glove compartment. These harnesses include a serial connection for a laptop computer and a 12 volt power supply connection. Various Caltrans district offices provided laptop computers for use during the data collection effort.



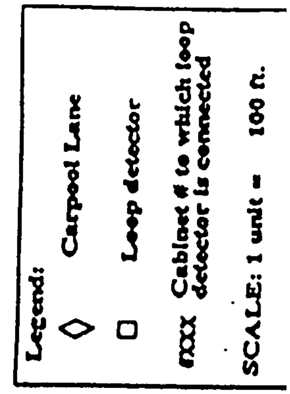
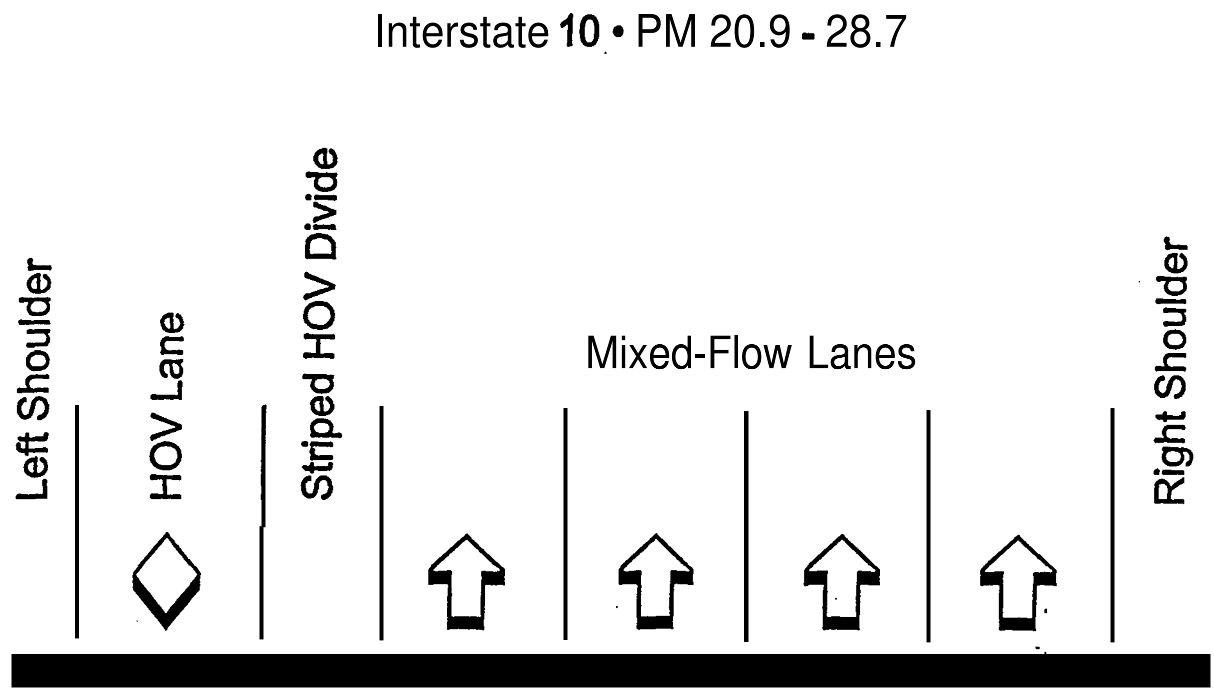


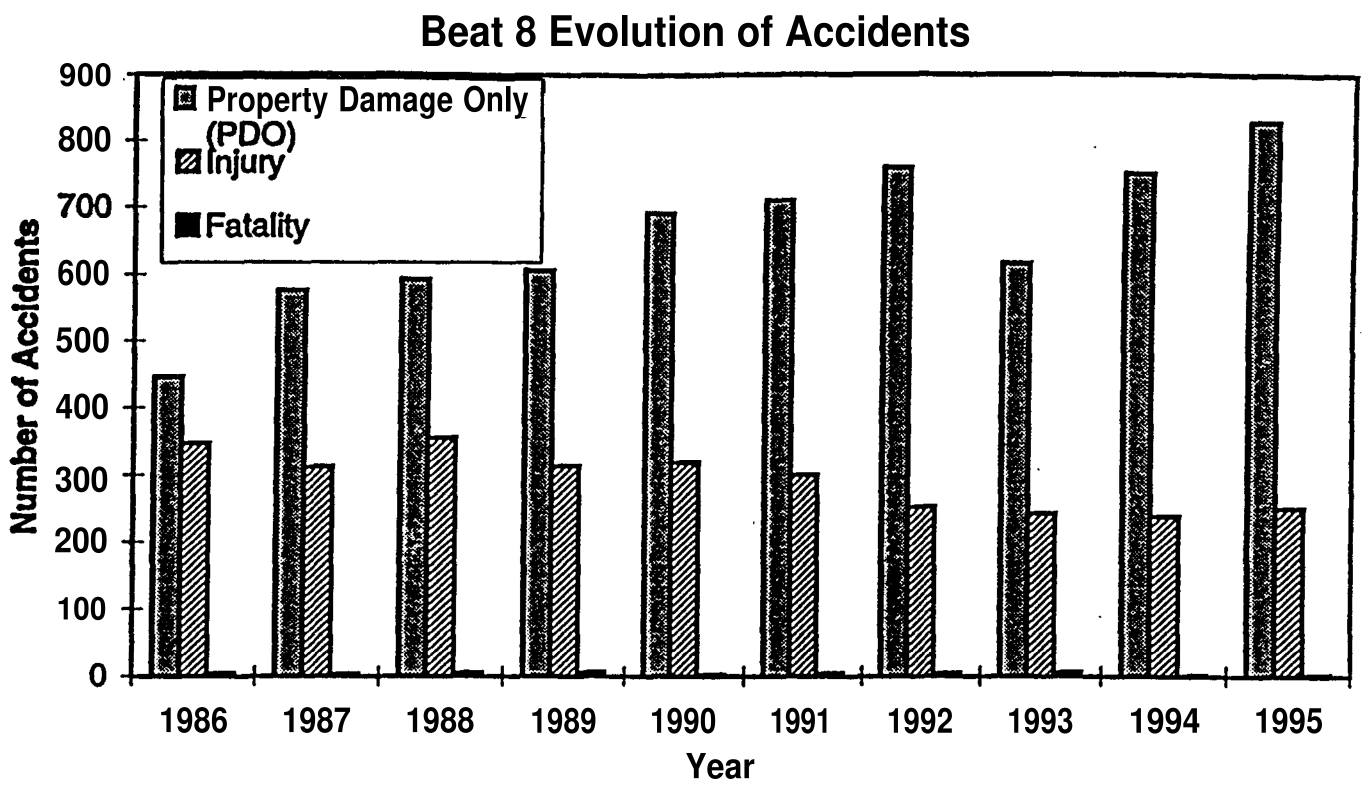
Figure 3.2 Los Angeles FSP Beat 8--I-10

Figure 3.3 Selected Test Site--Freeway Cross Section



Subsequent to renting the vehicles and properly instrumenting them, several test runs were performed to calibrate the in-vehicle equipment, and to verify that accurate and reliable data are provided. Next, training was conducted to familiarize the probe vehicle drivers with test driving procedures and incident reporting. The training of drivers was performed by U.C. Berkeley researchers and Wiltec managers in cooperation with the CHP and Caltrans staff.

A one-week pilot study was undertaken, including complete data collection and processing. Sample floating car data from the pilot study has been processed and the few problems found were quickly corrected. Sample loop data were also checked to verify that the loop detectors provide accurate data.



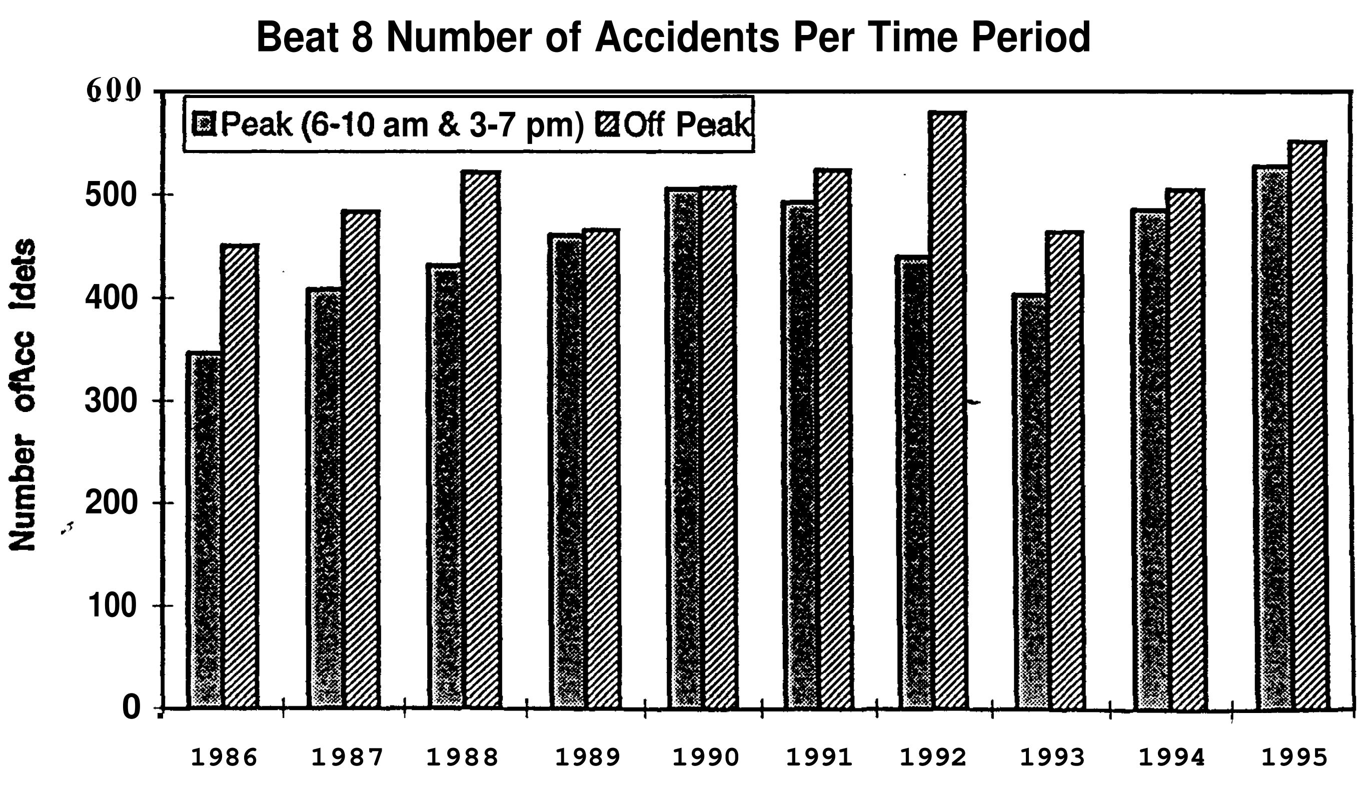


Figure 3.4 Accidents Beat *8 (Source: TASAS)*

3.3 Probe Vehicle Data

Probe vehicles recorded detailed incident data as well as speed traces. A Caltrans data collection program called "Congest" was used in the laptops. Information on probe vehicle trajectories is automatically gathered through the in-vehicle instrumentation.

Figure 3.5 shows the distributions and statistics for the arrival and departure headways of the probe vehicles. The headways were estimated by measuring the difference between the arrival and departure times of two adjacent vehicles. It is noted that there was some variability in the clocks on the computers in each probe vehicle. This contributes to the variability that is displayed on the figure. The mean headway was 5.7 minutes and the standard deviation was approximately 3.7 minutes. Some of the longer headways were due to one probe vehicle breakdown and severe congestion on some days during the data collection period.

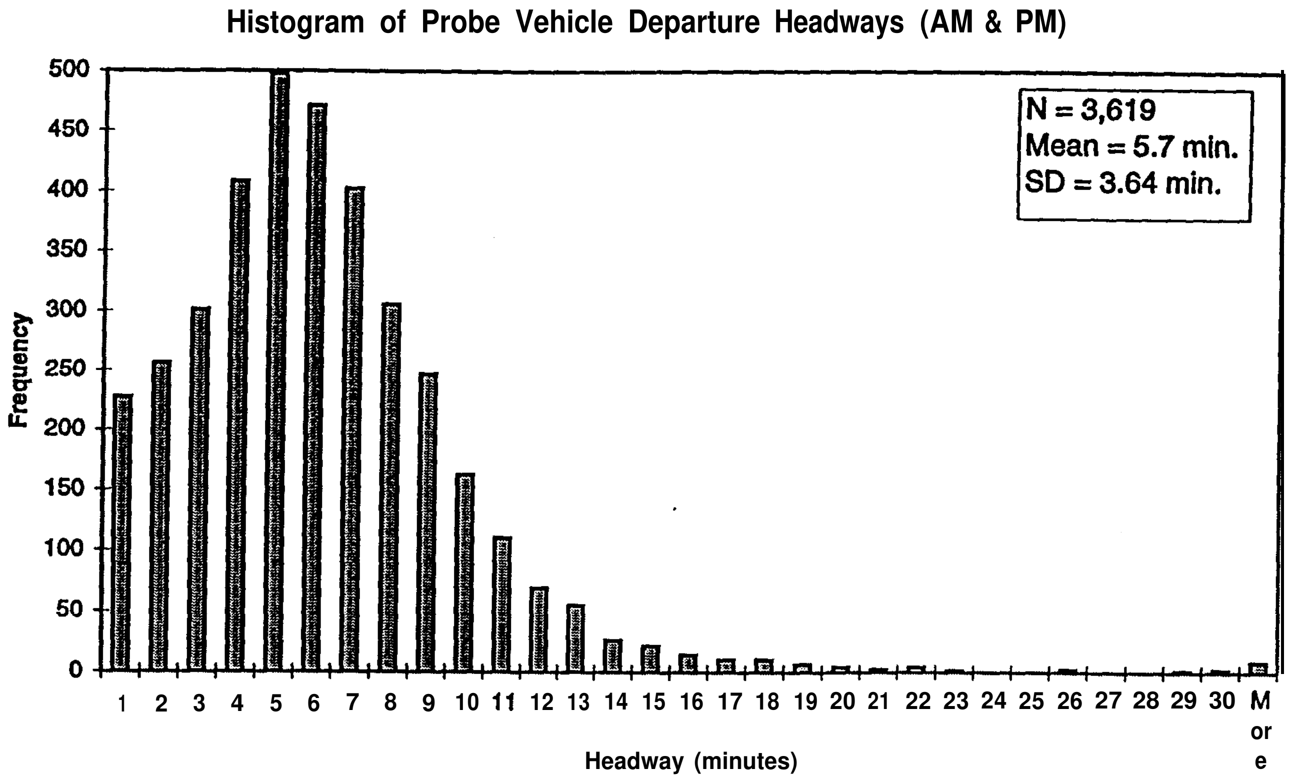
A system for probe vehicle data downloading and transmission to U.C. Berkeley was established, including a PC computer, disk loader and high speed modem, facilitating almost real-time data transfer (twice per day). Appendix C includes an automatically-generated probe vehicle report which was produced by a U.C. Berkeley custom program after each peak period data transfer. Summaries for each probe vehicle were automatically posted on a restricted access World Wide Web page for review by the researchers. Problems could easily be noted, and corrected by the data collection team during the next peak period.

Figure 3.6 shows a plot of probe vehicles travel times as a function of the start time of the run for a particular am peak period. Vehicles travel at nearly free-flow speeds on the eastbound offpeak direction. Average speeds on the westbound peak direction range from 26 to 39 mph between 6:30 to 8:30 am, and then gradually increase to 60 mph by the end of the morning peak.

3.4 Loop Detector Data

The loop detector data were collected to measure flow and occupancy on the selected study site. The District 7 Modcomp system gathered and preprocessed the 30-second data and transferred it directly to U.C. Berkeley via modem on an almost real-time basis (twice per day). This is in contrast to the I-880 study, when researchers and Caltrans staff were required to download the data directly from the controller cabinets in the field. Caltrans District 7 staff wrote an innovative, custom program which automated the data transfer process. After receiving the loop data via modem, U.C. Berkeley researchers were able to review the data within hours of the end of each peak period.

Figure 3.7 shows a sample traffic volume plots from two loop detectors in the study area. Traffic volumes exceeding 2,000 veh/h/lane have been recorded.



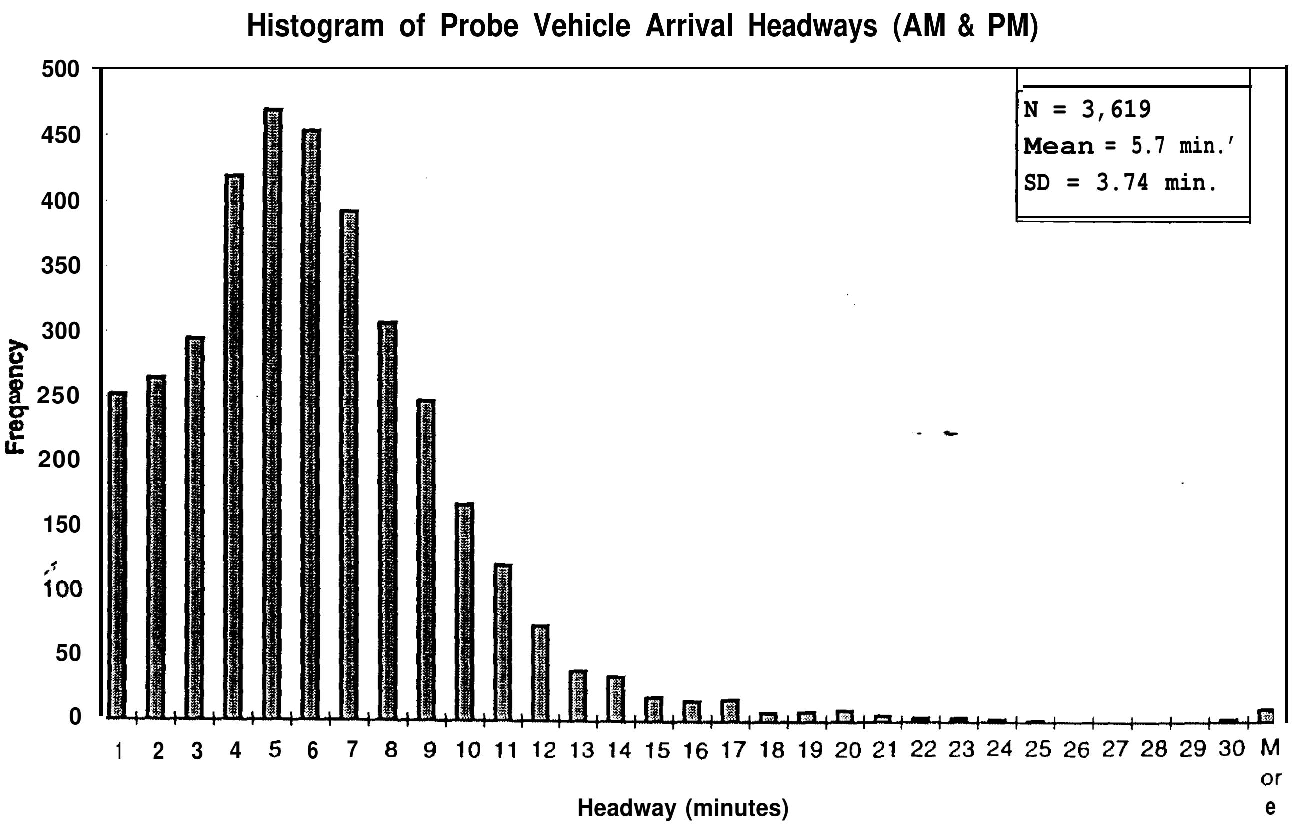


Figure 3.5 Probe Vehicle Headways

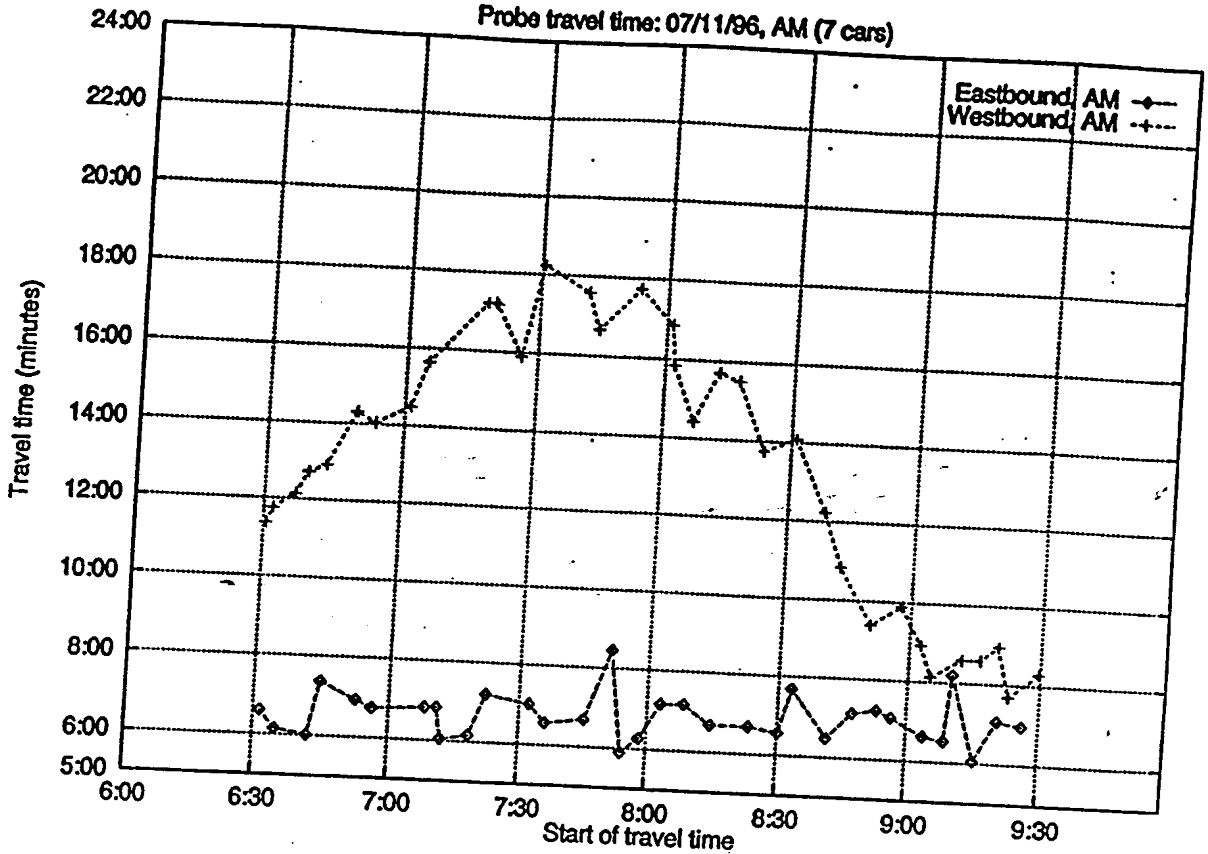


Figure 3.6 Probe Vehicle Travel Times

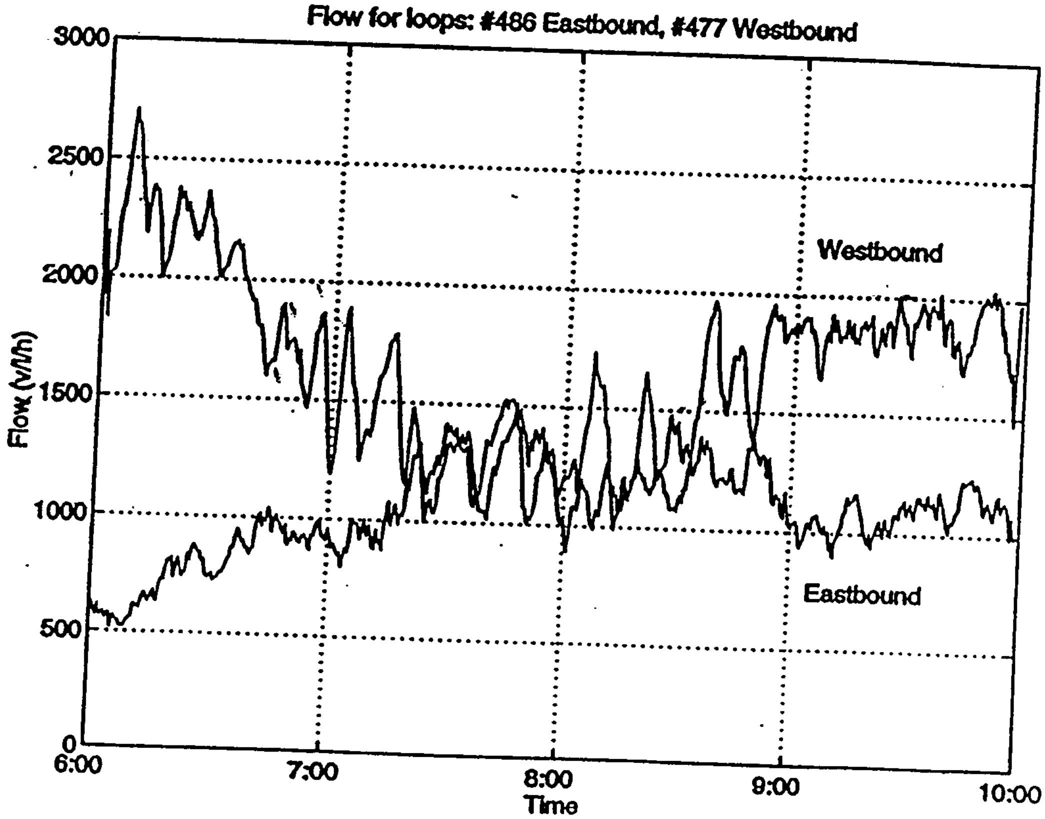


Figure 3.7 Loop Detector Volumes

3.5 Incident Data

Incident data were gathered through direct observations of probe vehicle drivers traveling at approximate 6 minute headways. The test cars were equipped with two-way radios. The drivers reported the following incident data:

- Incident type (accident, breakdown, debris).
- Severity (number of lanes affected)
- Description of the vehicles involved (color, type)
- Location (direction, postmile location, lane/shoulder)
- Presence of rotational tow or FSP, CHP, or other emergency vehicles.

This incident information is transmitted via radio to the field test supervisor at the site and is also registered by the drivers as a location flag on the on-board laptop computer. The incident logs recorded by the supervisor are sent twice per day via fax to U.C. Berkeley and entered into a database for analysis. The quality of radio transmission was thoroughly tested to ensure that the incident information is accurately transmitted. A sample incident field log is included in Appendix C.

3.6 Supplementary Incident Data

CHP/CAD Database: Incident reports "before" and during the field data collection were obtained fi-om the Los Angeles CHP/CAD system. This data is stored as FoxPro database entries, and is archived on Panasonic double sided WORM optical disk cartridges with a storage capacity of 1.4 GB (Panasonic LM-W14OOA). The CHP/CAD database includes records of all calls directed to the CAD center and information for each incident involving a CHP officer The detection of these incidents are from CHP calls, cellular 911 calls, Call Boxes, other public agencies' calls and FSP drivers' calls. The CAD incident logs include the call source/time, incident type and severity (accident, stall, breakdown, number of lanes affected), description of the vehicles involved (license plate number, color, type), location (direction, lane, upstream/downstream to the nearest exit), and reporting and clearance times (CHP, FSP if any, tow truck call, arrival and departure). .

The data were transferred from the WORM disks to a hard drive at the CHP CAD center in Vallejo. The data were subsequently entered into the research team's computers for processing. CHP/CAD data will be analyzed to determine incident response and clearance times for non-FSP conditions, and derive estimates of the reduction in incident durations due to the FSP service.

FSP Logs: tow truck drivers fill out an assist form each time they assist a motorist, as shown in Appendix C. These forms include information on type and location of the incident, type of assistance provided, and arrival and departure times of the FSP unit. The data from these forms are entered into a spreadsheet by Cahrans District 7 staff for further analysis. District 7 has provided the FSP log spreadsheets for use by the researchers for the time period of the field data collection.

TASAS Data: The Caltrans Traffic Accident Surveillance and Analysis Selective (TASAS) Record Retrieval files will also provide a complementary source for accident data. The data were primarily used in selecting the test site for the field data.

USC Incident Data: Researchers from the University of Southern California recorded incidents and their characteristics from the video surveillance system in Caltrans District 7 TMC. The data were collected during the Christmas holiday week of 1996, when FSP service is suspended on the Los Angeles beats. The data were made available to the research team for analysis. The information was used to obtain estimates of incident response times and durations without FSP service.

3.7 Database Development

As indicated above, there are three main data sources: probe vehicles, loop detectors, and incident logs. The probe vehicles provide travel times, speeds (leading to speed contour maps), and incident flags (incident locations shown on the vehicles' trajectories). The loop detectors provide volumes and occupancies. Finally, the incident logs provide detailed information about each incident observed. The combination of these data have provided a comprehensive database which fully describes traffic conditions and incidents for the 32 days of the study period.

Significant software modifications were required in the original FSP software (Petty, 1995) in order to complete the database development. The probe vehicle reports were sent via modem to U.C. Berkeley, and a custom program was developed to convert the CONGEST reports for each probe vehicle into a comprehensive report for all vehicles for each shift. In addition, software was developed to analyze each shift's loop detector data (30-second aggregation).

By virtue of the data transfer processes put into place, a daily effort was undertaken to review and analyze the probe vehicle speed data, incident reports and loop detector data. In addition, probe vehicle reports were generated twice a day, and loop data have also been undergoing continuous review.

Figure 3.8 shows an example of a speed contour diagram created directly from the speed data provided by the probe vehicle on-board computers. Superimposed on the contours are the "incident flags," generated by the probe vehicle drivers' computer key presses as they pass each incident. It can be clearly seen that a delay-causing incident was observed at approximately mile 7.0 a total of six times, and resulted in a reduction in freeway speed. This speed reduction means that drivers experienced incident delay. A backward moving shockwave can be visualized from the speed contours, as can the growth of the queue. Coincident with the last "x" representing the last time the incident was observed by Car 1, a forward moving shock appears, and the queue diminishes shortly afterward. By subsequently reviewing the incident logs for July 24, it turns out that this particular incident was a car tire at mile 7.0, as indicated on Figure 3.8. Figure 3.9 shows a loop detector occupancy contour diagram for the same day and direction based on the Modcomp system, and confirms the information that was provided from the processing of the probe vehicle data.

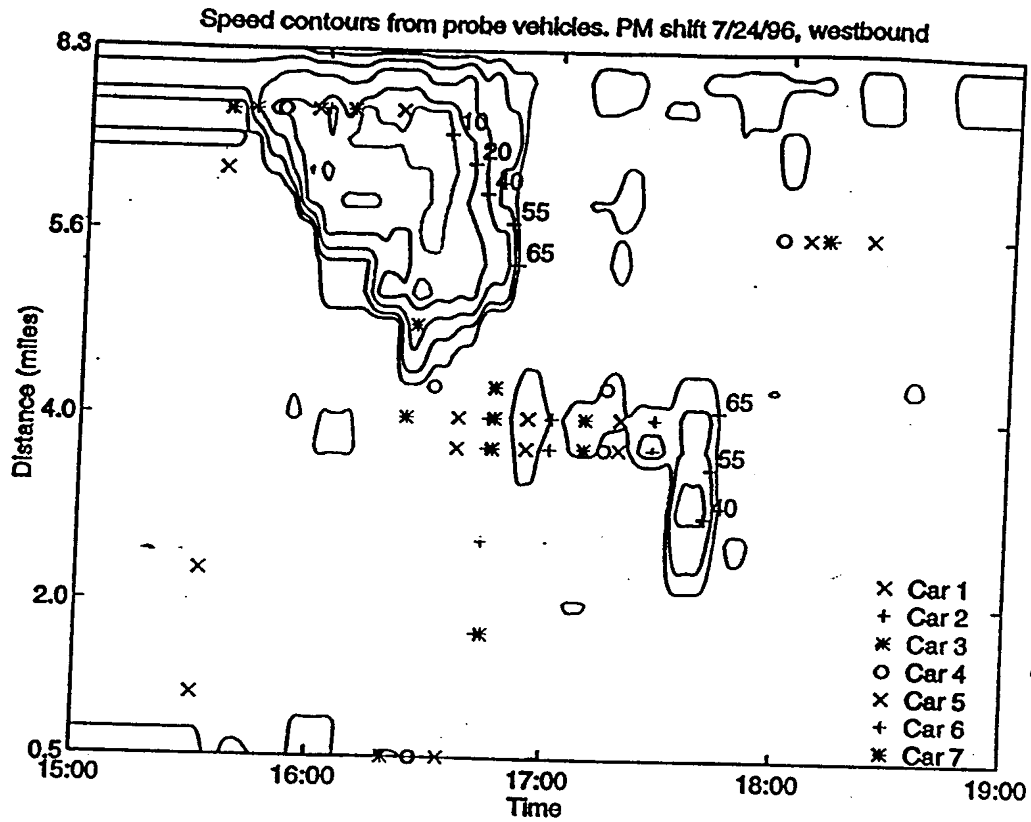


Figure 3.8 Probe Vehicle Speed Contours

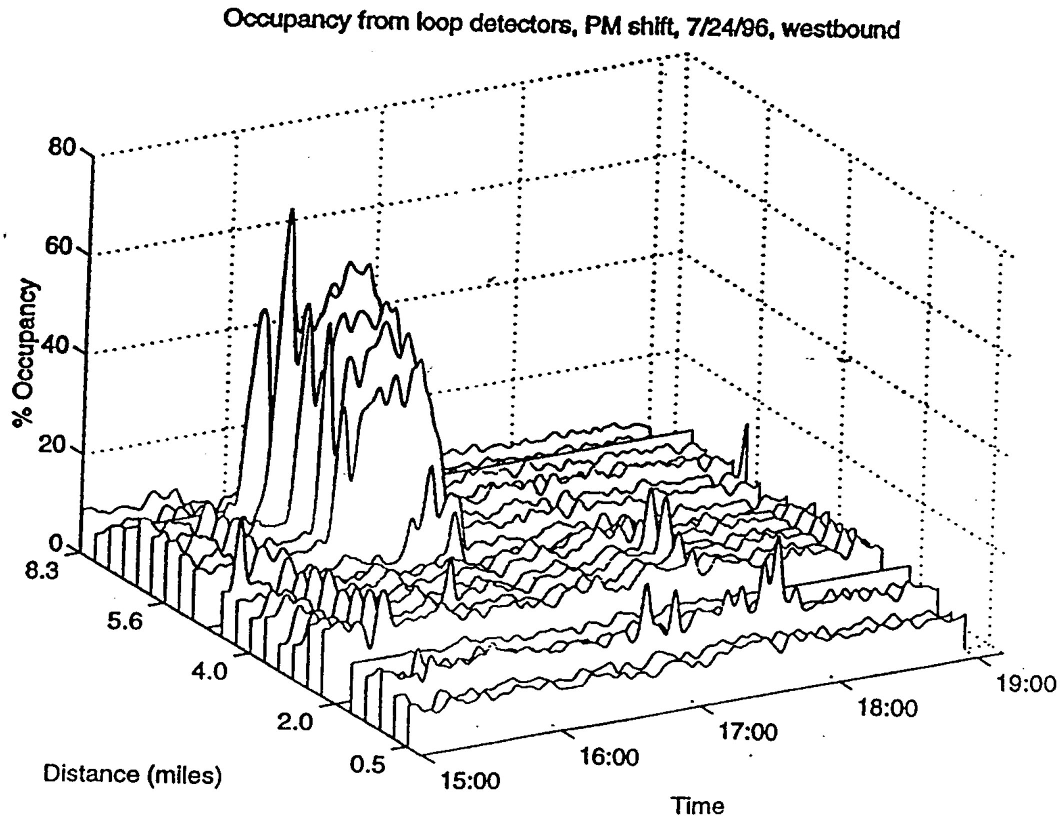


Figure 3.9 Loop Detectors Occupancy

In summary, a comprehensive database has been developed which completely describes the traffic conditions along Beat 8 for 32 weekdays, for a total of six hours each day. This 192-hour database includes detailed descriptions for 1,560 incidents, tach vehicle travel time traces for 3,619 runs (at 5.7 minute headways), and loop detector data (30-second flow and occupancy) from 240 loop detectors. Additional data include the electronic CHP/CAD logs and FSP logs for the entire study period.

CHAPTER4

ANALYSIS OF THE INCIDENT DATA

This Chapter presents the findings from the analysis of incidents observed by the drivers in the probe vehicles, and the incident data obtained from the CHP/CAD system and the FSP logs.

4.1 Incident Frequency and Characteristics

A total of 1560 incidents were observed in the study section throughout the data collection period. A total of 300 incidents (20 % of the total observations) were CHP ticketing and maintenance crews clearing related events. Although there may be some effects of those incidents on traffic flow, it is unlikely that these incidents would be affected by the FSP service, or any other traffic management measure, and therefore were excluded from further analysis.

Table 4.1 shows the classification of incidents based on their type and place of occurrence. Most of the incidents were breakdowns on the right shoulder. Note that the breakdown category includes abandoned vehicles and all other stops (e.g., check maps, etc.) The estimated incident rate on the study section was 92.8 incidents/million-veh-miles of travel, which is close to the incident rate for the I-880 freeway (104 incidents/MVM), but about half of the previously reported rates (Lindley 1986, Urbanek 1978). On the average, there were 1.3 incidents per directional freeway mile per data collection shift (i.e., 0.43 incidents/dir freeway mile/hour.

The number of in-lane incidents depends on the presence of shoulders, incident type, type of vehicles involved and the data collection methodology. In this study, in-lane incidents are those that are first witnessed on the freeway mainline. The proportion of the in-lane incidents was about 10.7 % (Table 4.1). It is likely, that a higher number of in-lane incidents would have been observed by other data collection methods (CCTV).

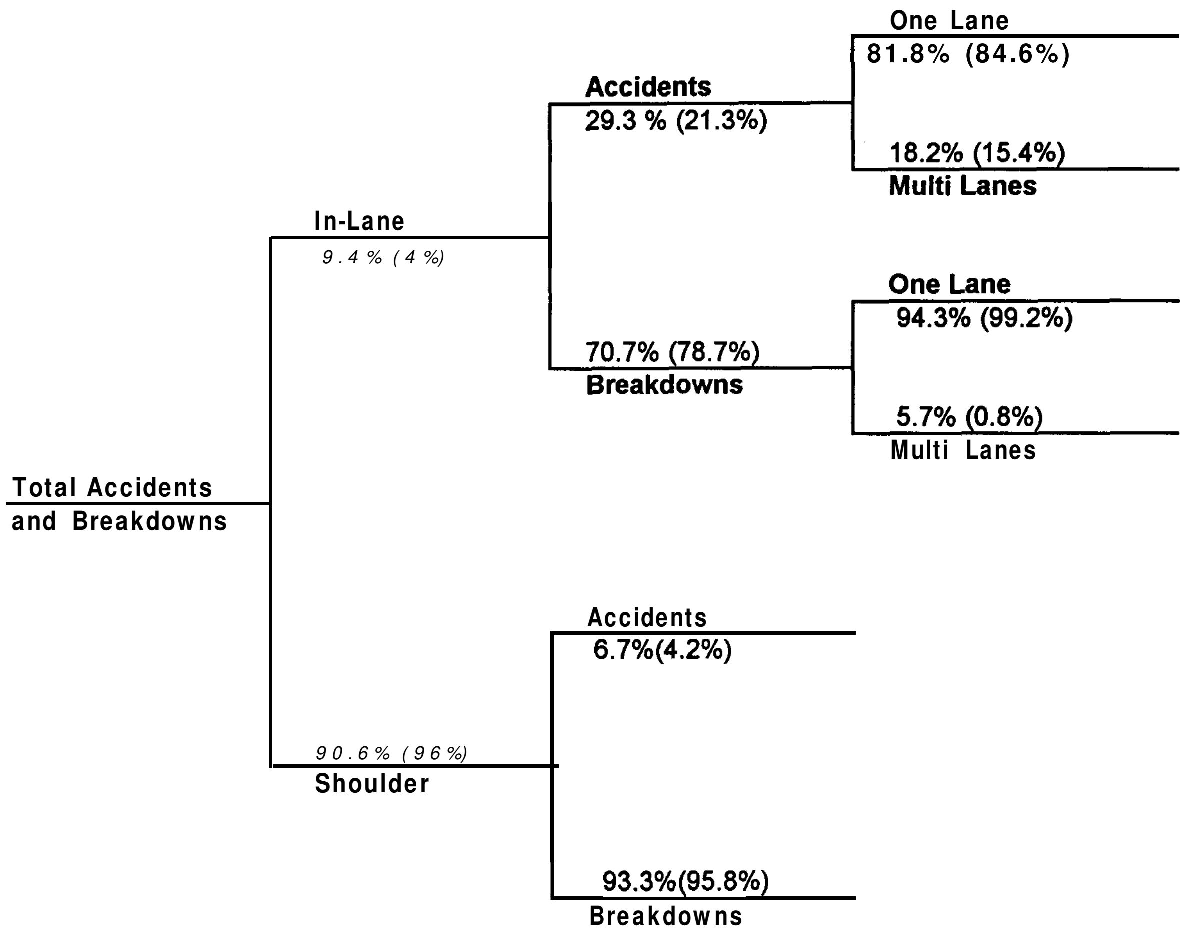
Figure 4.1 shows the incident tree that summarizes the overall incident patterns in the study area (excluding debris/pedestrian incidents). Also, shown are values reported by FHWA (Lindley, 1986) based on studies conducted in the 1970's. The study section has a much higher proportion of in-lane incidents (9.6 % compared to the reported 4 %) Also, there is a higher proportion of in-lane accidents (29 % vs. 21.3 %), and breakdowns occupying more than one travel lanes (5.7 % vs. 0.8 %).

The variation in the number of observed incidents per data collection period (shift) was due to time of day, day of the week, number and type of vehicles involved. Table 4.2 shows the incident frequency by time of day and direction of travel. More incidents were observed in the PM than the AM peak, particularly breakdowns on the right shoulder, because of the higher volumes in the afternoon peak period. The number of incidents was approximately the same for each direction of the study section. However, as it is shown on Table 4.2, about 58 % of the total incidents, and 78 % of all the accidents occurred during the peak travel time/direction (westbound AM peak and eastbound PM peak).

TABLE 4.1 Incident Classification
1560 field observations*

Incident Type	Location: L Shldr	Divide	In-Lane	R Shldr	Total	%**
Accident	2	12	24	43	81	6.5
Breakdown	14	107	87	865	1073	86.6
Debris/Peds	1	5	21	58	85	6.9
Clearing	1	2	4	110	117	
CHP Ticketing	0	68	0	115	183	
Total	18	194	136	1191	1539	
Total w/o Clearing/Ticketing	17	124	132	966	1239	100.0

• Incomplete information was reported for 21 incidents
*** Excludes Clearing/Ticketing incidents*



Legend:

XX: I-IO Data

(XX): FHWA Data

Figure 4.1 Incident Tree--Beat 8

TABLE 4.2 Incidents By Time of Day/Direction of Travel

Incident Type	EB Direction AM	EB Direction PM	WB Direction AM	WB Direction PM	Peak	ffPeak	*Total*
Accident	5	36	27	13	63	18	*81*
Breakdown	206	318	310	239	628	445	*1073*
Total	*211*	*354*	*337*	*252*	*691*	*463*	*1154*

Peak Time/Dir

The average incident frequency was 17.9 breakdowns and 1.35 accidents per data collection shift. The distributions of incident occurrence for all the incidents and per incident type were tested against statistical distributions. The Poisson distribution provided an adequate fit for the incident frequency, suggesting that the number of incidents at any time period is random and independent of the number of incidents in any other time interval. The form of the Poisson distribution is:

$$P(n) = (\exp(-m)\, m^n)/n! \qquad (4\text{-}1)$$

where $P(n)$ is the probability of having n incidents/shift, and m is the Poisson parameter. Figure 4.2 shows the fit of the Poisson distribution to the observed number of accidents and breakdowns in each 3-hr data collection shift.

Accidents accounted for 6.5 % of the total incidents. On the average, there were 2.7 accidents/six-hour peak period. Most of the accidents were non-injury accidents, and only about 6 % of all accidents involved more than two vehicles. Also, there was a higher frequency of accidents on segments with weaving areas and lane drops, especially on the western boundary of the study area near the I-710 interchange.

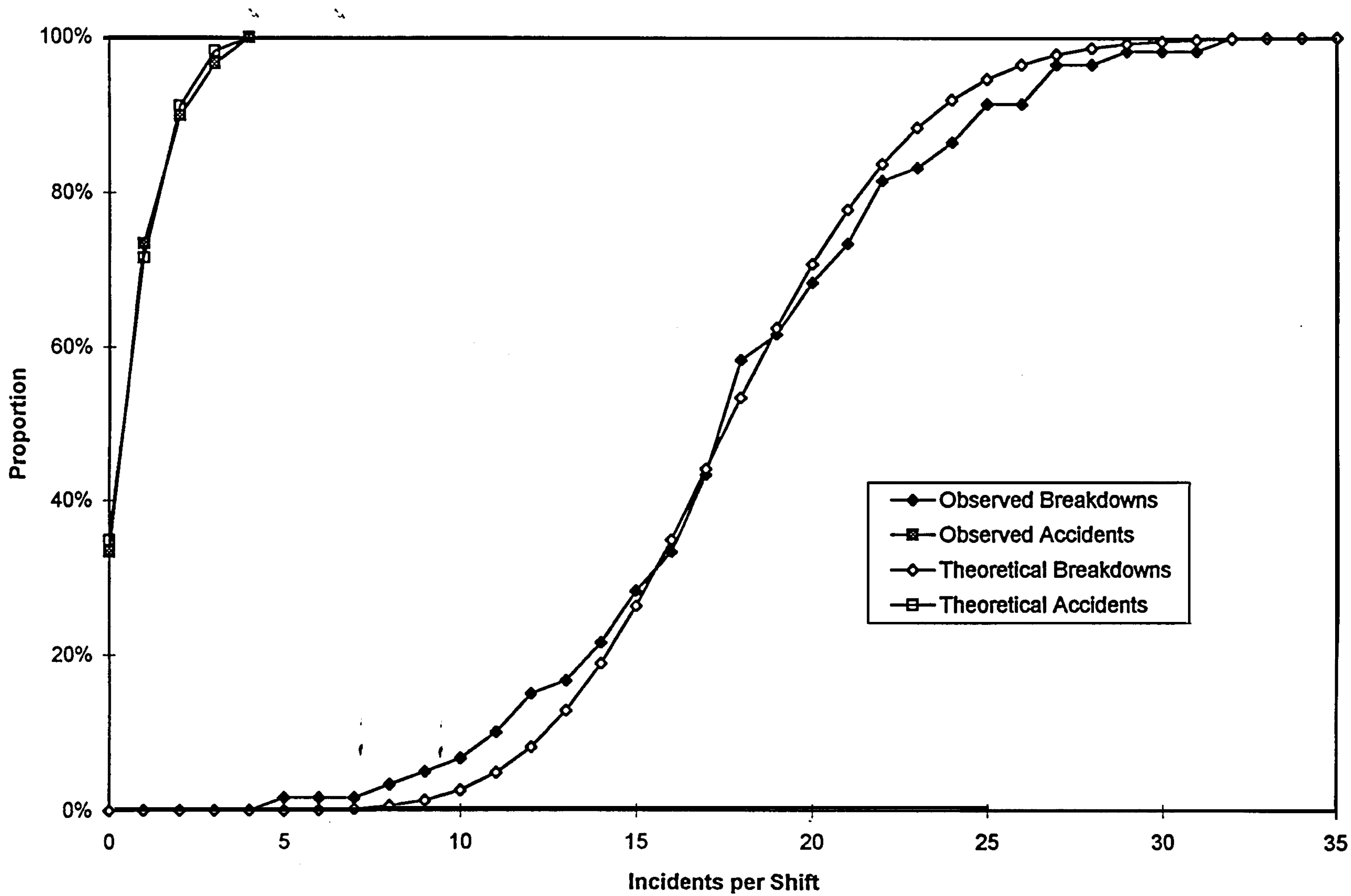


Figure 4.2 **Distributions Of Incident Frequency**

4.2 Incident Response and Clearance Times

The response time was calculated as the difference between the time the incident was first witnessed and the FSP (or other tow truck) arrival time; clearance time then was the difference between the tow truck arrival time and the time it leaves the incident scene. For those incidents involving the CHP, the response time was calculated as the difference between the time the incident was first witnessed and the arrival time of the first CHP unit. The clearance time was the difference between the arrival time of the first CHP unit and the time the last CHP unit left the incident scene. The response and clearance times could not be calculated for i) assisted incidents witnessed only once, and ii) cases where the tow truck did not clear the incident. Also, abandoned vehicles were excluded from the calculation of response/clearance times for assisted breakdowns.

The average response time for all the assisted incidents was 10.8 minutes (Table 4.3). All the incidents were assisted by the FSP. About 25 % of the assisted involved the CHP. The average clearance time for all assisted incidents was 12.8 minutes. The average clearance time for breakdowns on the shoulder was about 10 minutes indicating that most of those incidents were minor stalls. Accidents and lane blocking disablements took about 18 minutes on the average to clear.

4.3 Incident Durations

The total incident duration was calculated as the difference between the first and the last time the incident was witnessed by the probe vehicles' drivers. Of the 1154 incidents (accidents and breakdowns), 652 (56%) are classified as having zero duration (observed only once by the probe vehicles). The "true" mean duration of such incidents does not exceed the average headway of the probe vehicles (5.7 minutes). Most of those incidents (85 %) were breakdowns on the shoulders that were not assisted by the FSP.

Table 4.4 shows the mean and standard deviation of the durations for each incident type separately for assisted and non-assisted incidents (excluding the incidents observed only once). The average duration of all the incidents was 19.8 minutes. Assisted incidents lasted 23.6 minutes on the average, and non-assisted incidents 14.3 minutes. As expected, accidents had longer incident durations than breakdowns by about 10 minutes on the average for assisted accidents, and 4 minutes for the unassisted ones. The distributions of durations show that most of the incidents were of short duration (Figure 4.3). Approximately 70 percent of the breakdowns lasted less than 20 minutes, and about 65 percent of the accidents lasted up to 30 minutes.

Statistical distributions were tested to observed incident durations in a number of studies, and the lognormal distribution has been found as an adequate model for incident durations (Golob 1987, Giuliano 1989, Jones 1991). This distribution also theoretically appears to provide a good model for durations since incident duration consists of detection, response, and clearance times; each of those time components is dependent on the time it takes to complete the preceding activities (Golob 1987). A number of distributions were tested in this study and based on the Kolmorogov-Smimof (K-S) statistical test the lognormal distribution provides a reasonable fit to the field data.

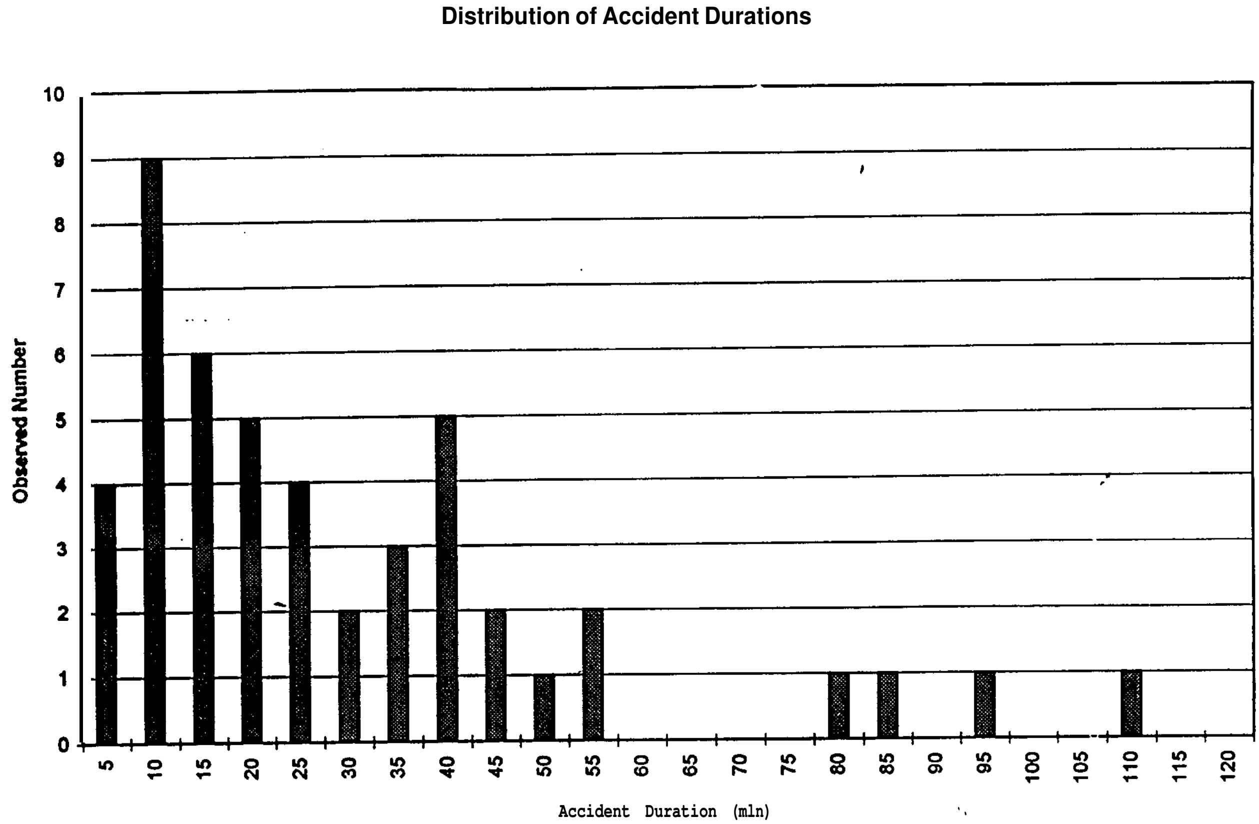
TABLE 4.3 Incident Response/Clearance Times (Min)

Incident Type	Response			Clearance			Duration		
	N	Mean	Sdev	N	Mean	Sdev	N	Mean	Sdev
Accident	33	14.1	8.7	33	18.3	7.9	33	32.4	24.8
Breakdown	271	10.4	8.2	271	12.1	5.1	271	22.5	20.6
All	304	10.8	8.3	304	12.8	5.8	304	23.6	21.2

TABLE 4.4 Incident Durations (Min)*

Incident Type	Assisted			Non-Assisted			All		
	N	Mean	Sdev	N	Mean	Sdev	N	Mean	Sdev
Accident	33	32.4	24.8	14	18.2	16.3	47	28.1	23.4
Breakdown	271	22.5	20.6	188	14.0	16.9	459	19.0	19.6
All	304	23.6	21.2	202	14.3	16.8	506	19.8	20.1

*Excludes incidents observed once



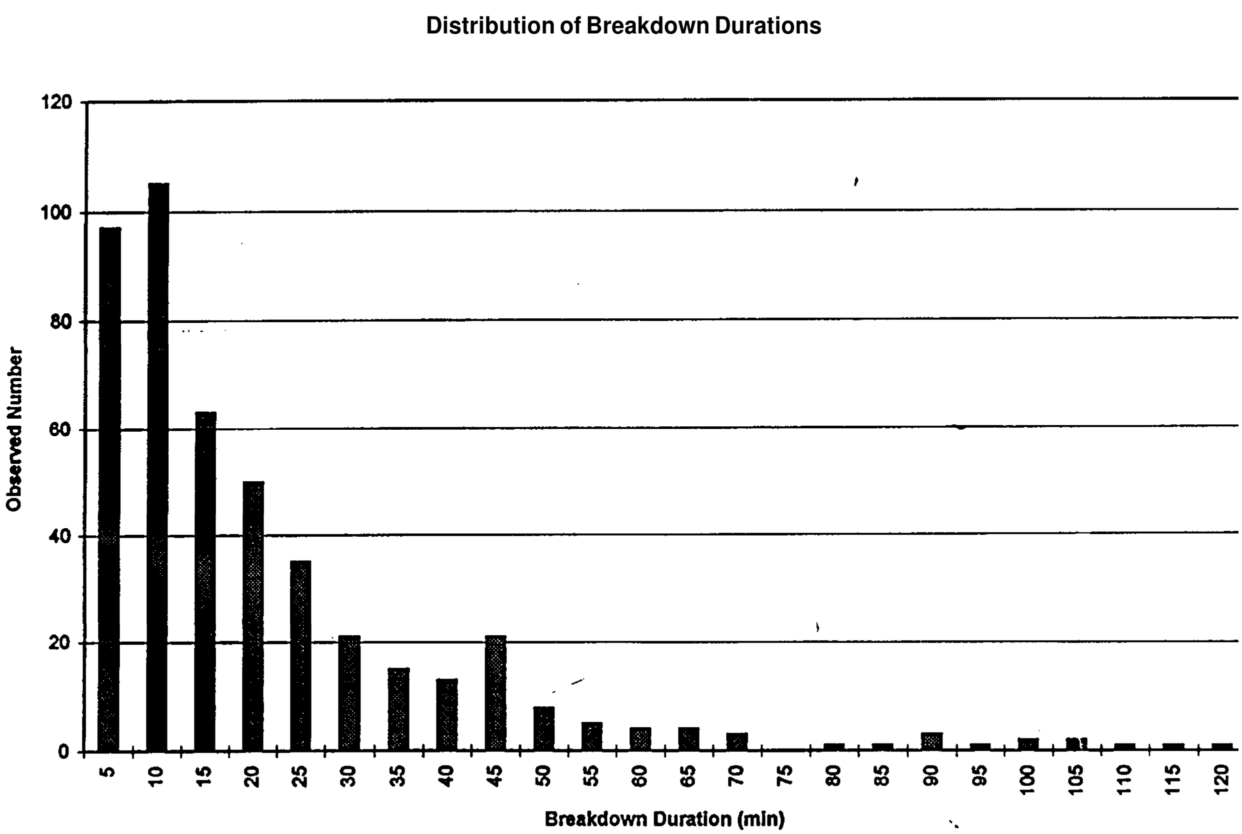


Figure 4.3 Distribution of Incident Durations

4.4 Analysis of CHP CAD Data

Sample incident data from the CHP/CAD logs were analyzed for Beat 8. The purpose of this analysis was to determine the average incident durations during the peak periods with FSP in operation, and the offpeak period with no FSP service. A total of 280 incidents were extracted from the computerized CAD logs. Approximately 90 percent of the incidents in the peak periods involved breakdowns assisted by the FSP tow trucks.

Table 4.5 below shows the incident durations for the peak and off-peak period. The average incident duration of 20.6 minutes during the peak periods is very close to the measured value of 22.5 minutes from the probe vehicles for breakdowns (Table 4.4). The average incident duration in the off-peak with no FSP service is longer by about 7 minutes (35 percent).

TABLE 4.5 Incident Durations--CHP/CAD Database (Min)

Time Period	N	Mean	Sdev
FSP Shift	166	20.6	19.7
OffPeak (w/o FSP)	114	27.9	23.1
All	280	23.6	20.4

4.5 Analysis of FSP Logs

The FSP vehicle drivers during the field study assisted a total of 1035 separate incidents (Table 4.6). This translates to 34.50 assists/day (1.44 assists/truck-hr). More assists occurred in the pm peak (56 % of the total). The breakdown of assists by type is shown in the Figure at the bottom of Table 4.6. Most of the assisted breakdowns had mechanical or electrical problems (32 %). Vehicles with flat tire and out of gas accounted for about 27 % of the assisted incidents, and 21 % of the incidents involved accidents. The remaining incidents were debris and other (abandoned vehicles, unable to locate, car fire, locked-out, etc.)

A total of 746 FSP assists (72 percent) occurred during the data collection shifts (Table 4.6). Table 4.7 shows the breakdown of FSP activity. Approximately 69 % of the incidents were assisted in the field, and about 23 % had to be towed off the freeway. About 70 incidents (9.4 0h) involved abandoned vehicles and incidents that the FSP drivers were unable to locate. In terms of incident type, FSP assisted 505 breakdowns and 159 accidents (24 %), excluding abandoned vehicles, unable to locate and debris removal.

The FSP logs provide information on the type of assist, incident location (in-lane or shoulders) and arrival/departure times of the FSP tow trucks. However, the computerized spreadsheets based on the Scantrons logs did not include information on the incident location at the specific beat (e.g., postmile or nearest freeway exit). Therefore, matching assisted incidents observed by the probe vehicles against the FSP logs had to be based on incident types and times (a lengthy and tedious process). The matching of the field observations and FSP logs yielded 193 incidents. Figure 4.4 shows the distribution of the time spent in each incident as reported by the FSP drivers for a) the total assists in the shift (746 incidents), and b) the matched sample with the field observations by the probe vehicle drivers. This confirms that the matched incidents are a representative sample of the total FSP assists during the data collection periods.

The probe vehicle drivers observed a total of 304 FSP assists with known start and end times, plus 133 assists observed once for a total of 437 assists. This is considerably less than the 746 assists reported by the FSP drivers. However, a number of assists involved vehicles on the ramps, unable to locate and abandoned vehicles (16 % of the total). Also, Figure 4.4 shows that in approximately 25 % of the assists, the time spent by the FSP was less than 5 minutes, and in about 48 % of the assists the FSP tow truck was there less than 10 minutes. Therefore, a portion of such incidents would be missed by the prove vehicles traveling at an average headway of 5.7 minutes and in some cases caught in the queue due to congestion.

TABLE 4.6 FSP Activity on Beat 8 (Source: FSP Logs)
Period: June 26--August 9, 1996 (30 weekdays)

Time Period	#assists
AM Peak (6-10 am)	454
AM Study Shift (6:30-9:30 am)	335
PM Peak (3-7 pm)	581
PM Study Shift(3:30-6:30 pm)	411
Total Assists	**1035**
Total Assists in Study Shifts	**746**

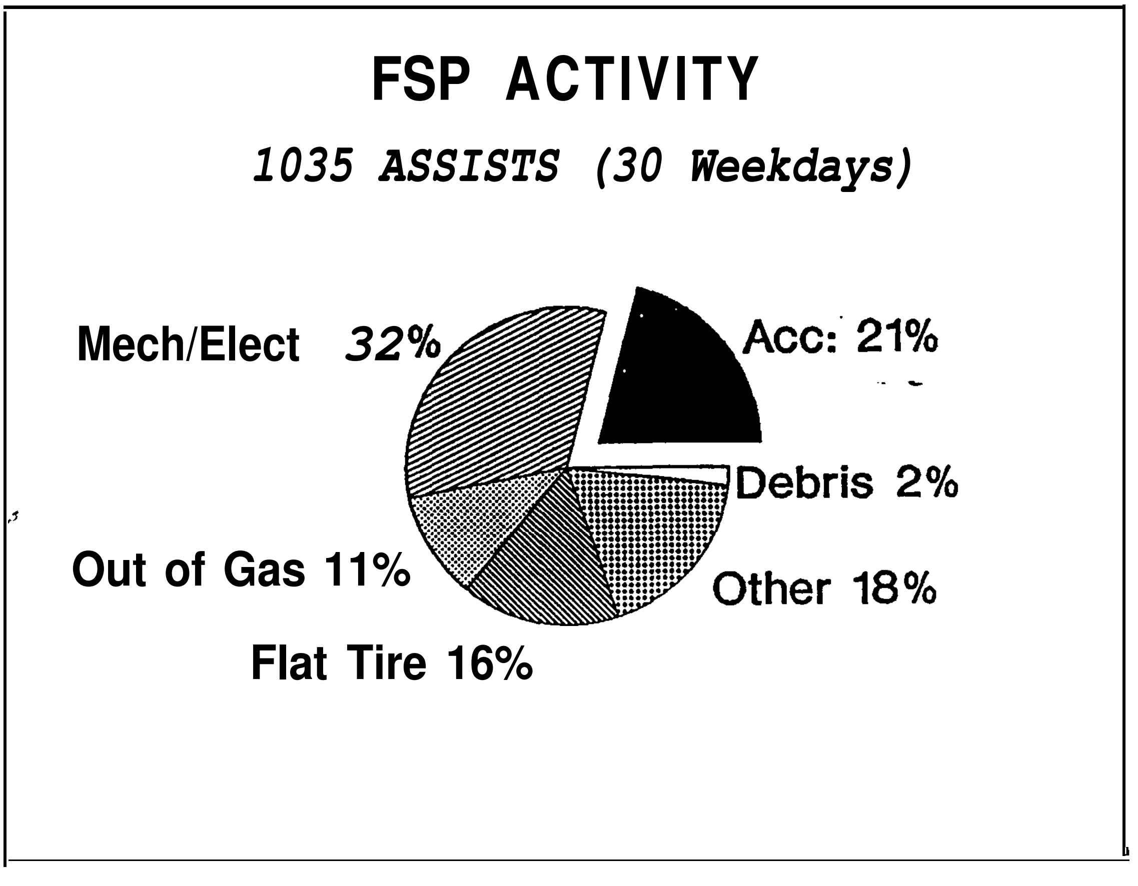
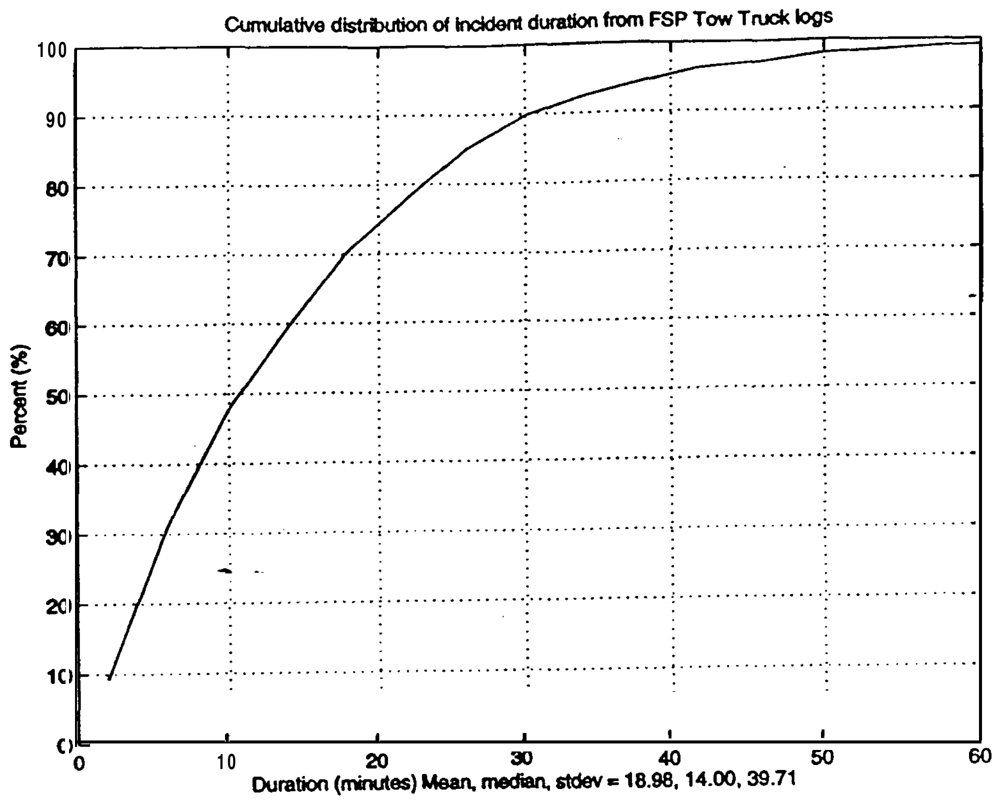


TABLE 4.7 FSP Activity During Study Shifts (Source: *FSP Logs*)

Incident Type	FSP Activity: Field Assist	Tow	Moved to Shoulder	Unable to Locate	Total
Accident	137	7	15	0	159
Breakdown					
Overheat	35	21	0	0	56
Mechanical	43	93	2	5	143
Electrical	15	19	1	2	37
Out of Gas	75	7	1	0	83
Flat Tire	102	17	1	0	120
Abandoned Veh	32	0	1	0	33
Other/Unknown	66	7	0	29	102
Total	368	164	6	36	574
Debris Removal	12	0	0	1	13
Total	**517**	**171**	**21**	**37**	**746**



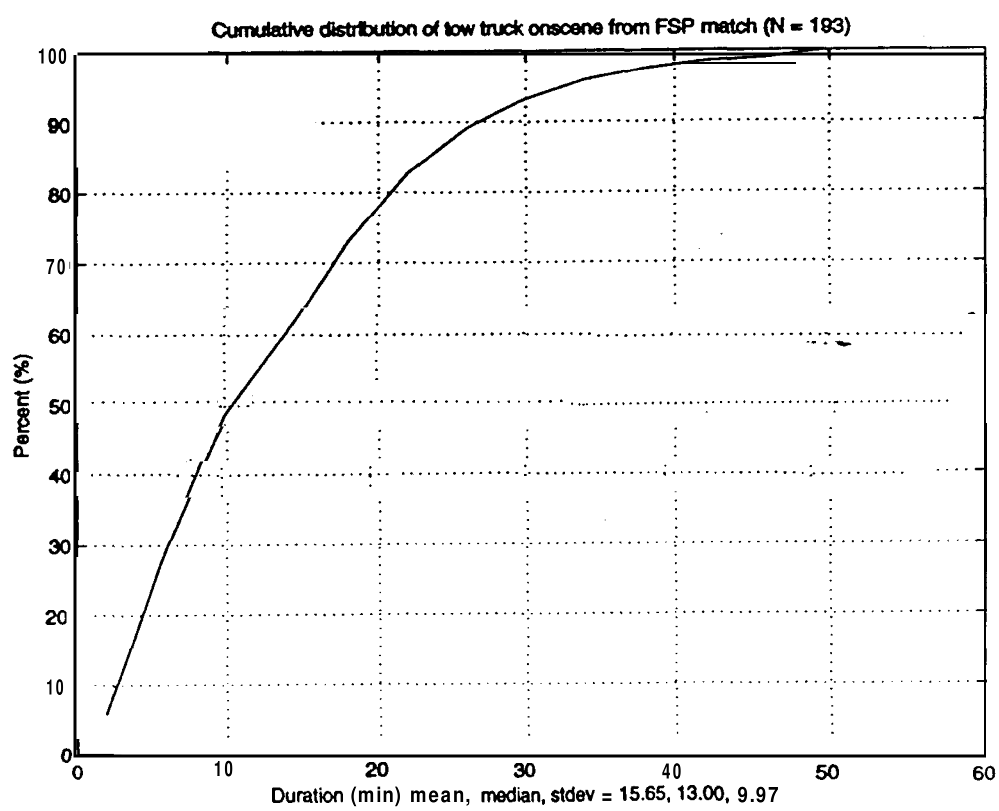


Figure 4.4 Distribution of Times "FSP on Scene"

4.6 Analysis of the USC Field Data

The purpose of the field data collection was to observe incident patterns without FSP service. The field data were collected by USC transportation graduate students through observations from CCTV cameras at the Caltrans District 7 TMC. Section of the I-5 and I-10 freeways were observed during the week of the Christmas holiday (12/25/96 through l/1/97) during the midday and afternoon peak periods. ***(Source: J Moore, "Prereport Summary and Data").***

A total of 57 incidents were observed. There were 18 accidents (31.6 %), 32 breakdowns (56 %) and 7 other events (debris, pedestrians, ticketing, and cleaning crews). Fiieen incidents were observed in the travel lanes (26 %).

Table 4.8 shows the statistics (mean and standard deviation) of observed incident durations per incident type separately for assisted and non-assisted incidents. Note that for accidents we listed the duration of all the accidents, and the durations of accidents that are likely to be helped by the FSP. The average duration of accidents was 59.9 minutes. However, they were four major accidents (multicar injury crashes and oil spills) that required specialized assistance for their removal from the freeway (multiple CHP units, ***hasmat*** teams and several tow trucks.) Although FSP service would be helpful in such incidents by assisting in the clearance and traffic control process, it is unlikely that they would clear such incidents. Excluding those major accidents, the average durations of the remaining accidents was ***35.6*** minutes.

Table 4.9 shows the average and standard deviation of the response and clearance times for the assisted incidents. It can be seen that the clearance times are similar to the ones observed by the probe vehicles for accidents and breakdowns on Beat 8 (Table 4.3). The major diierence is the response times. The incident response times without FSP was 26 minutes, and with FSP was 10.8 minutes (Table 4.3).-- a difference of 15 minutes in response times. Such a differences in response times was also observed in the I-880 study and was reported in the Caltrans LA Metro FSP evaluation (Caltrans, 1992).

TABLE 4.8 Incident Durations--USC Field Data (Min)

Incident Type	Assisted N	Assisted Mean	Assisted Sdev	Non-Assisted N	Non-Assisted Mean	Non-Assisted Sdev	All N	All Mean	All Sdev
Accident	14	59.9	44.5		N/A			N/A	
Accident--FSP*	10	35.6	12.1		N/A		10	35.6	12.1
Breakdown	9	39.9	29.8	10	22.1	12.4	19	30.5	23.6
All	19	37.6	21.8	10	22.1	12.4	29	32.3	18.5

Accident FSP: Excludes accidents that FSP is unlikeley to be of nay help (multicar injury accidents and spills)

TABLE 4.9 Incident Response/Clearance Times--USC Field Data (Min)

Incident Type	Response N	Response Mean	Response Sdev	Clearance N	Clearance Mean	Clearance Sdev	Duration N	Duration Mean	Duration Sdev
Accident--FSP*	10	20.6	9.7	10	15.0	7.9	10	35.6	12.1
Beakdown	9	32.1	26.9	9	7.8	5.1	9	39.9	29.8
All	19	26.0	20.1	19	11.6	7.5	29	32.3	18.5

CHAPTER 5

EVALUATION OF FREEWAY SERVICE PATROLS

5.1 Program Benefits

The benefits of the FSP service include travel time and fuel savings to the motorists because of the reduction in the incident delay and fuel consumption, reductions in the air pollutant emissions, and other benefits to the assisted motorists, CHP and the freeway operators.

5.1.1 Delay Savings

The delays caused by incidents were calculated according to the method described in Chapter 2. The methodology consists of estimating the delay on the study section from loop data on flows and probe vehicle speeds, mapping the congestion and incidents on the same diagram, associating pockets of congestion with incidents where the association is apparent, and calculating the delay per incident.

Figure 5.1 illustrates the process for estimating incident delay. The top part of the Figure shows the definition of the delay estimation, and a freeway density contour plot with a superimposed incident. The bottom part of the Figure shows the delay contours of each incident based on the field data for a particular data collection shift. It can be seen that incident number 943 causes a significant amount of delay, but the rest of the incidents in that particular data collection period did not cause any delay.

The delay was calculated for those incidents observed within the data collection shift and with observed start and end times, i.e., incidents observed once were excluded. Delays were calculated for a total of 198 assisted incidents (out of the total 304 assists with known durations). Incident related delay depends on the incident type, severity and duration. Figure 5.2 shows a plot of the incident delay as a function of the incident duration. As expected, delays increase with longer durations. However, there is a large number of incidents with zero delay (mostly minor stalls on the shoulder), and a number of short duration incidents with significant delays.

Next, we modeled each individual incident with a queuing diagram and estimated the delay for different values of duration, as described in Chapter 2. We increased the duration in each incident incrementally by the same amount and estimated the delay for each value of the duration. The difference in the estimates of delay for each value of duration and the measured delay would give as the delay benefit. This is illustrated in Figure 5.3. For example, let's assume that the measured delay for an assisted incident with duration of 20 minutes is 60 veh-hr. We model this incident with the queuing diagram and calculate the delay for a duration of 30 minutes to be 75 veh-hr. Then, the delay savings for the particular incident is 15 veh-hr for 10 minutes (or 33 percent) reduction in duration.

We modeled each individual incident for duration increase from 10 to 100 percent of the measured value. For each level of duration increase, we calculated the average delay savings (in veh-hr) for all the incidents. Figure 5.4 shows the delay savings per incident vs. the fractional increase in duration. The value of delay savings (and other MOEs) would be translated into monetary values for calculating the benefit/cost ratio.

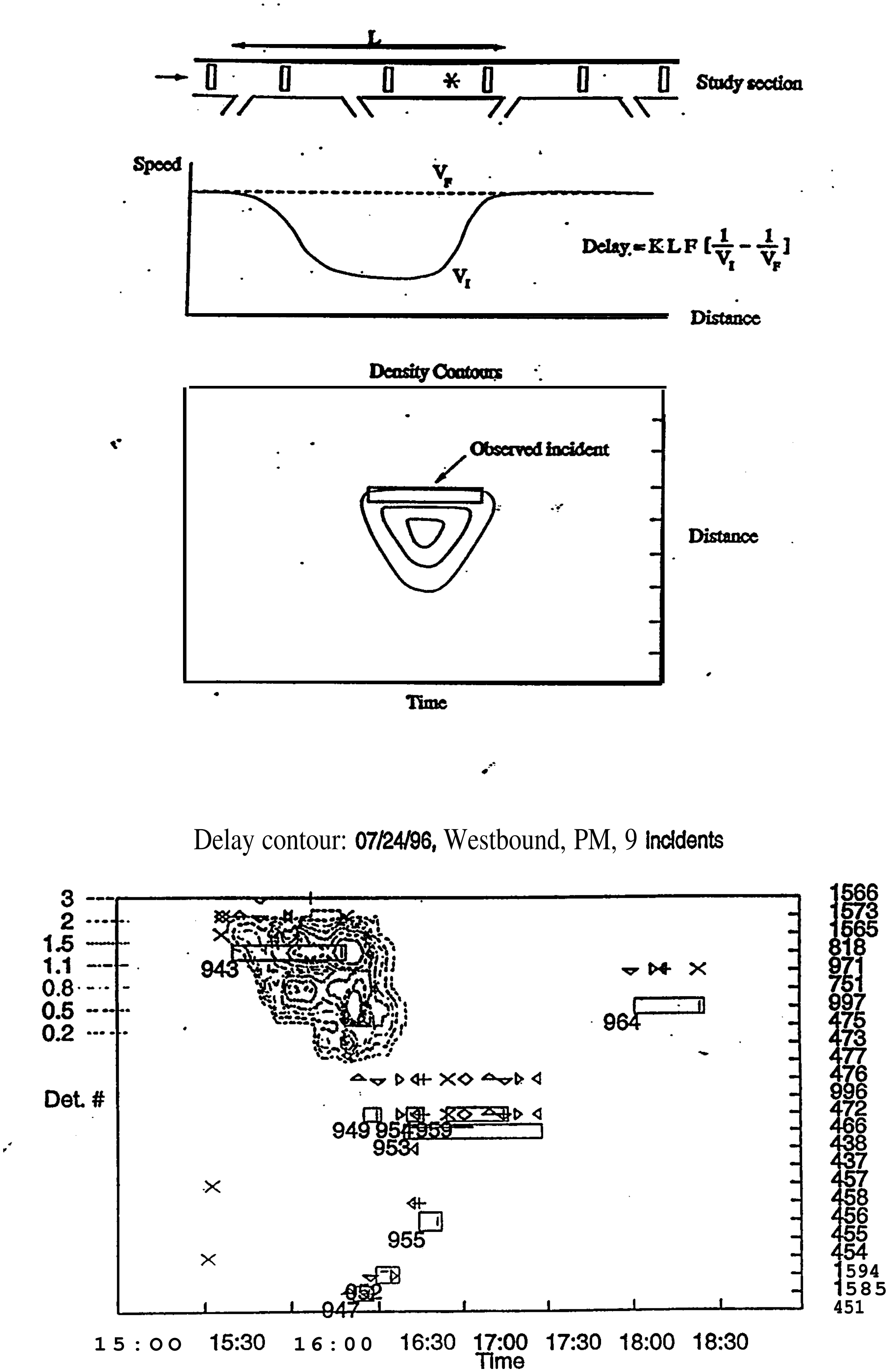


Figure 5.1 Process of Incident Delay Estimation

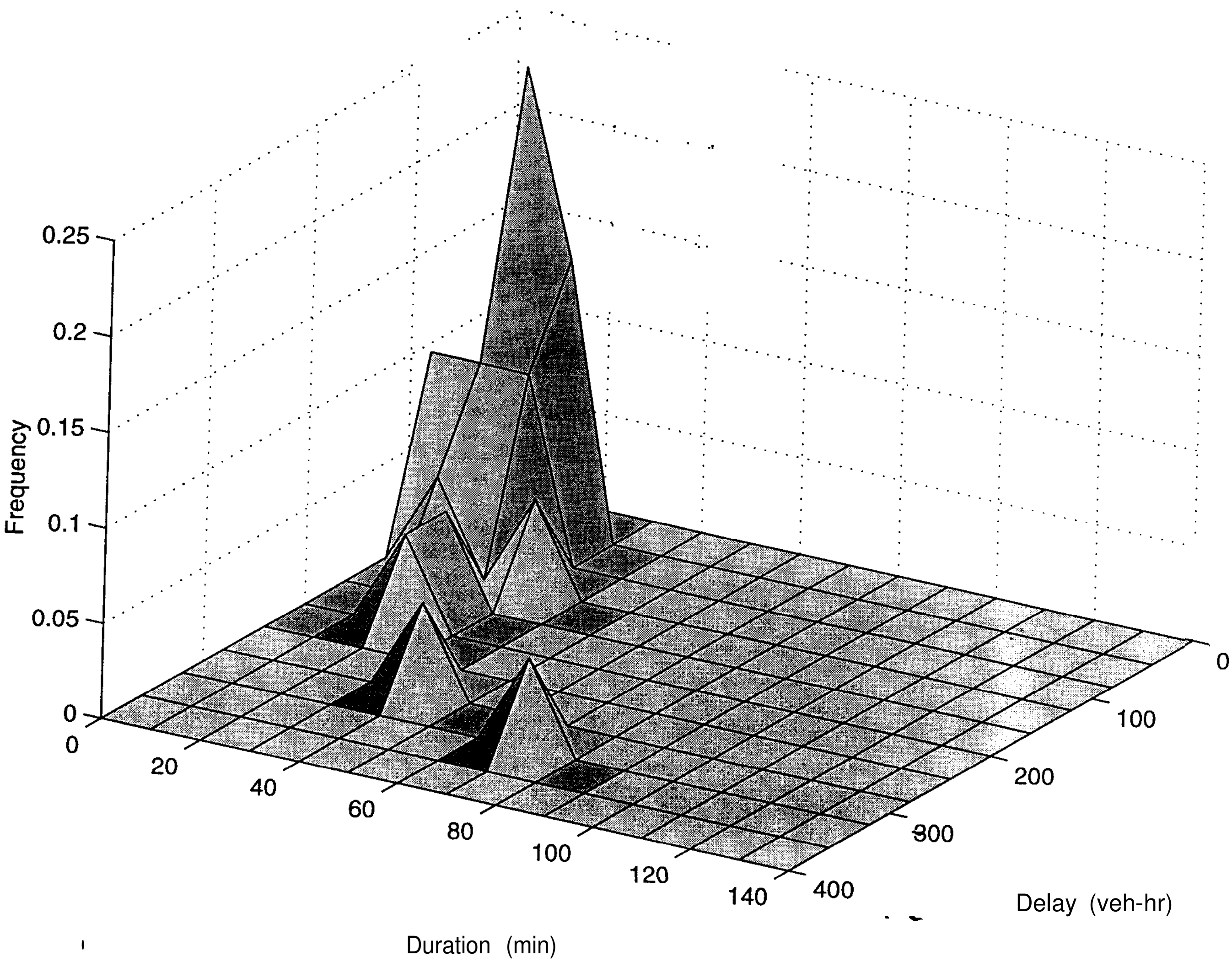


Figure 5.2 Distribution of Delay and Incident Duration

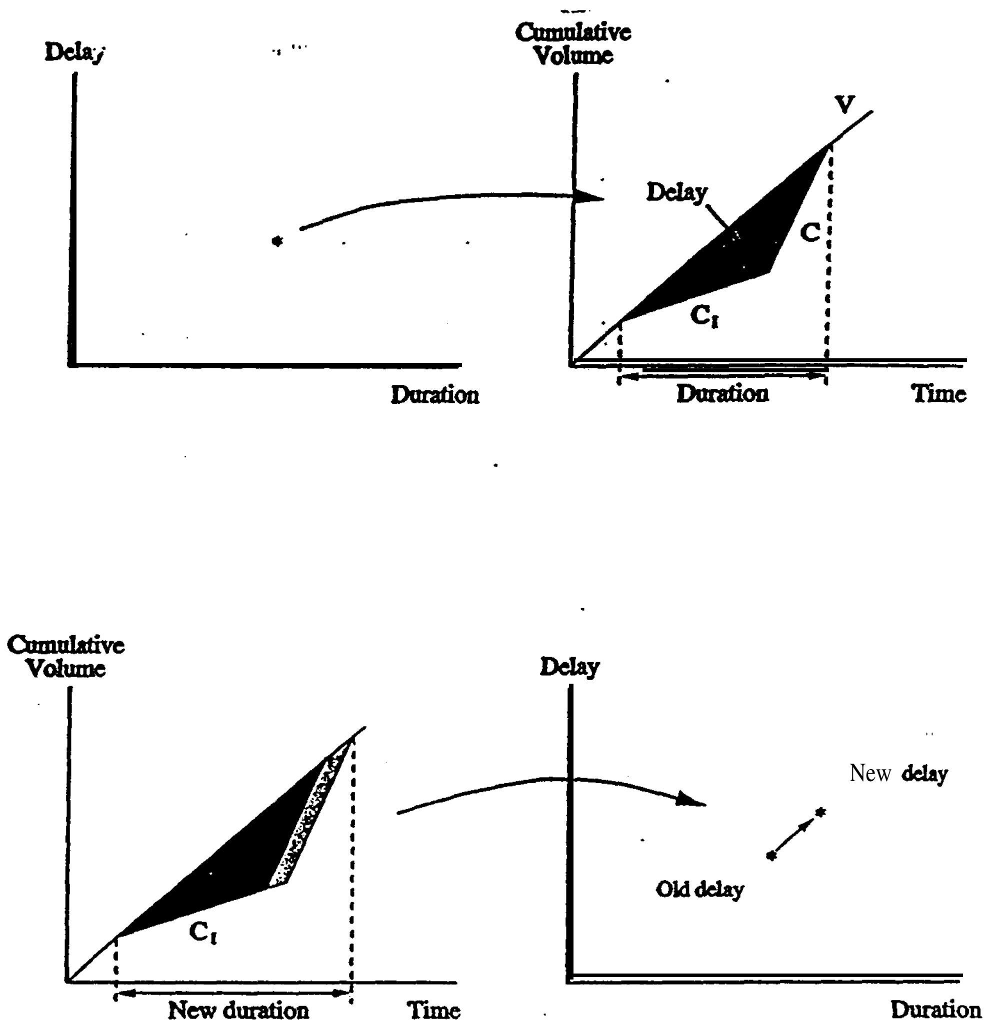


Figure 5.3 Process of Incident Modeling

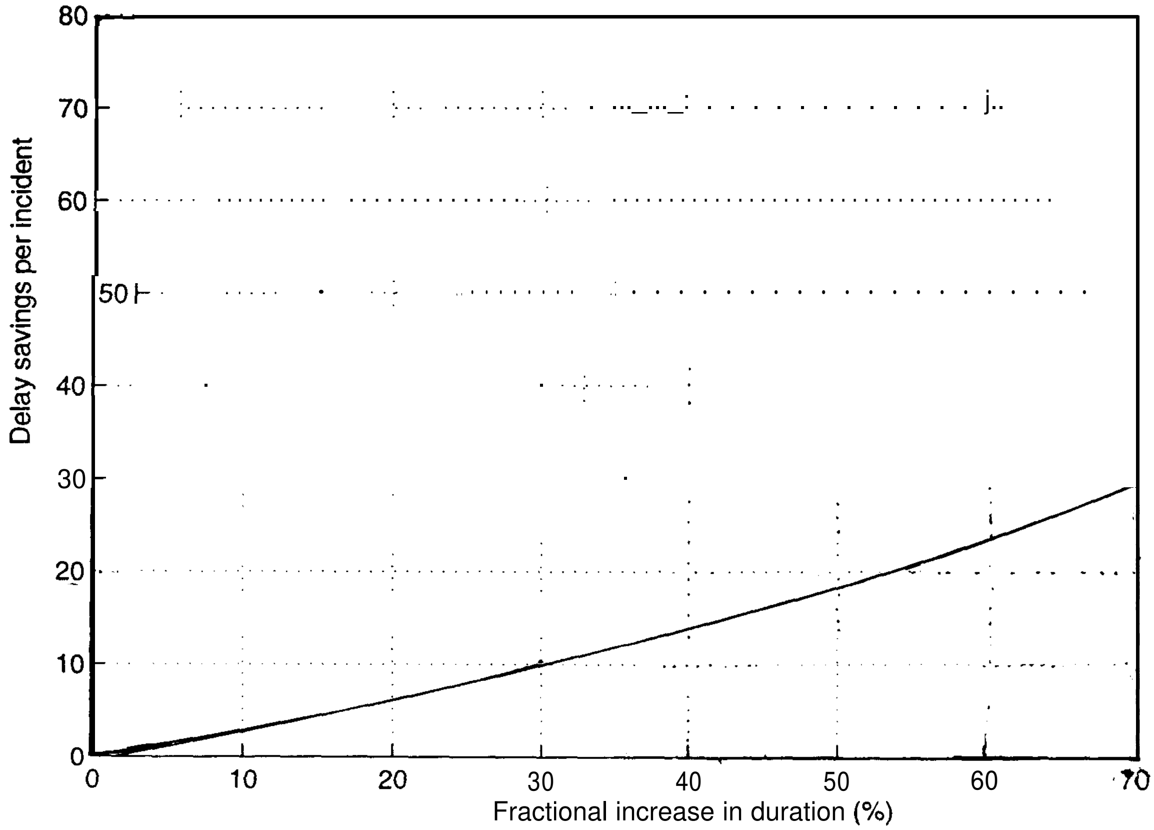


Figure 5.4 Delay Savings (veh-h) vs. Increase in Incident Duration (%)

5.1.2 Fuel Consumption and Emissions

The reduction of congestion delay due to faster response tiie to incidents results in higher average speeds and smoother traffic flows which reduce the amount of excess fuel consumption and air pollutant emissions. The amount of fuel consumption and emissions were calculated for the same assisted incidents for incremental increase in the incident durations as per the delay calculations.

5.1.3 Other Benefits

Benefits to motorists assisted by FSP: Drivers and passengers of the vehicles assisted by FSP receive time savings because of faster response time, and direct cost benefits because of the free service The cost of a tow truck attending a disabled vehicle can range from $5 for refueling to over $60 in case of towing off the freeway.

Benefits to CHP the FSP service results in a fewer number of incidents attended by CHP, and reduction in the time spent assisting motorists with vehicle breakdowns.

Benefits to the freeway operators: FSP service provides faster recovery of the freeway to normal conditions, and improved incident detection capabilities. The FSP roving trucks are able to locate the presence of incidents and report to the TMC and CHP. In addition, the in-vehicle equipment and software could provide information on the average speeds and other fi-eeway operational characteristics, which correlated with other data sources (loop detectors) would improve the TMC surveillance capabilities. A research project sponsored by the PATH program is investigating how FSP may be used as probe vehicles.

Improved safety: FSP vehicles provide a sense of security on the freeway, and the faster clearance of incidents may contribute to avoiding secondary accidents. The determination of the safety improvements, however, requires data on accident rates and traffic volumes on the FSP beats over long time periods.

5.2 FSP Costs

The costs of the FSP service at the test site were provided by the MTA staff (included in Appendix D of the report.) The total cost includes the capital, operating and administrative costs for providing the service, taking into account the hours of operation and the number of the tow trucks involved. The estimated cost per beat-hr is $165.72 for three tow trucks, and the total annual costs for the FSP service in Beat 8 is $33 1,445.67 for 246 service days.

5.3 Cost/Effectiveness

A measure of the FSP program cost-effectiveness was estimated by calculating the benefit/cost ratio based on the daily delay and fuel benefits to the motorists, and the total savings in air pollutant emissions (in Kg). The annual savings in MOEs were first calculated as follows:

$$S_d = s_{di} \ K \qquad (5\text{-}1)$$

where:

S_d: *daily MOE savings*
s_{di}: *MOE savings per incident*
K: number of delay causing incidents/day affected by FSP

The number of incidents affected by FSP was taken from the FSP logs during the study data collection shifts (Table 4.7). A total of 746 incidents were assisted by the FSP tow truck drivers. A portion of those incidents were off the freeway mailine, involved abandoned vehicles, and incidents of short duration as discussed in the analysis of FSP logs. Such incidents (221 assists or 29.6 % of the total) do not affect normal freeway operations. Therefore, the number of FSP assists considered in the evaluation of effectiveness was 746-22 1 = 525 incidents.

FSP operates for eight hours a day on the test site and the field observations and FSP logs (Table 4.7) cover only six hours. A total of 1035 incidents were logged by FSP drivers of which 746 were within the study shift (Table 4.6). Therefore, the 525 incidents in the study shift were adjusted to account for the hours of FSP operation as follows:

$$K = \frac{(\text{Total FSP Assisted Incidents})}{(\text{FSP assists in shift})(\text{days in field study})}(\text{adjusted\# of assists}) \qquad (5\text{-}2)$$

$$K = \frac{1035}{746 * 30}(525) = 24.28 \ \text{incidents/day}$$

The daily savings in the MOEs are summarized in Table 5.1 as a function of reduction in incident duration ranging from 10 to 15 minutes (which corresponds to fractional reduction in duration of about 42 to 63 percent).

The value of time for estimating the delay savings was taken as $10/hr, and the cost of fuel was taken as $1.1 S/gallon (excluding state and local taxes.) These values are the same ones used in the I-880 study (Skabardonis 1995). The calculation of the benefit/cost ratio based on the above assumed monetary value for the delay and fuel consumption MOEs and the reported costs are shown in the bottom of Table 5.1.

TABLE 5.1 FSP PROGRAM BENEFITS

MOE Savings	Reduction in Incident Duration (min) 10	12.5	15
Delay (veh-hr)	462.83	553.66	681.34
Fuel Consumption (gal)	384.02	465.08	579.14
Emissions (Kg)			
HC	50.28	60.15	74.02
CO	394.95	472.46	581.41
Nox	102.4	122.49	150.74
B/C RATIO	**3.8**	**4.6**	**5.6**

CHAPTER 6

CONCLUSIONS

6.1 Summary of the Study Findings

The purpose of this study was to evaluate the effectiveness of the Freeway Service Patrol (FSP) on a specific freeway section in Los Angeles. FSP Beat 8 (a 7.8 mile section of I-10 freeway was selected as the test site. An evaluation methodology was developed to estimate incident delays based on field data from loop detectors and probe vehicles, and derive estimates of savings in performance measures in the absence of data for before FSP conditions.

Field data were collected to develop a comprehensive computerized database which completely describes the traffic conditions along Beat 8 for 32 weekdays, for a total of six hours each day. The database includes detailed descriptions of 1,560 observed incidents, probe vehicle travel time traces for 3,619 runs (at 5.7 minute average headways), and 192 hours of loop detector data (30-second flow and occupancy) from 240 loop detectors. Additional data include the electronic CHP/CAD logs and FSP logs for the entire study period.

The findings from the analysis of the field data and the application of the evaluation methodology are summarized below:

The average frequency was 41 incidents/day during the peak periods (excluding CHP related events). The estimated incident rate was about 93 incidents per million vehicle miles of travel, and there were about 0.4 incidents per directional freeway mile per hour on the study section. Most of the incidents were vehicle breakdowns on the shoulders. Accidents accounted for 6.5 % of all incidents and approximately 10 % of all the incidents were blocking travel lanes. Time-of-day, day-of-the week, and traffic volumes accounted for most of the variabiity in the incident occurrence. The Poisson distribution provided an adequate fit for the observed frequency distribution of breakdowns per data collection shift.

Approximately 56 percent of all the incidents, were observed only once by the probe vehicles. The average duration of all incidents was 19.8 minutes. Incident type, severity and the type of assistance provided were the major factors affecting incident durations. Accidents and lane-blocking breakdowns lasted about 30 minutes on the average; disablements on the freeway shoulders lasted an average of 14 minutes. Assisted incidents lasted 23.6 minutes on the average, and non-assisted incidents 14.3 minutes. Approximately 70 percent of the breakdowns lasted less than 20 minutes, and about 65 percent of the accidents lasted up to 30 minutes.

FSP assisted 1,035 incidents during the field study (1.44 assists/truck-hr). Most of the assisted breakdowns had mechanical or electrical problems, followed by vehicles with flat tires and those that had run out of gas. Approximately 21 % of the assists were for accidents. The average response time for all assisted incidents was 10.8 minutes.

The analysis of the CHP/CAD data and field observations of incidents by USC indicate that incidents have longer response times and durations without FSP service. The USC data from two freeway sites indicate that the average response times without FSP are longer by 15 minutes for all incidents and about 20 minutes for breakdowns. CHP/CAD data indicate that the duration of assisted incidents was on the average 7 minutes longer without FSP during the off-peak periods along the study section.

The estimation of the incident specific delay, fuel consumption and emissions for assessing the FSP effectiveness was based on the difference in average travel speeds under normal and incident conditions using volume data from the loop detectors and probe vehicle speeds. The procedure first determines the exact incident locations and times by matching the data from the incident field logs and the probe vehicles, and the spatial and temporal area of influence of an incident based on the delays along the section calculated from the field data. Next, the average delay savings per incident were determined by modeling each incident with different values of duration, excluding minor stalls of short duration and abandoned vehicles.

- The estimated net benefits based on the average incident delay and fuel savings for a range of typical reductions in incident durations, indicate that FSP produces significant benefits. Estimation of a benefit/cost ratio indicates that the FSP is cost effective. For reduction in duration due to FSP in the order of 15 minutes, the benefit/cost ratio is greater than 5: 1. In addition, daily reductions in air pollutant emissions include a total of 60 Kg of hydrocarbons, 472 Kg of carbon monoxide and 122 kg of oxides of nitrogen.

- The FSP service provided additional benefits that were not included in the calculation of the benefit/cost ratio. The assisted motorists incurred time savings because of the faster response time and direct cost benefits because of the free service provided by FSP (estimated at $70/assist) Also, the FSP service results in fewer incidents attended, and reduction in the time spent on vehicle breakdowns by CHP officers, and serves as an incident detection and verification mechanism. Motorist feedback of surveys indicate that the FSP service receives excellent ratings. Furthermore, the presence of FSP provides a sense of security on the freeway, and the quicker removal of incidents could reduce secondary accidents.

6.2 Recommendations

The results of this study confirm that FSP is a successful, cost-effective operational program. Efforts should be directed to optimally deploying the FSP service on existing or new freeway beats. This in turn, requires a simple yet robust evaluation procedure to estimate the benefits along an existing or proposed beat based on data commonly available to partner agencies. Also, it is important to place the optimal number of required FSP trucks to obtain the maximum net benefit from the service. This study and the previous study on I-880 provide the databases needed to develop improved implementation procedures and guidelines for FSP deployment.

There is a need to investigate and quantify the safety benefits of the FSP service. Such work requires data on accidents, incident patterns and congestion levels over a long period of time. The FSP program, however, has been operational for more than five years in major metropolitan areas of the State, and sufficient data would be available. Furthermore, the database developed in this study could be used to determine the occurrence of accidents shortly after an incident has occurred.

Efforts should be undertaken to maximize the utilization of FSP as a mobile data source for incidents and freeway operating conditions in the context of the advanced traffic management and information systems (ATMIS). In-vehicle equipment and software could provide information on the average speeds and other freeway operational characteristics, which fused with other data sources (e.g., loop detectors, other probe vehicles) would improve the surveillance capabilities in the California TMCs.

The I- 10 field experiment in Los Angeles produced a large comprehensive database on incidents and freeway operating characteristics. The I-10 database, as well as the previously developed I-880 database, provide for the first time recent comprehensive data on freeway incident patterns for a range of operating conditions. These databases and the analyses performed could be used to update the typical values on incident frequency and characteristics, formulate improved guidelines for deployment and evaluation of incident management programs, as well as develop and calibrate improved incident detection algorithms and simulation models.

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APPENDIX A.

TEST SITE SELECTION

Source:

R. Bertini, K. Petty, A. Skabardonis, P. Varaiya, "The Los Angeles Freeway Service Patrol Evaluation: Test Site Selection and Database Development," California PATH Working Paper, UCB-ITS-PWP-97-I 6, University of California at Berkeley, 1997.

TEST SITE SELECTION

This chapter describes the process for selection of the freeway section for the FSP evaluation. The test site should meet several criteria for the successful completion of the study as well as the concerns of all interested parties.

3.1 Proposed Test Sites

Staff from Caltrans District 7, LAMTA and CHP prepared a list of potential sites for the field experiment that satisfy the following criteria (listed in order of importance):

- Functional surveillance system: loop detectors in place that provide reliable data on traffic volumes. Speed and occupancy data are also needed but their accuracy is limited by the existing surveillance system
- Congestion levels: traffic volumes close to or at capacity during the peak periods. Avoid congested locations because of bottlenecks outside the study beat
- Incident frequency: high frequency of incidents/accidents
- Geometries: narrow (or no) shoulders, mixed lanes (no HOV lane) no construction

The list of proposed sites and the degree they satisfy the above criteria was submitted to Caltrans Headquarters and ITS for review. The proposed sites were then ranked based on the above criteria and the top two sites were selected for more detailed evaluation

3.2 Test Site Evaluation Procedure

One of the objectives of this report is to document the procedure used to determine the preferred site for further detailed evaluation. The detailed evaluation will consist of the following steps:

1. Collection of data on the freeway section geometries, lane configurations and detector locations from Caltrans District 7 as-built plans and records.

2. Sample tach car runs will be performed to assess the suitability of the test site for field data collection. Suitable vehicle assembly areas, tach car calibration area and efficient on/off ramp connections will be mapped.

3. Sample loop detector data for the proposed site will be transferred from District 7's Modcomp system and checked for consistency and integrity.

4. Video recording will be performed at the proposed site for comparison with loop detector data in order to assess accuracy of loop data.

3.3 Test Site Proposals

Staff from Caltrans District 7, LAMTA and the CHP prepared a priority list of potential sites for the field experiment. The priority list for ten sites is shown in Table 3-l below.

The primary criteria considered for selecting the beat are:

- High volumes
- High incident frequency
- Narrow/no shoulders
- Relatively high detection density and high percentage of working loops
- Don't discard any beat for HOV or construction, but consider impacts on incident characteristics and impacts on congestion.

The above criteria are not prioritized. The beat which has the best combination of all criteria will be selected. As an additional check on the procedure used to evaluate potential evaluation sites, the FSP database was sorted by Beat using "number of lane blocking incidents" as the primary sort field. This information was then put in the category of "number of lane blocking incidents per centerline mile." One year of data were provided by District 7 staff for the short list, including:

- Beat Number
- Beat length (miles and described by Post Mile)
- Beat - hours of operations
- Number of FSP trucks on beat
- Number of in-lane incidents
- Number of incidents for beat
- Number of travel lanes
- Volume/hour/lane
- Percentage of loops active
- Loop spacing
- Average speed or speed contours

Based on the data provided in Table 3-1, three candidate sites were ultimately chosen for further detailed analysis (Beat 23, Beat 17, and 'Beat 8). After the first tier of additional analysis, Beat 17 was discarded. Subsequent to the final tier of site analysis, Beat 23 was discarded, and Beat 8 was selected as the site for the FSP Evaluation.

TABLE 3-1 TEST SITE PROPOSALS

BEAT EVALUATION

BEAT	FWY	POST MILES	DESCRIPTION	MILES	NO. OF TRUCKS	AM SHIFT	PM SHIFT	TOTAL ASSIST	TOTAL ASSIST INLANE
5,6	405	27.9-37.0	Mulholland to Imperial	9.1	3 + 4	6:00-10:00	3:00-7:00		
17	10	R4.5-13.8	Bundy Dr. to Vermont Ave.	9.3	4	6:30-10:00	2:30-7:00		
7	101	11.6-21.3	SR 134 to Reseda Blvd.	9.7	5	6:00-10:00	3:00-7:00		
16	5	6.8-13.8	I-605 to Eastern Ave.	7.0	4	6:00-9:30	2:30-7:00		
1	110	19.5-27.1	Martin Luther King Blvd. to Ave. 43	7.6	5	5:00-10:00	3:00-7:00	6866	1568
4	5	10.9-21.9	Garfield to Stadium Way/Riverside Dr.	11.1	5	5:45-9:45	2:45-6:45	7476	1215
8	10	20.9-28.7	Eastern Ave. to Santa Anita Ave.	7.8	3	6:00-10:00	3:00-7:00	8287	1008
19	405	0.30-13.8	Normandy Ave. to Orange County Line	13.6	5	6:00-10:00	3:00-7:00	9991	1046
23	710	18.4-27.4	Firestone Blvd. to Valley Blvd.	9	3	6:00-10:00	3:00-7:00	8873	1037
2*	101	4.4-0.00	Vermont Ave. to Jct 10/101 Sep.	9.1	4	6:00-10:00	3:00-7:00	5298	951

TABLE 3-1 TEST SITE PROPOSALS (CONTINUED)

BEAT EVALUATION

BEAT	FWY	POST MILES	DESCRIPTION	NO. LOOP STATIONS	% ACTIVE LOOPS	LOOPS /MILE	TRAFFIC VOLUME (AADT)
5,6	405	27.9-37.0	SR 187 to Mulholland Dr.	21	77.0	0.80	284,009
17	10	R4.5-13.8	Bundy Dr. to Vermont Ave.	29	93.0	0.25	248,000
7	101	11.6-21.3	SR 134 to Reseda Blvd.	17	100.0	1.63	290,000
16	**5**	**6.8-13.8**	I-605 to Eastern Ave.	**16**	**85.0**	**0.75**	**267,000**
1	**110**	**19.5-27.1**	**Martin Luther King Blvd. to Ave. 43**	**9**	**64.2**	**1.30**	**289,000**
4	**5**	**10.9-21.9**	**Garfield to Stadium Way/Riverside Dr.**	**34**	**75.6**	**0.70**	**247,000**
8	**10**	**20.9-28.7**	**Eastern Ave. to Santa Anita Ave.**	**49**	**87.6**	**0.34**	**249,000**
19	**405**	**0.30-13.8**	**Normandy Ave. to Orange County Line**	**37**	**55.4**	**0.74**	**240,000**
23	**710**	**18.4-27.4**	**Firestone Blvd. to Valley Blvd.**	**16**	**73.6**	**0.91**	**193,000**
2*	**101**	**4.4-0.00**	**Vermont Ave. to Jct 10/101 Sep.**	**16**	**86.1**	**0.61/0.39**	**237,000**

Notes:
1. AADT is Annual Average Daily Traffic from the 1994 Traffic Volumes on California State Highways.
2. Loops Active is an estimate of loop condition estimated from Modcomp.
3. Number of Loops is total number of northbound and southbound detector stations.
4. Beat 2* covers Routes 101,5 & 10:
   101 = PM 4.4 to PM 0.0, Vermont Ave. JCT 10/101 Sep.
   101 = PM 1.3 to PM 0.0, JCT 10/101 Sep. St 10/5 Sep. 53-1367L
   5 = PM 16.9 to 16.1, JCT 5/10/101 Sep. 53-1367 - Euclid Ave.
   10 = PM 20.9 to PM 18.3, Eastern Ave. - JCT 1 0/5/1 01 Sep.

TABLE 3-1 TEST SITE PROPOSALS (CONTINUED)

BEAT EVALUATION

			AM OPERATION		PM OPERATION		TOTAL	
BEAT	FWY	DIR	HOURS OF CONGESTION	AVG SPEED	HOURS OF CONGESTION	AVG SPEED	HOURS OF CONGESTION	AVE SPEED
5,6	405	N/B	0715-1000 (2:45)	31	1530-1915 (3:45)	26	6:30	28
		S/B	0615-1000 (3:45)	31	1515-2000 (4:45)	22	8:30	26
17	10	E/B	0700-0945 (2:45)	26	1645-1945 (3:00)	33	5:45	27
		W/B	0715-0915 (2:00)	27	1645-1945 (3:00)	30	5:00	29
7	101	N/B	0745-0900 (1:15)	37	1445-1930 (4:45)	22	6:00	18
		S/B	0700-0945 (2:45)	26	1500-1915 (4:15)	27	7:00	26
16	5	N/B	0630-0900 (2:30)	32	--	X	2:30	32
		S/B	--	X	1545-1930 (3:45)	30	3:45	30
1	110	N/B	0630-1000 (3:30)	29	1500-1915 (4:15)	21	7:45	25
		S/B	0645-0930 (2:45)	27	1500-1915 (4:15)	25	7:00	26
4	5	N/B	0615-1000 (3:45)	24	1500-1830 (3:30)	27	7:15	26
		S/B	0700-0845 (1:45)	27	1615-1845 (2:30)	31	4:15	28
8	10	E/B	--	X	1615-1915 (3:00)	26	3:00	26
		W/B	0630-0915 (2:45)	26	--the	X	2:45	26
19	405	N/B	0630-0900 (2:30)	42	--	X	2:30	42
		S/B	--	X	1545-1915 (3:30)	29	3:30	29
23	710	N/B	0645-0915 (2:30)	31	1645-1845 (2:00)	36	4:15	33
		S/B	--	X	1615-1830 (2:15)	29	2:15	29
2*	101	N/B	0630-0915 (2:45)	20	1645-1845 (2:00)	19	4:45	19
		S/B	0645-0900 (2:15)	32	1645-1900 (2:45)	19	5:00	25

Notes:
1. Hours of congestion are estimated from 1994 HICOMP Report.
2. X means not congested.

3.4 Test Site Congestion and Speeds

Since the congestion level is an important characteristic for the sites in question, the 1994 Statewide Highway Congestion Monitoring Program (HICOMP) Report was consulted next in order to get a general sense of average speeds during morning and afternoon peak congested periods. These speeds are shown in Table 3-l. The data summarized in Table 3-l will now be evaluated in order to make a preliminary recommendation of a specific site for further evaluation.

3.5 Preliminary Site Evaluation

According to the evaluation criteria described above, a process of comparison and elimination has been undertaken in order to arrive at a preliminary recommendation of sites for detailed evaluation. Table 3-l **is** the primary source of information relating to the suitability of the ten candidate sites. Table 3-2 has also been prepared in order to summarize the assessments of the sites.

The Bay Area FSP Evaluation was conducted on Route 880 in Alameda County. The following discussion includes some level of comparison of the Los Angeles sites to the Bay Area sites.

Functional Loop Detectors

In concert with the critical nature of the real time loop data, Beat 7 and Beat 1 were eliminated from further consideration due to the relatively large loop spacings (greater than one mile in both cases). Also, the estimate that only 67% of the loops on Beat 1 also results in the elimination of Beat 1. The "functional density" for the remaining Beats can now be calculated. For this analysis, the functional density is simply the distance between loops multiplied by the estimated percentage of active loops. Functional density for the remaining beats is shown in Table 3-2.

Therefore, from strictly a "functional loop density" standpoint, Beats 8 and 17 appear to be the optimal choices. In addition, Beats 5, 6, and 19 were discarded primarily due to a "functional loop density" less than one per mile. As a means of comparison to the Bay Area FSP study, the functional loop density for Route 880 is 2.90, which compares most closely with Beats 8 and 17 in Los Angeles.

Congestion Levels

In terms of AADT, all Los Angeles freeway segments have AADT greater than 200,000 vehicles per day, ranging from 205,000 to 284,000 vehicles per day. As shown in Table 3-1, congestion levels (as represented by speeds) vary significantly over the segments under consideration, as does the directionality of congestion. Several segments are highly directional, while portions of others are congested during both peak periods. This is especially true for segments that include major bottlenecks such as freeway-to-freeway interchanges. Beats 1, 5, 6, 7 and 19 were eliminated from consideration due to the unfavorable loop detector functionality. Therefore, Beats 2,4,8, 16, 17 and 23 will be assessed from the perspective of AADT and congestion. The term "directionality" is used to indicate whether there is only congestion on the particular segment in the peak direction. Table 3-2 shows the AADT for each route, along with an assessment of the "directionality" of congestion.

From this analysis, it appears that Beats 17,4, and 2 would be most desirable for analysis, since there is some level of congestion in both directions during both peak periods. From a strictly volume perspective, it is noted that Beats 16, 8, 17, and 4 have the highest daily estimated volumes, near 250,000 vehicles per day in all cases. We note that Route 880 had an AADT of approximately 180,000 vehicles per day, so all segments meet the criterion of having higher volume.

Assisted Incident Frequency

Several data series from Table 3-1 were next converted to provide the total number of assisted in-lane incidents per mile. This was done by dividing the total number of in-lane assists by the length of the beat in miles. The results for all ten beats under consideration are shown in Table 3-2. As shown, Beat 8 and Beat 23 have the highest numbers of in-lane assists since inception of the FSP program.

Geometries

By studying the shoulder ratings in Table 3-2, it is noted that there is not an excessive variation in shoulder characteristics. A lower weight has been assigned to the shoulder width as an evaluation criterion, since all segments have at least a 3.5-foot shoulder. In terms of comparison to Route 880, it is noted that the Bay Area segment has relatively good shoulders (minimum 8 feet) for most of the segment. A potential disadvantage of Beat 17 are the "continuous" auxiliary lanes and weaving maneuvers for most of the segment length. Beat 23 is also characterized by good, wide shoulders for the majority of its length, as is Beat 8. Beat 8 is somewhat complicated by the presence of the El Monte HOV facility, which includes one HOV lane in each direction.

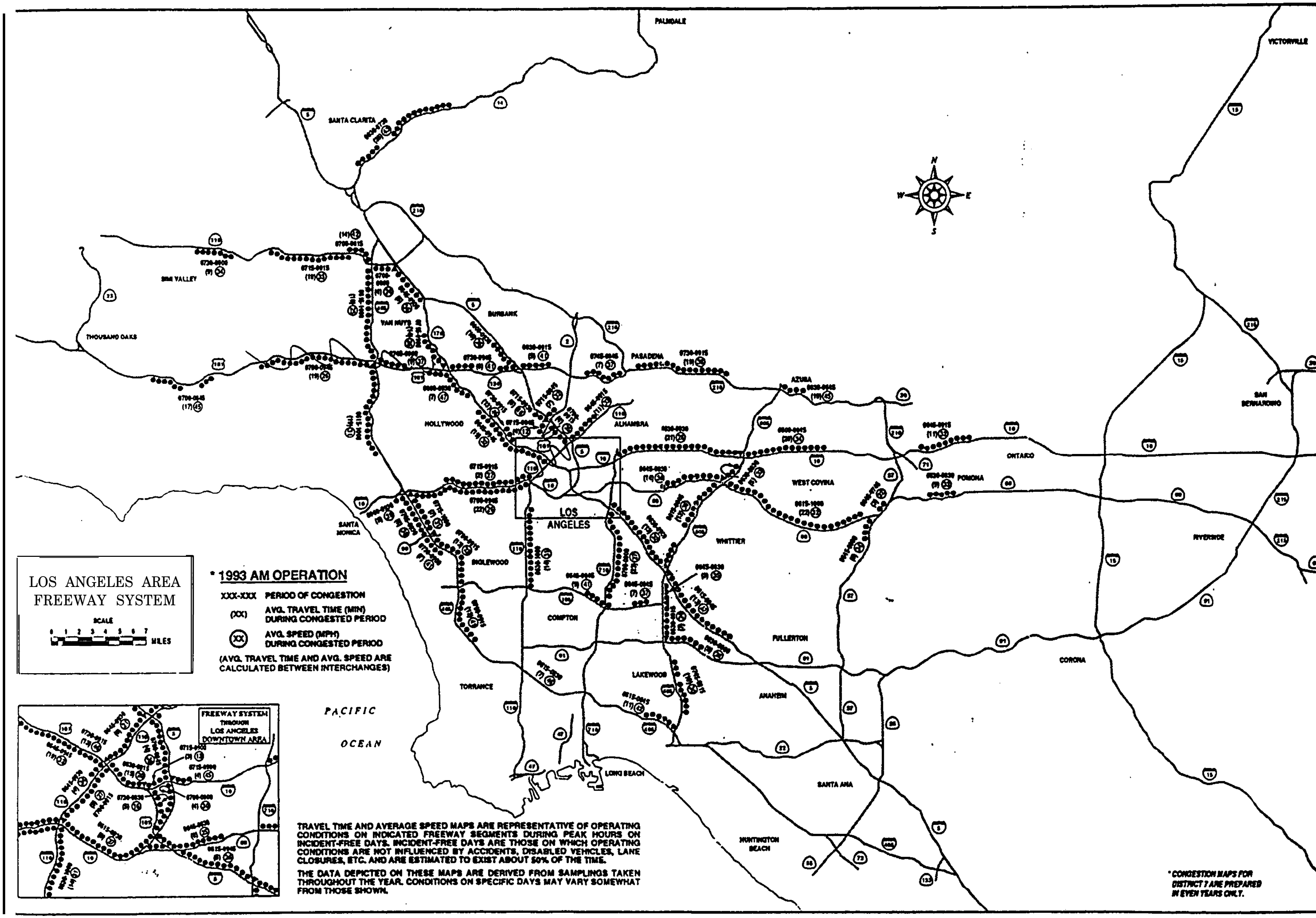
3.6 Preliminary Summary

Based on the above discussion, the key criteria are summarized in Table 3-2:

TABLE 3-2 SUMMARY TABLE

Beat	Route	Shoulder Rating	In-Lane Assists per mile	AADT	Directionality	Functional Loop Density
Bay Area	*880*	*8*		*180,000*	*Yes*	*2.90/mile*
5, 6	405	8		284,000	AM Yes PM No	0.97
17	10	8		248,000	No	3.80
7	101	5		290,000	Mixed	0.61
16	5	4		267,000	Yes	1.14
1	110	4.5	206	224,000	No	0.59
4	5	7	109	247,000	No	1.09
8	10	8	129	249,000	Yes	2.58
19	405	8	77	240,000	Yes	0.75
23	710	5	115	205,000	Yes	1.30
2	101	3.5	105	237,000	No	1.72

As discussed above, Beats 1, 4, 5, 6, 7, and 19 were discarded due to the undesirable working loop density (due primarily to large loop spacing). It has also been said that Beats 17, 8 and 23 appear to exhibit desirable congestion characteristics, particularly in comparison with Route 880 and consistent with the objective of studying a freeway segment with high AADT. Next, the incident rates (per mile) of the candidate beats have been compared to and it has been found that Beats 8 and 23 have favorable numbers. As shown on the HICOMP maps (Figures 3-1 and 3-2), much of Beat 23 is uncongested (south of Route 105). However, within Beat 23, Route 710 peak period speeds are relatively close to those on Beat 8 and Beat 17. However, the congestion on Beat 23 may be influenced by other freeways. Based on the above analysis it is proposed to look more closely at Beats 17, 23 and 8.


LOS ANGELES AREA
FREEWAY SYSTEM
SCALE
0 1 2 3 4 5 6 7
MILES
* 1993 AM OPERATION
XXX-XXX PERIOD OF CONGESTION
(XX) AVG. TRAVEL TIME (MIN) DURING CONGESTED PERIOD
XX AVG. SPEED (MPH) DURING CONGESTED PERIOD
(AVG. TRAVEL TIME AND AVG. SPEED ARE CALCULATED BETWEEN INTERCHANGES)
FREEWAY SYSTEM THROUGH LOS ANGELES DOWNTOWN AREA
PALMDALE
VICTORVILLE
SANTA CLARITA
SIMI VALLEY
THOUSAND OAKS
BURBANK
VAN NUYS
PASADENA
AZUSA
HOLLYWOOD
ALHAMBRA
LOS ANGELES
WEST COVINA
ONTARIO
POMONA
SAN BERNARDINO
RIVERSIDE
SANTA MONICA
INGLEWOOD
WHITTIER
COMPTON
FULLERTON
CORONA
TORRANCE
LAKEWOOD
ANAHEIM
LONG BEACH
SANTA ANA
HUNTINGTON BEACH
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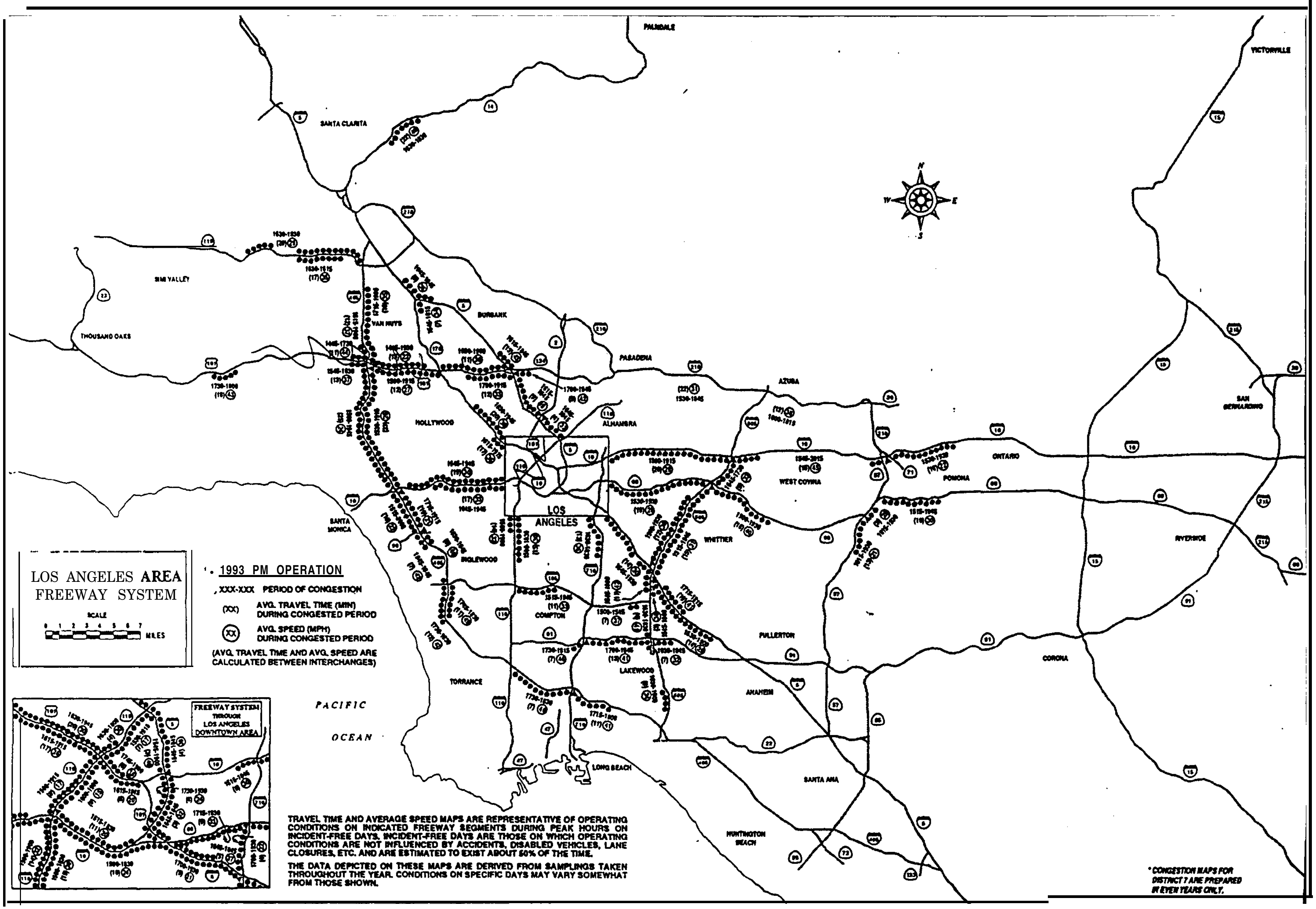
TRAVEL TIME AND AVERAGE SPEED MAPS ARE REPRESENTATIVE OF OPERATING CONDITIONS ON INDICATED FREEWAY SEGMENTS DURING PEAK HOURS ON INCIDENT-FREE DAYS. INCIDENT-FREE DAYS ARE THOSE ON WHICH OPERATING CONDITIONS ARE NOT INFLUENCED BY ACCIDENTS, DISABLED VEHICLES, LANE CLOSURES, ETC. AND ARE ESTIMATED TO EXIST ABOUT 50% OF THE TIME.
THE DATA DEPICTED ON THESE MAPS ARE DERIVED FROM SAMPLINGS TAKEN THROUGHOUT THE YEAR. CONDITIONS ON SPECIFIC DAYS MAY VARY SOMEWHAT FROM THOSE SHOWN.
* CONGESTION MAPS FOR DISTRICT 7 ARE PREPARED IN EVEN YEARS ONLY.


LOS ANGELES AREA FREEWAY SYSTEM
SCALE
0 1 2 3 4 5 6 7 MILES
1993 PM OPERATION
XXX-XXX PERIOD OF CONGESTION
(XX) AVG. TRAVEL TIME (MIN) DURING CONGESTED PERIOD
(XX) AVG. SPEED (MPH) DURING CONGESTED PERIOD
(AVG. TRAVEL TIME AND AVG. SPEED ARE CALCULATED BETWEEN INTERCHANGES)
FREEWAY SYSTEM THROUGH LOS ANGELES DOWNTOWN AREA
PALMDALE
VICTORVILLE
SANTA CLARITA
SIMI VALLEY
THOUSAND OAKS
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SANTA MONICA
INGLEWOOD
WEST COVINA
WHITTIER
POMONA
ONTARIO
SAN BERNARDINO
RIVERSIDE
COMPTON
FULLERTON
TORRANCE
LAKEWOOD
ANAHEIM
CORONA
LONG BEACH
SANTA ANA
HUNTINGTON BEACH
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TRAVEL TIME AND AVERAGE SPEED MAPS ARE REPRESENTATIVE OF OPERATING CONDITIONS ON INDICATED FREEWAY SEGMENTS DURING PEAK HOURS ON INCIDENT-FREE DAYS. INCIDENT-FREE DAYS ARE THOSE ON WHICH OPERATING CONDITIONS ARE NOT INFLUENCED BY ACCIDENTS, DISABLED VEHICLES, LANE CLOSURES, ETC. AND ARE ESTIMATED TO EXIST ABOUT 50% OF THE TIME.
THE DATA DEPICTED ON THESE MAPS ARE DERIVED FROM SAMPLINGS TAKEN THROUGHOUT THE YEAR. CONDITIONS ON SPECIFIC DAYS MAY VARY SOMEWHAT FROM THOSE SHOWN.
* CONGESTION MAPS FOR DISTRICT 7 ARE PREPARED IN EVEN YEARS ONLY.

3.7 Detailed Test Site Evaluation

Wiltec has been retained for the traffic data collection efforts. In order to verify the congested speed estimates for Beat 23 and Beat 17, Wiltec performed some travel time and speed runs along the freeways on Tuesday, December 5,1995, during the **AM** and **P.M.** peak periods. Beat 8 was not subjected to this travel time test since the site is near Beat 17.

This preliminary survey was very simple, but has provided some valuable information. A summary of the data collected appears in Table 3-3. Results of these travel time surveys are shown in Figures 3-3 and 3-4.

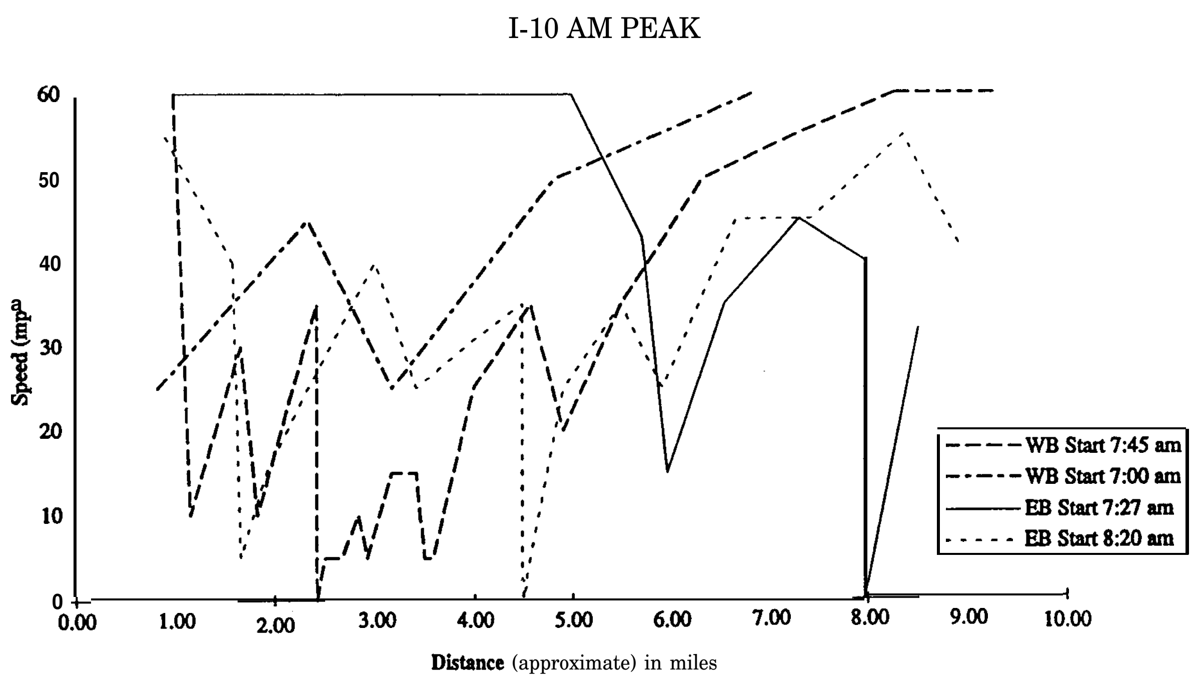
On Beat 23, in general higher speeds are more prevalent. In fact, for the A.M. peak there is tight bunching of speeds between 50 mph and 60 mph in the southbound direction. Northbound **A.M.** peak traffic exhibits stop-and-go characteristics. The **P.M.** peak exhibits higher variability, with some stretches of up to 70 mph travel.

On Beat 17, the average speeds are also relatively high. However, there are several periods of very low speeds, with many more fluctuations. Opposite to Beat 23, Beat 17 exhibits greater variability during the **P.M. peak** period.

TABLE 3-3 SUMMARY OF TRAVEL TIME RUNS - DECEMBER 5,1995

Beat 17	**Start Time**	9.29 Miles	**Time (min)**	**Average Speed**
AM	7:00	W	10	56
	7:27	E	12	46
	7:45	W	23	24
	8:20	E	17	33
PM	4:00	W	9	62
	4:14	E	9	62
	4:29	W	11	51
	5:03	E	10	56
	5:18	W (Acc.)	16	35
	5:43	E	12	46
Beat 23	**Start Time**	**19.59 Miles**	**T i e (min)**	**Average Speed**
	7:00	S	19	62
	7:26	N	33	36
	8:03	S	20	59
	8:33	N	20	59
	4:00	S	25	47
	4:27	N	29	41
	4:58	S	32	37

FIGURE 3-3 I-10 A.M. AND P.M. PEAK



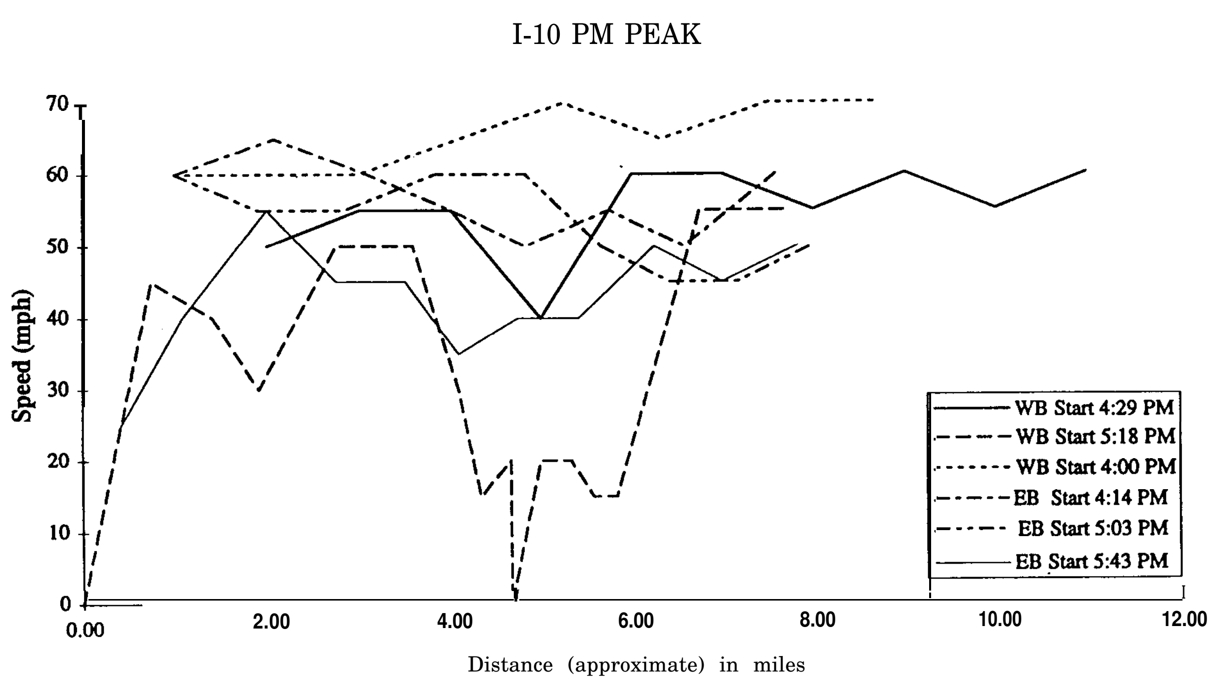
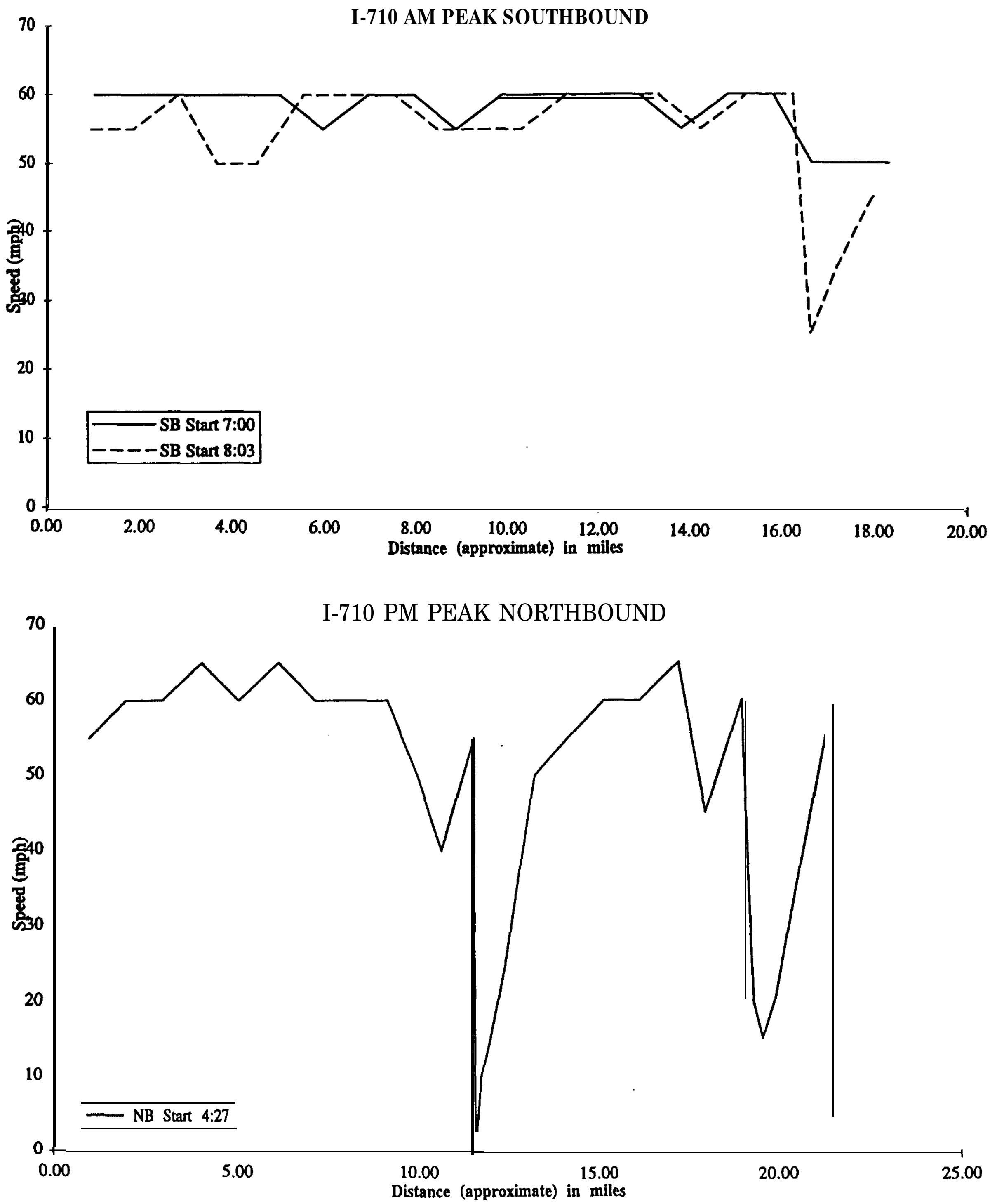


FIGURE 3-4 I-710 A.M. AND P.M. PEAK



3.8 Refinement of Sites for Further Analysis

Subsequent to the travel time runs on Beat 17, and based on discussions with Caltrans, CHP and the LAMTA, Beat 17 was eliminated as a candidate site. The presence of continuous auxiliary lanes was a major determinant in making this decision. It was felt that the presence of auxiliary lanes would mask the potential congestion reduction benefits achieved with the implementation of the FSP program. This meant that only Beat 23 and Beat 8 were subjected to the final stage of site selection analysis, as described below.

3.9 Beat 23 (Route 710) Loop Data Assessment

The preliminary site selection analysis has led to the performance of further detailed analysis on the Route 710 (Long Beach Freeway) site, approximately between the Junction with Pacific Coast Highway in Long Beach (PM 7.887) and just north of the Gravois Avenue Overcrossing in Alhambra, approximately one mile north of the Route 10 Junction (PM 27.387). This corresponds to FSP Beats 23 and 30.

From ***the*** Caltrans/Maxwell ***Laboratories Southern California' Only Online Real-Time Traffic Reports*** page on the World Wide Web (http://www.scubed.com/caltrans/transnet.html),a list of "sensor locations" was also obtained which provide real time traffic speed data over the Internet. There are 24 Southbound "sensors" listed and 20 Northbound "sensors," for a total of 44. Each of these sensors appears to be producing a reasonable speed range indicator; for 35 MPH, 20-35 MPH, and < 20 MPH. These ranges are indicated by green, yellow and red dots, respectively. This provides some level of preliminary confidence that loop detectors are working out in the field and providing data to the Modcomp computer.

District 7 also provided an Ordered Freeway Printout from Modcomp covering this portion of Route 710 listing data for 25 Southbound and 25 Northbound loop detector zones, for a total of 50. These data are summarized on the attached Table 3-4 and Table 3-5 for Northbound and Southbound Route 710. It is noted that there are seven "zones" which do not appear as "sensor locations" on the Internet, and there is one sensor location that appears twice. This accounts for the difference of 6 (50 - 44) which was observed.

TABLE 3-4 NORTHBOUND ROUTE 710 ZONES

NORTHBOUND ROUTE 710

Roadway 31

Postmile	Cross Street	Zone	Up Zone	Down Zone	Modem No.	Controller Number	Field 170 Loc. No.	0 Installed	1 Operational	2 Mainline Detectors	3 On Ramp Detectors	4 Metered	5 Instrumented	6 Off Ramp	7 Instrumented	8 Coll/Dist	9 Instrumented	A Opp. Side Detectors	B Secondary Side	C Zone Diverge	D Zone Converge	E Zone Converge	F Unused
9.72	Pacific	123	0	151	9	2	450	Yes	Yes	No	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No
10.69	Del Amo 1	151	123	126	9	16	451	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No
11.00	Del Amo 2	126	151	264	9	17	452	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No
12.13	Long Beach	264	126	715	24	5	453	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No
13.25	Atlantic	715	264	401	24	6	454	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No
14.10	Alondra	401	715	1807	24	13	455	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No
14.38	Compton	1807	401	403	24	1	2209	Yes	Yes	Yes	No	No	No	No	No	No	No	Yes	Yes	No	No	No	No
14.90	Rosecrans 1	403	1807	404	6	17	456	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
15.10	Rosecrans 2	404	403	1804	6	18	457	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No
15.30	S of 105	1804	404	1647	6	15	2647	Yes	Yes	Yes	No	No	No	No	No	No	No	Yes	Yes	No	No	No	No
15.90	King 1	1647	1804	720	24	7	458	Yes	Yes	Yes	No	No	No	No	No	No	No	Yes	Yes	No	No	No	No
16.10	Fm Rt 105	720	1647	1650	24	18	2902	Yes	Yes	Yes	No	No	No	No	No	Yes	Yes	No	No	No	Yes	No	No
16.50	King 2	1650	720	405	24	20	2210	Yes	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	No	No	No	No
16.90	Imperial 1	405	1650	130	24	15	462	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
17.05	Imperial 2	130	405	399	24	16	463	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No
18.42	Firestone 1	399	130	400	16	12	464	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No
18.51	Firestone 2	400	399	154	16	13	465	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No
19.50	Florence 1	154	400	132	16	2	466	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No
19.76	Florence 2	132	154	661	16	1	467	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No
22.14	Atlantic 2	661	132	663	16	20	695	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
22.54	Washington	663	661	900	16	16	468	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
23.16	S of 5	900	663	133	16	11	312	Yes	Yes	Yes	Yes	No	No	No	No	No	No	Yes	No	No	No	No	No
23.50	Olympic	133	900	897	16	5	469	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No
24.31	S of 60	897	133	134	23	4	2359	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
24.43	Third	134	897	0	23	6	470	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No

TABLE 3-5 SOUTHBOUND ROUTE 710 ZONES

SOUTHBOUND ROUTE 710

Roadway 32								0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
Postmile	Cross Street	Zone	Up Zone	Down Zone	Modem No.	Controller Number	Field 170 Loc. No.	Installed	Operational	Mainline Detectors	On Ramp Detectors	Metered	Instrumented	Off Ramp	Instrumented	Coll/Dist	Instrumented	Opp. Side Detectors	Secondary Side	Zone Diverge	Zone Converge	Zone Converge	Unused
24.85	Brooklyn	139	0	140	23	8	472	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No
24.54	Third	140	139	896	23	9	473	Yes	Yes	Yes	No	Yes	Yes	No	No	No	No	No	No	No	No	No	No
24.30	S of 60	896	140	822	23	5	2539	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes	No	No	No	No	No	No
23.71	Eastern	822	896	143	23	10	2255	Yes	Yes	Yes	No	No	No	Yes	No	No	No	No	No	No	No	No	No
23.47	Olympic	143	822	1900	16	6	474	Yes	Yes	Yes	No	Yes	Yes	No	No	No	No	No	No	No	No	No	No
23.16	S of 5	1900	143	407	16	11	312	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes	Yes	No	No	No	No
22.53	Washington	407	1900	408	16	17	475	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No
21.95	Atlantic 2	408	407	145	16	18	476	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No
19.76	Florence 2	145	408	161	16	3	478	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No
19.50	Florence 1	161	145	410	16	4	479	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	No	No	No	No
18.51	Firestone 2	410	161	411	16	14	480	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No
18.42	Firestone 1	411	410	146	16	15	481	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
16.98	Imperial 2	146	411	147	24	17	482	Yes	Yes	No	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No
16.92	Imperial 1	147	146	635	24	14	483	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No
16.50	King 2	635	147	634	24	20	2210	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	No	No	No	No	No
15.90	King 1	634	635	1004	24	7	458	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	Yes	No	No	No	No	No
15.30	S of 105	1004	634	719	6	15	2647	Yes	Yes	Yes	No	No	No	No	No	No	No	Yes	No	No	No	No	No
15.25	Fm Rt 105	719	1004	797	6	19	2901	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No
15.01	Rosecrans 2	797	719	796	24	11	459	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No
14.73	Rosecrans 1	796	797	1007	24	8	460	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
14.38	Compton	1007	796	152	24	1	2209	Yes	Yes	Yes	No	No	No	No	No	No	No	Yes	No	No	No	No	No
13.83	Alondra	152	1007	962	24	12	461	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No
13.11	N of 91	962	152	367	24	3	2313	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No	No
11.89	Long Beach	367	962	153	24	4	88	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No
10.95	Del Amo 1	153	367	0	9	18	84	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No

Preliminary Loop Data Analysis

This is a preliminary analysis of the loop detector data received from Caltrans for the Los Angeles area. This analysis is being conducted for two reasons. The first is to make sure that the loop data are being read and interpreted correctly. There was some initial concern about matching zones to loop detectors or matching up lanes with offsets in each data record. The second reason that this analysis has been done is to verify what loop detectors are working correctly. If there is a discrepancy in what loops appear to be working then a clear understanding is necessary.

The data that were provided by Caltrans District 7 are for two days, November 6 and 7, 1995. The zone to loop detector mapping was also provided by Caltrans District 7. The program written by Cheu, Prosser and Ritchie (UC Irvine) and the mapping provided by Caltrans were used to extract the data from the tapes. (7) To automate the loop data verification process a small analysis program was written to read in the occupancy files and generate some statistics. The statistics were generated for every detector site and every lane. Hence, for each direction there were 22 detectors x 4 lanes = 88 numbers per day.. Note that zone 634 in the southbound direction could not be found on the tapes. The statistics that we choose to generate were:

- Number of data points above 50% occupancy.
- Number of data points between 50% and 0% occupancy.
- Number of data points below 0% occupancy.
- Mean of the occupancy.
- Standard deviation of the occupancy.

The value of 50% occupancy was chosen as a threshold based on experience with the I-880 30-second data. These statistics were used to look for things in the data that were visibly not valid, such as a case where the output was always 32. Note that these tests are only detailed enough to determine if the data is not being reported. More detailed tests will be needed to determine if the thresholds are set correctly and if the detectors are over- or under-counting. An example of the output for the southbound direction for lane 2 is given in Table 3-6. In this table, an example of a loop detector that is not valid is in zone #1007. Here the output is always below 0 which indicates that there are no data for these time periods. If, for example, a loop detector is deemed not valid if the mean occupancy is less than zero, then from this table it turns out that on November 7, 1995 there were 9 invalid loop detectors in lane 2.

TABLE 3-6 SAMPLE STATISTICS FOR NOVEMBER 7,1995 SB LANE 2

Zone#	#Points	#Pts > 50	50≥#Pts≥ 0	0 > #Pts	Mean	Std Dev
139	2341	0	2191	150	6.3	3.86
140	2341	0	2300	41	4.4	3.17
896	2341	0	0	2341	-1.0	0.00
822	2341	59	2089	193	11.9	12.02
143	2341	43	2297	1	10.2	11.23
1900	2341	114	1898	329	15.3	18.45
407	2341	62	2278	1	11.5	14.88
408	2341	0	0	2341	-1.0	0.00
145	2341	0	0	2341	-1.0	0.00
410	2341	0	2337	4	-0.0	0.04
411	2341	2	2335	4	10.8	5.69
147	2341	0	2279	62	-0.0	0.16
635	2341	0	2022	319	4.7	3.58
1004	2341	0	2290	51	7.1	3.87
719	2341	0	2321	20	7.0	3.73
797	2341	0	1852	489	-0.1	1.54
796	2341	0	2312	29	-0.0	0.11
1007	2341	0	0	2341	-1.0	0.00
152	2341	0	2136	205	9.5	6.50
962	2341	0	2340	1	5.9	3.23
367	2341	0	2339 2		-0.0	0.03
153	2341	0	2338	3	6.8	5.36

To determine if a loop detector was not providing proper data, the mean occupancy was first examined. If this was less than zero then the loop detector was automatically labeled invalid. If the occupancy was reasonable then the standard deviation was examined to make sure there was some variance around the mean. In cases that seemed odd (like the variance was very low or very high) plots of the occupancy versus time were constructed to verify what was occurring. So while most of the analysis was determined by only looking at the means and variances, there were some cases where it was determined that the detectors were invalid from studying the actual occupancy plots. The findings are summarized in Table 3-7. These tables list the total number of invalid detectors in each lane in each direction. So, on November 7, 1995 there were a total of 5 1 invalid loop detectors out of 176 leaving only 7 1% of the detectors working. This results in a functional loop density of approximately 1.1 loops per mile.

Perhaps something worth knowing is which loops are invalid on both days (instead of those that are periodically questionable). These would probably correspond to loop detectors that are definitely in need of repair. Table 3-8 is a list of the loop detectors that were found to be invalid on both days.

TABLE 3-7 INVALID LOOPS

November 6,1995

	Lane Number				
Direction	1	2	3	4	**Total**
North	4	4	5	7	20
South	6	9	7	7	29
Total	10	13	12	14	49

November 7,1995

	Lane #				
Direction	**1**	**2**	**3**	**4**	**Total**
North	4	4	5	7	20
south	6	9	9	7	31
Total	10	13	14	14	57

TABLE 3-8 INVALID ON BOTH DAYS

Zone	Lane#			
	1	2	3	4
North				
1807	x	x	x	x
404	x	x	x	x
1647				x
405	x	x	x	x
132	x	x	x	x
897				x
134				x
South				
896	x	x	x	x
1900				x
408	x	x	x	x
145	x	x	x	x
410		x		
147	x	x	x	
797	x	x	x	x
796	x	x	x	
1007	x	x	x	x
367		x		x

Subsequent to this analysis there were some concerns, particularly whether the loops listed in Table 3-8 were definitely invalid. It was also observed that some loops seem to sporadically go out on some days, and it was hoped that there would be some opportunity to repair some detectors prior to commencing the data collection effort.

3.10 Beat 8 (Route 10) Loop Data Assessment

Based on the test site proposals, it was determined that Beat 8 along Route 10 should be given the same level of scrutiny as Beat 23 along Route 710. Therefore, an extensive site analysis for Beat 8 was also performed. Beat 8 is located on Route 10 from PM 20.9 to PM 28.7. The list of good loop detectors is provided in Table 3-9. The list of invalid detectors for December 7, 1995 is given in Table 3-10 below. An x marks a nonfunctioning loop detector.

TABLE 3-9 NUMBER OF GOOD LOOPS FOR DECEMBER 7,1995

Direction	Lane Number				Total
	1	2	3	4	
East	1 1/25	10/25	7/25	10/25	38/100
West	10/25	10/25	11/25	10/25	41/100
Total	21/50	20/50	18/50	20/50	79/200

A sample of the statistics for December 7, 1995 for lane 4 for the eastbound and then the westbound loops are given in Tables 3-11 and 3-12 below.

TABLE 3-10 INVALID LOOPS BEAT 8

Eastbound December 7, 1995

	Lane			
Zone	1	2	3	4
942	x	x	x	x
941	x	x		
940				x
968	x	x	x	x
998	x	x	x	x
752	x	x	x	x
972	x	x	x	x
483	x	x	x	x
484	x	x	x	x
486				
485				
1581	x	x	x	x
482				
481				
436				
444				
449				
445				
446				
440	x	x	x	x
447	x	x	x	x
448	x	x	x	x
1653	x	x	x	x
450	x	x	x	x
452	x	x	x	x

Westbound December 7, 1995

	Lane			
Zone	1	2	3	4
451				
1585		x	x	x
453	x	x	x	x
1594	x	x	x	x
454	x	x	x	x
455	x	x	x	x
456	x	x	x	x
458				
457				
437				
438				
466				
472				
996			x	
476			x	
474			x	
473	x	x	x	x
475	x	x	x	x
997	x	x	x	x
751	x	x	x	x
971	x	x	x	x
818	x	x	x	x
1565	x	x	x	x
1573	x	x	x	x
1566	x	x	x	x

TABLE 3-11 SAMPLE STATISTICS FOR DECEMBER 7, 1995, EASTBOUND LANE 4

Zone	No. Points	#>50	50>#>0	0>#	Mean	Std. Dev.
942	2341	0 (0.00)	1154 (0.49)	1187 (0.51)	-0.5	0.50
941	2341	36 (0.02)	1118 (0.48)	1187 (0.51)	4.8	10.95
940	2341	0 (0.00)	623 (0.27)	1718 (0.73)	-0.3	1.42
968	2341	0 (0.00)	0 (0.00)	2341 (1.00)	-1.0	0.00
998	2341	0 (0.00)	0 (0.00)	2341 (1.00)	-1.0	0.00
752	2341	0 (0.00)	0 (0.00)	2341 (1.00)	-1.0	0.00
972	2341	0 (0.00)	0 (0.00)	2341 (1.00)	-1.0	0.00
483	2341	0 (0.00)	0 (0.00)	2341 (1.00)	-1.0	0.00
484	2341	0 (0.00)	0 (0.00)	2341 (1.00)	-1.0	0.00
486	2341	4 (0.00)	1146 (0.49)	1191 (0.51)	2.9	5.95
485	2341	5 (0.00)	1146 (0.49)	1190 (0.51)	5.8	8.60
1581	2341	1154 (0.49)	0 (0.00)	1187 (0.51)	55.2	57.01
482	2341	4 (0.00)	1146 (0.49)	1191 (0.51)	5.6	8.66
481	2341	7 (0.00)	1141 (0.49)	1193 (0.51)	3.6	6.89
436	2341	9 (0.00)	1144 (0.49)	1188 (0.51)	4.0	7.44
444	2341	5 (0.00)	1147 (0.49)	1189 (0.51)	6.0	9.07
449	2341	13 (0.01)	1141 (0.49)	1187 (0.51)	4.1	7.97
445	2341	3 (0.00)	1151 (0.49)	1187 (0.51)	4.7	7.88
446	2341	12 (0.01)	1142 (0.49)	1187 (0.51)	5.9	10.06
440	2341	0 (0.00)	0 (0.00)	2341 (1.00)	-1.0	0.00
447	2341	0 (0.00)	0 (0.00)	2341 (1.00)	-1.0	0.00
448	2341	0 (0.00)	0 (0.00)	2341 (1.00)	-1.0	0.00
1653	2341	0 (0.00)	11 (0.00)	2330 (1.00)	-1.0	0.07
450	2341	4 (0.00)	1148 (0.49)	1189 (0.51)	4.5	8.11
452	2341	0 (0.00)	0 (0.00)	2341 (1.00)	-1.0	0.00

TABLE 3-12 SAMPLE STATISTICS FOR DECEMBER 7, 1995, WESTBOUND LANE 4

Zone	No. Points	#>50	50>#>0	0>#	Mean	Std. Dev.
451	2341	2 (0.00)	1152 (0.49)	1187 (0.51)	3.6	6.29
1585	2341	0 (0.00)	1152 (0.49)	1189 (0.51)	-0.5	0.50
453	2341	11 (0.00)	0 (0.00)	2330 (1.00)	-0.5	6.91
1594	2341	0 (0.00)	0 (0.00)	2341 (1.00)	-1.0	0.00
454	2341	0 (0.00)	0 (0.00)	2341 (1.00)	-1.0	0.00
455	2341	0 (0.00)	0 (0.00)	2341 (1.00)	-1.0	0.00
456	2341	1154 (0.49)	0 (0.00)	1187 (0.51)	48.8	50.50
458	2341	21 (0.01)	1131 (0.48)	1189 (0.51)	4.9	9.63
457	2341	36 (0.02)	1118 (0.48)	1187 (0.51)	5.5	11.39
437	2341	3 (0.00)	1150 (0.49)	1188 (0.51)	5.4	9.28
438	2341	0 (0.00)	1153 (0.49)	1188 (0.51)	4.9	7.67
466	2341	28 (0.01)	429 (0.18)	1884 (0.80)	2.2	9.66
472	2341	59 (0.03)	1095 (0.47)	1187 (0.51)	2.9	12.20
996	2341	12 (0.01)	1142 (0.49)	1187 (0.51)	5.3	9.29
476	2341	21 (0.01)	1130 (0.48)	1190 (0.51)	4.0	8.94
474	2341	7 (0.00)	1146 (0.49)	1188 (0.51)	5.7	9.56
473	2341	0 (0.00)	0 (0.00)	2341 (1.00)	-1.0	0.00
475	2341	0 (0.00)	0 (0.00)	2341 (1.00)	-1.0	0.00
997	2341	0 (0.00)	0 (0.00)	2341 (1.00)	-1.0	0.00
751	2341	0 (0.00)	0 (0.00)	2341 (1.00)	-1.0	0.00
971	2341	0 (0.00)	0 (0.00)	2341 (1.00)	-1.0	0.00
818	2341	0 (0.00)	0 (0.00)	2341 (1.00)	-1.0	0.00
1565	2341	0 (0.00)	623 (0.27)	1718 (0.73)	1.0	3.74
1573	2341	0 (0.00)	1154 (0.49)	1187 (0.51)	3.6	5.52
1566	2341	0 (0.00)	1154 (0.49)	1187 (0.51)	-0.5	0.50

Caltrans District 7 undertook a maintenance effort to improve the validity of the loop data for Beat 8. Following that effort, new data were retrieved and analyzed for several days in May 1996. Table 3-13 lists the number of good loop detectors for May 14, 1996. The list of invalid detectors is given in Table 3-14 below. An x marks a broken loop detector.

TABLE 3-13 NUMBER OF VALID LOOPS FOR BEAT 8 MAY 14,1996

Direction	LaneNumber				Total
	1	2	3	4	
East	24/25	23/25	24/25	23/25	94/100
West	18/25	21/25	17/25	19/25	75/100
Total	42/50	44/50	41/50	42/50	169/200

TABLE 3-14 INVALID LOOPS BEAT 8

Eastbound May 14, 1996

	Lane			
Zone	1	2	3	4
942				
941				
940			x	
968				
998				
752	x			
972				
483				
484				
486				
485				
1581				
482				
481				
436				
444				
449				
445				
446				
440				
447				
448	x			
1653	x	x	x	
450				
452				

Westbound May 14, 1996

	Lane			
Zone	1	2	3	4
451				
1585	x		x	x
453	x	x	x	x
1594				
454	x	x	x	
455				
456	x	x	x	x
458				
457				
437				
438				
466				
472		x		
996		x		
476	x			
474				
473				
475				
997				
751	x	x	x	x
971				
818	x	x	x	x
1565				
1573				
1566				

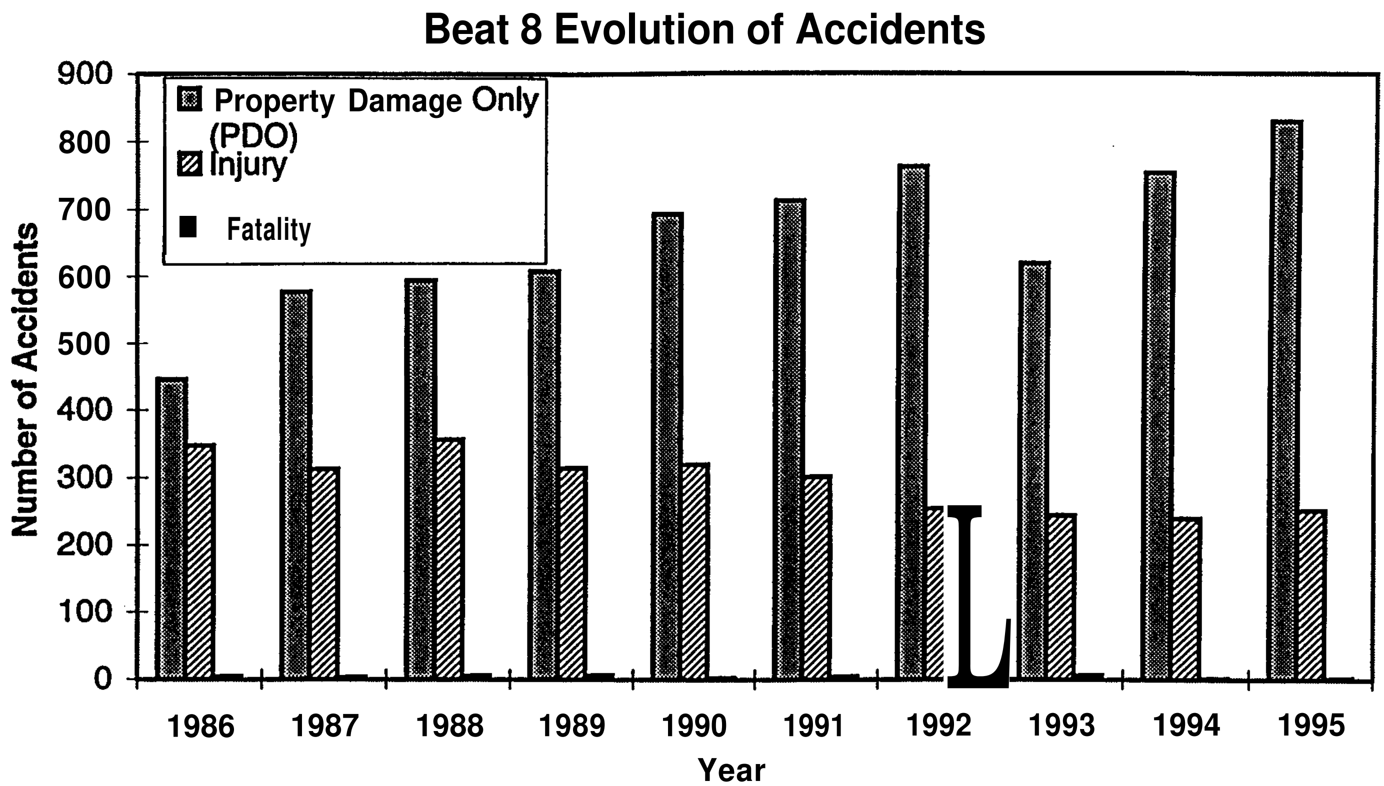
3.11 Accident Analysis

Accident data from Beat 8 and Beat 23 were retrieved from the Caltrans Traffic Accident Surveillance and Analysis Selective (TASAS) Record Retrieval system and analyzed over a ten-year period. Figures 3-5 and 3-6 show the results of this analysis. FSP tow trucks currently patrol this site with three trucks for eight hours per day (6:00 - 10:00 a.m. and 3:00 to 7:00 p.m.). Historical accident data for Beat 8 shows that the number of property damage only (PDO) accidents has steadily increased over the last ten years (from 450 to 850 per year), while the number of injury accidents has decreased (from 350 to 250 per year). Accident analysis also shows that approximately 50% of the accidents occur during peak periods.

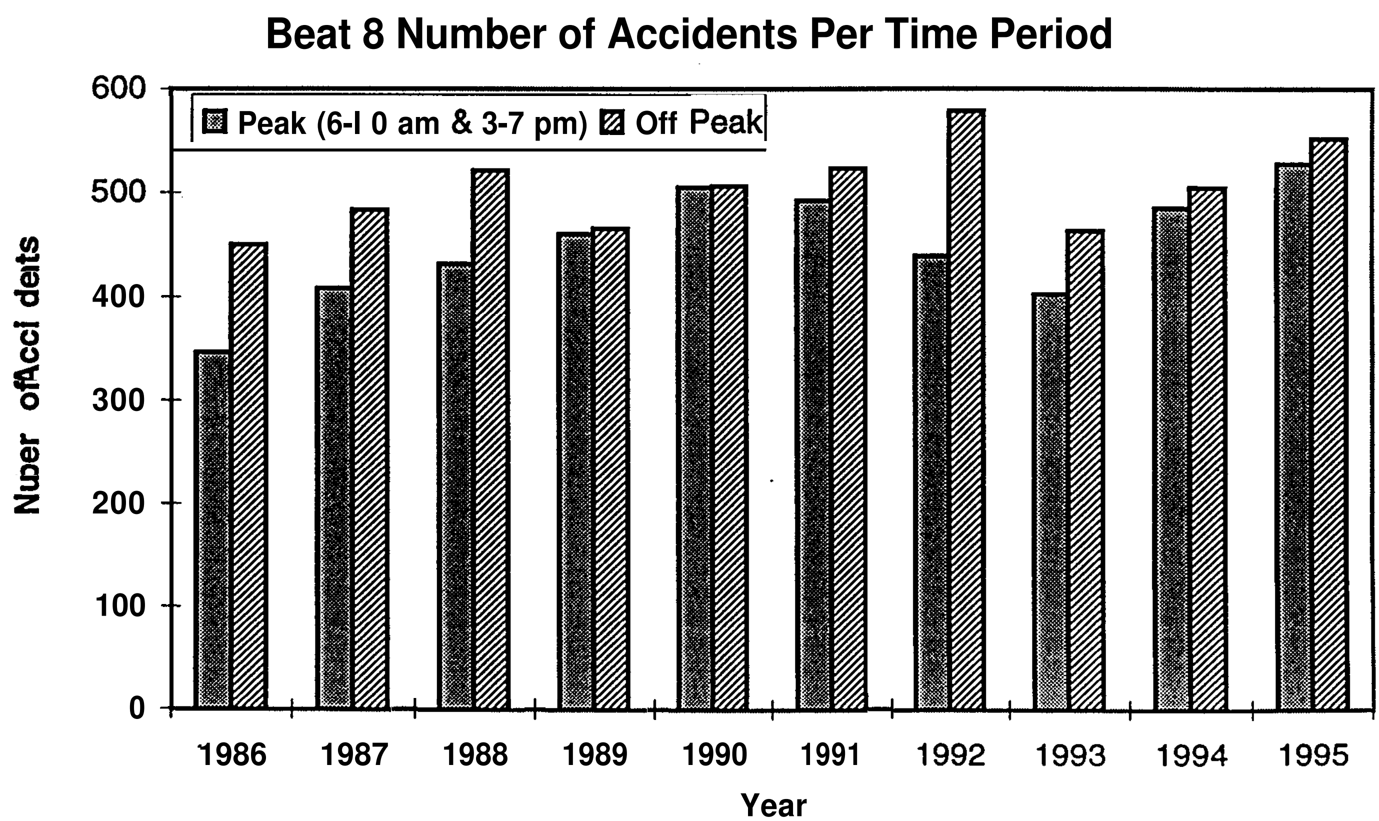
To the extent that the numbers of property damage only (PDO) accidents have steadily increased, it may be the case that PDO reporting has improved with the introduction of the FSP service, and improved auto safety devices may have led to the reduced injuries.

In looking at the numbers of accidents during the peak periods, it is shown that on Beat 8, clearly 50% of the accidents do occur during the peak 8 hours of the day. On Beat 23, however, it seems that more accidents have occurred during the off-peaks, at least through 1993.

FIGURE 3-5

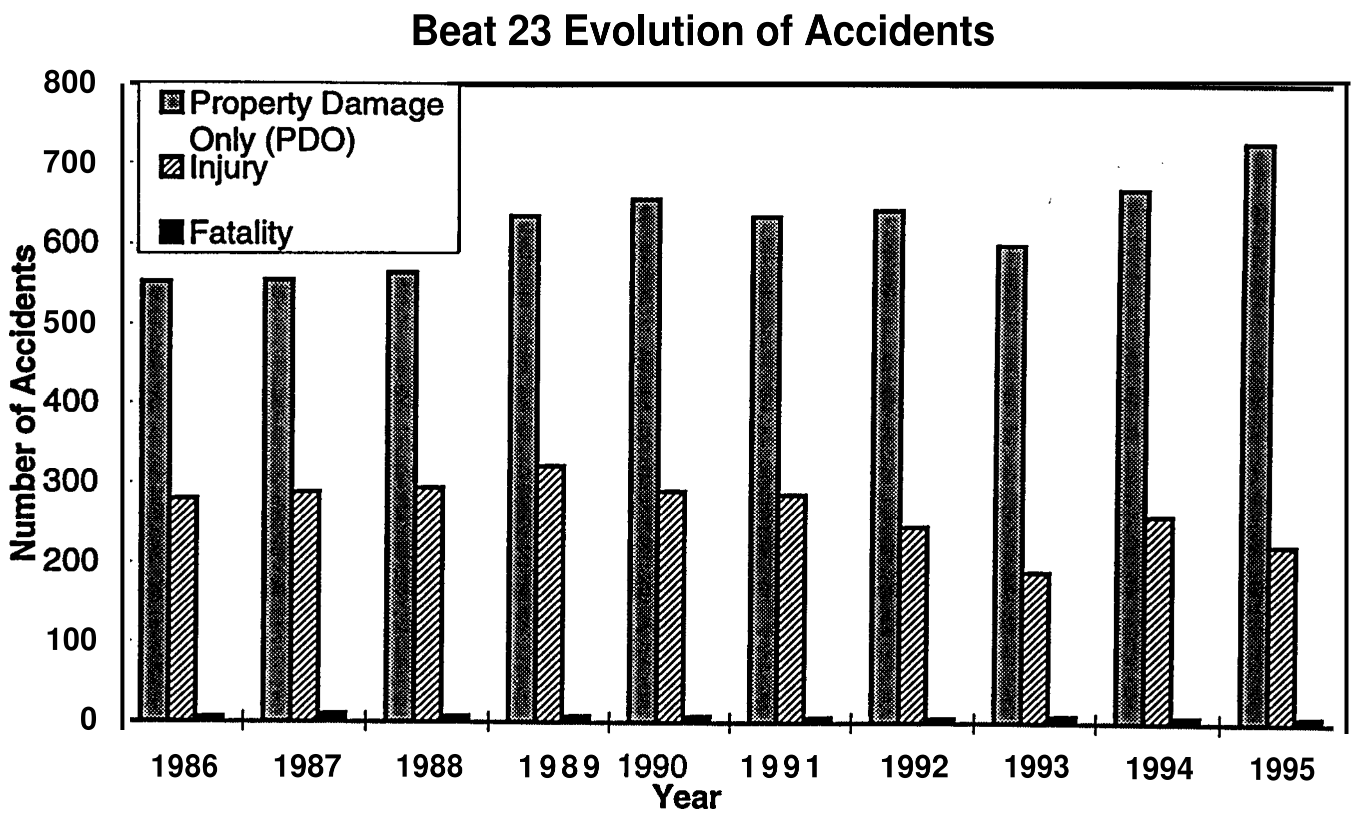


Beat 8 Evolution of Accidents
Property Damage Only (PDO)
Injury
Fatality
Number of Accidents
900
800
700
600
500
400
300
200
100
0
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
Year

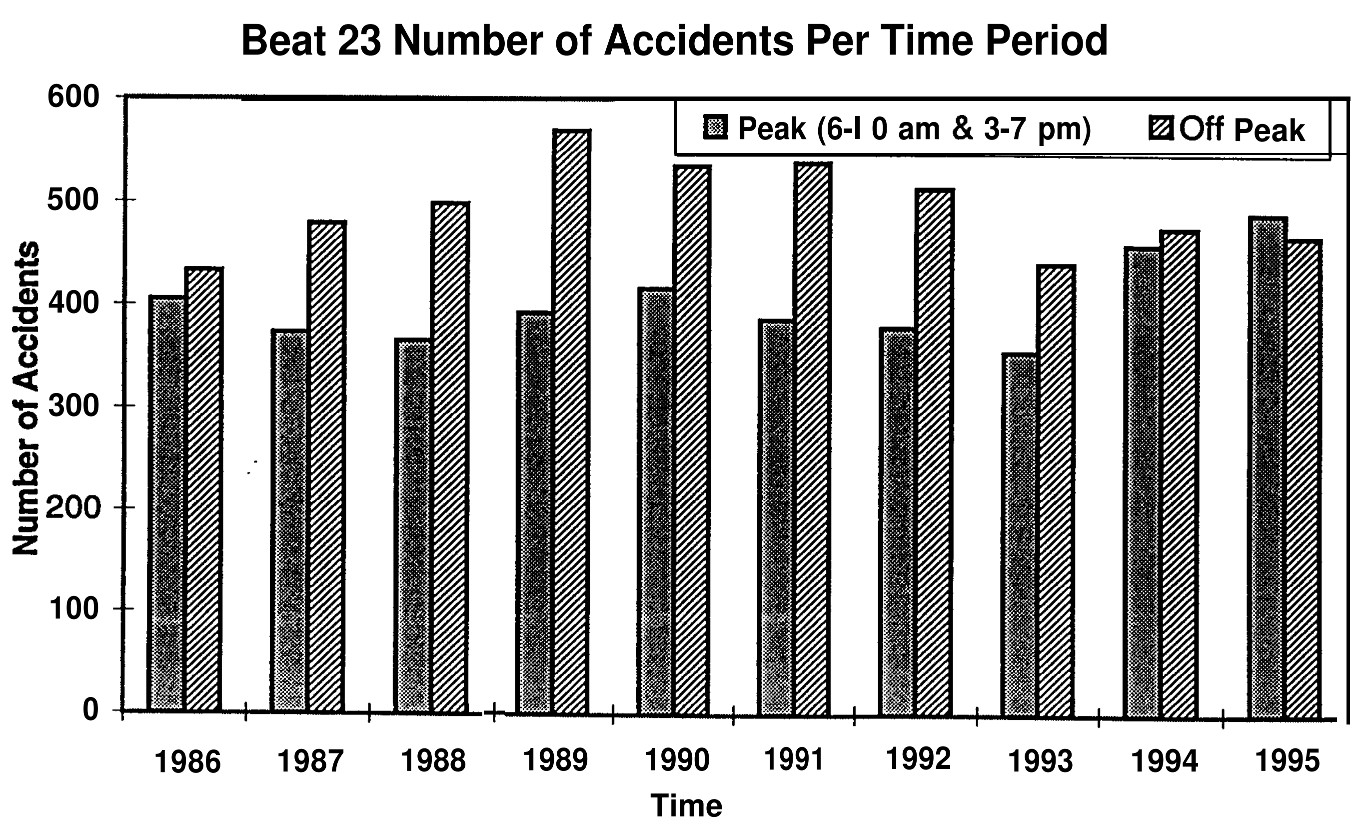


Beat 8 Number of Accidents Per Time Period
Peak (6-I 0 am & 3-7 pm)
Off Peak
Nuber ofAcci dets
600
500
400
300
200
100
0
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
Year

FIGURE 3-6



Beat 23 Evolution of Accidents
Property Damage Only (PDO)
Injury
Fatality
Number of Accidents
0
100
200
300
400
500
600
700
800
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
Year



Beat 23 Number of Accidents Per Time Period
Peak (6-l 0 am & 3-7 pm)
Off Peak
Number of Accidents
0
100
200
300
400
500
600
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
Time

3.12 Final Site Selection Recommendation

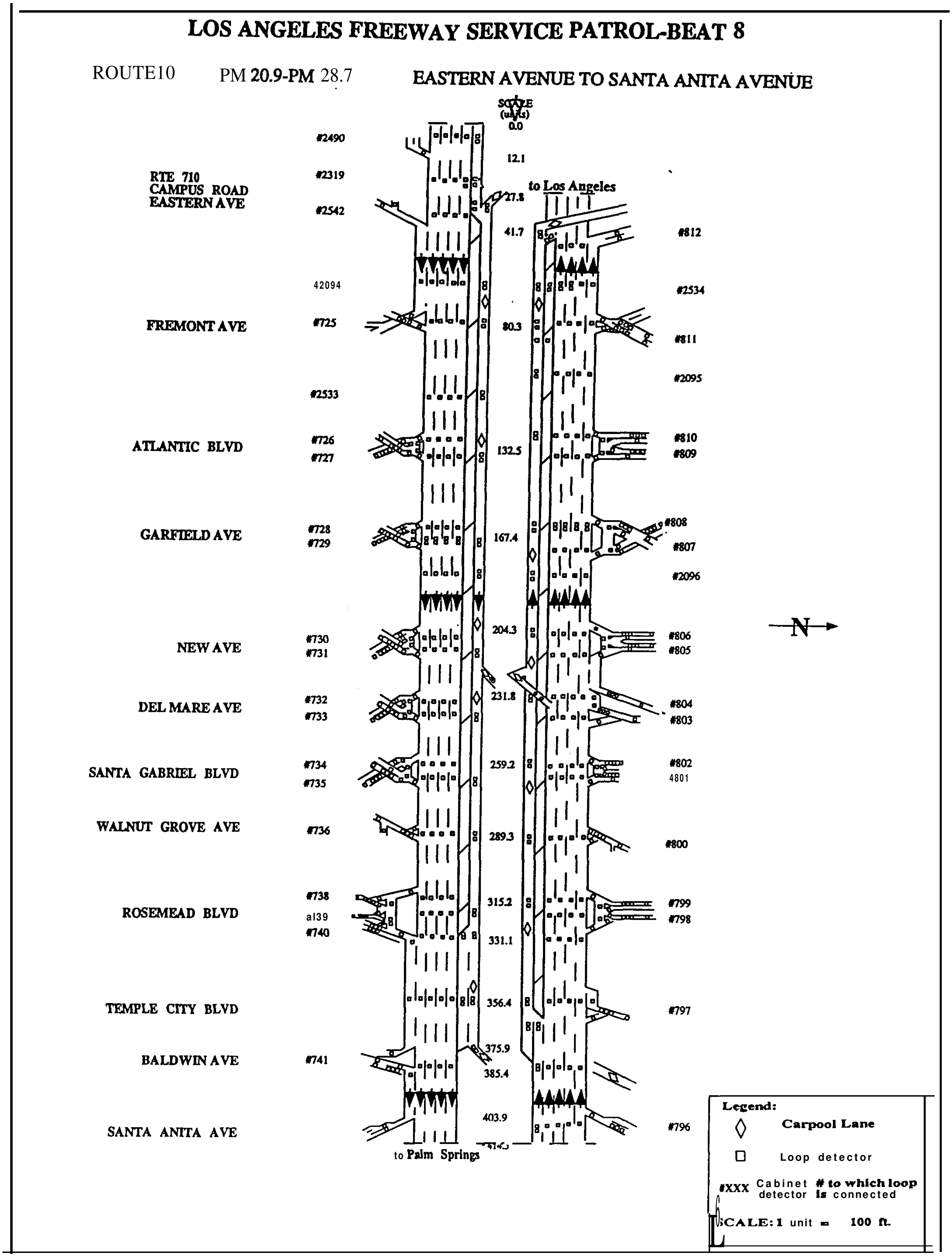
Table 3-15 shows the final comparison between Beats 8 and 23. Due primarily to the richness of the loop data and satisfactory compliance with the other evaluation criteria, it is recommended that data collection proceed on Beat 8. A schematic of the geometries on this beat are shown in Figure 3-7. Beat 8, located on I-10, was selected based on its exceptionally high loop density rating, as well as its high ADT, large number of total assists, and large number of in-lane assists.

Beat 8 is a 12.5 km (7.8-mile) segment of I-10, the San Bemadino Freeway, between Eastern Avenue and Santa Anita Avenue, in the cities of El Monte and Alhambra , in Los Angeles County, California. Beat 8 is characterized by an AADT of 249,000 (compared to 1-880's AADT of approximately 180,000). There are 49 loop detector stations equipped with Type 170 controllers, with a total of 203 single loop detectors, of which approximately 88% are active. This translates into one active loop station every 0.57 km (0.34 mile). The controllers collect flow and occupancy data every 30 seconds, and then feed these data via telephone lines to the Caltrans Modcomp computer. The Modcomp system then generates data for the Traffic Management Center (TMC). These data are also disseminated via local cable television and over the World Wide Web (http://www.scubed.corn/caltrans/transnet.html.

TABLE 3-15 SITE SELECTION RECOMMENDATION

Parameter	**Beats**	
	Beat 8	***Beat 23***
In-lane assists per truck	***336***	***346***
Total assists per truck	***2,762***	***2,958***
AADT	***249,000***	193,000
Loop density (l/mi.)	***0.34***	0.905
Ave. response rate, min.	***22***	***26***
Hours of congestion	***7.25***	***3.00***
Slowest directional speed	***26***	***29***

FIGURE 3-7 SELECTED STUDY AREA - FSP BEAT 8



APPENDIX B.

EVALUATION METHODOLOGY

Source:

K. Petty, R. Bertini, A. Skabardonis, P. Varaiya"The Los Angeles Freeway Service Patrol Evaluation: Evaluation Methodology and Preliminary Findings: California PATH Working Paper, UCB-ITS-PWP-97-17, University of California at Berkeley, 1997.

Chapter 2

Overview of the Methodology

The methodology that we have developed can be listed in these steps:

1. Measure the delay and duration for each incident ("after").
2. Model the delay caused by each incident with the standard queuing diagram.
3. For each incident, estimate what the increase in incident duration would be if there was no FSP service present.
4. For each incident, calculate the new delay for the new duration based on the model determined in step 2 ("before").
5. For all of the incidents, find the new delay. Compare the old delay, which is the ."before" delay, with the new, or "after," delay to get the savings and then get the benefit to cost ratio.

The problem that we are trying to solve with this (or any) methodology is how to get the delay per incident in the before study (when the incidents were assisted only by non-FSP tow trucks). Since we can't measure this value we have to estimate it using the measurements available and some model. What the above methodology represents is a combination of assumptions that when applied to the data that we can measure will allow us to predict the before study delay per incident.

Hence we claim that the above methodology will allow us to calculate the benefit to cost ratio in the LA Area without the aid of a before study. While there are some assumptions that we need to make we will show that they are rather reasonable. We believe that this methodology minimizes not only the number of assumptions needed but also minimizes the reliance on the results from the I-880 Study.

Note that there are a few ways to estimate the delay versus duration curve without a before study. A historical perspective might help to clarify why we chose the above method. What we were originally considering is to parameterize the delay versus duration curve from the I-880 before study by some model. We would then use this model to predict the delay in the LA Area before case. The problem with this approach is that the model couldn't take into account the geometries of the freeway, like the conditions of the shoulders. Hence, we couldn't use our model on a location that didn't have shoulders similar to I-880 (and the LA site doesn't). Therefore we decided to start from a slightly different perspective. Instead of assuming that the delay versus duration curve would be similar in both locations we decided to essentially model the delay versus duration curve for every incident. Thii would allow us to take into account the different geometries for each and every incident. In light of other studies done in LA this assumption seems pretty reasonable. Hence, this methodology will allow us to draw conclusions about the LA area which will incorporate the expected higher flows and smaller shoulders. Consequently, this calculation will be done without reference to the delay calculations done in the I-880 Study. A more detailed summary of the steps that'incorporate the methodology are given below.

In step 1 we will use the loop detector flow data and the probe vehicle speed data to generate density plots of the entire study section. We will then use these plots to identify the delay induced by specific incidents. From thii we can determine the delay and duration for every incident. The key thing here is that these plots will reflect the higher flows and smaller shoulders in the LA area. The specific steps involved in making these plots are discussed in Chapter 3.

Once we have these points (the delay and duration), we will fit a standard queuing model to them for each incident in step 2. What we are really trying to determine here is the incident capacity. Since we know the delay that the incident caused, the duration of the incident, and the demand, and we can assume a value for the discharge capacity we can determine from a standard queuing model the incident capacity. Note that this will automatically take into account the geometries at the incident site. These models will allow us to make predictions about the incident delay under different tow truck response scenarios. The details of this step are discussed in Chapter 4.

Once we have these incident modeled, we will adjust for the fact that the FSP tow trucks over-sample the short duration incidents in step 3. An examination of the I-880 data indicates that this effect needs to be taken into account. Section 4.2.1 will examine this effect and will discuss how we can compensate for it. This compensation will give us a set of points that reflect the true effect of the FSP tow trucks.

Finally in steps 4 and 5 we will use the models to calculate the delay generated by each type of incident for the calculated before study duration and the measured after study duration. These values will then give us the final benefit to cost ratio. The calculated before study duration will come from the LA area CAD database. The problems associated with generating the before duration from the CAD database are discussed in Chapter 5.

The following sections of this paper give the details of each step in the methodology. They also present some results when these steps are applied to the data from the I-880 FSP Study. Throughout the paper we will give arguments as to why this is the best method to estimate the benefits from the FSP tow trucks.

Chapter 3

Incident Delay Estimation

Estimating the incident delay from field data and developing delay versus duration relationships is the biggest part of the study in the sense that it will consume the most time. The estimation process is going to be done much like it was done in the I-880 study. The various steps that need to be done for thii are as follows:

1. The density contour plots will be generated of the study section.
2. The incident locations and durations will be overlaid on these plot.
3. The plots will be examined by hand to associate build-ups in density with specific incidents wherever possible. This involves drawing bounding boxes on the density plots.
4. Based on the bounding boxes, delays will be calculated for each incident.
5. Plots of delay versus duration for different types of incidents will be generated.

These are exactly the same steps that were followed in the I-880 study with only one important difference. Since the loop detectors in the LA area are single trap loop detectors it is not possible to accurately measure speed. Therefore, the calculations of density and delay have to rely on the loop detector flow and the probe vehicle speeds. This is not necessarily a problem but it needs to be verified that the density plots calculated from the probe vehicle speeds and the loop detector flows are similar to the ones made solely from the loop detector data. This line of inquiry leads to another question as to whether the percentage of probe vehicles in the traffic stream will be high enough to.accurately measure the speed. To answer these questions we provide a short summary of the meaning of delay in our setting.

3.1 Loop Speed Based Delay

One way to compute delay is to completely rely on the loop detector measurements of speed and flow. When doing this, we can use the standard formula to compute the delay at each loop detector for each output period:

$$D_k(i) = L_k \frac{\Delta T}{60} F_k(i) \left(\frac{1}{V_k(i)} - \frac{1}{V_T} \right) \tag{3.1}$$

Where $D_k(i)$ is the delay on segment k at time period i, L_k is the length of segment k in miles, AT is the time slice in minutes, $F_k(i)$ is the flow on segment k at time period i, v,(i) is the speed on segment k at time period i, and V_T is the threshold or congestion speed. Then, we sum these values up over the length and duration of our incident to get one value:

$$D_{inc} = \sum_{k=1}^{N} \sum_{i=1}^{M} D_k(i) \tag{3.2}$$

Where we assume that there are N sections and M time periods for our incident. Note that there are different ways to compute thii delay depending on what you choose for the threshold speed V_T. For example, one could choose V_T to be a constant or to be the average speed for a particular time of day. It is generally assumed that thii delay calculation gives you the most accurate results.

3.2 Probe Speed Based Delay

Another method to calculate the delay is to use the probe vehicle speeds and the loop detector flows. This calculation is done when there is no speed data from the loop detectors (or when we don't trust the speed values). To calculate this delay we can use the same equation as in the loop based method but substitute in the probe vehicle speeds for the loop speeds:

$$D_k(i) = L_k \frac{\Delta T}{60} F_k(i) \left(\frac{1}{V_{k,probe}(i)} \quad \frac{1}{V_T} \right) \tag{3.3}$$

Where $V_{k,probe}(i)$ is the speed at the loop detector location k at time period i from the probe vehicles. Since the probe vehicles are not always on top of the loop detectors this method requires some interpolation to get the data. Note that you can still set the threshold speed, V_T, to be whatever speed you like.

This calculation for probe speed based delay has a number of problems. The biggest is that the accuracy of our measurement depends on the density of probe vehicles. Therefore anything that perturbs the uniform density of'the probe vehicles will also perturb the uniform sampling of the speed surface. Hence, whenever there is an incident and our probe vehicle is stuck in the queue our picture of the density'of the freeway is warped. This is in contrast to the loop speed based delay measurements which are oblivious to traffic queues. A plot of the effect of probe vehicle density on speed surface accuracy is given in Figure 3.1. This figure is simply a measurement of the distance between the double trap based speed surface (which is assumed to be the best), the single trap based speed surface, and the speed surfaces generated when we have 1, 2, 3 or 4 probe vehicles. Note that for 4 probe vehicles the density of probes in the traffic stream is approximately 0.13%. This says that if we think that the single trap loop

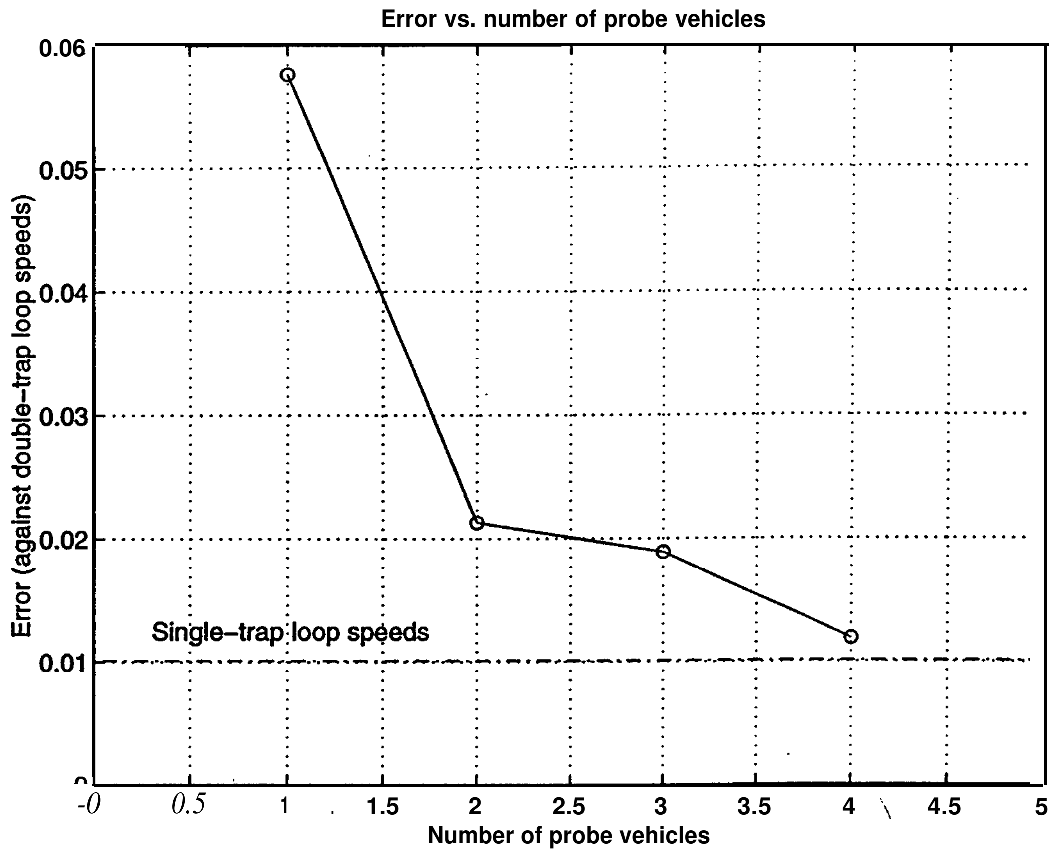


Figure 3.1: Errors introduced by probe vehicles.

speeds are not accurate, then we shouldn't think that the probe vehicle loop speeds (at this density) are any more accurate. Hence, the percentage of probe vehicles on the Los Angeles test section will be larger than 0.13%.

Related to the sampling problem is the question of interpolating the speeds when there is no probe vehicle data. The form of the delay calculation requires a speed value for every loop detector and for every output period (usually every 30 seconds). This means that we have to do two things: 1) figure out exactly where the probe vehicles are at every instant, 2) interpolate between the times when the probe vehicles pass over a loop detector. The first problem is basically a noise problem because we aren't exactly sure where the vehicle is at any given moment. We can dismiss this by arguing that the locations are close enough and hence the speed measurements aren't going to be that far off. But the second problem is more likely to give us trouble. A detailed look at what we do to get the probe vehicle speeds for the delay calculation will show us why. The process is given in Figure 3.2. The left side of Figure 3.2 is the distance vs. time plot of freeway with the probe vehicle trajectories overlaid. The dotted lines mark out the "regions of attraction" for each loop detector and time period. The program assigns to the dot in the middle of the region the average of all the speed points inside the region. Although the probe trajectory is physically a continuous line, the data is only reported

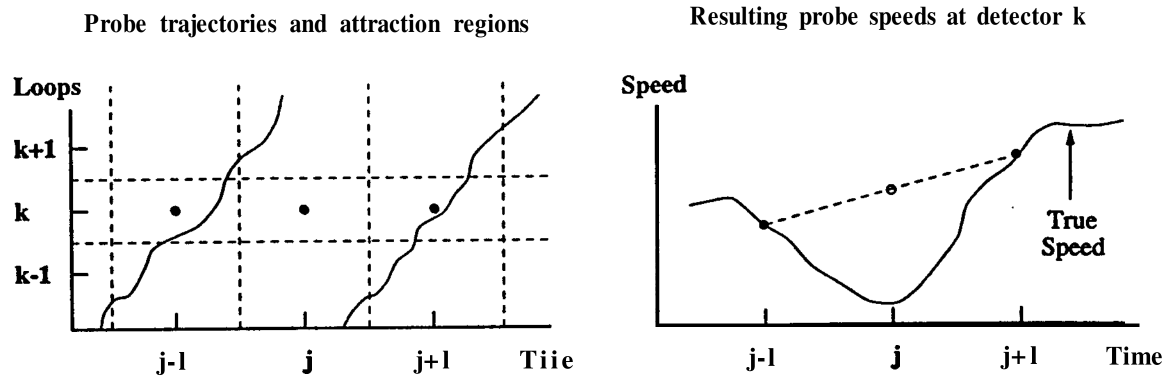


Figure 3.2: Interpolation of probe trajectories to get speeds.

once every second and hence we can get an average. Note that thii average is over the entire distance of the loop detector segment, and over the time period. The thing to note is that in thii example no probe vehicle trajectory fell in the time period-loop detector pair of (j, k). Therefore this speed will have to be interpolated. That action is represented on the right side of Figure 3.2. Here we have two data points and we simply interpolate with a straight line to get the data point in the middle. This is indicated by the empty circle at the grid coordinates (j, k). The problem here is that we have no idea what the speed is in the middle of these two points (as indicated on the plot by the true speed line). If the two vehicles are far apart in time then the speeds at that location could be fluctuating wildly and we would never know it.

3.3 Probe Travel Time Based Delay

Another method to calculate delay based on probe data is to record the increase in travel times for each probe vehicle and then multiply this by the'flow to get vehicle-hours. This setup could be used when there are probe vehicles driving around on the segment, but there is only one or two accurate loop detector stations on the entire segment. In this situation you would only accurately know the flow for one or two places and hence it makes sense to use this form of delay calculation.

This calculation is done with the following equation:

$$\mathrm{D(i)} = F(i)\ (\mathrm{TT}_{prob}(i) - \mathrm{TT}_{avg}(i)) \tag{3.4}$$

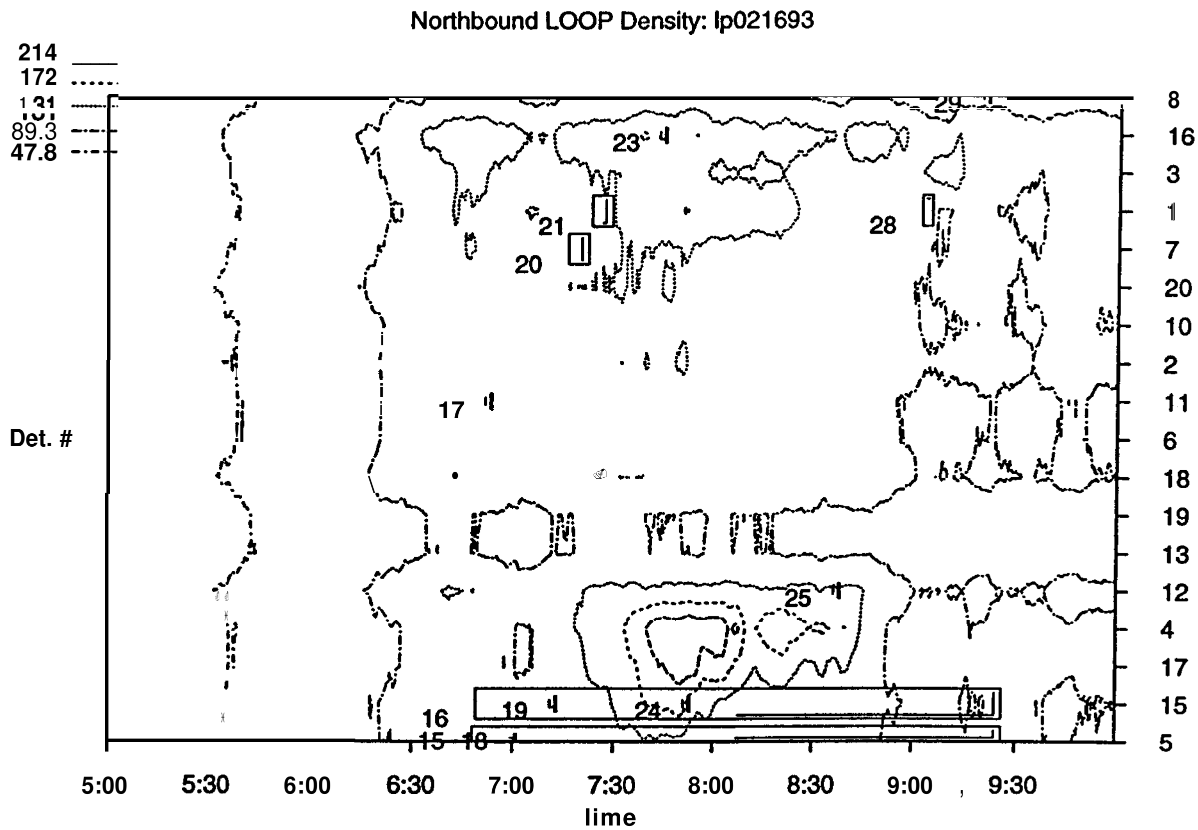
Where D(i) is the delay in vehicle-hours for time period i, F(i) is the average flow down the freeway during time period i, $\mathrm{TT}_{prob}(i)$ is the travel time down the freeway for the probe vehicle for time period i, and $\mathrm{TT}_{avg}(i)$ is the average travel time down the freeway at time period i (possibly based on historical data or some constant speed). This will give you an aggregate value of delay. Although this form of delay calculation in interesting, it is not applicable to the LA FSP study because we will need to obtain the delay for a specific incident. This method only provides you with delay for an entire section of the freeway. Hence we will not be able to use this method in LA.

3.4 Choice of the Incident-Free Speed

One of the more questionable points is what threshold, V_T (the incident-free speed), should one choose to carry out the delay calculations? Should you use the average speed down the freeway as a function of location and time? Or should one use a constant speed? A logical answer would be that we want to be able to measure whenever an incident causes the traffic stream to fluctuate and hence causes delay. If we were trying to see thii with a constant threshold of 35 mph then we won't see any delay for an incident that causes the traffic to slow down to 40 mph for an hour. On the other hand, if we know that there is recurrent congestion at one location during one time of the day, then it would be incorrect to classify that as incident induced delay. So the logical choice would be to use the average traffic speed which is a function of location and time for the threshold excluding incidents.

3.5 Comparison of Methods for Calculating Incident Delay

Despite the problems mentioned above, the use of the probe vehicle speeds and the loop detector flows to calculate the density of traffic and hence delay, is quite accurate. Thii is illustrated in Figure 3.3. The plot on the top of Figure 3.3 is a contour plot of the density of vehicles on the freeway that was calculated from the loop detector speeds and flows. The plot on the bottom was calculated with the probe vehicle speeds and the loop detector flows. Hence we feel that with a high enough density of probe vehicles, the two measures of delay will be equivalent.


Northbound LOOP Density: lp021693
214
172
131
89.3
47.8
Det. #
29
23
21
20
28
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16
15
18
8
16
3
1
7
20
10
2
11
6
18
19
13
12
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17
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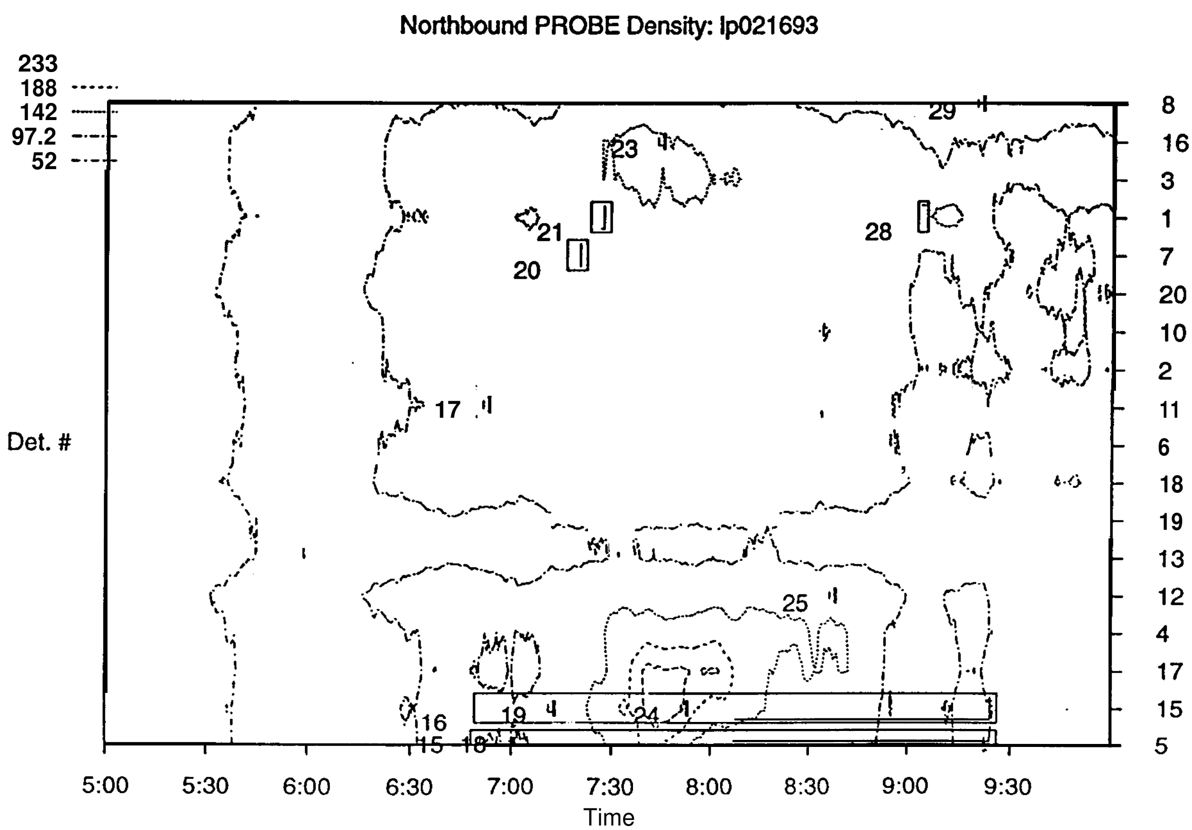
lime


Northbound PROBE Density: lp021693
233
188
142
97.2
52
Det. #
29
23
21
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16
15
18
8
16
3
1
7
20
10
2
11
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18
19
13
12
4
17
15
5
5:00
5:30
6:00
6:30
7:00
7:30
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9:00
9:30
Time

Chapter 4

Modeling the Effects of FSP

4.1 Incident Delay Modeling

In this section we will discuss the way that we decided to model the incidents. What we would like to do is to come up with .a model, based on physical reality, that we can use to predict the delay based on the characteristics of the incident (duration, severity) and the local freeway (traffic volume, shoulder width). The normal way of doing this is to measure some data, come up with a physical model with some dependent parameters, and then fit the parameters in the model to the data.

The problem with this approach is that it tends to "mush" the data together and it doesn't represent physical reality. The approach that we have taken is a bit more robust. After the previous step we will have a plot of the delay versus duration for all of the incidents, much like the representation given in Figure 4.1.

Each point in Figure 4.1 represents an incident. The question that we are faced with is,

> "If the tow truck service changes, that is, FSP service is introduced, and the incident durations change in some manner, how does the delay for each incident change?"

The way that we attempt to answer this is we first model each incident with a standard queuing model as in Figure 4.2. That diagram on the right side of Figure 4.2 is a picture of the cumulative flow during an incident versus time.. The line represented by V is the cumulative number of vehicles that want to pass down the freeway. The slope of this line, V, is the demand on the freeway in vehicles per hour. When the incident occurs, the capacity of the freeway is reduced to a slope of C_I vehicles per hour. In this model the freeway stays restricted to this lower capacity for the duration of the incident, t. Once the incident has cleared, after t minutes, the built-up queue will discharge at the capacity of the freeway C (maybe). This volume will be maintained until the queue is dissipated at some later time. The delay caused by this incident is the shaded area. The units of this shaded area are in vehicle-hours. It represents the cumulative amount of time that these vehicles had to wait in this queue due to this incident.

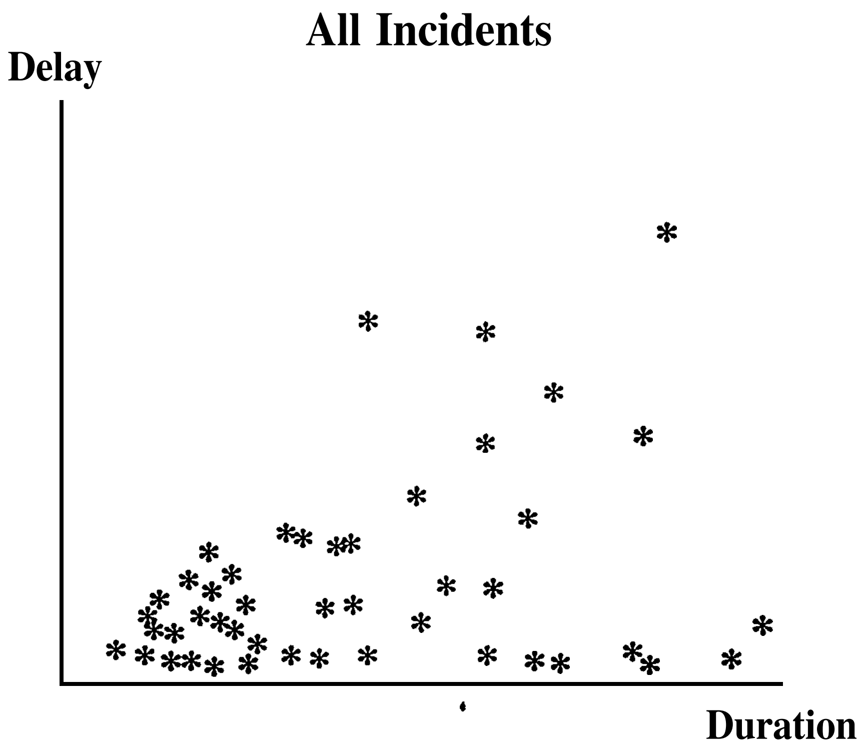


Figure 4.1: Raw data after first step of methodology.

There are, of course, some problems with this model that stem from two different sources. The first source is that this is not what happens in reality, and the second source is in our measurement technique. In reality, the line given by C_I is not a constant. One can think up many different stages of an incident: the vehicle initially blocks one lane, the vehicle is moved to the side of the road, the tow truck and a CHP officer show up, the vehicle is towed away, the CHP officer leaves. Every one of these possible stages is going to have a different effect, in terms of capacity reduction, on the traffic stream. So hoping that we can model it as a single straight line is probably a bit optimistic. The second problem arises in the way that we measured the durations of the incidents. Since we measured the durations with the probe vehicles we are only sampling the start and end times by the probe headway (5 to 7 minutes). Hence we are always under estimating the duration of the incident. Since the delay generated by the incident depends on the square of the duration any error here will be difficult for our models.

Never-the-less, we can put these objections aside and attempt to fit our data to the model given in the equations below:

$$\text{Delay} = \frac{1}{2}t^2(V - C_I) + \frac{1}{2}t^2\frac{(V - C_I)^2}{(C - V)} \quad (4.1)$$

$$= \frac{1}{2}t^2(V - C_I)\frac{(C - C_I)^2}{(C - V)} \quad (4.2)$$

We can get a few of these parameters, like demand, *V*, and capacity, C, and duration, t, from

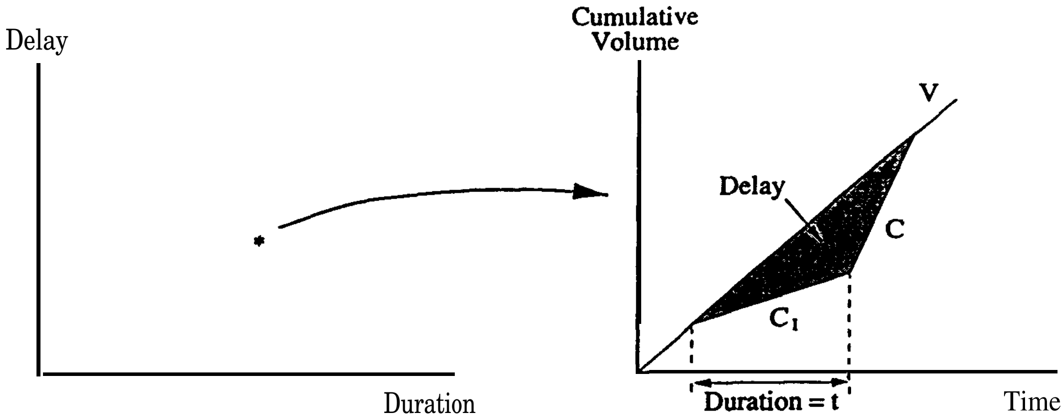


Figure 4.2: Modeling of a single incident.

the field measurements. What we don't know, and what we would be trying to fit in our model, is the amount of capacity reduction, C_I, due to a specific incident. So this value, C_I, is going to be a function of the characteristics of the incident and the local freeway (like whether or not there are shoulders). Since we know all of the other terms in equation 4.2 we can simply solve for C_I for each incident. ,

4.2 Incident Durations Before FSP

The next step in our methodology is to determine the duration of the incidents when there is no FSP tow truck service in place. Thii is a difficult problem because we don't have any field data "before" and also due to the presence of the oversampling of the short duration incidents by the FSP tow trucks. In the section below we examine the oversampling problem and discuss ways to compensate for it.

4.2.1 Correcting for the over-sampling of incidents

A common way to estimate the reduction in incident duration due to the FSP tow trucks is to simply take the difference between the before incident duration and the after. The results on incident duration for the I-880 FSP Study are given in Table 4.1. If, for the assisted

	Duration (min)		Fraction (%)	
Incident Type	Before	After	Before	After
Assisted Breakdowns	37.6	21.1	18	41.2
Non-assisted Breakdowns	22.6	22.8	82	58.8

Table 4.1: Incident durations

breakdowns, we simply subtract the after duration from the before duration we get a reduction of: 37.6 – 21.1 = 16.5 minutes. Almost all studies take this reduction and use it in the queuing diagram to calculate the delay savings. However, you can see in Table 4.1 that the fraction of assisted incidents went up from 18% in the before study to 41.2% in the after study. Let's assume for a moment that the only breakdowns assisted by the FSP tow trucks in the after study were breakdowns that really needed assistance - they couldn't have moved otherwise. This would imply that in the before study only 50% of the breakdowns that really needed help were assisted. This is hard to believe. How did these people ever get off the freeway if they truly needed assistance?

So the assumption that the FSP tow trucks were helping only those breakdowns that needed help is probably incorrect. A more likely assumption is that the FSP tow trucks helped a lot of breakdowns that otherwise wouldn't have needed help. Things like people stopping to read a map, switch drivers, or to change their own tire[1]. In these cases it is reasonable to assume that the FSP tow trucks did nothing to help out the situation. Never-theless, the observed incident was recorded as an assisted breakdown. Due to the nature of these incidents their durations are very short. Therefore, these short breakdowns, that normally wouldn't have been helped, are pulling down the average duration of the assisted breakdowns in the after study. As we will show later, thii phenomena can be viewed as an oversampling of the short duration breakdowns by the FSP tow trucks.

Armed with this assumption we will attempt to separate the reduction in assisted breakdown duration into two parts: 1) the reduction due to the FSP tow trucks arriving at the scene earlier, and 2) the reduction due to the oversampling of short duration breakdowns. The benefits attributed to the FSP tow trucks should only come from the first type of reduction. This is illustrated using the I-880 study. We begin by looking at the cumulative distributions of the incident durations for the assisted and non-assisted breakdowns. These plots are given in Figure 4.3.

'Note that in the FSP database, an assisted breakdown is any time that one of the probe vehicles witnessed an FSP tow truck stopped by a motorist.

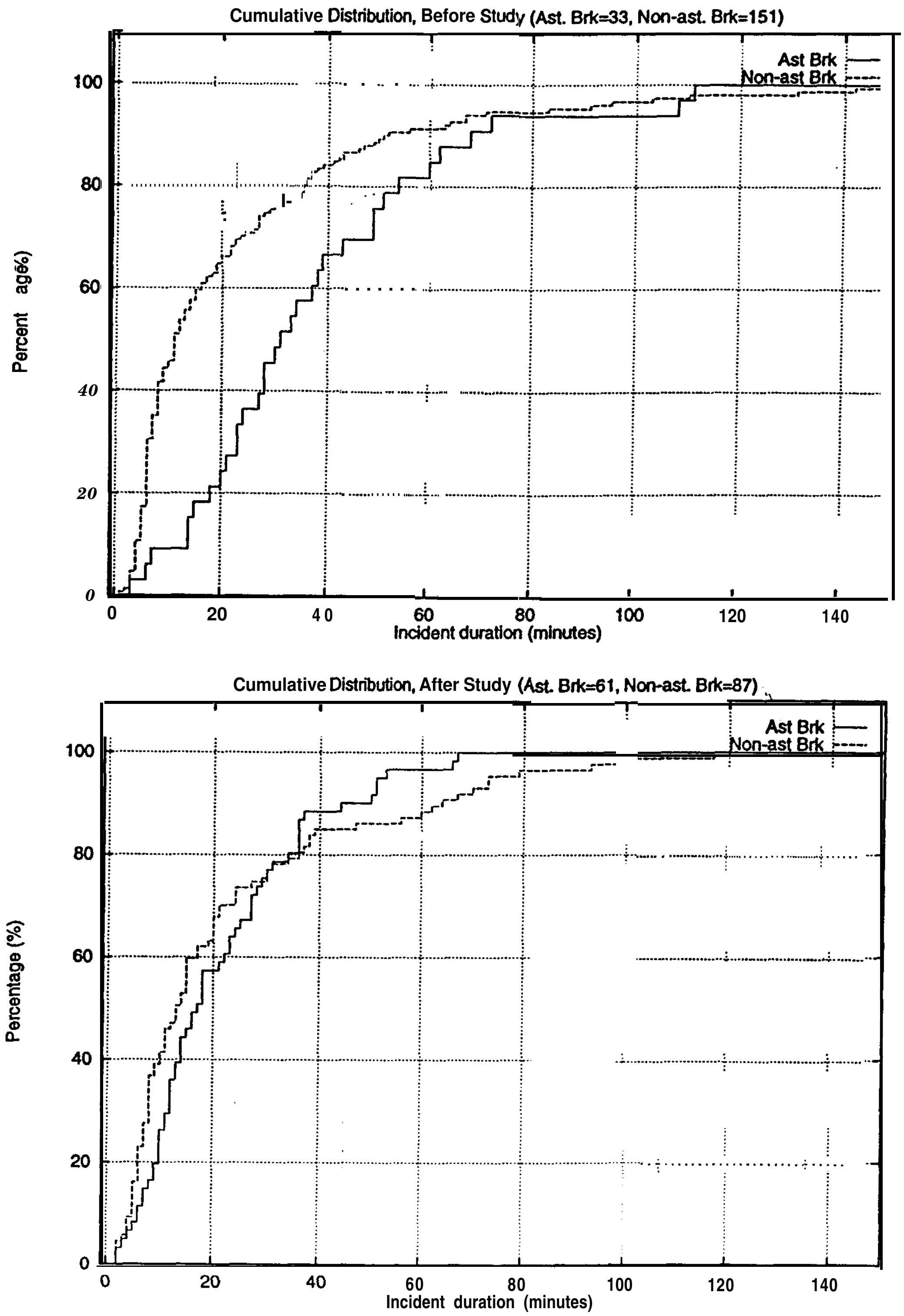


Figure 4.3: Cumulative distributions for assisted breakdowns

The cumulative distributions show pretty much what you would expect. The average duration of the assisted breakdowns in the after study has been reduced[2]. But it is hard to tell from these plots how exactly to proceed. We need to break the shift in duration into two parts and the cumulative distributions just don't provide enough information. To get a better picture of what we are looking at we should consider the density distributions. Since the number of points that we have for each density plot is rather small, the actual density plots don' t provide much information. Hence we present an idealized picture of what is going on in Figure 4.4. The top half of Figure 4.4 shows Venn diagrams of the breakdowns in the before and after

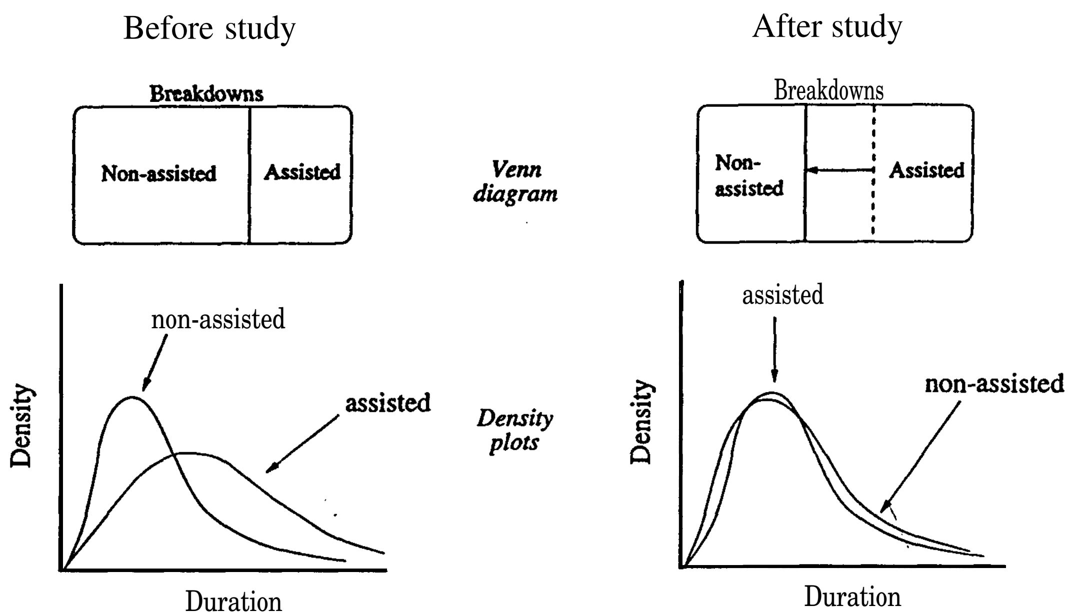


Figure 4.4: Density distributicas for assisted breakdowns

study. Each diagram represents the entire set of breakdowns. The left half are the non-assisted breakdowns and the right half are the assisted breakdowns. The assumption is that in the after study the FSP tow trucks not only assisted all of the incidents that would normally have needed assistance, but they also assisted a significant fraction of the incidents that would normally have not needed assistance. Hence, in the Venn diagram for the after study, the assisted breakdown pool on the right has grown to include some of the normally non-assisted incidents. This can also be seen in the density plots on the bottom of Figure 4.4. The non-assisted breakdowns by nature have a shorter duration than the assisted breakdowns. Hence their densities are concentrated at a lower duration than the assisted breakdowns. This can clearly be seen in the density plots for the before study. But in the after study the distributions are basically right on top of each other. What this shows is that the distribution of the assisted breakdowns in the after study is incorrect.

By assumption we know that the pool of assisted breakdowns in the after study has some incidents in it that would normally not have been assisted. To correct this we need to subtract

[2]Note that a lower average delay corresponds to a cumulative distribution plot that is farther to the left on the graph.

these incidents from the pool of assisted breakdowns. This will get rid of the over sampling bias that is being introduced by the nature of the FSP tow trucks. Our first step is to determine the amount that the short incidents were oversampled. Thii can be done by examining the fraction of assisted incidents for each duration. This should tell us what percentage of incidents, at each duration, were assisted. A generalization of these curves is given in Figure 4.5. On the left side

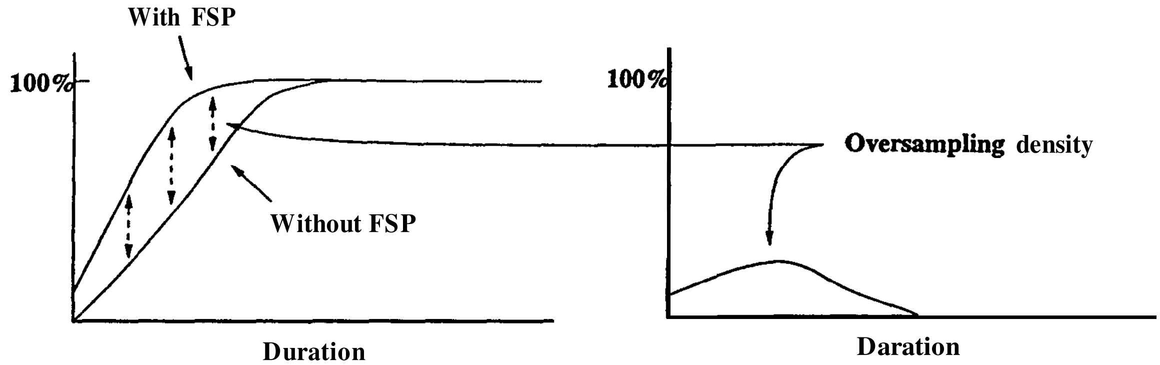


Figure 4.5: Fraction of assisted incidents and density of oversampling.

of Figure 4.5 is a plot of the fraction of assisted breakdowns per duration for the before study and the after study. As you can see, the fraction of assisted breakdowns in the after study is higher for shorter duration incidents. This reflects the fact that the FSP tow trucks were helping more short duration incidents. The difference between these two curves can be viewed as the fraction of incidents that are oversampled by the FSP tow trucks. Thii difference is given on the right side of Figure 4.5. This will be referred to as the oversampling density. The key point is that if you multiply the oversampling density by the density of the non-assisted breakdowns then this will give you the density of non-assisted breakdowns that were oversampled. This is the density distribution at which the non-assisted breakdowns were added to the assisted breakdown pool by the FSP tow trucks. So this is the distribution that we need to subtract off of the assisted breakdown distribution to correct for the oversampling. The process of oversampling is given in Figure 4.6. The upper left plot of Figure 4.6 is the density of the non-assisted breakdowns, the middle plot of Figure 4.6 is the oversampling density and the plot on the lower left is the product of the two. This is the over-sampled non-assisted breakdown density. This is what is added to the "true" assisted breakdown density to get what we have observed. So to fix the problem of the FSP tow trucks oversampling the short duration incidents we simply need to subtract off the density given in the lower left-hand plot of Figure 4.6.

The problem is that we don't know how much to subtract. Since we are saying that the reduction in duration is due to two parts, the oversampling and the quick FSP arrival time, we need a way to determine the contribution of each part. Indeed, we could subtract off the over-sampled non-assisted breakdown density until the average duration of assisted breakdowns for the after study was the same as for the before study. But this would imply that the reduction in assisted breakdown duration was due entirely to oversampling short duration incident. This would clearly be incorrect.

A better approach would be to assume that the fraction of breakdowns needing assistance is

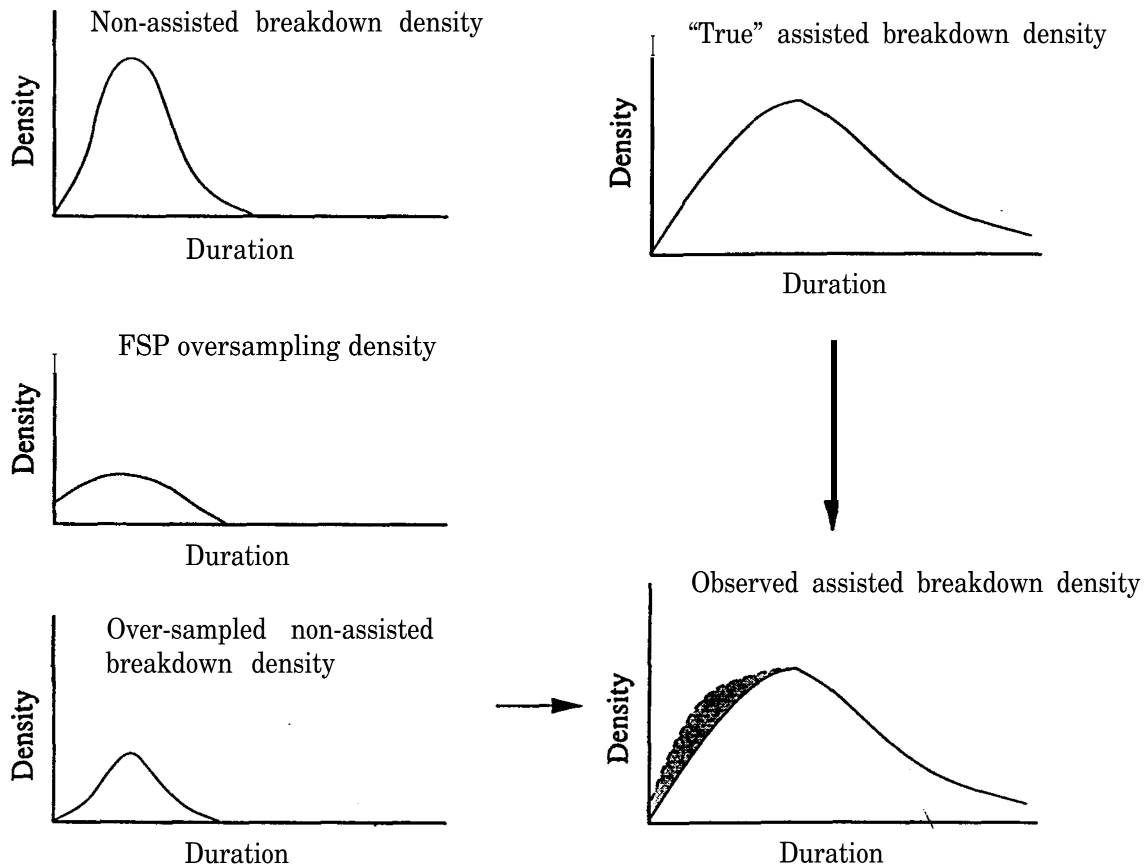


Figure 4.6: The process of oversampling.

a constant. Since it would be hard to imagine that the FSP tow trucks caused an increase in breakdowns needing assistance, this seems reasonable. Hence we should subtract off the over-sampled non-assisted breakdown density until the fraction of assisted breakdowns in the after study is the same as the fraction of assisted breakdowns in the before study. The resulting density distribution will be the correct distribution of assisted breakdowns. Therefore the true effect of the FSP tow trucks on the assisted breakdowns would be the difference between the average of this new distribution and the average of the assisted breakdowns in the before study. This two part process is given in Figure 4.7. The left side of Figure 4.7 represents the shift due to the oversampling of the short duration normally-non-assisted breakdowns. The right side of the figure represents the shift in the assisted breakdown distribution due to the FSP tow trucks arriving on the scene faster than radio dispatched tow trucks.

This two part decomposition of the assisted breakdown duration reduction was done on the I-880 FSP data. From Table 4.1 you can see that the original reduction in duration was 16.5 minutes. But when the decomposition is done the results are as follows:

- Reduction due to oversampling short duration breakdowns: 9.8 minutes.

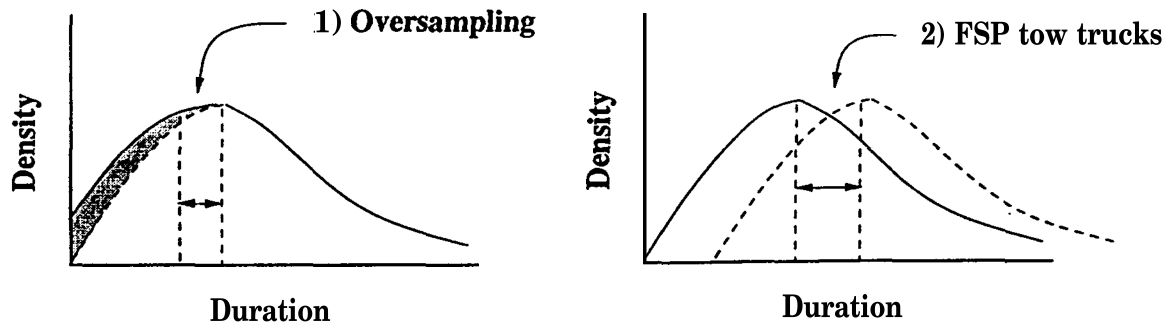


Figure 4.7: Effect of FSP tow trucks on assisted breakdowns.

- Reduction due to quick FSP tow trucks: 6.7 minutes.

Thii shows us that the major factor in the reduction of duration is due to the oversampling of short duration breakdowns by the FSP tow trucks.

4.2.2 Estimating Incident Duration Without a "Before" Study

The steps given above work great if you have the results from both a before and an after study. But how would they apply to a situation like the LA study where you have only the after study results? In order to use the method above, a few assumptions about the characteristics of the incidents need to be made:

1. The correct percentage of assisted breakdowns is given from the I-880 before study. This is assumed to be a constant 18% for all locations and all freeways. Previous studies have shown that this is a viable percentage for the LA area.
2. The correct sampling density for the assisted breakdowns without the tow trucks can be recovered from the LA area CAD logs.

If thii is the case, then we can proceed from the discussion above with the following steps:

1. Take new sampling distribution.
2. Find difference between new sampling distribution and sampling distribution for the I-880 before study.
3. Multiply this distribution by the distribution of the before study non-assisted breakdowns.
4. Subtract off resulting distribution until the proportion of assisted breakdowns matches the proportion of assisted breakdowns in the before study.

These steps should allow us to correct for the over-sampling of the short duration incidents by the FSP tow trucks.

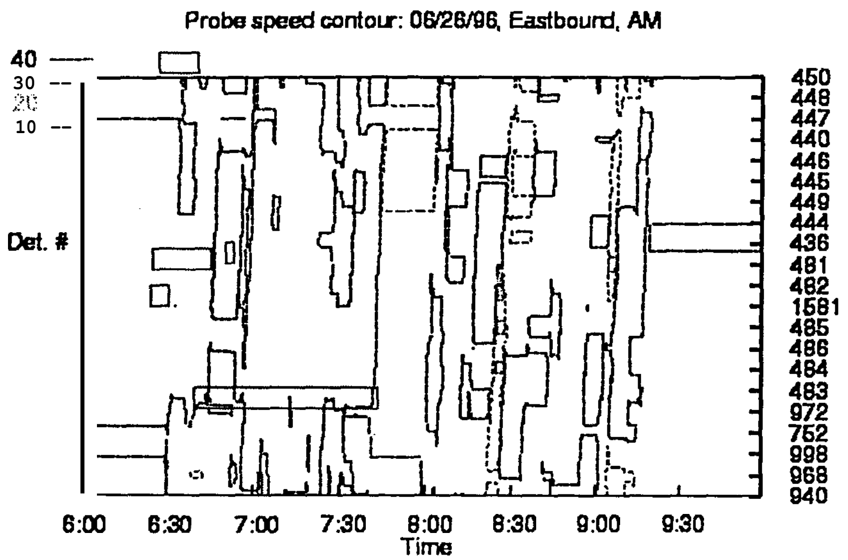
APPENDIX C.

SAMPLE FIELD DATA

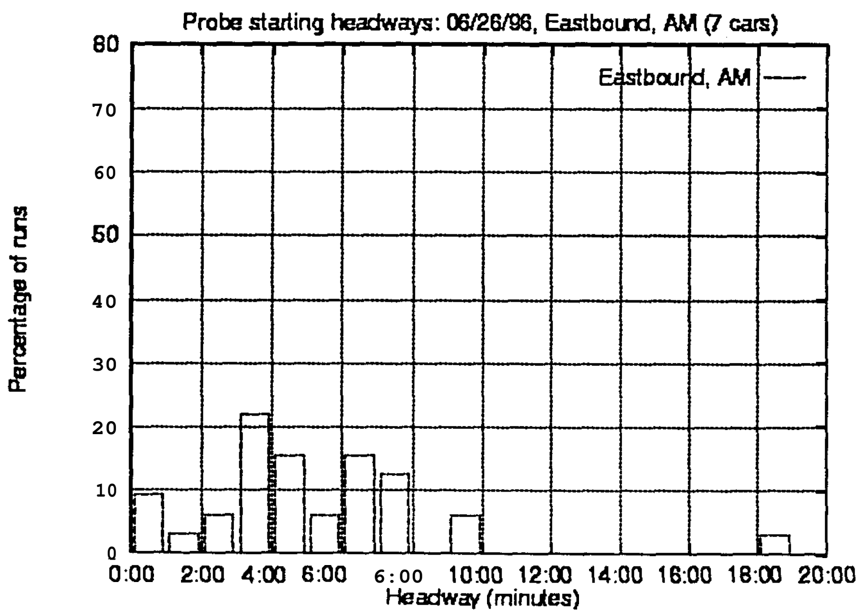
Probe Vehicle Runs
Incident Report
FSP Log

Probe data: 06/26/96 AM shift

Eastbound contour plot:

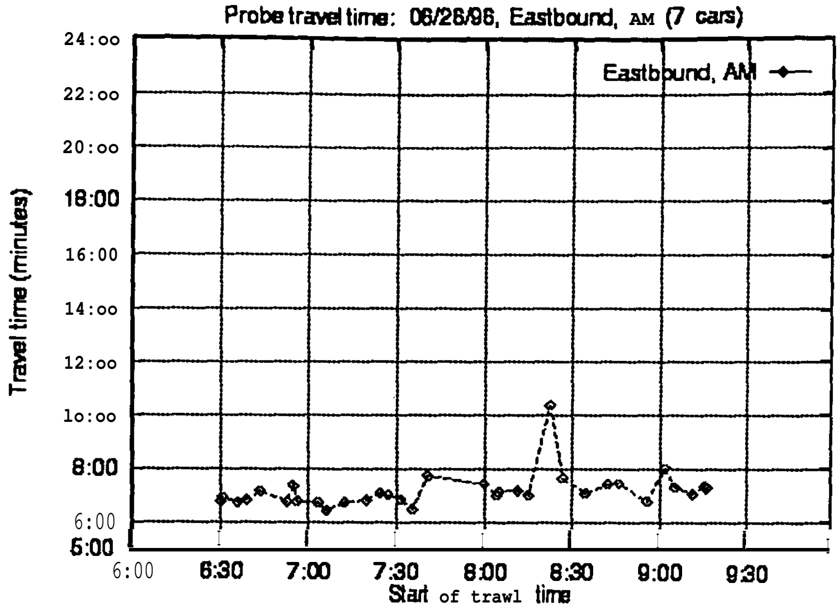


Eastbound headway distribution:

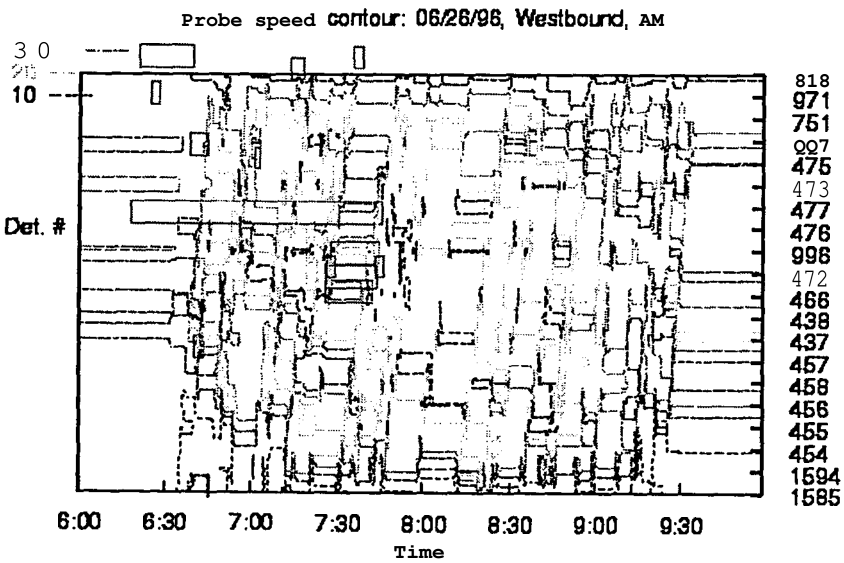


Eastbound travel time:

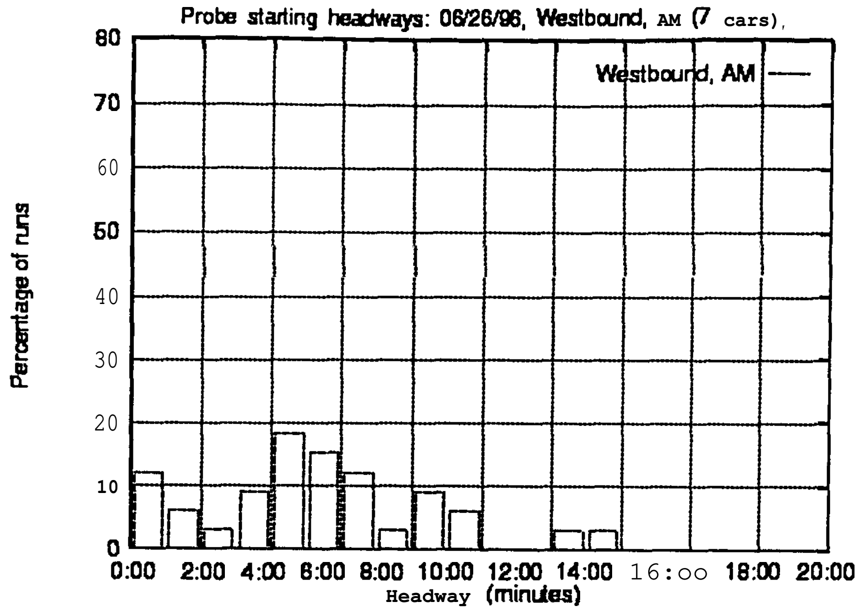
FIGURE 4-2 AUTOMATIC PROBE VEHICLE REPORT



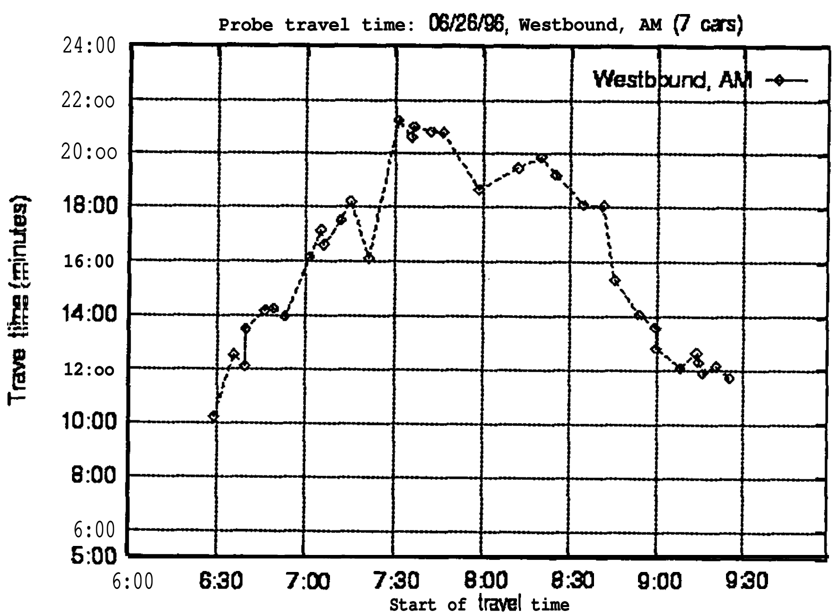
Westbound contour plot:



Westbound headway distribution:



Westbound travel time:



Detailed report of probe runs:

```
Summary for probe transfer Tran_6_26_96.b:
  Zip file seems intact
  Main zip file contains 7 files:
      file labeled 1 :  6/26  ->  car 1
      file labeled 2 :  6/26  ->  car 2
          WARNING: Multiple sub-directories (using 062696a2)
      file labeled 3 :  6/26  ->  car 3
      file labeled 4 :  6/26  ->  car 4
          WARNING: Multiple sub-directories (using 062696a4)
      file labeled 5 :  6/26  ->  car 5
      file labeled 6 :  6/26  ->  car 6
```

file labeled 7 : 6/26 -> car 7

Summary of probe vehicle activity:

Car	Date	Driver	Calibration	# Runs (# Incs) rt10-e	# Runs (# Incs) rt10-w
1	6/26	SANTIAGO , ROBERT	0.820	5 (16)	7 (27)
2	6/26	SANTIAGO , ISABEL	0.823	2 (2)	3 (5)
3	6/26	CASTILLO , ANGIE	0.815	5 (12)	6 (19)
4	6/26	CUMMINGS , MIKE	0.821	6 (6)	6 (12)
5	6/26	TORRES , HECTOR	0.832	6 (5)	5 (5)
6	6/26	MCGREGOR , DAX	0.835	6 (4)	5 (5)
7	6/26	ZELADA , ANDY	0.882	4 (3)	4 (7)

Detailed summary of every run:

****

CAR: 1, SANTIAGO, ROBERT, 6/26

Run	Start time	Duration	Total Distance	Speed	#Incs	INCIDENTS Num	Time	Loc
rt10-e								
1	6:43:59	428 (0:07:08)	39237 (7.43)	62.5	3			
						1	179	16215
						2	213	19318
						3	417	38354
2	7:12:54	402 (0:06:42)	39199 (7.42)	66.5	2			
						1	195	19254
						2	377	37285
3	7:41:25	464 (0:07:44)	39270 (7.44)	57.7	5			
						1	81	7811
						2	99	9341
						3	210	19460
						4	265	24064
						5	437	37338
4	8:22:49	621 (0:10:21)	39279 (7.44)	43.1	4			
						1	5	389
						2	40	3182
						3	102	7791
						4	360	19244
5	9:02:26	481 (0:08:01)	39293 (7.44)	55.7	2			
						1	85	7714
						2	117	10712
rt10-w								
1	6:29:27	613 (0:10:13)	36030 (6.82)	40.1	2			
						1	345	22323
						2	597	35021
2	6:53:38	838 (0:13:58)	35979 (6.81)	29.3	2			
						1	492	22284
						2	824	35080
3	7:21:56	967 (0:16:07)	35995 (6.82)	25.4	5			
						1	212	11307
						2	285	14219
						3	316	15199
						4	549	22316
						5	951	35020
4	7:59:06	1120 (0:18:40)	36029 (6.82)	21.9	2			
						1	747	22331
						2	1101	34831
5	8:20:53	1 (0:00:01)	0 (0.00) B	0.0	7			
						1	0	0
						2	0	0
						3	0	0
						4	0	0
						5	0	0

									6	0	0
									7	0	0
6	8:41:47	1084	(0:18:04)	36054	(6.83)		22.7	5			
									1	555	16691
									2	596	17680
									3	616	18242
									4	670	19866
									5	790	23305
7	9:16:41	715	(0:11:55)	35977	(6.81)		34.3	4			
									1	310	17739
									2	312	17832
									3	349	19427
									4	407	22513

****

CAR: 2, SANTIAGO, ISABEL, 6/26

Run	Start time	Duration		Total Distance			Speed	#Incs	INCIDENTS Num	Time	Loc
rt10-e											
1	8:27:16	458	(0:07:38)	39217	(7.43)		58.4	1			
									1	93	9165
2	9:05:34	437	(0:07:17)	39256	(7.43)		61.2	1			
									1	120	10860
rt10-w											
1	8:04:26	1196	(0:19:56)	39414	(7.46)	B	22.5	2			
									1	690	22268
									2	1119	34409
2	8:45:49	921	(0:15:21)	35987	(6.82)		26.6	3			
									1	69	4903
									2	515	19073
									3	616	22446
3	9:15:00	738	(0:12:18)	36253	(6.87)		33.5	0			

****

CAR: 3, CASTILLO, ANGIE, 6/26

Run	Start time	Duration		Total Distance			Speed	#Incs	INCIDENTS Num	Time	Loc
rt10-e											
1	6:53:11	404	(0:06:44)	39584	(7.50)		66.8	2			
									1	172	16469
									2	383	37746
2	7:20:24	408	(0:06:48)	39581	(7.50)		66.1	1			
									1	81	8124
3	8:00:17	444	(0:07:24)	40417	(7.65)	H	62.1	4			
									1	8	672
									2	93	8221
									3	403	37771
									4	403	37771
4	8:34:59	423	(0:07:03)	39519	(7.48)		63.7	2			
									1	90	8218
									2	209	19575
5	9:11:58	422	(0:07:02)	39610	(7.50)		64.0	3			
									1	91	8151
									2	330	31355
									3	399	37727
rt10-w											
1	6:36:02	751	(0:12:31)	36037	(6.83)		32.7	2			
									1	426	22336
									2	687	32416
2	7:01:54	969	(0:16:09)	36054	(6.83)		25.4	2			
									1	531	22375
									2	749	28283
3	7:31:41	1274	(0:21:14)	36047	(6.83)		19.3	3			
									1	359	13912
									2	482	16729

Run	Start time	Duration		Total Distance	Speed	#Incs	Num	Time	Loc
							3	763	22309
4	8:12:25	1169	(0:19:29)	36031 (6.82)	21.0	3			
							1	543	18266
							2	726	22346
							3	1146	34541
5	8:54:31	844	(0:14:04)	36049 (6.83)	29.1	4			
							1	415	16706
							2	500	19504
							3	556	22387
							4	835	35494
6	9:21:04	730	(0:12:10)	36041 (6.83)	33.7	5			
							1	256	16703
							2	272	17780
							3	292	18445
							4	350	19484
							5	404	22381

- ⊠⊠⊠

CAR: 4, CUMMINGS, MIKE, 6/26

Run	Start time	Duration		Total Distance	Speed	#Incs	INCIDENTS Num	Time	Loc
rt10-e									
1	6:31:04	414	(0:06:54)	39150 (7.41)	64.5	0			
2	6:55:20	441	(0:07:21)	39168 (7.42)	60.6	1			
							1	179	16247
3	7:27:44	419	(0:06:59)	39221 (7.43)	63.8	1			
							1	89	8010
4	8:05:02	427	(0:07:07)	39234 (7.43)	62.6	2			
							1	16	1547
							2	89	7887
5	8:42:41	444	(0:07:24)	39169 (7.42)	60.2	1			
							1	91	7908
6	9:16:40	435	(0:07:15)	39285 (7.44)	61.6	1			
							1	85	7818
rt10-w									
1	6:39:54	727	(0:12:07)	35934 (6.81)	33.7	2			
							1	429	23252
							2	672	32240
2	7:06:40	996	(0:16:36)	36018 (6.82)	24.7	2			
							1	95	7781
							2	780	28162
3	7:36:54	1260	(0:21:00)	35929 (6.80)	19.4	1			
							1	673	20316
4	8:20:18	1193	(0:19:53)	35673 (6.76)	20.4	2			
							1	203	7845
							2	1165	34154
5	9:00:02	816	(0:13:36)	35937 (6.81)	30.0	3			
							1	363	16563
							2	389	17664
							3	807	35359
6	9:25:47	704	(0:11:44)	35862 (6.79)	34.7	2			
							1	309	18281
							2	584	29720

****

CAR: 5, TORRES, HECTOR, 6/26

Run	Start time	Duration		Total Distance	Speed	#Incs	INCIDENTS Num	Time	Loc
rt10-e									
1	6:30:28	404	(0:06:44)	39960 (7.57) H	67.4	1			
							1	21	2235
2	6:56:47	405	(0:06:45)	39969 (7.57) H	67.3	0			
3	7:25:00	423	(0:07:03)	39994 (7.57) H	64.5	1			
							1	89	8054
4	8:04:26	419	(0:06:59)	39961 (7.57) H	65.0	1			

Run	Start time	Duration	Total Distance	Speed	#Incs	Num	Time	Loc
						1	87	8048
5	8:46:25	446 (0:07:26)	39998 (7.58) H	61.1	1			
						1	89	8010
6	9:15:44	441 (0:07:21)	40127 (7.60) H	62.0	1			
						1	93	8019
rt10-w								
1	6:40:09	810 (0:13:30)	36645 (6.94)	30.8	0			
2	7:05:31	1028 (0:17:08)	36619 (6.94)	24.3	1			
						1	852	29084
3	7:36:07	1237 (0:20:37)	36621 (6.94)	20.2	1			
						1	660	20697
4	8:25:20	1153 (0:19:13)	36616 (6.93)	21.7	2			
						1	599	18596
						2	991	28894
5	9:00:13	770 (0:12:50)	36595 (6.93)	32.4	1			
						1	762	36078

****

CAR: 6, MCGREGOR, DAX, 6/26

Run	Start time	Duration	Total Distance	Speed	#Incs	INCIDENTS Num	Time	Loc
rt10-e								
1	6:36:24	402 (0:06:42)	38989 (7.38)	66.1	0			
2	7:03:42	402 (0:06:42)	38965 (7.38)	66.1	0			
3	7:32:14	409 (0:06:49)	39011 (7.39)	65.0	1			
						1	80	7705
4	8:11:46	429 (0:07:09)	38990 (7.38)	62.0	1			
						1	89	7934
5	8:56:09	405 (0:06:45)	38653 (7.32) L	65.1	1			
						1	78	7805
6	9:24:11	398 (0:06:38)	37326 (7.07) B	63.9	1			
						1	62	6113
rt10-w								
1	6:46:41	852 (0:14:12)	35728 (6.77)	28.6	0			
2	7:12:18	1050 (0:17:30)	35688 (6.76)	23.2	1			
						1	874	28369
3	7:42:43	1250 (0:20:50)	35806 (6.78)	19.5	1			
						1	1047	27880
4	8:35:03	1087 (0:18:07)	35730 (6.77)	22.4	2			
						1	488	16555
						2	682	20135
5	9:08:54	725 (0:12:05)	35754 (6.77)	33.6	1			
						1	343	19366

****

CAR: 7, ZELADA, ANDY, 6/26

Run	Start time	Duration	Total Distance	Speed	#Incs	INCIDENTS Num	Time	Loc
rt10-e								
1	6:39:28	408 (0:06:48)	39193 (7.42)	65.5	0			
2	7:06:45	385 (0:06:25)	39176 (7.42)	69.4	0			
3	7:36:11	388 (0:06:28)	39200 (7.42)	68.9	2			
						1	77	7727
						2	232	24029
4	8:15:19	419 (0:06:59)	39435 (7.47)	64.2	1			
						1	84	7776
rt10-w								
1	6:49:33	856 (0:14:16)	35926 (6.80)	28.6	1			
						1	460	22361
2	7:15:38	1092 (0:18:12)	35906 (6.80)	22.4	2			
						1	237	11317
						2	715	22284
3	7:46:44	1247 (0:20:47)	35923 (6.80)	19.6	2			
						1	550	18108
						2	1043	27966

4	9:14:18	758	(0:12:38)	36311 (6.88)	32.7	2		
						1	307	16628
						2	365	19084

Breakdown of distances (miles) for evaluation:

rt10-e:	bad	<	7.20	<	low	<	7.35	<	good	<	7.55	<	high	<	7.70	< bad
rt10-w:	bad	<	6.60	<	low	<	6.75	<	good	<	6.95	<	high	<	7.10	< bad

Evaluation of probe runs:

Car	Date	Driver	Calib.	Dir	#Runs	Bad	Low	Good	High
1	6/26	SANTIAGO, ROBERT	0.820	rt10-e	5	0	0	5	0
				rt10-w	7	1	0	6	0
2	6/26	SANTIAGO, ISABEL	0.823	rt10-e	2	0	0	2	0
				rt10-w	3	1	0	2	0
3	6/26	CASTILLO, ANGIE	0.815	rt10-e	5	0	0	4	1
				rt10-w	6	0	0	6	0
4	6/26	CUMMINGS, MIKE	0.821	rt10-e	6	0	0	6	0
				rt10-w	6	0	0	6	0
5	6/26	TORRES, HECTOR	0.832	rt10-e	6	0	0	0	6
				rt10-w	5	0	0	5	0
6	6/26	MCGREGOR, DAX	0.835	rt10-e	6	1	1	4	0
				rt10-w	5	0	0	5	0
7	6/26	ZELADA, ANDY	0.882	rt10-e	4	0	0	4	0
				rt10-w	4	0	0	4	0
TOTALS									
				rt10-e	34	1	1	25	7
				rt10-w	36	2	0	34	0
				TOTAL:	70	3	1	59	7

Starting headway statistics for this shift:

Date	Shift	Direction	Side	#Runs	Mean	Std Dev	Min	Max
6/26	Am	rt10-e	start	33	311.6	207.3	36	1132
6/26	Am	rt10-w	start	34	320.6	196.6	11	799

Ending headway statistics for this shift:

Date	Shift	Direction	Side	#Runs	Mean	Std Dev	Min	Max
6/26	Am	rt10-e	end	33	312.6	216.2	44	1112
6/26	Am	rt10-w	end	34	323.4	217.9	22	892

FIGURE 4-4

SAMPLE INCIDENT LOG

WILTEC - FSP SURVEY INCIDENT REPORT

BY: Andy DATE: 7-18-96 PERIOD: P.M. PAGE: 02/7

TIME	CAR NO	DIR	MILE NO	INCIDENT					
				DESCRIPTION	VEHICLE	ASSISTANCE	REASON	OTHER	LOCATION
HR . MIN		E - EB W - WB		Color eg: Black White Blue Other eg: UPS RTA	MC - Motor Cycle Car Truck Van Semi - Semi Truck Bus	CHP POL - Other Police or Sheriff FT - Fire Truck FSP - Freeway Service Patrol PT - Private Tow AMB - Ambulance CT - CALTRANS	ACC - Accident BD - Break Down TKT - Ticket UNK - Unknown	PED - Pedestrian Debris Cones Flares Signs	HOV - HOV Lane DIV - HOV Divide Lane LS - Left Shldr Lane 1 Lane 2 Lane 3 Lane 4 RS - Right Shldr
410	06	WB	2.5	Blue	Car	FSP	BD		RS
410	06	WB	2.7			FSP			RS
413	10	WB	4.2	Brown	Toyota		Bd		RS
415	06	WB	5.5	Red	TRUCK		STUDY		RS
				BLACK	TRUCK				
				Red	TRUCK				
422	07	WB	2.5	Blue	Dodge		BD	1 Ped	RS
423	07	WB	4.1			FSP			RS
424	07	WB	4.8	WHITE	TRUCK	FSP	BD	1 Ped	RS
425	07	WB	5.4	Red	TRUCK		STUDY		RS
				BLACK	TRUCK				
				Red	TRUCK				
428	02	EB	3.1	GREY	MAZDA		BD		Lane 1
429	10	WB	4.1			FSP			RS
430	10	WR	5.4	Red	TRUCK		STUDY		RS

FIGURE 4-5 FSP ASSIST FORM

MOTORIST ASSIST FORM

Right / Wrong

DATE			TIME	TIME	DRIVER	BEAT
MO	DAY	YR	ARRIVED	DEPARTED	ID	ID

USE MILITARY TIME

DISABLED VEHICLE LICENSE NO. / 1 California 2 Other

MOTORIST NAME

MOTORIST ADDRESS (optional)

LOCATION OF DISABLED VEHICLE

LOCATION DISABLED VEHICLE TOWED TO

How long did motorist wait for (you) the Freeway Service Patrol?

Fill in the number of minutes →

Did you tow vehicle to:
1 Shoulder 2 Off Freeway 3 No Tow

Did the motorist need additional assistance?
1 Yes 2 No

At what speed was traffic traveling prior to this assist?
1 under 20 mph 2 21 to 30 mph' 3 31-40 mph 4 above 40 mph

Problem with the vehicle:
51 Out of Gas 54 Over Heated 57 Flat Tire 60 Accident
52 Electrical Problem 55 Vehicle Fire 58 Locked Out 61 Abandoned
53 Debris Removal 56 Mechanical Problem 59 Other 62 Unknown

Type of vehicle assisted:
1 Auto 2 Van 3 Pickup 4 Truck less than 1 ton 5 Truck more than 1 ton
6 Motorcycle 7 Dig Rig 8 No assist due to oversize 9 Other

Vehicle location was:
1 Found By You 2 Dispatched By CHP 3 Dispatched By Caltrans

Disabled vehicle was:
1 In Freeway Lanes 2 On Left Shoulder 3 On Right Shoulder
4 On A Ramp 5 Other 6 Unable to Locate

TURN OVER TO COMPLETE

239734

DO NOT MARK IN THIS AREA

APPENDIX D.

LOS ANGELES FSP PROGRAM COSTS

Source: *MTA Memorandum (5/21/97)*

May 21,1997

TO: ROBERT BERTINI

FROM: ALISON ANDREAS

SUBJECT: METRO FREEWAY SERVICE PATROL COST ESTIMATE

Non-Capital Costs for Beats 1-43

Costs reflected below exclude both insurance and the Drivers' Tips Fund. Insurance is not included because no claims have been paid and the tips account is not included in FSP's operating costs.

1. Operational Costs - Tow Contractor Costs for All Beats

Yearly Truck Hours: 246 days x 8 hours x 150 trucks = 295,200 Hours

Average Contract Expenditure Cost Per Truck Hour:
$41.91
(Number derived from the average of monthly hourly rates for one year)

Total Contract Cost: $12,371,832.00
295,200 Hours x $41.91

2. Operational Costs - not including tow contractors

Business Reply Mail (returned Scantrons)	$ 19,354.62
Graphics & Printing	$ 4,285.71
Communications Equipment Maintenance	$ 5,835,09
Scantron Supplies & Maintenance	% 26,226.11
CHP Pagers	$ 2,640.00
L.A. Cellular	$ 1,200.00
L.A. County Radio (radio transmission)	$ 684,000.00
Total:	$ 743,541.53

3. Administrative Costs

MTA Staff *(salary, benefits, overhead)	$ 131,882.70
Caltrans Staff** (statistics/supplies)	$ 480,000.00
CHP Staff*** (dispatch/training/supervision)	$698,361 .OO
Travel & Training	$ 940.29
Merchandise (supplies & commendables)	$ 32,647.38
Total:	$1,479,670.55

- M TA salaries are paid by SAFE
- *M TA does no tpay salaries for staff at Caltrans

***CHP Staff and Materials are paid 60% by Caltrans & 40% by MTA

4. Capital Costs

Radios	$ 97,142.00
L.A. Radio Frequency Equipment	$ 696,000.00
Motorola Frequency ($5 million over 7 years)	$ 714,285.71
TMSI Addition ($780,000 over 7 years)	$ 111,500.85
Westinghouse Contract ($1.1 million over 7 years)	$ 157,142.85
Total:	**$1,776,071.40**

<u>Total Costs for all FSP Beats</u>

Operational Costs - Tow Contractor Costs	$12,371,832.00
Operational Costs - Non- Tow Contractor Costs	$ 743,541.53
Admiiistrative Costs	$ 1,479,670.55
Capital Costs	$ 1,776,071.40
Total:	$ 16,371,115.48

<u>Total Costs for Beat 8*</u>

*Beat 8 is a 3-Truck Beat

Yearly	246 Service Days
Truck Hours (246 days x 8 hours x 3 trucks)	5904
% of FSP Service (5904/295,200 x 100)	2%

Per Year	$ 331,445.67
Per Service Day	$ 1325.78
Per Truck Hour	$ 55.24
Per Beat Hour	$ 165.72