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Evaluation of the Bay Area Incident Response System (BAIRS)

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EVALUATION OF THE BAY AREA INCIDENT RESPONSE SYSTEM (BAIRS)

Michael Mauch, Koohong Chung, Soyoung Ahn & Alexander Skabardonis
September 2005

ABSTRACT

The Bay Area Incident Response System (BAIRS) is an integrated Web and GIS based incident tracking system that provides tools to improve California's Department of Transportation (Caltrans) incident management capabilities. Currently, BAIRS aids District 4 Maintenance respond to and track over 33,000 incidents per year throughout the San Francisco Bay area.

The report presents the findings from the evaluation of the BAIRS system based on field data on incidents and traffic conditions. Through the implementation of BAIRS, incident response and clearance times were reduced by about 15%. Incident related delays were reduced by 210,000 vehicles-hours annually. The estimated BAIRS benefit-cost ratio is 5:1 based on the incident delay savings. Other benefits that are not reflected in the benefit-cost ratio include reduced fuel consumption and mobile emissions, and improved safety and access for emergency response vehicles.

Keywords:
BAIRS, incidents, delay

EXECUTIVE SUMMARY

A significant amount of congestion delay on freeways is caused by incidents (accidents, breakdowns, spilled loads and other random events). It is important that effective and efficient management procedures are in place to quickly detect, verify, respond and clear incidents to minimize their adverse impacts to the traffic stream. The Bay Area Incident Response System (BAIRS) is a computerized incident management tool implemented by Caltrans District 4 in San Francisco Bay Area to improve their incident management capabilities. Since its inception in June 2003, BAIRS has been assisting District 4 to respond and manage over 33,000 incidents per year.

BAIRS uses a real-time web-based set of databases integrated into Geographic Information System (GIS) software to identify and map the location of the incident and the location and availability of Caltrans maintenance supervisors, workers, and equipment. The responding supervisor can locate the nearest maintenance crew, equipment and materials using laptop computer and BAIRS. By providing real-time communication and access to information, BAIRS keeps both the Dispatcher and the responding maintenance crew up-to-date with all pertinent information about the incidents. BAIRS modernized several outdated paper-pencil based and labor intensive incident logging and tracking procedures.

The study described in this report, performed an evaluation of the effectiveness of the BAIRS system in reducing incident delays based on field data. Data on incidents and their characteristics were collected “before” and “after” the implementation of BAIRS. Overall, BAIRS reduced the incident durations by about 15%. Incident related delays were calculated based on field data on flows and speeds from loop detectors. The annual delay saving benefits from BAIRS due to shorter incident durations is 210,000 vehicle-hours. BAIRS benefit-cost ratio is in the order of 5:1. Other benefits that are not reflected in the estimated benefit-cost ratio include reduced fuel consumption and mobile emissions, and improved safety and access for emergency response vehicles.

The study also developed recommendations for improvements to the existing BAIRS system, and possible implementation to other Caltrans Districts.

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CHAPTER 1
INTRODUCTION

1.1 Problem Statement

In response to traffic incidents on freeways and state routes, Caltrans dispatches highway maintenance personnel who work with law enforcement and other public safety individuals to control traffic, clean-up accidents, remove debris, clean-up hazardous spills, etc. However, the process of dispatching personnel has always been cumbersome and time consuming. To that end, it can take as much as 90 minutes to get Caltrans personnel on the scene; including the time to identify and contact the correct responding party, and then time for maintenance personnel to travel to the site [1].

Knowing that every minute of delay has a significant impact on traffic, Caltrans District 4 Maintenance division investigated methods to more efficiently manage traffic incidents in the San Francisco Bay Area. Specifically, the District sought to expedite the incident resolution process by focusing on reducing the time needed to dispatch maintenance crews, assess need and gather resources. Based on a study of the dispatching process and corresponding personnel response times to clear incidents, the following issues were identified [2]:

1. Multiple calls are frequently required to secure appropriate response personnel,
2. Contact and availability information is not frequently updated, causing delays in contacting the appropriate party to dispatch,
3. For after-hours incidents, maintenance crews responsible for the area are dispatched, even though they often live much further away than other potential responders.
4. Limited information about incidents results in an inability to determine which tools and resources are needed to resolve the incident prior to arriving on-scene; thus, additional time was needed to get the necessary tools and resources on-scene.

In August 2002, District 4 initiated the Bay Area Incident Response System (BAIRS) project to develop a new system that streamlines dispatching and incident response processes. The project aimed to use cutting-edge technology to empower Maintenance personnel with real-time information in the field. This would allow dispatchers to quickly mobilize the personnel and resources closest to an incident to reduce costly transit times and begin clearing incidents faster [3]. The outcome, BAIRS, is a computerized incident management and tracking system that assists Caltrans maintenance supervisors to respond more efficiently to traffic incidents in District 4.

The BAIRS system has been operational since June of 2003 and is being used to improve response times and management reporting of over 33,000 incidents per year [4]. However, no evaluation study had been performed to quantify the effectiveness of the BAIR system in terms of reductions response and clearance times, and delay savings from the faster incident clearances.

1.2 Objectives of the Study

The objectives of this research project were to evaluate the effectiveness of the BAIRS system; to quantify the reductions in response and clearance times, estimate the incident delay savings attributable to BAIRS, determine the benefit-cost ratio of BAIRS, and provide state-wide implementation recommendations.

1.3 Organization of the Report

This report documents the methods and data used to evaluate the BAIRS system and the findings of the evaluation. Incident management systems and an overview of BAIRS are in Chapter 2. Chapter 3 contains the study methodology. The study's findings are presented in Chapter 4. The benefits, costs, and benefit-cost estimates are reported in Chapter 5. Conclusions and recommendations for statewide implementation are in Chapter 6.

CHAPTER 2
BACKGROUND

2.1 California's Incident Management Systems

TMS Master Plan [5]: In 2002, California Department of Transportation (Caltrans) introduced a Transportation Management Systems (TMS) Master plan to improve its use of the existing transportation system to improve its use of the existing transportation system by harnessing information technology to support productivity improvement management strategies. Three major areas of change were identified in the TMS Master Plan with respect to incident management:

1) Advance Caltrans' implementation of their incident management roles to the point that they demonstrate true state of the art,
2) Continually improve working relations with partners, and
3) Expand the use of tools to increase safety and decrease clearance times.

Quick Strike Response Teams [6]: In early 2003, Caltrans Division of Maintenance Quick Strike Response Teams was developed with the goal of initiating response to incidents in a timely and effective manner ensuring minimal disruption to the traveling public. The Quick Strike Response Team initiative purpose was to minimize congestion by reducing response times to incidents on the State highway system by pre-assigning and prioritizing field emergency activities to the closest responders within an assigned Maintenance Region.

InterCAD [7]: San Diego Regional Interconnect Project (InterCAD), a showcase Early Start Project that was originally developed to improve highway incident management in San Diego County. InterCAD enables swift coordination interagency response even to multi-jurisdictional incidents. Specifically, InterCAD improves the transfer of time critical and incident related information between operations within the participating agencies' communications centers. InterCAD provides fast, secure data messaging and e-mail system between Computer Aided Dispatch (CAD) supervisors at emergency service, first response, law enforcement, and transportation agencies.

InterCAD's Phase I, completed in 1996, was a concept demonstration and feasibility analysis, and was funded by local funds and the Service Authority for Freeway Emergencies (SAFE). Phase II started shortly after, and included an expansion and demonstration of the Phase I capabilities. The following agencies participated in the Phase II operational tests:

- Caltrans District 11 Transportation Management Center (TMC)
- Federal Fire Department
- Heartland Communications
- California Department of Forestry/Cleveland National Forest.

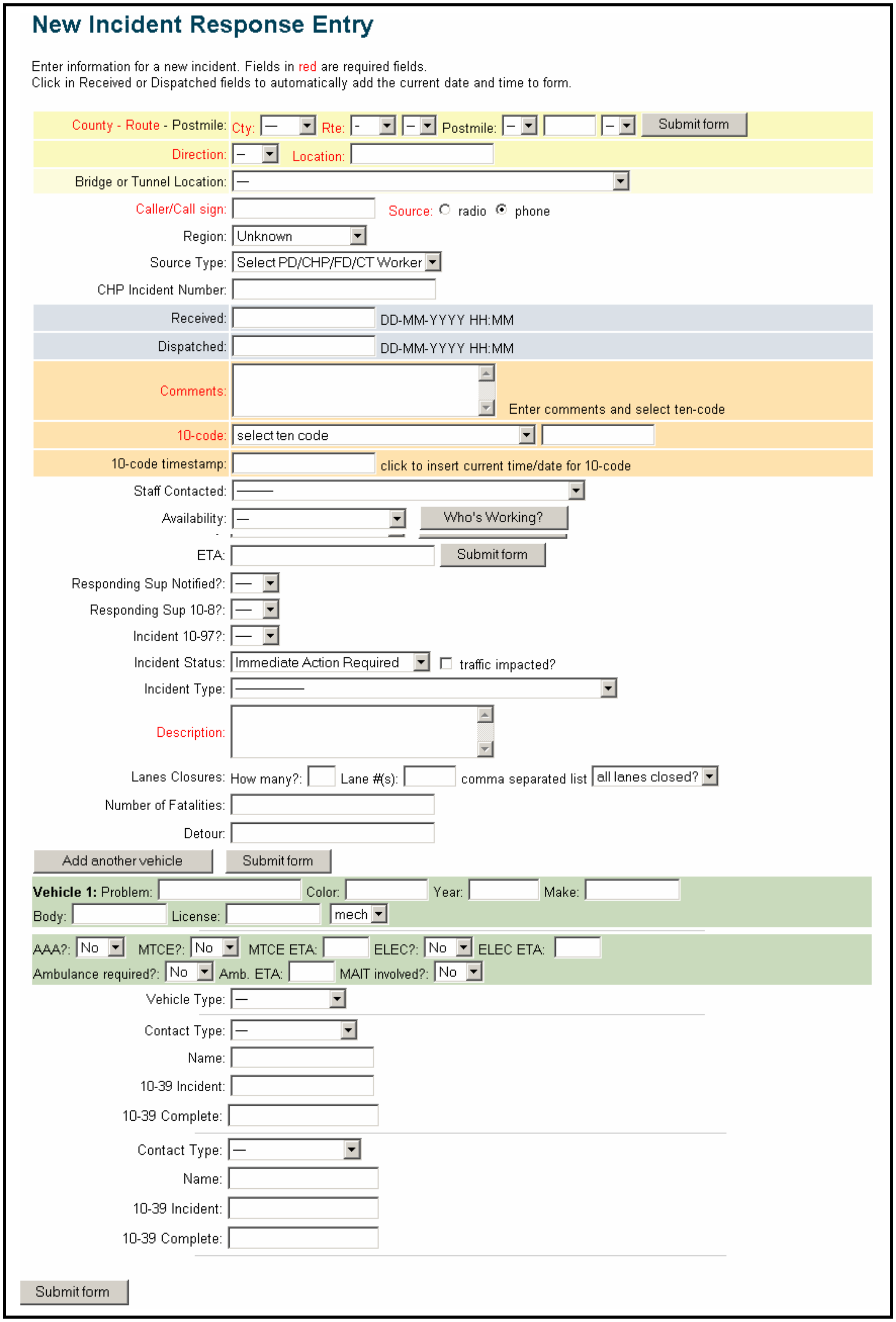
2.2 Description of the BAIRS System

In August 2002, District 4 began the tasks of updating their incident management procedures and the development of a new incident management system, streamline the dispatch and incident response process. During these efforts, District 4 management wisely incorporated information technology in the incident management process aiding in reduced incident response and clearance times. The foremost outcome of these efforts, the Bay Area Incident Response System (BAIRS), a custom-built Web and Geographic Information System (GIS) based computer application. BAIRS empowers Maintenance personnel with real-time information in the field, allowing dispatchers to quickly mobilize the personnel and resources closest to an incident to reduce costly transit times and begin clearing incidents faster.

BAIRS utilizes the latest in Internet technologies to create a web-based incident log. This incident log, tied to Geographic Information System (GIS) capabilities, is especially useful when dispatching personnel from their home locations (e.g. after normal Caltrans work hours or on weekends). With BAIRS, any maintenance supervisor can locate the specific coordinates of the incident and plot the location on a map. From there, the closest and/or most capable crew is identified and contacted using online (and up-to-date) contact and availability information. The responding supervisor uses her/his wireless laptop to locate the nearest equipment and materials needed to clear the roadway. Since the technology provides real-time communication and access to information, both the dispatcher and the responding crew are kept up-to-date with all pertinent information. Figures 2.1 thru 2.6 show several of the BAIRS menus, forms, and GIS based mapping and database query capabilities.

BAIRS computerized incident logging procedures and databases replace TMC/District Communication Center (DCC) paper-based logging and tracking procedures (e.g. Caltrans post-mile books, call-out lists, regional directories, notification guidelines, various paper maps and guides, paper telephone books, directories, and contact sheets) along with several management reports. Additionally, BAIRS provided Caltrans Maintenance with increased incident information available to both dispatchers and supervisors, web-based incident logs, enhanced reporting capabilities, incident management performance metrics, and GIS capable mobile devices.

Figure 2.1: BAIRS Opening Screen (Splash Screen)



New Incident Response Entry

Enter information for a new incident. Fields in red are required fields.
Click in Received or Dispatched fields to automatically add the current date and time to form.

County - Route - Postmile: Cty: — Rte: - – Postmile: – – Submit form

Direction: – Location:

Bridge or Tunnel Location: —

Caller/Call sign: Source: radio phone

Region: Unknown

Source Type: Select PD/CHP/FD/CT Worker

CHP Incident Number:

Received: DD-MM-YYYY HH:MM

Dispatched: DD-MM-YYYY HH:MM

Comments: Enter comments and select ten-code

10-code: select ten code

10-code timestamp: click to insert current time/date for 10-code

Staff Contacted: ———

Availability: — Who's Working?

ETA: Submit form

Responding Sup Notified?: —

Responding Sup 10-8?: —

Incident 10-97?: —

Incident Status: Immediate Action Required traffic impacted?

Incident Type: —————

Description:

Lanes Closures: How many?: Lane #(s): comma separated list all lanes closed?

Number of Fatalities:

Detour:

Add another vehicle Submit form

Vehicle 1: Problem: Color: Year: Make:

Body: License: mech

AAA?: No MTCE?: No MTCE ETA: ELEC?: No ELEC ETA:

Ambulance required?: No Amb. ETA: MAIT involved?: No

Vehicle Type: —

Contact Type: —

Name:

10-39 Incident:

10-39 Complete:

Contact Type: —

Name:

10-39 Incident:

10-39 Complete:

Submit form

Figure 2.2: BAIRS Incident Input Form

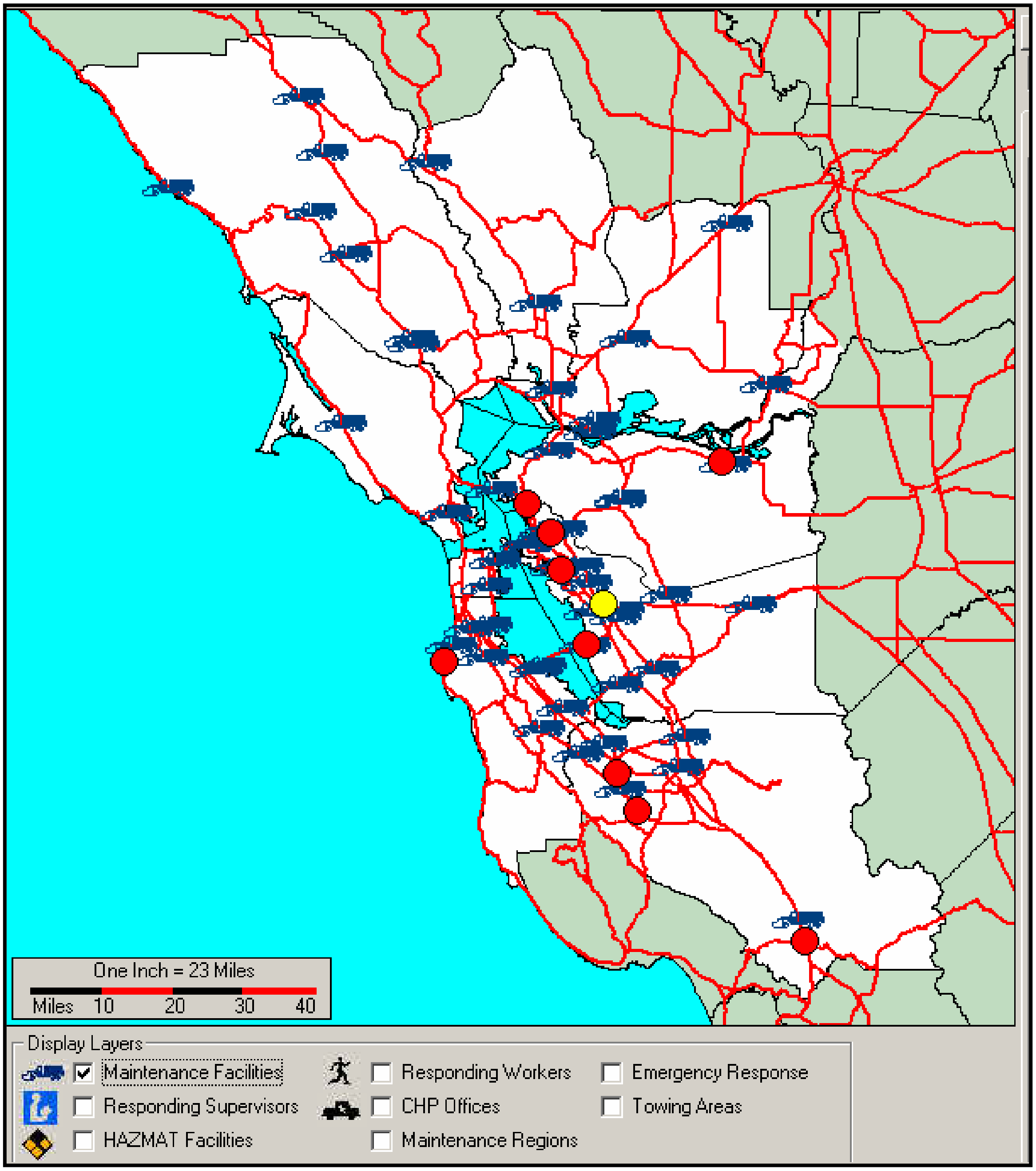


Figure 2.3: BAIRS User Screen

Note: The "Maintenance Facilities" box is checked to show location of all Maintenance Facilities in District 4, along with the location of open/active incidents.

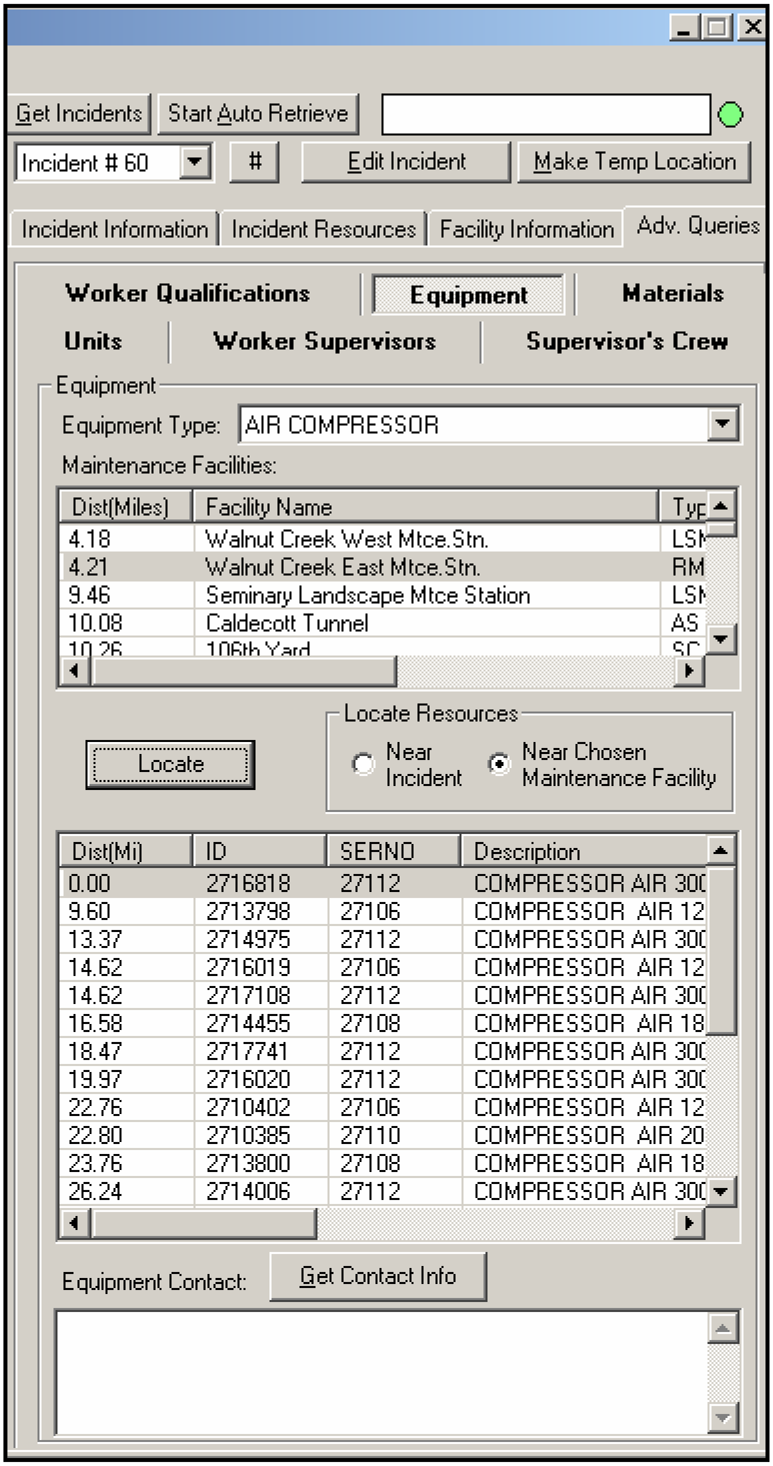


Figure 2.4: BAIRS Available Equipment User Screen

Note: BAIRS allows advanced queries on maintenance supervisors, workers, equipment, and materials. For example, users can select by "Equipment Type" if looking for a specific type of unit or locate all equipment either near maintenance yard or near an incident.

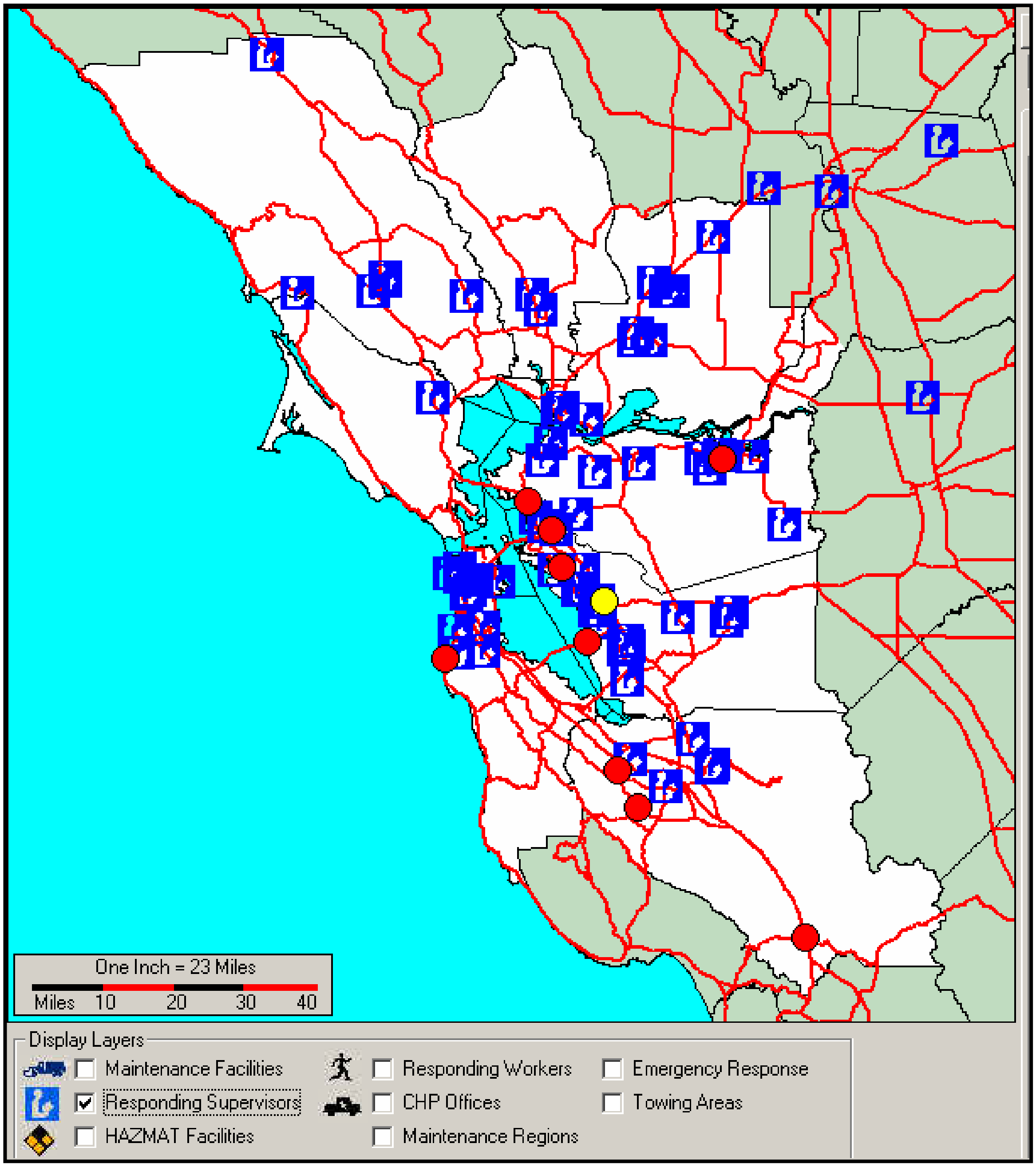


Figure 2.5: BAIRS User Screen

Note: The "Responding Supervisors" box is checked to show home location of (available) Maintenance Supervisors in District 4, along with the location of open/active incidents.

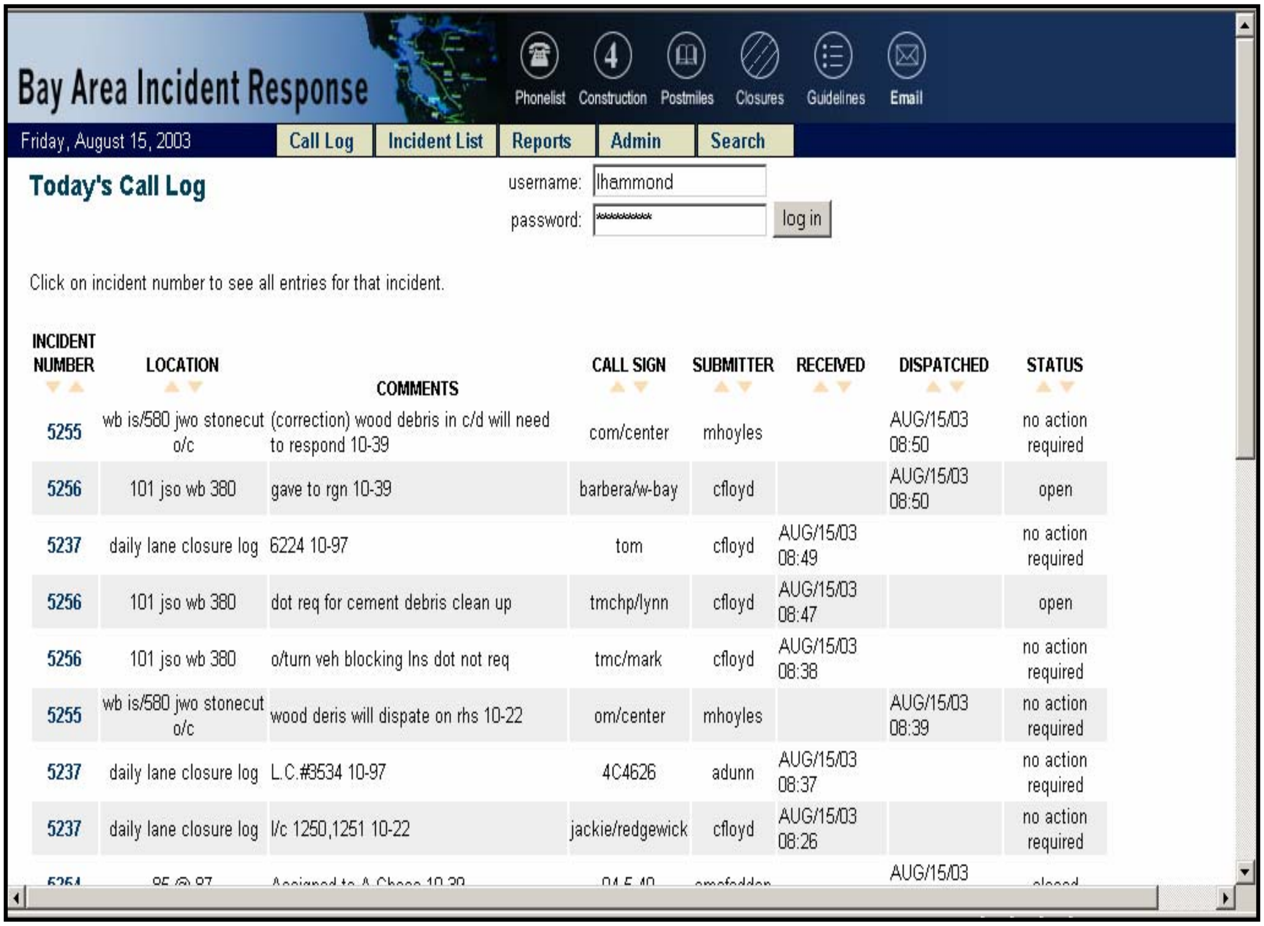


Figure 2.6: BAIRS User Screen – User Interactive Incident Logs

Note: Summary incident reports are readily available for dispatch personnel, maintenance supervisors, and management reporting. Detailed and real-time incident reports are available by simply clicking on any of the listed incident numbers.

CHAPTER 3
METHODOLOGY

3.1 Research Approach

To measure the incident response time and clearance time savings from BAIRS, field data on incident response and clearance times were obtained and analyzed from the BAIRS incident database and from Caltrans DCC/CAD and CHP incident logs (i.e. incidents occurring prior to BAIRS implementation and managed using traditional incident management techniques). This produced "Pre-BAIRS" and "With-BAIRS" incident duration and response time distributions to be compared, revealing the response and clearance time savings attributable to BAIRS. These duration and response time distributions, made known information regarding incident duration, but did not quantify the associated incident induced traffic delays. As such, traffic delays needed to be measured or estimated, then correlated to incident characteristics and durations.

Initially, BAIRS logged incidents were matched (in time and space) to traffic delays observed in flow and speed contour plots from loop detector data. Thereby, the observed delays were attributed (i.e. matched) to incidents that Caltrans Maintenance responded to the BAIRS logged incidents. Figure 3.1 displays average detector occupancy (a proxy for vehicular density) which show traffic congestion as darker areas in the time-space plane for the northbound direction of I-880 freeway on January 22 2004. The plot has been overlaid with CHP and BAIRS incidents to correlate observed delays specific incidents. Table 3.1 lists the incidents which are shown in Figure 3.1. Figure 3.2 shows average detector occupancy with incidents overlaid for the I-880 southbound direction on June 19 2004, and Table 3.2 lists the incidents shown in Figure 3.2.

However, this approach could not be reliably applied largely because the BAIRS incident delays were not sufficiently isolated, in time and space, to reliably measure their associated delays. Often incident induced delays were intermixed with delays from other nearby incidents and intermixed with delays from other causes (examples include delays from Oakland Coliseum and Arena events, delays upstream of recurrent bottlenecks and from the time-of-day HOV lane restrictions). Additionally, in many cases the incidents logs contained insufficient information to be located in the time-space plane. For example, the FSP incident logs do not contain sufficient information to locate specific incidents in space. There were only three BAIRS incidents on I-880 Southbound on June 19th, only one of which could be mapped in the time-space plane.

To complicate matters even more in terms of evaluating BAIRS incidents, not all freeway incidents are responded to by Caltrans maintenance crews and thus not logged in BAIRS. Some incidents are responded to by CHP officers, some attended to by FSP tow-trucks. Other incidents that could cause delays (e.g. fender benders) never appear anywhere in CHP, BAIRS, FSP logs. Moreover, several of these observed delays could have been reasonably matched to multiple incidents (e.g. one or more in BAIRS and/or CHP logs). Other BAIRS and CHP logged incidents flagged as "lane blockages" and as "impacting traffic" had no observable traffic impacts based on Caltrans traffic flow and speed data.

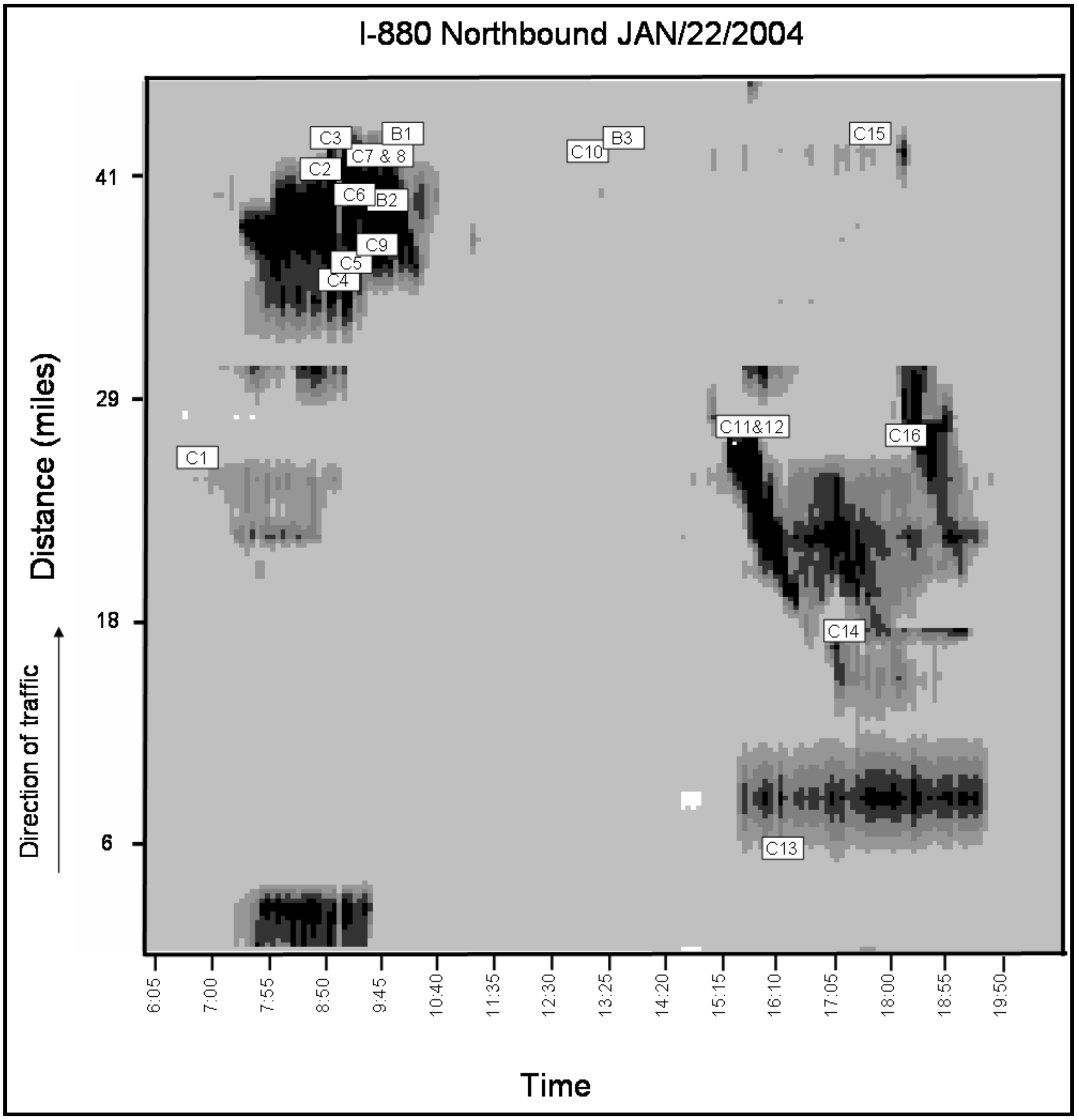


Figure 3.1: Delay and Incident Mapping (I-880 Northbound, January 22 2004)

Table 3.1: Incident Details (I-880 Northbound, January 22 2004)

Incident Number	Post Mile	Time	Incident Description
C1, CHP	25.87	6:39 AM	Traffic Hazard - Vehicle in Center Divider
C2, CHP	40.39	8:41 AM	Traffic Hazard - Vehicle
C3, CHP	41.91	8:49 AM	Traffic Collision - Ambulance Responding
C4, CHP	34.81	8:59 AM	Traffic Collision - Property Damage
C5, CHP	35.70	9:10 AM	Traffic Collision - No Details
C6, CHP	38.96	9:18 AM	Traffic Hazard - Vehicle in Center Divider
C7, CHP	40.97	9:27 AM	Traffic Collision - Property Damage
C8, CHP	41.37	9:35 AM	Traffic Collision - Ambulance Responding
C9, CHP	36.38	9:37 AM	Request for Traffic Break
C10, CHP	41.20	1:00 PM	Traffic Hazard - Debris/Objects
C11, CHP	27.40	3:25 PM	Traffic Collision - No Details
C12, CHP	26.84	3:39 PM	Hit and Run - No Injuries
C13, CHP	5.12	4:09 PM	Traffic Collision - No Details
C14, CHP	17.04	5:10 PM	Traffic Collision - No Details
C15, CHP	42.11	5:37 PM	Traffic Hazard - Vehicle in Center Divider
C16, CHP	26.84	6:10 PM	Traffic Collision - Minor Injuries
B1, BAIRS	42.10	9:58 AM	NEED DOT ASAP W/SWEEPER AND SHOVELS FOR O/T'D CEMENT MIXER
B2, BAIRS	38.70	9:43 AM	DOG/CD
B3, BAIRS	41.90	1:34 PM	LONG CHAIN ROLLED UP RS

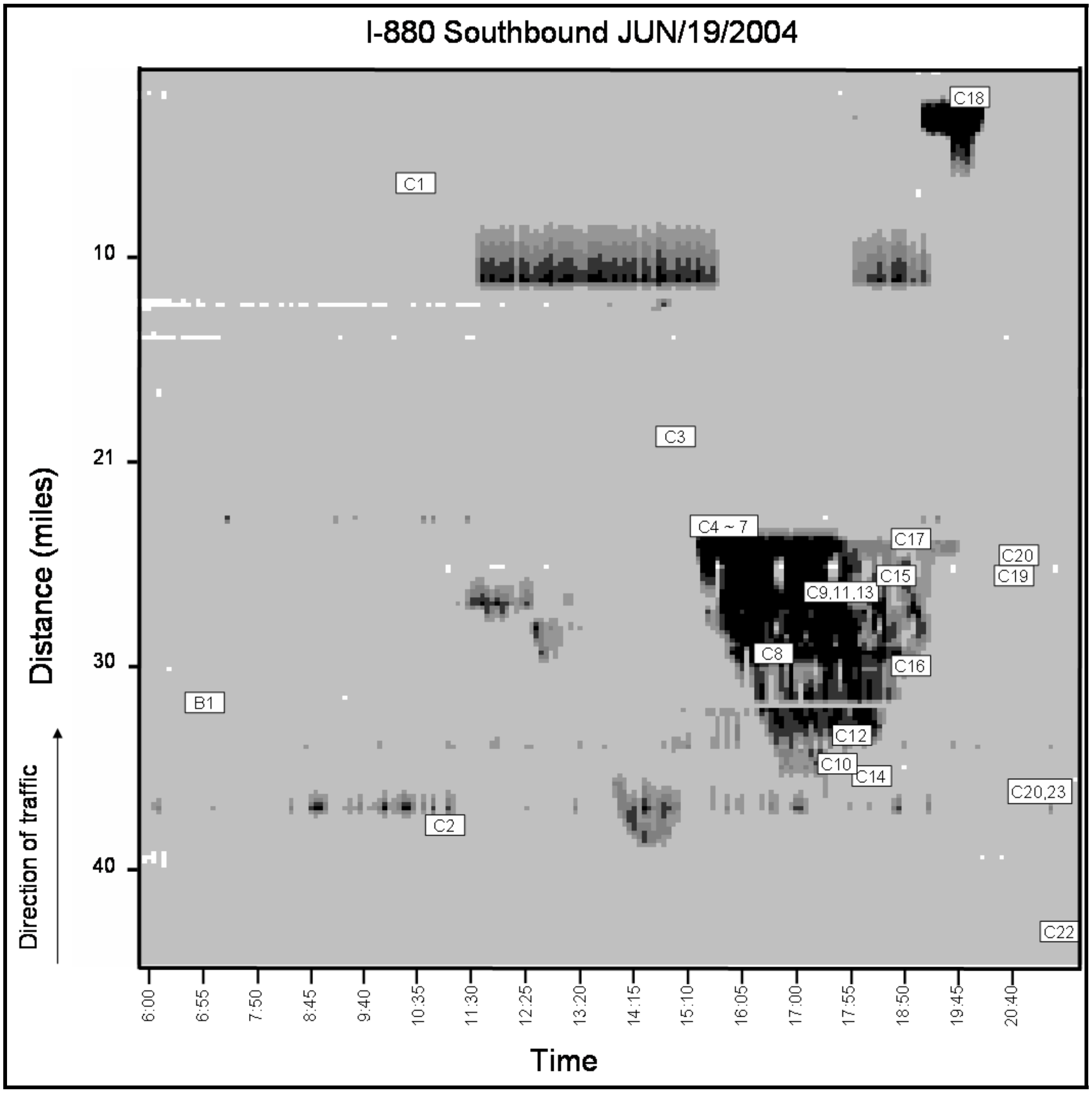


Figure 3.2: Delay and Incident Mapping (I-880 Southbound, June 19 2004)

Table 3.2: Incident Details (I-880 Southbound, June 19 2004)

Incident Number	Post Mile	Time	Incident Description
C1, CHP	7.33	10:23 AM	Traffic Collision - Property Damage
C2, CHP	38.91	10:53 AM	Traffic Hazard - Vehicle
C3, CHP	20.15	2:48 PM	Pedestrian on the Roadway
C4, CHP	24.55	3:24 PM	Traffic Collision - Ambulance Responding
C5, CHP	24.55	3:36 PM	Traffic Collision - No Details
C6, CHP	23.98	3:38 PM	Traffic Hazard - Debris/Objects
C7, CHP	24.55	4:05 PM	Traffic Collision - Property Damage
C8, CHP	30.65	4:29 PM	Hit and Run - No Injuries
C9, CHP	27.78	5:31 PM	Traffic Collision - No Details
C10, CHP	35.90	5:35 PM	Traffic Collision - Property Damage
C11, CHP	27.78	5:50 PM	Hit and Run - No Injuries
C12, CHP	34.71	5:51 PM	Traffic Collision - Property Damage
C13, CHP	27.58	5:53 PM	Traffic Collision - Property Damage
C14, CHP	36.56	6:08 PM	Traffic Collision - No Details
C15, CHP	26.98	6:33 PM	Traffic Hazard - Vehicle
C16, CHP	31.08	6:48 PM	Hit and Run - Injuries or Fatalities
C17, CHP	24.95	6:51 PM	Traffic Hazard - Vehicle
C18, CHP	2.75	7:51 PM	Traffic Collision - Ambulance Responding
C19, CHP	26.98	8:34 PM	Disabled Vehicle
C20, CHP	25.89	8:39 PM	Traffic Hazard - Vehicle in Center Divider
C21, CHP	36.56	8:49 PM	Pedestrian on the Roadway
C22, CHP	43.72	9:45 PM	Disabled Vehicle
C23, CHP	36.36	9:54 PM	Disabled Vehicle
B1, BAIRS	33.04	6:51 AM	debris on rhs cardboard boxes on rhs

With these complications, it was not pragmatic to attempt correlating delays with BAIRS logged incidents directly. Therefore, a statistical approach was developed. Linear regression techniques were utilized to build statistical models which estimated the average vehicular delays per BAIRS incident. Separate weekday and weekend models were built as it was unfounded to expect that the average delay per incident on a weekend to be the same as the average delay per incident during a normal non-holiday weekday. Furthermore, weekdays were segregated into weekday peak periods (AM = 5am – 9am, PM = 3pm – 8pm), daytime (7am – 8pm), nighttime (midnight – 7am and 8pm – midnight) to enable more reliable parameter estimation correlating incidents with delays. Likewise, weekend days were segregated into daytime (7am – 8pm), nighttime (midnight – 7am and 8pm – midnight).

3.2 Data

To correlate incidents to traffic delays, both incident data and traffic data are required. Section 3.2.1 describes the incident data and data sources used for these analysis and Section 3.2.2 describes the traffic data used.

3.2.1 Incidents

Incident data were obtained from four different sources. California Department of Transportation (Caltrans) District Communications Center (DCC) provided information/data on incidents that occurred in District 4 prior to BAIRS implementation. BAIRS logged incidents were provided by District 4 Maintenance. Freeway Service Patrol assisted incident data were provided by District 4 Traffic Operations staff, and CHP logged incidents were obtained via PeMS.

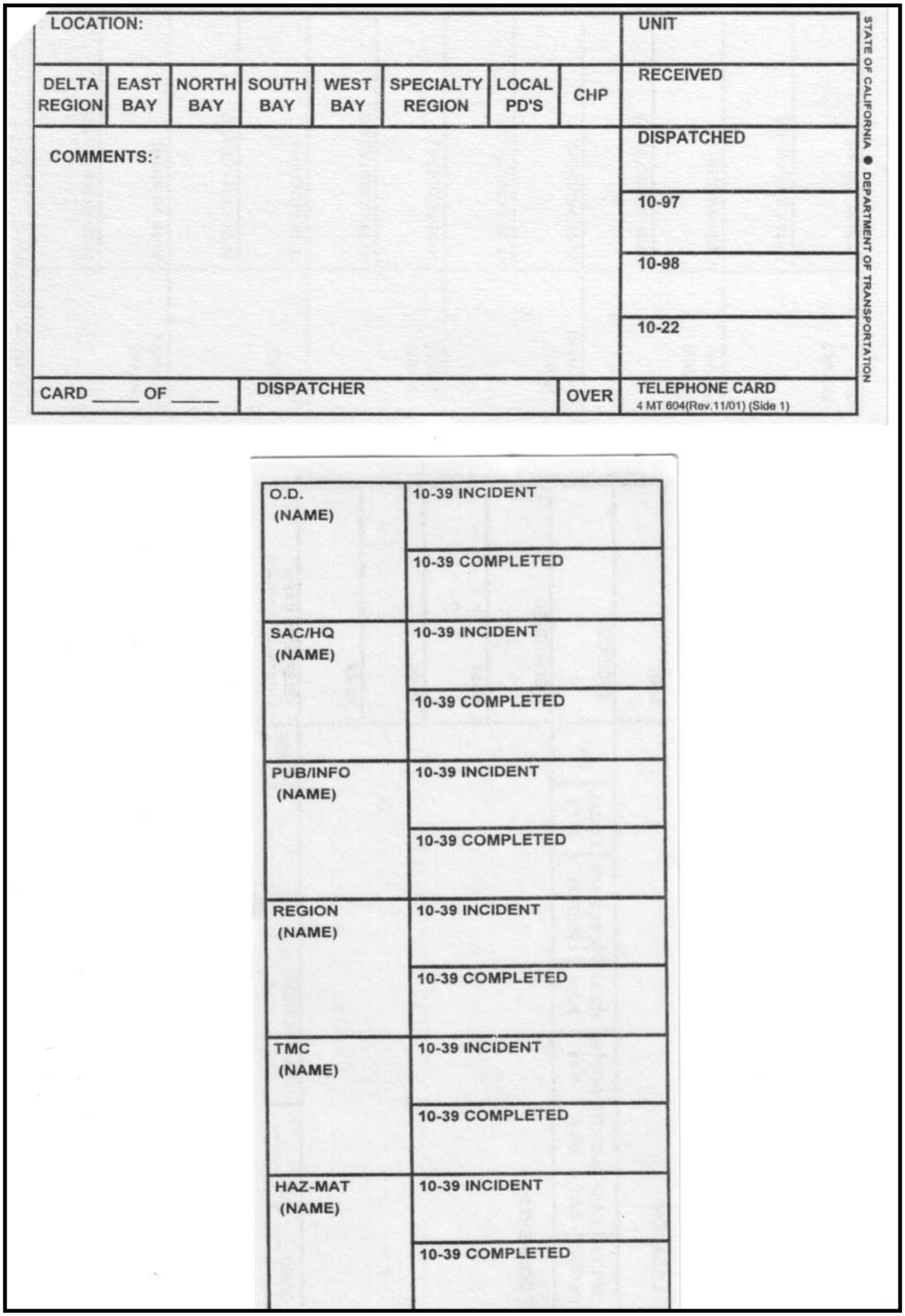
Caltrans/DCC (manually logged) Incidents: Prior to BAIRS, incidents were manually logged on incident cards by Caltrans District Communications Center (DCC) staff. Figure 3.3 shows a blank TMC/DCC incident log card. The cards were made available by BAIRS managers, and the research team entered data from over 300 of these incident cards into a database for incidents that occurred between August 2002 and April 2003, creating a pre-BAIRS incident database.

BAIRS Incidents: BAIRS was implemented in June 2003. BAIRS helps District 4 Maintenance respond to over 33,500 incidents per year throughout District 4, or on average about 92 incident responses per day. The incident database itself is an Oracle database kept on a Caltrans server located in Sacramento at Caltrans-HQ. The BAIRS incident database was provided by BAIRS management and Division of Information Services.

The BAIRS incident data was used to create two BAIRS incident databases. The first containing incident durations and response times was used to create response-time and incident duration frequency distributions to be compared to the Pre-BAIRS response-time and incident duration frequency distributions; thus revealing the response and clearance time savings. The second BAIRS database contained data Interstate 880 incidents for quantifying the relations between incidents and traffic delays.

A with-BAIRS incident database was created using the District-wide BAIRS incidents from BAIRS inception date (June 1, 2003) through September 2004 which contained 2,673 incident records; each with complete incident duration and response time data (specifically: begin-incident-time-stamp, responding-supervisor-at-scene-timestamp, and end-incident-timestamp). The responding-supervisor-at-scene-timestamp was blank for many of the logged BAIRS incidents. As such, response times could not be measured for many of the logged incidents – it was valid for only 7.2% of the BAIRS logged incidents. For other logged incidents, either the begin-incident-timestamp or the end-incident-timestamp were blank or not valid.

A second with-BAIRS database was created using the BAIRS incident data on I-880 to quantify relations between incidents and traffic delays. Using data for the first six months of 2004 (January 1 thru June 30, 2004), the resulting database includes 546 northbound and 397 southbound incidents. Of these, 320 (59%) Northbound and 248 (62%) Southbound had valid Caltrans post-miles for spatial mapping of incidents. With this, about 40% of all BAIRS logged incidents on 880 could not be located in the time-space plane, which is absolutely necessary in order to directly attribute traffic delays to individual incidents.



LOCATION:
UNIT

DELTA REGION	EAST BAY	NORTH BAY	SOUTH BAY	WEST BAY	SPECIALTY REGION	LOCAL PD'S	CHP

RECEIVED

COMMENTS:

DISPATCHED

10-97

10-98

10-22

CARD _____ OF _____
DISPATCHER
OVER
TELEPHONE CARD
4 MT 604(Rev.11/01) (Side 1)

STATE OF CALIFORNIA ● DEPARTMENT OF TRANSPORTATION

O.D. (NAME)	10-39 INCIDENT
	10-39 COMPLETED
SAC/HQ (NAME)	10-39 INCIDENT
	10-39 COMPLETED
PUB/INFO (NAME)	10-39 INCIDENT
	10-39 COMPLETED
REGION (NAME)	10-39 INCIDENT
	10-39 COMPLETED
TMC (NAME)	10-39 INCIDENT
	10-39 COMPLETED
HAZ-MAT (NAME)	10-39 INCIDENT
	10-39 COMPLETED

Figure 3.3: TMC/DCC Incident Log Card (front and back)

Freeway Service Patrol (FSP) Incidents: Data on incidents assisted by FSP were provided by Caltrans District 4 Office of Traffic Systems. On an average non-holiday weekday Caltrans sponsored tow-trucks from six different FSP Beats assist over 80 motorists on Interstate 880 from 6:00 to 10:00 AM and from 3:00 to 7:00 PM. On weekends and holidays, FSP assistance is not provided on I-880. At the time of the assist, the tow-truck drivers record the date and time of day, assist duration, freeway name and direction, incident description data (e.g. traffic accident, flat tire, out-of-gas), and some incident location data (e.g. on- or off-ramp, left shoulder, right shoulder, in-lane). However, the FSP-assisted incidents are not recorded in sufficient detail to determine the location along the freeway (i.e. a post-mile, ramp location, or cross-street). Table 3.3 lists the proportion of assists that occurred in-lane, on left or right shoulders, and at on or off ramps.

Table 3.3: FSP-Assists, Freeway Locations

Location Description	Percent of FSP-Assists
In-Lane	10.3%
Right Shoulder	78.5%
Left Shoulder	3.9%
On-Ramp/Off-Ramp	7.3%
Total	100.0%

California Highway Patrol (CHP) Incidents: California Highway Patrol (CHP) incident data were extracted from CHP incident logs archived in the freeway Performance Measurement System (PeMS) [8]. PeMS has been collecting and archiving CHP incident data from the reports on their Traffic Incident Information Page (http://cad.chp.ca.gov/) since March 20, 2000. The CHP reported incidents in PeMS contain data on incident date and time, description, severity, location, and duration. There is one log entry each and every time that an incident's status is updated by CHP/DCC, which means that major incidents may have multiple entries (e.g. one for when the incident is first called in, one for when an officer arrives on the scene, one for when an ambulance arrives on the scene, etc.).

There were 6,913 CHP loggings in the first six months of 2004 (January 1 thru June 30 2004) that occurred on Interstate 880. A portion of these entries were incomplete, not containing direction of travel, post-mile, or adequate location data to equate to a Caltrans post-mile; 5,739 of the 6,913 logged incident entries (83%) contained sufficient information to locate. Therefore, 17% of the CHP incidents could not be mapped in the time-space plane to be matched up to observed traffic delays. Furthermore and unfortunately, incident durations were blank for the CHP incidents on Interstate 880 prior to BAIRS inception (June 1 2003). This meant that the CHP incidents could not be used to measure changes in response-times and/or clearance-times attributable to BAIRS.

3.2.2 Traffic Conditions

There were few relatively long freeway stretches that had adequate loop detector coverage for purposes of estimating incident delays in District 4. The most plausible freeways were I-80 in Contra Costa County, I-880, SR-17, SR-85, and SR-101 in Santa Clara and San Mateo Counties. The freeway chosen for the BAIRS evaluation was Interstate 880 from I-280 in San Jose to I-580 in Oakland. Interstate 880 was chosen because it was a relatively long and diverse urban freeway with the best overall detector coverage (i.e. reliably functioning detectors). On an average day, between 40 and 45 mainline (i.e. freeway) detector stations in each direction were reliably reporting vehicle counts and speed data to measure traffic delays along I-880 between I-280 in San Jose and I-580 in Oakland. Caltrans 5-minute average vehicular speed and traffic flow data were extracted from the PeMS system and used to estimate vehicle miles of travel (VMT), vehicle hour of travel (VHT) and traffic delays along Interstate 880. Figure 3.4 shows the East Bay region with Interstate 880 from Oakland to San Jose. Appendix A shows the freeway vehicle detector locations along I-880.

Figure 3.4: Interstate 880, Oakland to San Jose

For the weekday analyses, valid data were obtained for 110 weekdays in January through June 2004. I-880 northbound and southbound directional traffic data were extracted and analyzed separately. Thus the weekday database contained 220 records, 110 northbound and 110 southbound. For the weekend analyses, 42 weekend days were used (all weekend days with valid data from January 17 through June 27 2004) which provided 84 total weekend records, 42 northbound and 42 southbound. I-880 average VMT and VHT are listed in Table 3.4; and I-880's VMT and VHT are shown in Figures 3.5 and 3.6 respectively for the month of March 2004.

Table 3.4: VMT and VHT on Interstate 880

	VMT (veh-miles)		VHT (veh-hrs)	
	I-880 N	I-880 S	I-880 N	I-880 S
Mean	3,758,778	3,814,205	62,729	62,475
Standard Deviation	314,631	300,954	8,341	7,901

Time-of-day traffic flows, in units of vehicles per hour per lane, are in Figure 3.7 and 3.8, respectively displaying northbound and southbound traffic volumes measured at Caltrans post-mile 24.6 near 98th Street in Oakland for 167 non-holiday weekdays for January–August 2004. Figures 3.9 and 3.10 respectively show I-880 northbound and southbound hourly traffic volumes at Caltrans post-mile 1.3 near Bascom Avenue in San Jose for the same 167 non-holiday weekdays for January–August 2004.

Figure 3.11 and 3.12 show the measured northbound and southbound travel-times by time-of-day for I-880 by time of day for the 121 days with valid travel-time (i.e. average vehicular speeds) data for non-holidays in January–June 2004. As well, the 25th, 50th (i.e. median) and 75th percentiles are shown on these plots. Free-flow travel-times of just under 40 minutes for the 40+ mile long interstate correspond to a freeflow speed of between 69 and 70 mph.

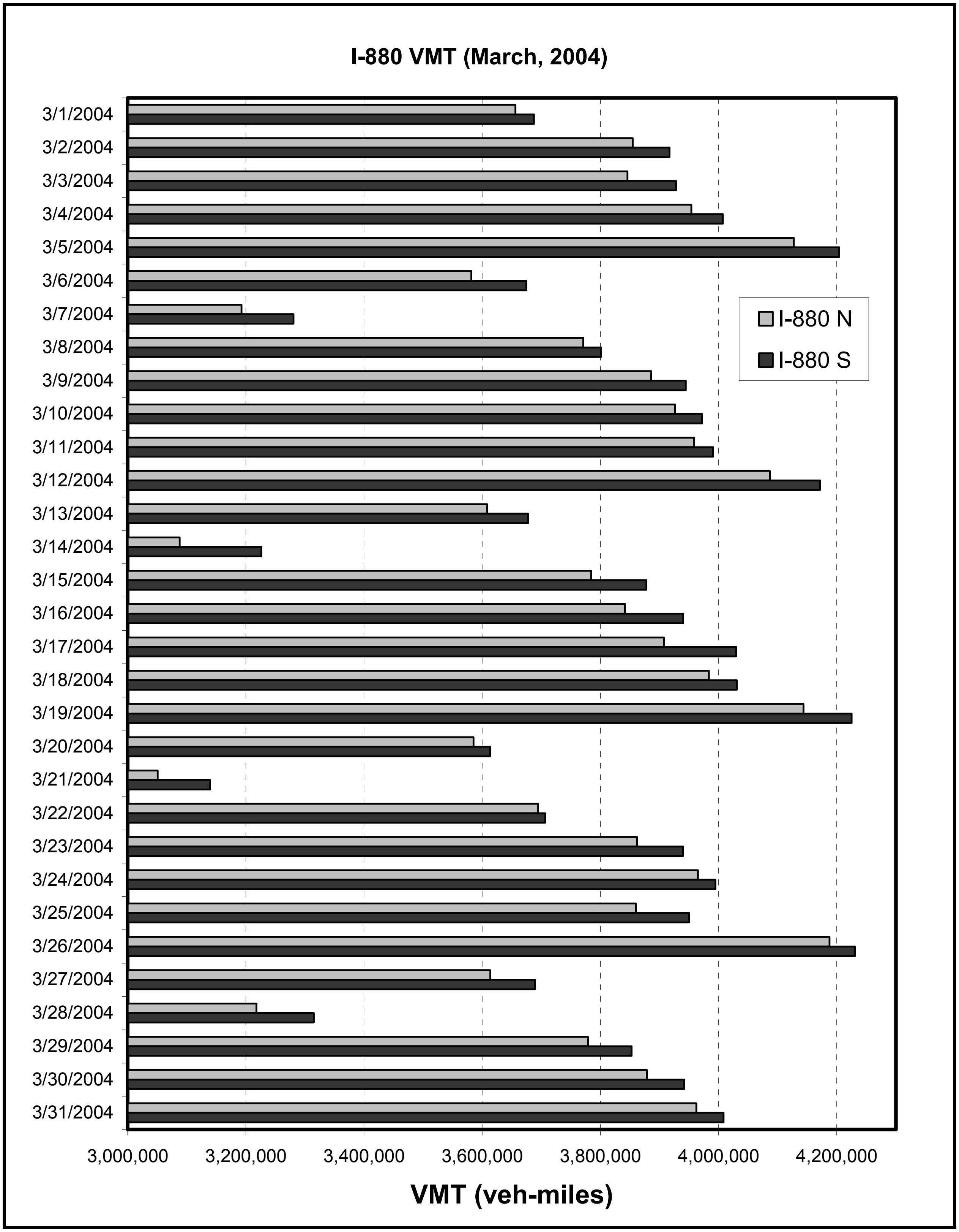


Figure 3.5: Vehicle Miles of Travel (VMT) on Interstate 880

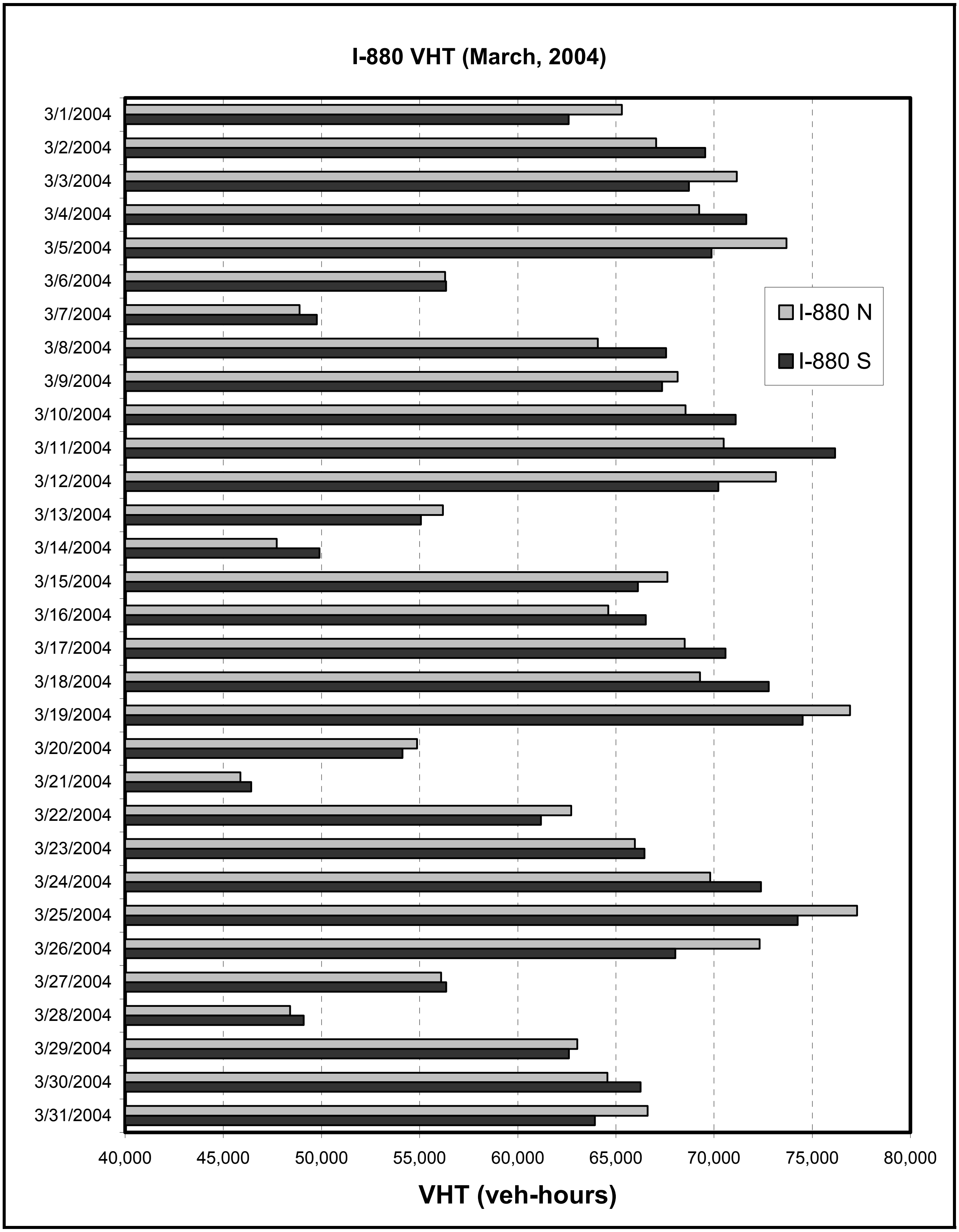


Figure 3.6: Vehicle Hours of Travel (VHT) on Interstate 880

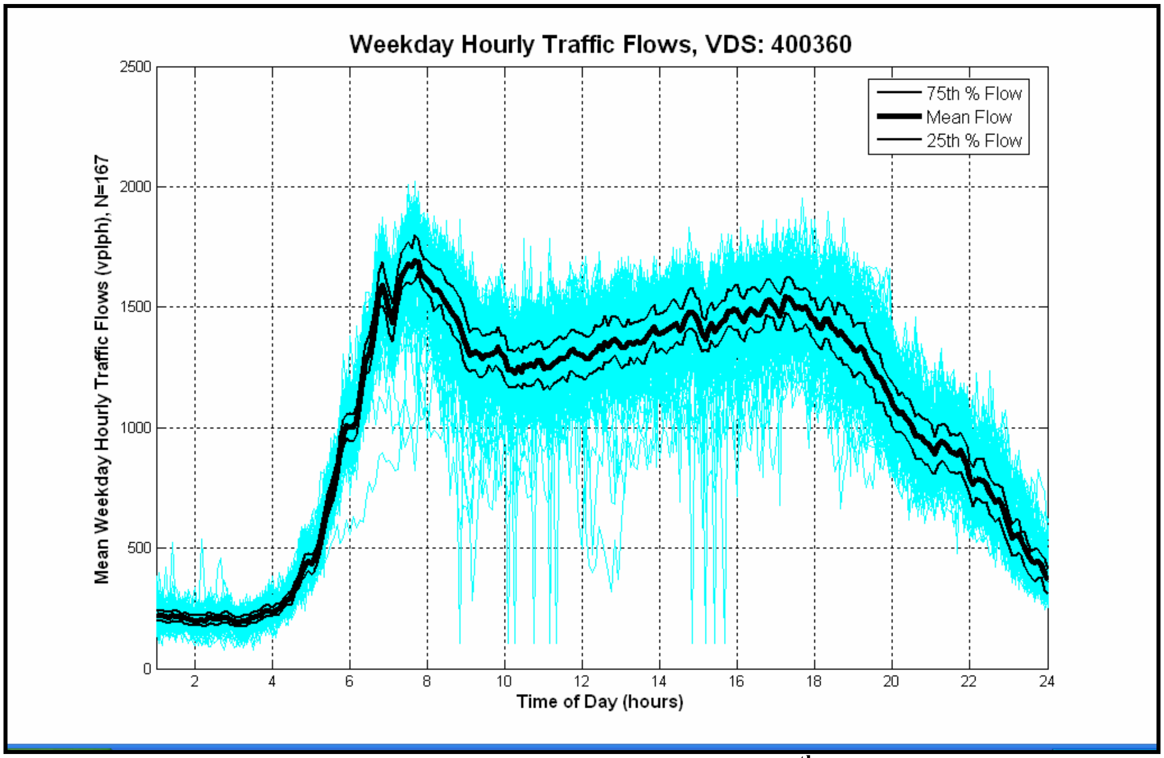


Figure 3.7: Hourly Vehicle Flows I-880 North by 98th Street in Oakland

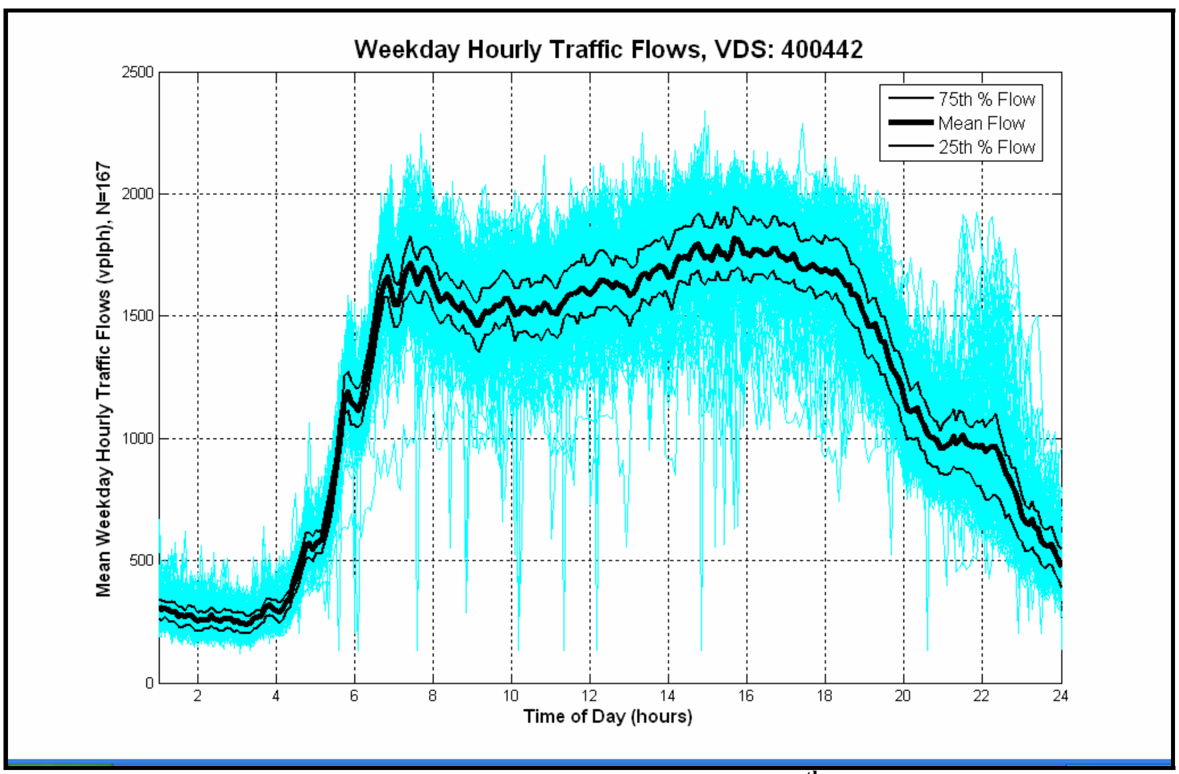


Figure 3.8: Hourly Vehicle Flows I-880 South by 98th Street in Oakland

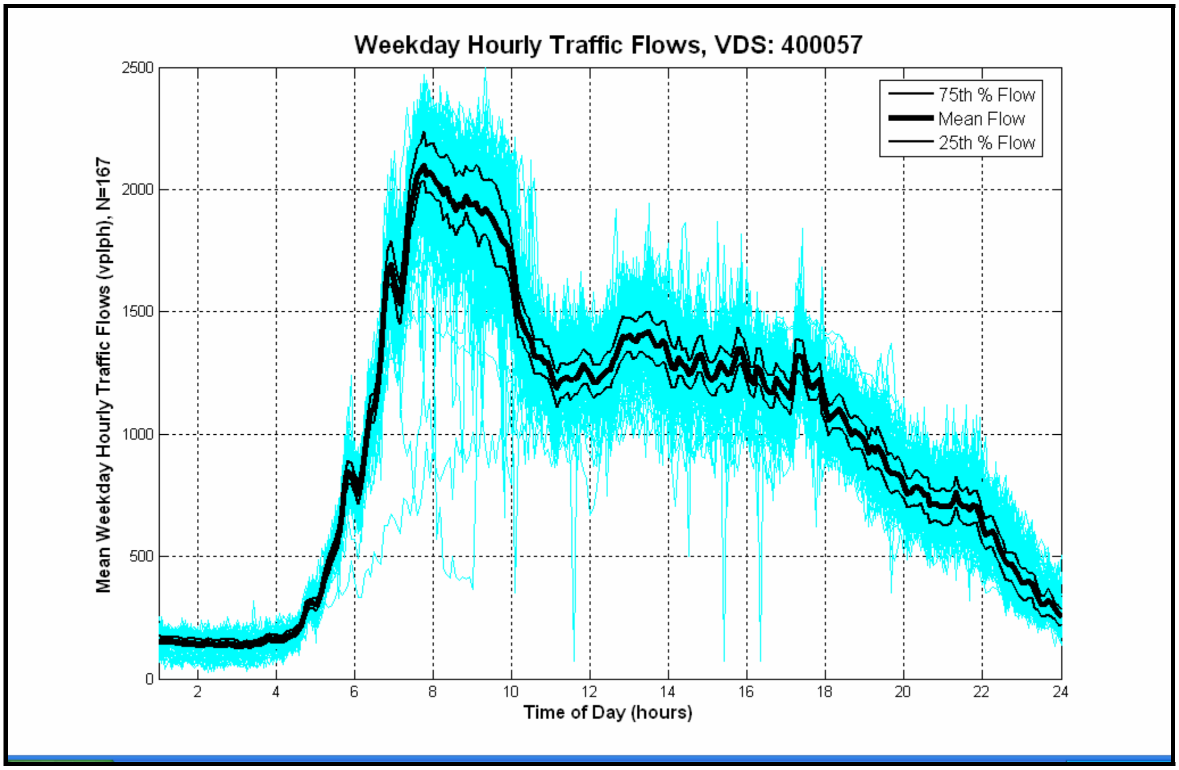


Figure 3.9: Hourly Vehicle Flows I-880 North by Bascom Avenue in San Jose

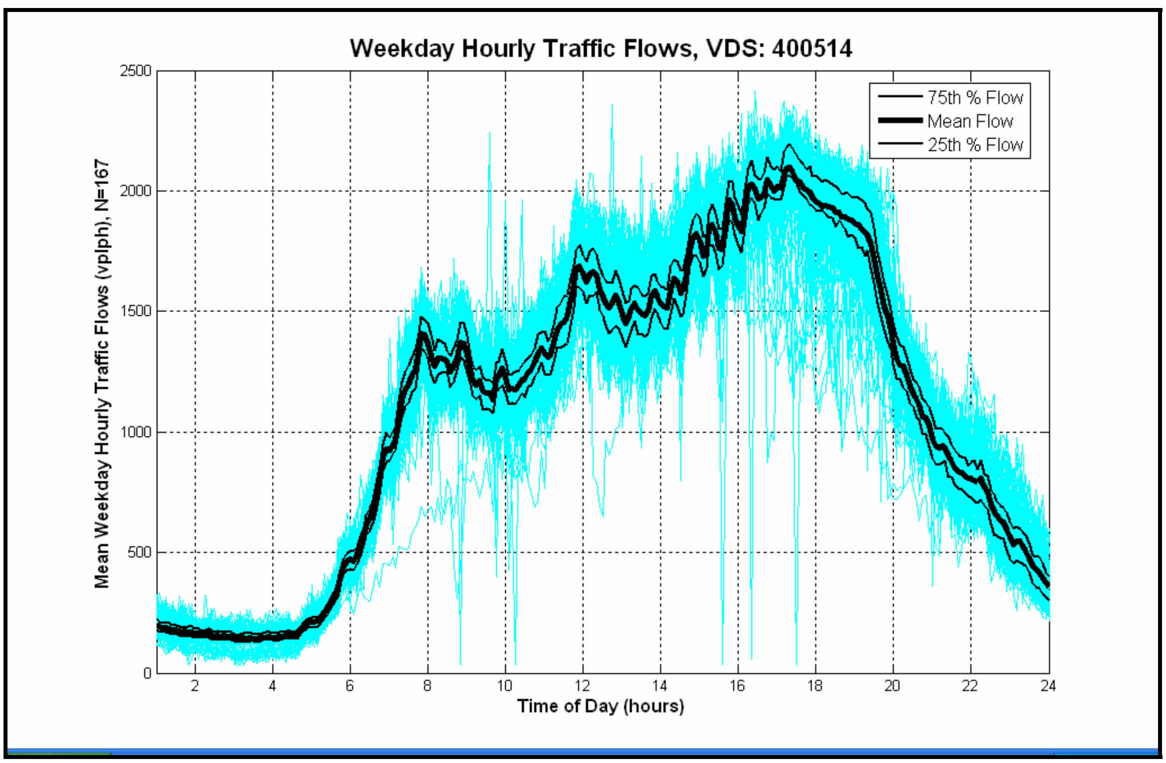


Figure 3.10: Hourly Vehicle Flows I-880 South by Bascom Avenue in San Jose

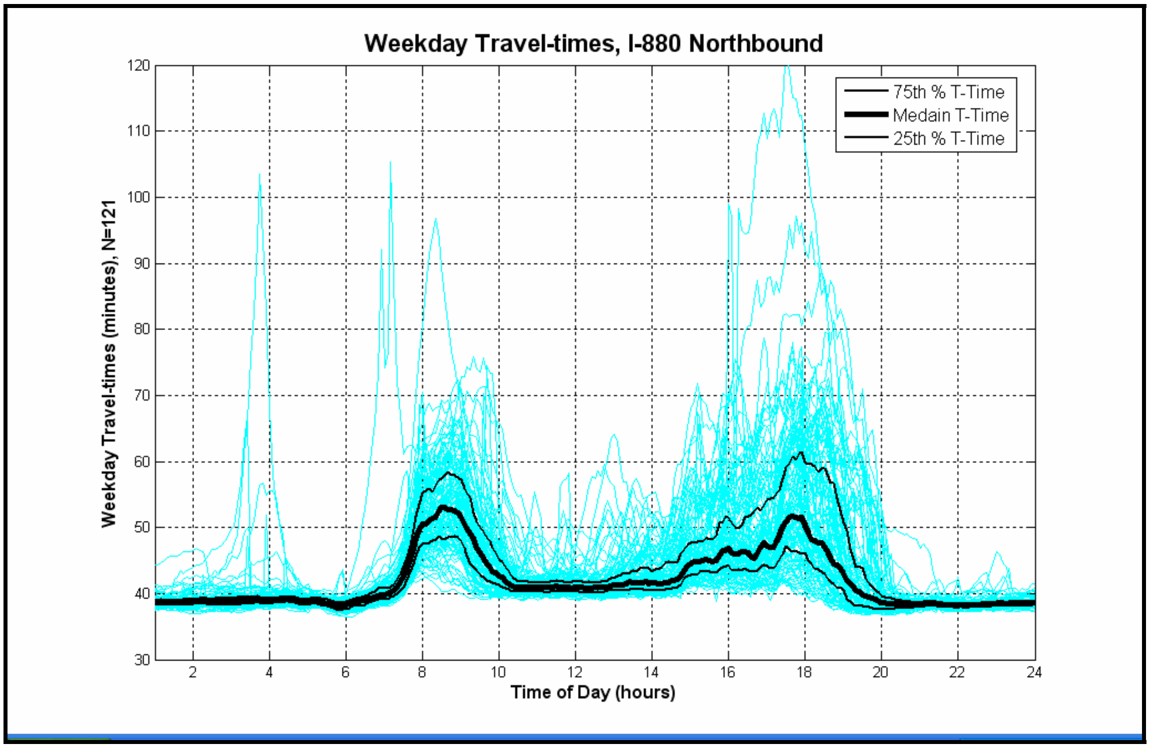


Figure 3.11: Northbound Travel-times thru I-880

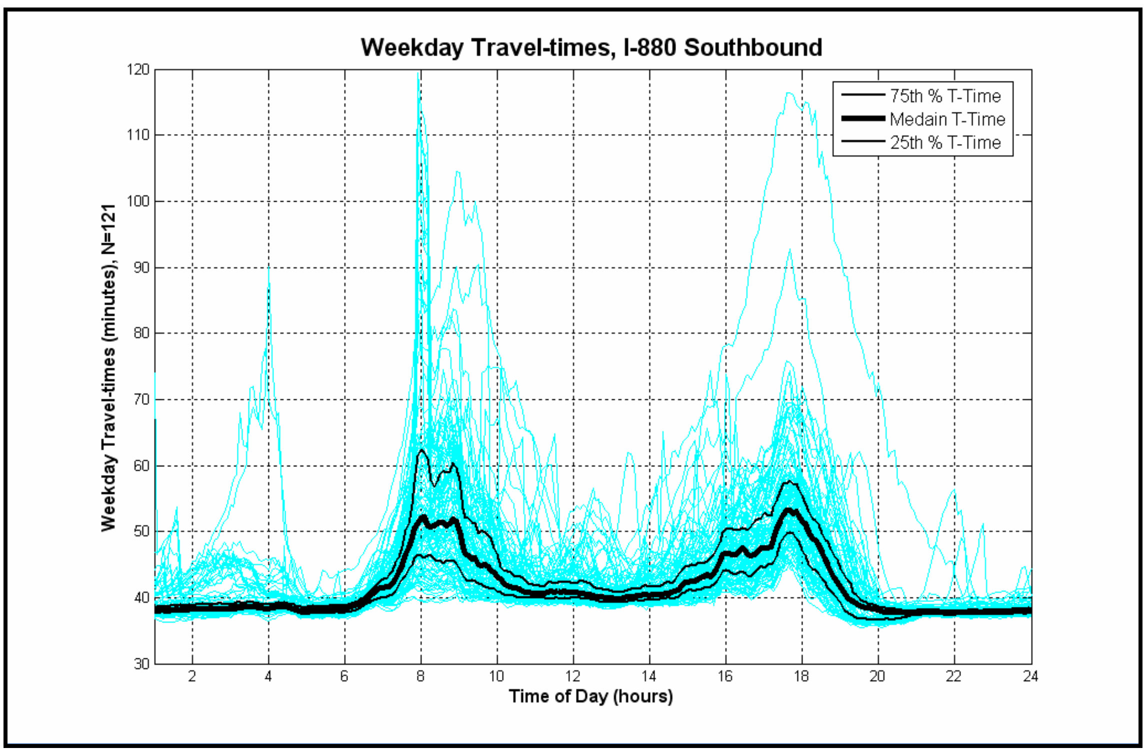


Figure 3.12: Southbound Travel-times thru I-880

To gain some insights into how well Interstate 880 represented the average District 4 freeway, traffic flow profiles (in percent of ADT) for Interstate 880 were compared to those created for the Freeway Service Patrol for District 4. Figure 3.13 shows the average speeds for Interstate 880 and for District 4. Average speeds were estimated as the ratio of VMT to VHT (i.e. (VMT/VHT). Interstate 880 and District-wide VMT and VHT estimates were obtained via PeMS for 2004. Figure 3.14 displays the average weekday traffic profiles (in percent of daily traffic) for I-880 and for District 4. Figure 3.15 displays the average weekend traffic profiles for I-880 and District 4.

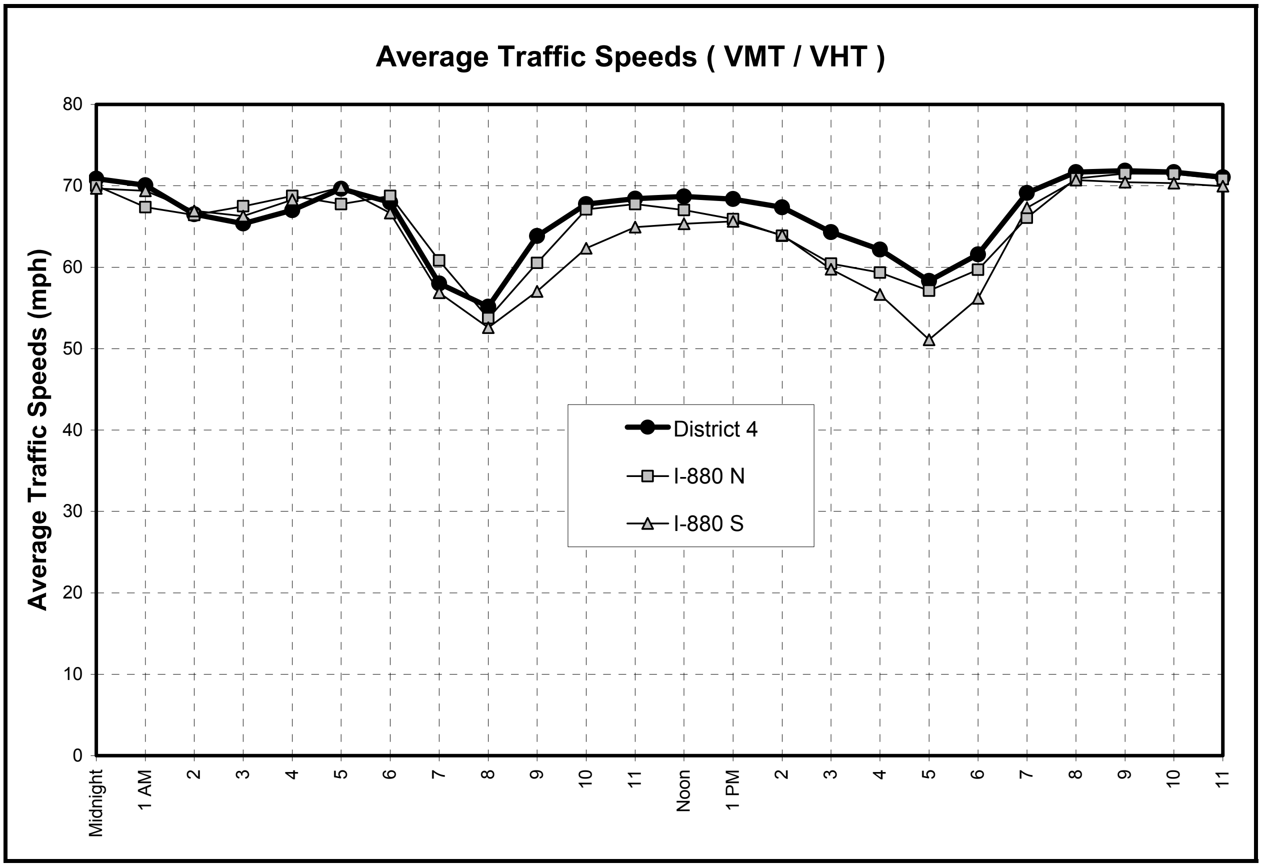


Figure 3.13: Average Traffic Speeds for Interstate 880 and District 4

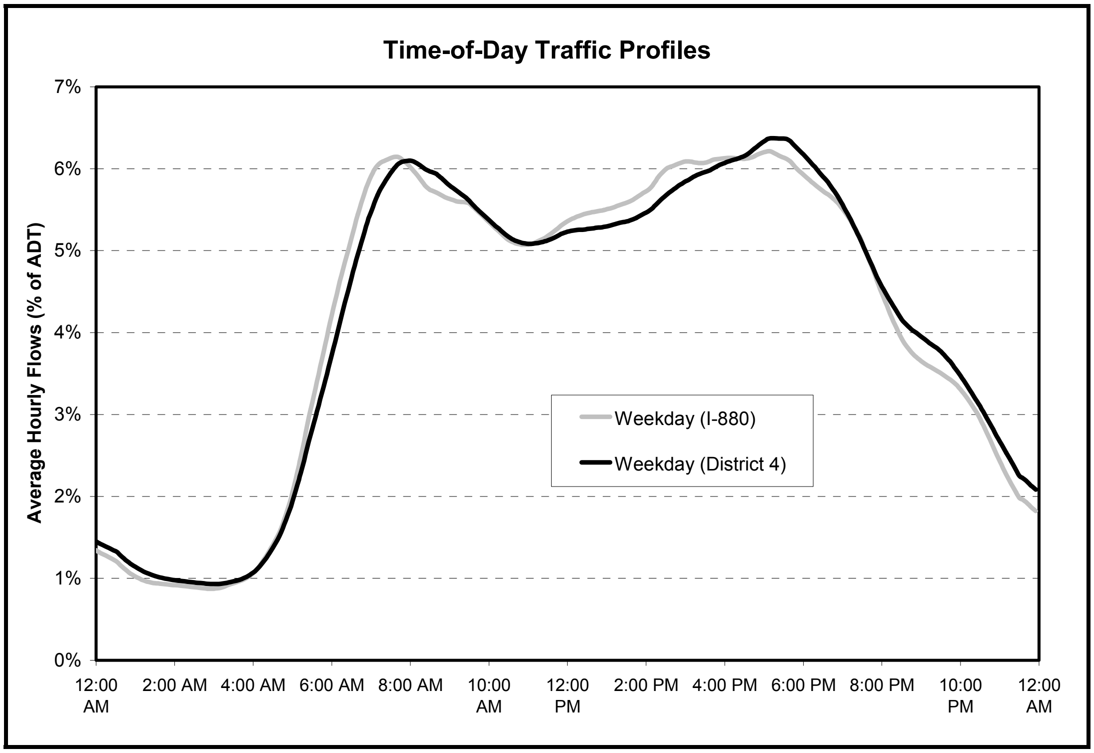


Figure 3.14: Weekday Traffic Flow Profiles for Interstate 880 and District 4

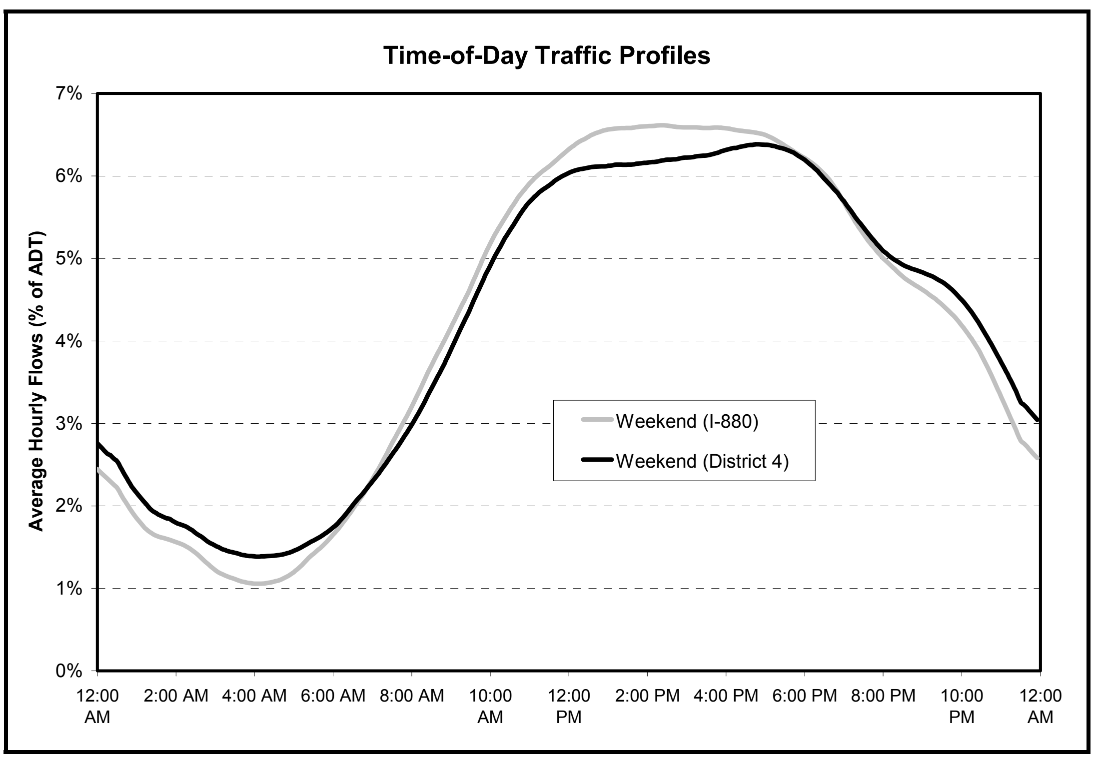


Figure 3.15: Weekend Traffic Flow Profiles for Interstate 880 and District 4

CHAPTER 4
FINDINGS

4.1 Incident Durations

The change in average incident duration is the difference between the average incident duration prior to BAIRS (or pre-BAIRS) and the average incident duration with-BAIRS. Incident duration and incident response time frequency histograms were created and compared using the pre-BAIRS and with-BAIRS incident data (see Figures 4.1 and 4.2). From these duration distribution plots and summary statistics, it was obvious that they have been changes in the process of reporting (or in the logging) of incidents with the introduction of BAIRS. It seemed very unlikely that the observed differences were solely from response and clearance time savings attributable to BAIRS. For example:

1. The shortest observed pre-BAIRS incident duration was 18 minutes. In comparison, 736 with-BAIRS incidents had durations less than 18 minutes (27.5% of the incidents); 148 with-BAIRS incidents had durations in the range of 0 – 2 minutes (5.5% of the incidents).

2. The longest pre-BAIRS incident duration observed was 429 minutes. Whereas 96 of the 2,673 with-BAIRS incidents had durations over 430 minutes (3.6%); 46 incidents had durations over 2,000 minutes. Upon inspection, some of the long duration loggings were maintenance related (e.g. roadway, guard-rail, or sign damage awaiting repairs). Others appeared to be erroneous loggings. Many did not contain sufficient information to determine whether these were valid long duration incidents or not.

From discussions with BAIRS management staff, it was learned that some of the maintenance supervisors had been logging incidents into BAIRS after the incidents were actually cleared. As such, these incidents may have erroneous (usually very short) logged response times and incident durations. This is consistent with the relatively large number of incidents with durations less than one or two minutes observed in the BAIRS incident logs. These erroneous entries downwardly bias estimates of median and mean with-BAIRS incident response times and incident-durations. This, in turn, exaggerates BAIRS reductions in incident durations and response-times.

Thus, simple mean and/or median incident durations and response times are not appropriate measures for estimating response time savings, incident duration reductions, and the associated delay savings. Unfortunately, it is not known which BAIRS logged incidents have valid durations and which do not. However, the longer duration incidents were presumed to be more reliable as the erroneously logged incidents have short durations and short response times. On the other hand, it is quite plausible that at least some of the short durations and short response times are valid with-BAIRS entries; which ones and what proportion are not known.

Prior to BAIRS, incidents were manually logged on incident cards by Caltrans District Communications Center (DCC) staff. A new incident card was created when DCC was notified of an incident. Later these cards were updated when DCC notified Maintenance that an incident had occurred, and updated again when the supervisor called in to inform DCC that he/she arrived at the incident scene, and yet again when the supervisor informed DCC that the incident was cleared. Many of the incident cards were incomplete; the time that the supervisor arrived at the incident scene and/or the incident clearance times were not entered.

Another plausible explanation for the lack of short incidents in the pre-BAIRS dataset might simply reflect that the manual incident cards were not being updated for minor incidents, thus incident response times and incident durations were not obtainable for these minor (i.e. short duration) incidents. If the introduction of BAIRS did in fact change the proportion of short duration incidents that were completely logged, then this reporting change would likewise bias any comparisons between the Pre-BAIRS and the With-BAIRS incidents.

To obtain incident duration reduction estimates less sensitive to these biases, log-linear curves were fitted to the incident duration distributions using only those incidents with durations of 10 minutes or greater, effectively deleting all records with durations less than 10 minutes. This effectively removed the short duration incidents (which were assumed to be biasing the comparison) from both the pre-BAIRS and the with-BAIRS datasets. This process was repeated using only incidents with minimum duration of 20 minutes, 30 minutes, etc. Table 4.1 lists the mean incident durations for both the pre-BAIRS and the with-BAIRS incidents using the truncated duration datasets as just described.

The mean pre-BAIRS incident duration was 115 minutes (using all incidents). As such, one-half of the mean pre-BAIRS duration was about 60 minutes. Removing those incidents with durations less than ½ of the mean duration (i.e. 60 minutes) from both the pre-BAIRS and the with-BAIRS incident databases, then re-estimating and comparing the mean durations revealed that a 15% reduction of the mean incident duration attributable to BAIRS. Table 4.2 shows the changes to the number of incident records in the Pre-BAIRS and the With-BAIRS datasets when those incidents with durations < 60 minutes are removed. It is clear from Table 4.2 that there are significantly more incidents with short durations in the With-BAIRS dataset than for Pre-BAIRS. See Figure 4.3 for duration histograms with duration >= 60 minutes. This is consistent with the hypotheses that more of the minor (e.g. short duration incidents) were being logged with the introduction of BAIRS than with the older manual incident logging methods and that some of the incidents might be logged post-incident by the supervisors thus downwardly biasing the incident durations.

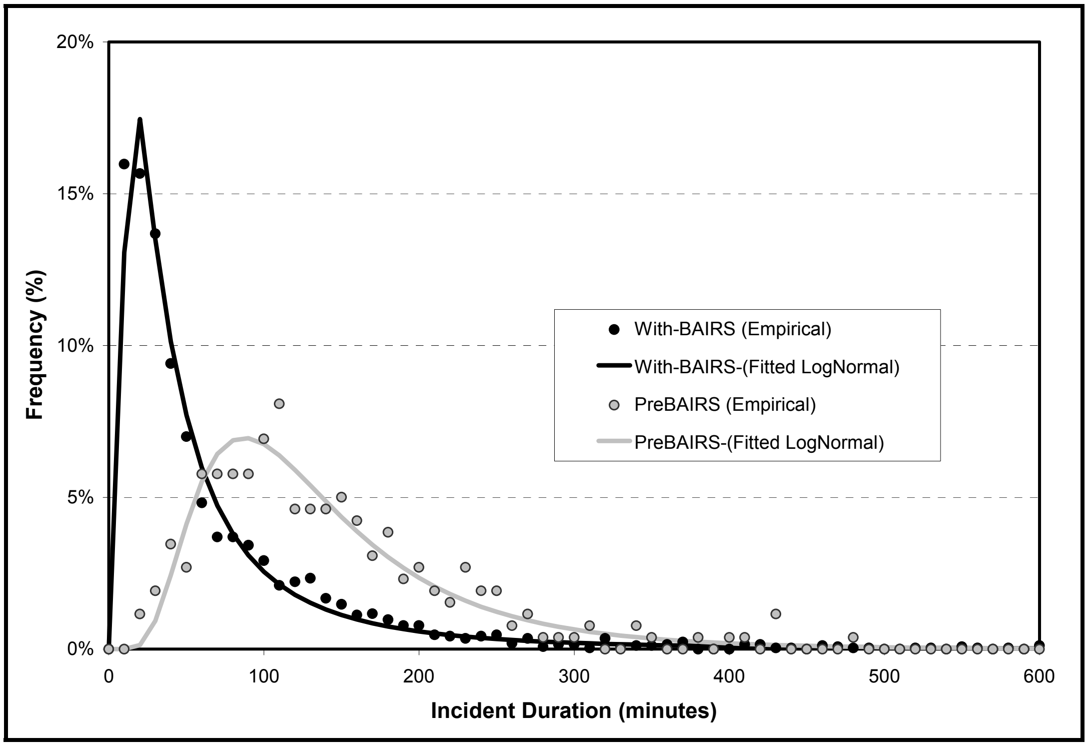


Figure 4.1: Incident Duration Histograms (using all incident data)

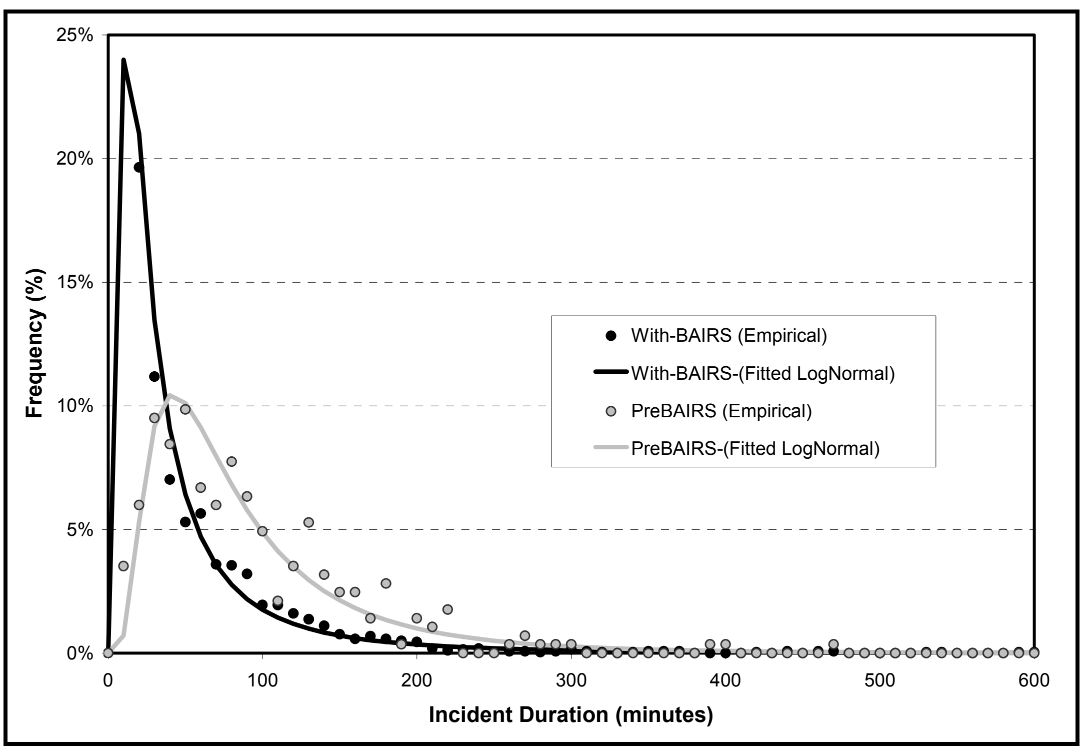


Figure 4.2: Response-time Histograms (using all incident data)

Table 4.1: Incident Durations (From Incident Duration Distributions)

Mean Incident Duration			BAIRS Incident-Duration Savings	
Minimum-Used (minutes)	Pre-BAIRS (minutes)	With-BAIRS (minutes)	(minutes)	(percent)*
0	115.75	35.55	80.19	69.3%
10	115.75	46.48	69.26	59.8%
20	117.10	59.95	57.16	49.4%
30	119.35	76.34	43.01	37.2%
40	123.34	91.19	32.15	27.8%
50	126.27	104.87	21.40	18.5%
60	132.72	115.58	17.14	14.8%
70	139.21	124.38	14.82	12.8%
80	145.78	134.48	11.30	9.8%
120	173.74	164.11	9.63	8.3%

* Note: Incident duraiton Savings as a percent of mean Pre-BAIRS Incident-duration (i.e. 115.75 minutes).

Table 4.2: Number of Pre-BAIRS & BAIRS Incident Records

	Pre-BAIRS	With-BAIRS
Duration < 60 minutes	37	1,703
Duration >= 60 minutes	223	970
Total	260	2,673

As was done using the pre-BAIRS and with-BAIRS incident durations, response time distributions were created. The BAIRS response time reductions were estimated using the same techniques to estimate duration reductions – removing those incident records with short response times. The mean pre-BAIRS response time was 66 minutes; one-half of the mean was 33 minutes. Removing incidents with response times less than ½ of the mean response time (i.e. 30 minutes) resulted in a 30% response time reduction and a 17% duration reduction. Table 4.3 shows the reductions in response time and incident duration for the Pre-BAIRS and With-BAIRS datasets with the short response time records removed. Figure 4.4 shows the response time distributions for incidents with response times >= 30 minutes.

From conversations with BAIRS management, it was learned that most of the incident duration reductions are from reductions in response-times. This conjecture is consistent with the incident duration reductions produced using incident-duration distributions and response-time distributions. The duration reduction was generally in the same range using the response-times distribution.

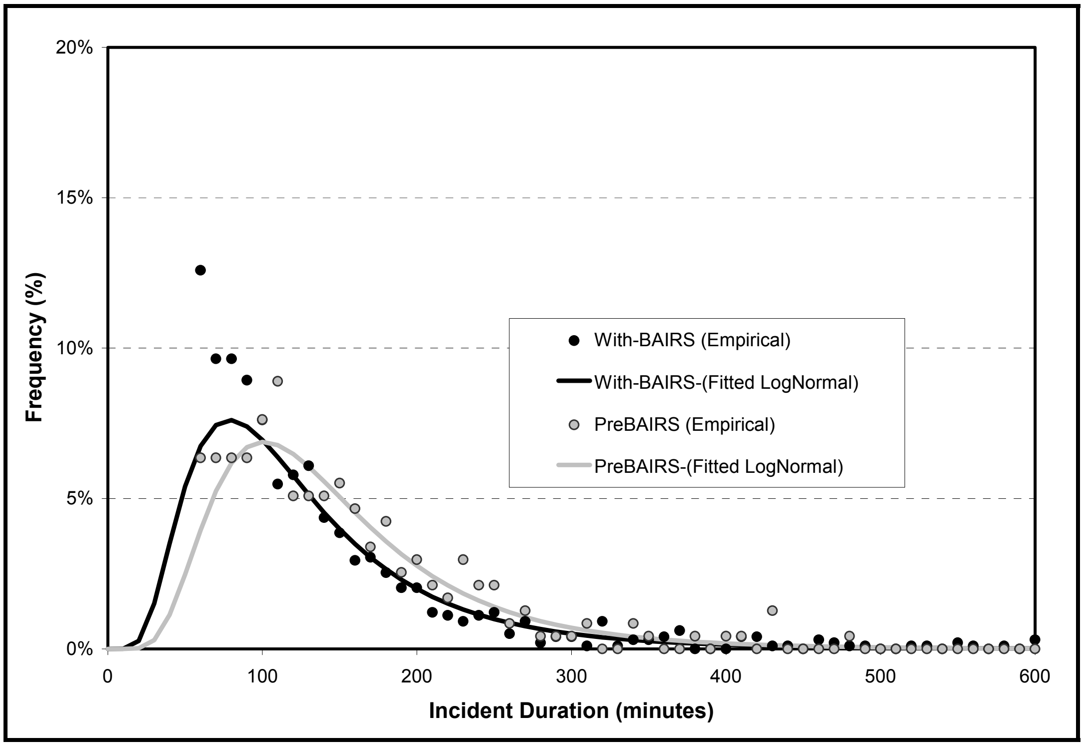


Figure 4.3: Incident Duration Histograms (Data: Duration >= 60 minutes)

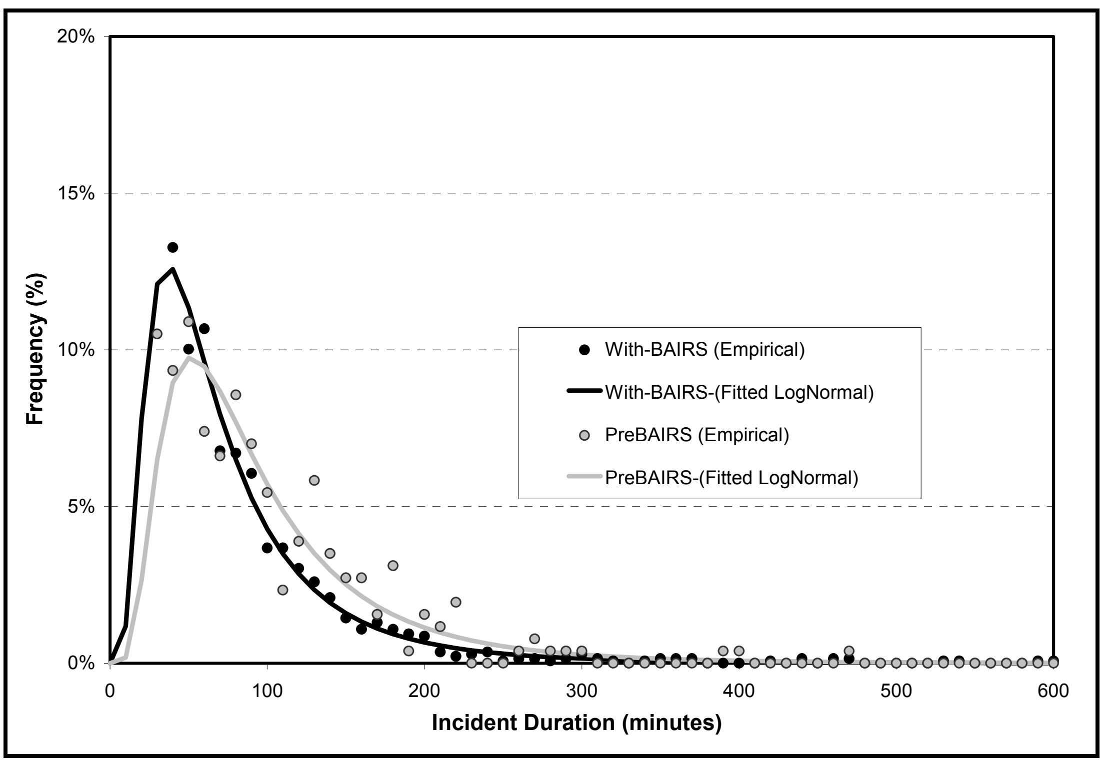


Figure 4.4: Response-time Histograms (Data: Response Time >= 30 minutes)

Table 4.3: Incident Durations (From Response Time Distributions)

Response-times	Mean Incident Duration		BAIRS Incident-Duration Savings	
Minimum-Used (minutes)	Pre-BAIRS (minutes)	With-BAIRS (minutes)	(minutes)	(percent)*
0	115.75	72.68	43.06	37.2%
10	115.75	72.68	43.06	37.2%
20	115.75	84.15	31.59	27.3%
30	115.75	95.93	19.82	17.1%
40	115.75	100.88	14.87	12.8%
50	115.75	103.02	12.73	11.0%
60	115.75	100.86	14.89	12.9%

* Note: Incident-duration Savings as a percent of mean Pre-BAIRS Incident-duration (i.e. 115.75 minutes).

Table 4.4: Number of BAIRS Response Time Records

	Pre-BAIRS	With-BAIRS
Response Time < 30 minutes	54	1,520
Response Time >= 30 minutes	230	1,153
Total	284	2,673

4.2 Estimation of Incident Delays

The traffic delays associated with incidents was estimated using linear regression techniques on the I-880 traffic and incident data that was described in Section 3. Two separate delay models were built, one estimating average delays per incident for weekends/holidays and one estimating average delays for non-holiday work days.

4.2.1 Weekend Delay Model

Several different models were developed, estimating delays as a function of VMT, BAIRS incidents, CHP incidents, special events at the Coliseum/Arena and precipitation. Table 4.5 lists the variables and variable descriptions for the I-880 weekend dataset.

The correlation between CHP incidents and delay was much stronger than the one between BAIRS incidents and delay. Correspondingly, the parameter estimates obtained using CHP incidents were far more reliable than those for BAIRS incidents, as were the model's overall goodness-of-fit statistics (e.g. using F-statistic comparisons). The best delay estimating model (for weekends) was:

$$Delay = 100.53 \times \left(\frac{VMT}{1{,}000{,}000} \right)^2 + 156.26 \times (ChpDay)$$

where:

D*elay* = average vehicular delay per incident (in vehicle-hours-of-travel, VHT),
VMT = daily vehicle-miles-of-travel,
ChpDay = CHP logged incidents that occurred between 7am and 8pm.

This means that (on average) there are an additional 156 vehicle-hours of traffic delays for each weekend-daytime incident that CHP officers respond to. Table 4.6 lists the model parameters and goodness-of-fit statistics shows for the weekend delay model.

Additional models were built to estimate vehicular delays from incidents which occurred during the night-time (either between midnight to 7am or between 8pm and midnight). The relation between night-time incidents and the delays was too weak to obtain (non-zero) parameter estimates with any degree of reliability. This probably reflects the relatively large amount of unused capacity during these off-peak hours where volume-to-capacity (V/C) ratios can be well below 0.5. As such, night-time incidents must be very large to cause measurable delays.

During model building, alternative models were developed which used all incidents (regardless of the time of day that the incidents occurred). These models did not perform as well as the final model above which estimates delay using only those incidents that occurred during the 7am to 8pm time period.

The CHP incidents that Caltrans Maintenance also responded to (i.e. logged in BAIRS) is known because "CHP_INCIDENT_NBR" is a field in the BAIRS incident database. This enables determining the subset of CHP subset of incidents that will have reduced response and clearance times from BAIRS.

Table 4.5: Variable Definitions, Weekend Delay & Incident Database

- **BairsAll** incidents are the total BAIRS logged incidents regardless of time of day.
- **BairsDay** incidents are those BAIRS incidents that occurred during 7am – 8pm.
- **BairsNight** incidents = BairsAll – BairsDay incidents.

- **ChpAll** incidents are all CHP logged incidents regardless of the time of day.
- **ChpDay** incidents are those CHP incidents that occurred during the hours of 7am to 8pm.
- **ChpNight** incidents = ChpAll – ChpDay incidents.

- **BairsChpAll** incidents are the total daily incidents that were responded to by Caltrans maintenance (i.e. logged in BAIRS) which also had a reference number in BAIRS field "CHP_INCIDENT_NBR".
- **BairsChpDay** incidents are those BairsChp incidents that occurred during 7am – 8pm.
- **BairsChpNight** incidents = BairsChpAll – BairsChpDay.

- **EventPM** is the number of special events at the Oakland Coliseum or the Oakland Arena (e.g. an Oakland A's or a Warriors Game) on a given day, provided by SMG/Network Associates Coliseum & The Arena in Oakland, Oakland, CA 9451.
- **Precip** is the measured daily rainfall (in inches) measured Department of Water Resource's Oakland North (ONO) station.

- **VMT** is total (i.e. daily) measured vehicle miles of travel estimated using the PeMS 5-minute traffic volumes.
- **VHT** is total measured vehicle hours of travel estimated using the PeMS 5-minute traffic volumes and the PeMS 5-minute (mean) traffic speeds.
- **FreeflowVHT** is the VHT that would have occurred if all vehicles been able to travel at their desired speed (i.e. freeflow speed). The freeflow speed was estimated to be the unweighted average of the vehicular speeds measured from midnight to 4:00am across all non-holiday weekdays during the months of February and March 2004. This empirically obtained mean freeflow speed was 69.5 miles per hour via PeMS I-880 traffic speed data.
- **Delay** is the difference between that actual (measured) VHT and freeflowVHT.

Table 4.6: Incident Delay Estimation Model, Weekend Analysis (S-Plus Output)

```
Call: lm(Delay~(-1)+I((VMT/1000000)^2)+ChpDay,
      data = I880BairsWW, subset = (WeekEnd == 1))

Residuals:
   Min     1Q Median    3Q  Max
 -2654 -852.3 -154.4 460.7 6436

Coefficients:
                      Value Std. Error  t value Pr(>|t|)
I((VMT/1000000)^2) 100.5284  37.2384     2.6996   0.0084
            ChpDay 156.2616  33.6518     4.6435   0.0000

Residual standard error: 1332 on 82 degrees of freedom
Multiple R-Squared: 0.8501
F-statistic: 232.5 on 2 and 82 degrees of freedom, the p-value is 0

Correlation of Coefficients:
       I((VMT/1000000)^2)
ChpDay -0.9419
```

4.2.2 Weekday Delay Model

From BAIRS managers, supplementary valuable information about BAIRS was ascertained. Specifically, the introduction of BAIRS did not reduce incident durations or response times during the normal Caltrans maintenance work hours (from 7am to 4pm on non-holiday weekdays) – because Caltrans supervisors and crew are already “on the job” at the maintenance yards during this time period (7am – 4pm, M-F non-holidays). Therefore, no delay reducing benefits were attributed to BAIRS during the 7am – 4pm weekday time periods.

As was done with the weekend analysis, several different weekday models were developed, estimating delays as a function of VMT, BAIRS incidents, CHP incidents, FSP-assists, special events at the Coliseum/Arena and precipitation. Table 4.7 lists the variables and variable descriptions for the I-880 weekend dataset.

Again, the correlation between CHP incidents and delay was much stronger than the one between BAIRS incidents and delay. Correspondingly, the parameter estimates obtained using CHP incidents were far more reliable than those for BAIRS incidents, as were the model’s overall goodness-of-fit statistics (e.g. using F-statistic comparisons). The best delay estimating model (for non-holiday weekday) was:

$$Delay = 470.45 \times \left(\frac{VMT}{1{,}000{,}000} \right)^2 + 165.22 \times (ChpWH) + 139.12 \times (ChpNWH),$$

where:
Delay = average vehicular delay per incident (in vehicle-hours-of-travel, VHT),
VMT = total daily vehicle-miles-of-travel,
ChpWH = CHP logged incidents that occurred during normal Caltrans Maintenance work hours (7am – 4pm).
ChpNWH = CHP logged incidents that occurred outside normal Caltrans Maintenance work hours (i.e. midnight – 7am or 4pm – midnight).

This model may be interpreted as:

- There is an additional 165 vehicle-hours of traffic delays for each weekday incident that CHP responds to during the 7am to 4pm time period.
- There is an additional 139 vehicle-hours of traffic delays for each weekday incident that CHP responds to during Caltrans Maintenance non-work-hours (4pm – 7am).

Table 4.8 lists the model parameters and goodness-of-fit statistics shows for the weekend delay model.

The CHP incidents that Caltrans Maintenance also responded to (i.e. logged in BAIRS) is known because “CHP_INCIDENT_NBR” is a field in the BAIRS incident database. This enables determining the subset of CHP subset of incidents that will have reduced response and clearance times from BAIRS.

Table 4.7: Variable Definitions, Weekday Delay & Incident Database

- **BairsAll** incidents are the total BAIRS logged incidents regardless of time of day.
- **BairsNWH** incidents are those BAIRS incidents that occurred outside normal Caltrans Maintenance work hours (midnight to 7am, or 4pm to midnight).
- **BairsWH** incidents = BairsAll – BairsNWH.

- **ChpAll** incidents are all CHP logged incidents regardless of the time of day.
- **ChpNWH** incidents are those CHP logged incidents that occurred outside normal Caltrans Maintenance work hours (midnight to 7am, or 4pm to midnight).
- **ChpWH** incidents = ChpAll – ChpNWH.

- **BairsChpAll** incidents are total daily incidents that were responded to by Caltrans maintenance (i.e. logged in BAIRS) which also had a reference number in BAIRS field "CHP_INCIDENT_NBR.
- **BairsChpNWH** incidents are incidents that were responded to by Caltrans maintenance (i.e. logged in BAIRS) which also had a reference number in BAIRS field "CHP_INCIDENT_NBR that occurred outside normal Caltrans Maintenance work hours.
- **BairsChpWH** incidents = BairsChpAll – BairsChpNWH.

- **FspAssists** incidents are the total daily number of Freeway Service Patrol (FSP).
- **FspAstTrHazard** incidents are the FSP assists which coded as being traffic accidents (as opposed to debris removals or disabled vehicle assists) and those which occurred in freeway's traffic lanes (as opposed to occurring on the left shoulder, right shoulder or on/off ramp).
- **FspAstInLane** are the FSP assists that occurred in freeway's traffic lanes (as opposed to occurring on the left shoulder, right shoulder or on/off ramp).

- **EventPM** is the number of special events at the Oakland Coliseum or the Oakland Arena (e.g. an Oakland A's or a Warriors Game) on a given day, provided by SMG/Network Associates Coliseum & The Arena in Oakland, Oakland, CA 9451.
- **Precip** is the measured daily rainfall (in inches) measured Department of Water Resource's Oakland North (ONO) station.

- **VMT** is total (i.e. daily) measured vehicle miles of travel, estimated using the PeMS 5-minute traffic volumes.
- **VHT** is total (i.e. daily) measured vehicle hours of travel, estimated using the PeMS 5-minute traffic volumes and the PeMS 5-minute (mean) traffic speeds.
- **FreeflowVHT** is the VHT that would have occurred if all vehicles been able to travel at their desired speed (i.e. freeflow speed). The freeflow speed was estimated to be the unweighted average of the vehicular speeds measured from midnight to 4:00am across all non-holiday weekdays during the months of February and March 2004. This empirically obtained mean freeflow speed was 69.5 miles per hour via PeMS I-880 traffic speed data.
- **Delay** is the difference between that actual (measured) VHT and freeflowVHT.

Table 4.8: Incident Delay Estimation Model, Weekday Analysis (S-Plus Output)

```
Call: lm(Delay~(-1)+I((VMT/1000000)^2)+ChpWH+ChpNWH,
      data = I880Bairs2)

Residuals:
   Min    1Q Median   3Q   Max
 -5621 -2303 -47.13 1827 18306

Coefficients:
                      Value Std. Error  t value Pr(>|t|)
I((VMT/1000000)^2) 470.4475  55.7019     8.4458   0.0000
             ChpWH 165.2239  56.1669     2.9417   0.0036
            ChpNWH 139.1228  58.6794     2.3709   0.0186

Residual standard error: 3330 on 217 degrees of freedom
Multiple R-Squared: 0.9139
F-statistic: 767.9 on 3 and 217 degrees of freedom, the p-value
is 0

Correlation of Coefficients:
       I((VMT/1000000)^2)   ChpWH
 ChpWH -0.6507
ChpNWH -0.6182             -0.1369
```

4.2.3 BAIRS Incident Delays

The District-wide annual vehicular delays (in vehicle-hours-of-travel, VHT) were estimated using:

1. Daily average number of incidents that Caltrans Maintenance (BAIRS) and CHP responded to (District-wide),
2. Estimated average delay per incident, and
3. Number of weekday and weekend/holiday days per year.

The average number of incident that Caltrans Maintenance and CHP responded to District-wide were obtained directly from the Caltrans BAIRS and CHP incident logs. The average vehicular delays per incident were estimated via linear regression techniques as just described. Table 4.9 shows there are about 3.5 million vehicle-hours of delay annually for BAIRS incidents in District 4. Reiterating, the estimated 3.5 million vehicle-hours of delay is the annual District-wide vehicular delay from incidents that BAIRS responded to, not BAIRS delay savings. The following Chapter quantifies BAIRS delay savings, the end product of combining these District-wide traffic delays with the response and clearance time savings described in Section 4.1.

Table 4.9: Annual Vehicular Delays (BAIRS Assisted Freeway Incidents)

Incident Day-of-Week & Time-of-Day Category	Mean Number of Daily Occurances*	Delay Per Incident (VHT) **	Weekend and Holiday (Days / Year)	Annual Delay (VHT / Year)
Weekend Daytime (7am-8pm)	35.08	156.26	115	631,898
Weekend Nighttime (8pm-7am)	13.28	-	115	-
Weekday Workhours (7am-4pm)	60.32	165.22	250	2,488,854
Weekday Non-workhours (4pm-7am)	10.72	139.12	250	372,432
Total:				3,493,183

Notes: * Caltrans District 4, District-wide average for 2004.
** I-880 estimated (January -- June 2004).

CHAPTER 5

EVALUATION

5.1 BAIRS Benefits

BAIRS benefits were calculated by combining the response and clearance time savings presented in Section 4.1 with the incident delays from Section 4.2.

An average incident duration reduction of 15% was obtained via fitting log-linear curves to incident duration data (excluding incidents with durations less than ½ of the mean duration, i.e. less than 60 minutes). Using the same methods of fitting log-linear curves to Maintenance response times revealed a 17% average duration reduction. To be conservative, the 15% duration reduction was used for calculating BAIRS benefits. A 21% average delay savings was attributed to BAIRS, estimated using the fitted log-linear incident duration distributions and the theoretically accepted relation that traffic delays are proportional to the square of the incident duration [9]. The value of time used for estimating the value of the delay savings was $10.00 per vehicle-hour, which is $8.00 per person-hour with a 1.25 average vehicle occupancy rate; a rather conservative estimate for the San Francisco Bay area in 2005. With these, the District-wide delay saving benefits from BAIRS is 210,000 vehicle-hours of delay saved annually – a $2.1 million benefit to Bay area motorist. BAIRS delay savings benefits are summarized in Table 5.1.

Table 5.1: BAIRS Delay Savings Benefits

Incident Day-of-Week & Time-of-Day Category	Annual Delay (VHT / Year)	Delay Savings (in percent)	Annual Delay Savings (VHT / Year)	Annual Delay Savings ($ / Year)
Weekend Daytime (7am-8pm)	631,898	21%	133,587	$ 1,335,871
Weekend Nighttime (8pm-7am)	-	21%	-	$ -
Weekday Workhours (7am-4pm)	2,488,854	0%	-	$ -
Weekday Non-workhours (4pm-7am)	372,432	21%	78,734	$ 787,344
Total:			212,321	$ 2,123,214

The only BAIRS benefits quantified for benefit-cost estimates were reductions to response and clearance times and their associated delay savings to motorists. However, in reality, BAIRS provides Bay area residents with many additional benefits that BAIRS is not credited for in the benefit-cost estimates. For example, reduced traveler delays equate to fuel savings for motorists and reduced mobile emissions (i.e. improved air quality), improved safety, and improved access for emergency response vehicles.

Moreover, Caltrans District 4 has capitalized on several new management tools from BAIRS, including:

- Emergency contact numbers for Region Management Staff, Safety, Toll Bridges, District Communication Center Supervisors, Etc. are available.
- Construction contacts and closure lists are also available.
- Post-mile log for all routes in District 4.

- Guidelines for notification in case of work related emergencies, deaths, injuries, etc.
- Emergency contractor list for equipment to respond to major incidents.

Additional benefits to Caltrans have been realized as stated on the Computerworld Honors Award web page [10]:

The BAIRS application was designed to provide responding personnel with up-to-date incident and resource information at all hours, both in the office and field. This allows responders to make more informed decisions, thus expediting the incident response process and reducing overall traffic congestion. Specifically, by combining wireless and GIS technology, the BAIRS system provides a long list of benefits to the District and the public, including:

A) Reduction of Labor-Intensive Paper Documentation
The BAIRS application eliminates nearly all paper documentation that dispatchers had previously used to organize and track an incident's status. This includes paper radio/telephone cards, post-mile books, call-out lists, regional directories, notification guidelines, paper maps, paper telephone books, directories, and contact sheets. By eliminating paper documentation and manual processing, dispatchers work more efficiently and are able to access archived information more quickly. For example, before BAIRS, dispatchers would spend hours sorting through filed paperwork to create management reports and locate incident information for internal and legal purposes. Now this information can be called up in seconds.

B) Standardization of the Dispatching Process
By reviewing the old dispatching process, streamlining the process to leverage BAIRS functionality, and training all responding supervisors, dispatchers and supervisors now work together more efficiently because they follow a common process. In addition, after repeated responses the process becomes almost second nature, which allows supervisors to more clearly focus on the task at hand, especially during emergencies.

C) Improved Access to Resources
The BAIRS GIS tool allows users to search for personnel, equipment, and materials nearest the incident or any District 4 maintenance facility. The system allows dispatchers and responders to search for workers with specific qualifications and identify available quantities of materials at maintenance yards. Access to this information allows dispatchers to send the nearest supervisor to an incident to assess the situation and quickly establish a Caltrans presence. Dispatchers or supervisors can then locate nearby equipment and/or materials for the clean up and contact the most qualified operator nearest the yard to pick them up and bring them to the scene.

D) Decreased Travel time and Exposure Thus Enhancing Safety
By locating the nearest, most capable supervisor, Caltrans workers spend less time traveling and resolving incidents, thus reducing exposure to potential accidents and other safety hazards. In addition, by expediting the arrival of a Caltrans responder, roadway hazards are removed more quickly, risks of secondary collisions are reduced, and roadway safety is

improved for the traveling public and employees. This will prove to be a major benefit for society as a whole.

E) Mobile Devices Increase Productive Field Time for Supervisors
By providing supervisors with a wireless tool to coordinate activities and locate resources, they can spend more time in the field with their crews, thus increasing production and awareness of their responsible areas. This also improves workforce moral as Caltrans supervisors generally prefer to spend their time in the field, instead of in the office. Ultimately, BAIRS provides supervisors with the best of both worlds: they are no longer bound by the need to use a desktop in the office, but can still employ the latest technology to enhance their ability to respond to incidents.

F) Homeland Security/Disaster Recovery
In the event of a terrorist attack or major disaster, the BAIRS application can be used to help coordinate an immediate Caltrans response and track high-priority assistance and reconstruction. In order to increase the effectiveness of a multi-agency emergency response, District 4 partnered with California Highway Patrol (CHP) and other local emergency agencies while developing the BAIRS application and planning for emergency response. In the event of a major disaster, BAIRS would be used to help coordinate joint responses and provide responders with information on available CHP offices and other local facilities to expedite disaster recovery. Since BAIRS stores GIS data locally on each laptop, responders could still use the system to locate and contact other personnel via radio, even if the telecommunications network is unavailable. Also, the system could be used to locate detours and alternate routes of transportation for evacuations and access to disaster areas.

G) Reduced Environmental Pollutants and Natural Resource Usage
By reducing overall response and incident resolution times, the BAIRS application will decrease the amount of time drivers spend on congested roadways. In turn, this will reduce harmful emissions and fuel consumption by vehicles idling in incident-induced traffic. Moreover, should a hazardous material spill occur on the roadway, BAIRS would put a responder on scene more quickly and can be used to locate the nearest Haz-Mat team to contain the spill and reduce environmental damage.

5.2 BAIRS Costs

The costs analysis was conducted annualizing the capital, start-up and operating costs over a 12 year period (the first 12 years of BAIRS). As such, the initial start-up and capital costs for the BAIRS project were equally distributed among the first 12 years of the BAIRS project. The (usable) life expectancy of the laptop computers used by the BAIRS supervisors and management was assumed to be 6 years.

Two consulting contracts with Deloitte Consulting LLP covered all consulting fees for the first three years of the BAIRS project. For costing estimates, it was assumed (and verified by District 4 BAIRS management to be a reasonable estimate) that consulting fees would be limited to $50,000 per year for the remaining 9 years of the 12 year cost analysis. These consulting fees would cover maintenance of and upgrades to BAIRS, including software installation and updates on new laptops as needed. Computer, software, and Caltrans staff costs were provided by District 4 BAIRS management staff.

Table 5.2: Estimated BAIRS Costs (12 year life cycle)

Capital Cost Category	Quantity	Unit Costs	Total Costs	No. of Occururances	Annual Costs
Caltrans D4 Maintenance Staff (PY's)	2.50	$ 122,250	$ 305,625		
Deloite -- Contract Services			$ 125,000		
Deloite -- BAIRS Improvement Program			$ 170,000		
Capital/Strart-up Costs (not incl computers)			$ 600,625	1	$ 600,625
LapTop Computers	185	$ 892	$ 165,000	2	$ 330,000
Total Capital Costs (12 year period):					**$ 930,625**

Operational Costs	Quantity	Unit Costs		Years	Annual Costs
Telecom Fees (Laptops)	185.00	$20		12	$44,400
Consulting Fees	1.00	$50,000		9	$450,000
Caltrans HQ Staff	1.57	$112,470		12	$2,118,935
Caltrans D4 Maintenance Staff	1.00	$ 122,250		12	$1,467,000
Caltrans D4 GIS Staff	0.20	$112,470		12	$269,928
Total Operating Costs (12 year period):					**$4,350,263**

Total (12 year) Capital Costs:		$ 930,625
Total (12 year) Operating Costs:		$4,350,263
Total Annualized Costs:		**$ 440,074**

Cost data source: Caltrans District 4 BAIRS Coordinator. A 63% overhead rate was applied to Caltrans employee costs to account for employee retirement and health benefits and for other costs incurred by Caltrans which are above the gross salaries paid to workers (source: Caltrans State TMC Program Senior).

Additionally, cost analyses were performed annualizing the capital, start-up and operating costs over a 6 year period (the first 6 years of BAIRS) instead of the previously used 12 year period. This revealed the sensitivity of average annual costs to the time span used in the cost analysis. As shown in Table 5.3, if the capital and setup costs are averaged over a 6 year period then BAIRS average annual cost increases to about $478,000/year from the previously estimated $440,000/year as shown in Table 5.2 for the 12 year period.

5.3 Benefit/Cost Ratio

Table 5.4 shows the estimated BAIRS delay savings benefits, costs, and the associated benefit-cost ratios using two cost life cycles (i.e. 12 years and 6 years). The findings from empirical data revealed that BAIRS reduced average incident durations by 15% (obtained from log-linear fitted distributions with durations/response-times greater than half their means). The estimated BAIRS benefit-cost ratio is 4.8:1 using a 12 year costing period and to 4.5:1 using a 6 year costing period.

It is interesting to note that BAIRS would still have a benefit-cost ratio above 1:1 even if BAIRS only reduced the average incident duration by 3-4% for those incidents that occurred during Caltrans Maintenance non-work hours (midnight–7am, and 4pm–midnight) on non-holiday weekdays or during the daytime (7am–8pm) on holidays/weekends, and had no additional delay savings benefits during the nighttime or during the normal Caltrans Maintenance workday – and giving BAIRS no credit for any of the additional benefits previously listed in Section 5.1 of this report.

Table 5.3: Estimated BAIRS Costs (6 year life cycle)

Capital Cost Category	Quantity	Unit Costs	Total Costs	No. of Occururances	Annual Costs
Caltrans D4 Maintenance Staff (PY's)	2.50	$ 122,250	$ 305,625		
Deloite -- Contract Services			$ 125,000		
Deloite -- BAIRS Improvement Program			$ 170,000		
Capital/Strart-up Costs (not incl computers)			$ 600,625	1	$ 600,625
LapTop Computers	185	$ 892	$ 165,000	1	$ 165,000
Total Capital Costs (6 year period):					**$ 765,625**

Operational Costs	Quantity	Unit Costs		Years	Annual Costs
Telecom Fees (Laptops)	185.00	$20		6	$22,200
Consulting Fees	1.00	$50,000		3	$150,000
Caltrans HQ Staff	1.57	$112,470		6	$1,059,467
Caltrans D4 Maintenance Staff	1.00	$122,250		6	$733,500
Caltrans D4 GIS Staff	0.20	$112,470		6	$134,964
Total Operating Costs (6 year period):					**$2,100,131**

Total (6 year) Capital Costs:		$ 765,625
Total (6 year) Operating Costs:		$2,100,131
Total Annualized Costs:		**$ 477,626**

Cost data source: Caltrans District 4 BAIRS Coordinator. A 63% overhead rate was applied to Caltrans employee costs to account for employee retirement and health benefits and for other costs incurred by Caltrans which are above the gross salaries paid to workers (source: Caltrans State TMC Program Senior).

Table 5.4: Estimated Annual Delay Savings and Benefit-Cost Ratio

BAIRS Cost Assumptions	Annual Benefit (VHT / Year)	Annual Benefit ($ / Year)	Annual Costs ($ / Year)	Benefit to Cost Ratio
Cost Annualized over 12 Year Period	212,321	$ 2,123,214	$ 440,074	4.82
Cost Annualized over 6 Year Period	212,321	$ 2,123,214	$ 477,626	4.45

CHAPTER 6
CONCLUSIONS

6.1 Summary of the Study Findings

Overall, BAIRS proved to be a cost effective program for District 4 maintenance. Using only traveler delay savings as a cost-effectiveness measure, BAIRS benefit-cost ratio is essentially 5:1. In addition to this, BAIRS provides several other noteworthy benefits to both the public and to Caltrans. For example, reducing incident response times and incident clearance times improves safety on California's freeways, reduces mobile emissions, and also shortens emergency vehicle response times to other incidents. Through BAIRS, District 4 has updated/replaced several manual processes and paper-based tools:

- TMC/DCC Paper Radio and Telephone Cards
- Post-mile book
- Call-out lists
- Regional Directories
- Notification Guidelines
- Paper maps and guides
- Telephone books, directories, and contact sheets
- Manual reports.

Since BAIRS inception, BAIRS management have been requesting and received regular feedback from District 4's TMC, DCC, and Maintenance supervisors (the primary BAIRS users) to continue to improve BAIRS functionality and usability. Currently BAIRS management and Deloitte Consulting LLP are working to:

1. Make the incident logging forms more intuitive (user friendly) and to reduce the time required to log incidents by Maintenance supervisors.
2. Provide additional exception handling and internal error checking; for example, insuring that the "traffic impacted" field is checked for all impacting incidents.
3. Update training procedures, training manuals and user's manuals.
4. Provide additional management reporting functionality:
    a) Replace manual reporting with computerized (automated) report generation.
    b) Provide on-line database query capabilities for specialized data summaries and reports.

6.2 Recommendations

During the BAIRS evaluation review team meetings, team members postulated that no single incident response system would be best for all Districts. District size (both geographically and in terms of demand for incident response), along with Maintenance's responsibilities and needs vary widely from District to District. Additional comments indicated that many of the Districts have existing systems that are suiting their needs (e.g. District 3's Quick Strike Team and District 6's TMC CAD based incident response system), and these Districts may be reluctant to adopt a new system. Furthermore, questions regarding which of these systems (if any) is best suited for statewide implementation have not been studied; neither informally (i.e. ad hoc methods) nor by technically defensible quantitative analyses. Even with BAIRS' wide range of benefits to District 4, a complete and quantitative evaluation of Caltrans' other incident response and tracking systems needs to be conducted to determine whether BAIRS is more effective than those used by other Caltrans Districts.

Moreover, it is quite plausible that a combination of BAIRS components along with other components of the Quick Strike Team (and/or from other Caltrans incident management programs) might prove to be more effective than choosing any single program. These programs are not necessarily mutually exclusive, nor does one program have to be adopted, as is, and in its entirety. For example, the Quick Strike Team directed that [11]:

- Selected leadworkers who live in close proximity to the maintenance stations were issued home storage permits if the Supervisor lives too far from his area to respond in a timely manner.
- In the metropolitan area, at least one four yard equipped with a tailgate sander is left loaded at the maintenance station with a minimal mount of dry sand to expedite its response to spills.

These are directives that District 4 could implement that might provide additional response and clearance time savings, which do not conflict with nor reduce the effectiveness of BAIRS. Likewise, many of the BAIRS components (e.g. Web and GIS based incident logging and tracking, automated incident and response summary report generation) might prove valuable compliments to other District incident management practices.

Prior to choosing to move toward a standardized statewide incident management/tracking system to be used by all Districts, Caltrans should conduct an evaluation to determine if a "one size fits all" incident management system is best suited for all Districts or if local decision making and incident management is more effective and efficient than state-wide standardized practices. If a standardized (statewide) incident management/tracking system is deemed the most efficient and effective option, an alternative analysis should follow, comparing the effectiveness of BAIRS with those systems used by other Districts. If BAIRS is chosen for wide-scale implementation, it is recommended that BAIRS be implemented as a demonstration project in one or two cooperative Districts prior to statewide implementation in all Districts; observing and documenting implementation issues, and resolving these issues within the demonstration Districts prior to statewide implementation.

REFERENCES

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[2] Computerworld Honors Web Page: http://www.cwheroes.org/his_4a_detail.asp?id=4913 (June 14, 2005).

[3] Computerworld Honors Web Page: http://www.cwheroes.org/his_4a_detail.asp?id=4913 (June 14, 2005).

[4] Data source: BAIRS incident database provided by Caltrans District 4 BAIRS Management (data inclusion dates: June 2003 – September 2004).

[5] TMS Incident Management Business Plan, California Department of Transportation, December 2002.

[6] Caltrans Memorandum, Subject: Major Incident Response, Lawrence H. Orcutt, Chief, Division on Maintenance, Dated: January 15, 2003

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[8] California's performance measurement system: Improving freeway efficiency through transportation intelligence, by P. Varaiya, July 2001, appears in TR News, 218, Jan-Feb 2002.

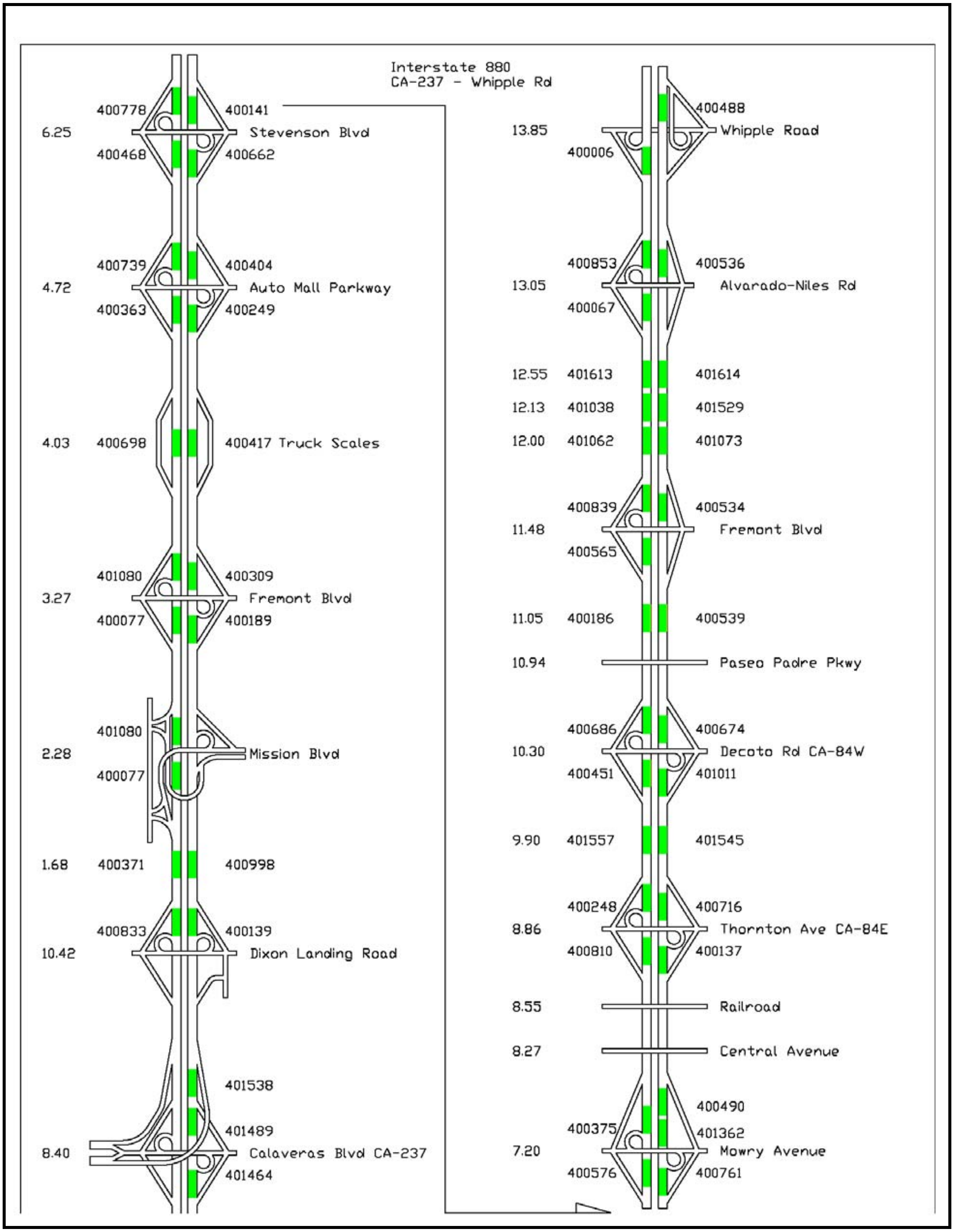
[9] Incidents on the Freeway: Detection and Management, K. F. Petty, Department of Electrical Engineering and Computer Science, University of California, Berkeley, California. Committee: P. Varaiya, S. Sastry, C. Daganzo. Fall Semester 1997.

[10] Computerworld Honors Web Page: http://www.cwheroes.org/his_4a_detail.asp?id=4913 (June 14, 2005).

[11] Caltrans Memorandum, Subject: Major Incident Response, Lawrence H. Orcutt, Chief, Division of Maintenance, Dated: January 15, 2003

APPENDIX A.

I-880 LOOP DETECTOR LOCATIONS



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Stevenson Blvd
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400739
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Auto Mall Parkway
400363
400249
4.03
400698
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400077
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400371
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8.40
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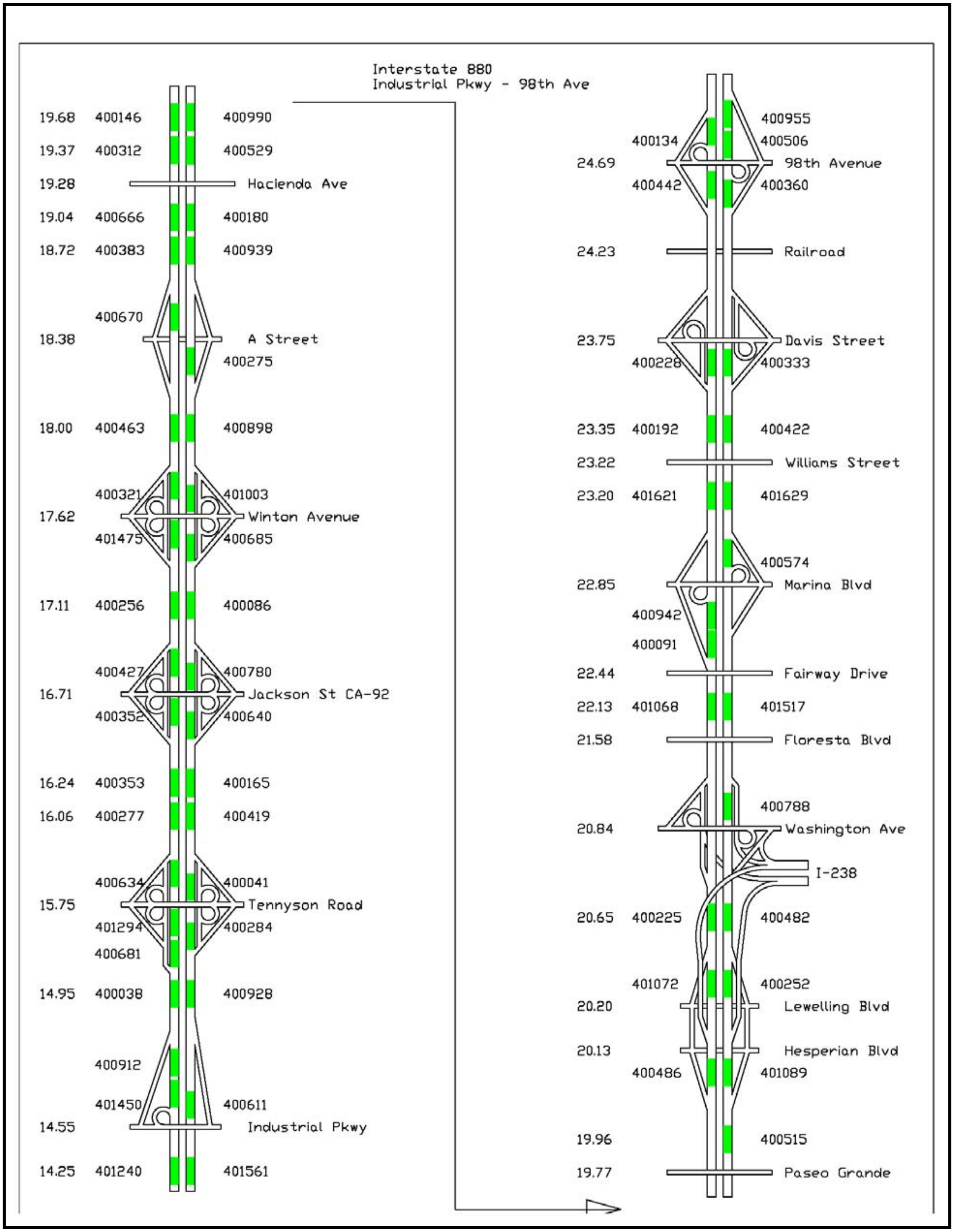

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400670
18.38 A Street
400275
18.00 400463 400898
400321 401003
17.62 Winton Avenue
401475 400685
17.11 400256 400086
400427 400780
16.71 Jackson St CA-92
400352 400640
16.24 400353 400165
16.06 400277 400419
400634 400041
15.75 Tennyson Road
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400681
14.95 400038 400928
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400091
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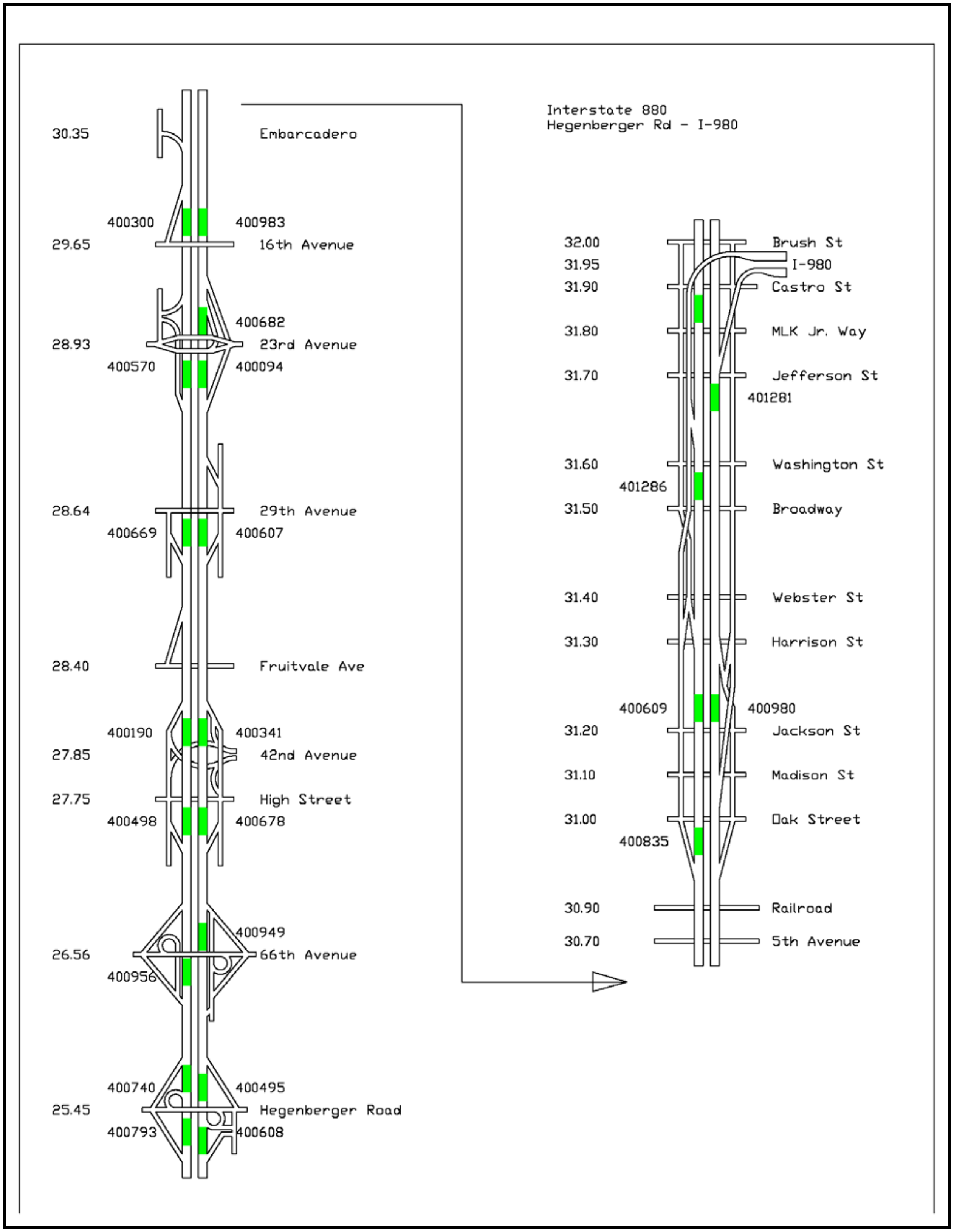
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29th Avenue
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400607
28.40
Fruitvale Ave
400190
400341
27.85
42nd Avenue
27.75
High Street
400498
400678
400949
26.56
66th Avenue
400956
400740
400495
25.45
Hegenberger Road
400793
400608
32.00
Brush St
31.95
I-980
31.90
Castro St
31.80
MLK Jr. Way
31.70
Jefferson St
401281
31.60
Washington St
401286
31.50
Broadway
31.40
Webster St
31.30
Harrison St
400609
400980
31.20
Jackson St
31.10
Madison St
31.00
Oak Street
400835
30.90
Railroad
30.70
5th Avenue