System Metrics Group, Inc.

in association with

CLR Analytics, Inc.

Corridor System Management Plan (CSMP)

Orange County SR-91 Corridor

Final Report

August 2010

State Route 91

Corridor System Management Plan

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1. INTRODUCTION

This document represents the Final Report for the Orange County State Route 91 (SR-91) Corridor System Management Plan (CSMP) developed by the California Department of Transportation (Caltrans). The Orange County SR-91 CSMP Corridor runs in an east-west direction from I-5 in Buena Park (postmile R3.6) to the Orange/Riverside County line (postmile 18.9).

This full technical CSMP contains the results of a two-year study that included several key steps:

- Stakeholder Involvement (discussed below in this Section 1)
- Corridor Description and Performance Assessment (Sections 2 and 3)
- Bottleneck Identification and Performance (Section 4)
- Bottleneck Causality Analysis (Section 5)
- Scenario Development and Evaluation (Section 6)
- Conclusions and Recommendations (Section 7).

This CSMP is the direct result of the November 2006 voter-approved Proposition 1B (The Highway Safety, Traffic Reduction, Air Quality, and Port Security Bond Act of 2006). This ballot measure included a funding program deposited into a Corridor Mobility Improvement Account (CMIA).

To receive CMIA funds, the California Transportation Commission (CTC) guidelines required project nominations to describe how mobility gains from funded corridor improvements would be maintained over time. Project proposals with CSMPs would be given a higher priority in the funding approval process. Hence, a CSMP aims to define how corridors will be managed over time, focusing on operational strategies in addition to the already funded expansion projects. The goal is to get the most out of the existing system and maintain or improve corridor performance. The CMIA will partially fund an eastbound auxiliary lane from SR-241 to SR-71, and a lane addition from SR-55 to Gypsum Canyon Road.

The Orange County SR-91 CSMP involved corridor stakeholders including representatives from cities bordering the SR-91 CSMP Corridor, and the Orange County Transportation Authority (OCTA). The stakeholders were briefed at critical milestones by the consulting team. Feedback from these stakeholders helped solidify the findings of the performance assessment, bottleneck identification, and causality analysis using their intimate knowledge of local conditions. Moreover, various stakeholders have provided support and insight, and shared valuable field and project data without which this study would not have been possible.

This report presents a corridor performance assessment, identifies bottlenecks that lead to congestion, and diagnoses the causes for these bottlenecks. Alternative investment strategies were modeled using 2007 as the Base Year and 2020 as the Horizon Year.

This CSMP should be updated by Caltrans on a regular basis since corridor performance can vary dramatically over time due to changes in demand patterns, economic conditions, and delivery of projects and strategies. Such changes could influence the conclusions of the current CSMP and the relative priorities in investments. Therefore, it is recommended that updates occur no less than every two to three years. To the extent possible, this document has been organized to facilitate such updates.

The report references locations on SR-91 using two types of postmiles: a California postmile (CA PM) and an absolute postmile (Abs PM). A California postmile is assigned to a geometric feature on the freeway when the freeway was built. The absolute postmile is the actual centerline distance down the freeway from the beginning of the route to the end of the route. Unless otherwise noted, all postmiles presented in this report are CA PM.

The following discussion provides background to the system management approach in general and CSMPs in particular.

What is a Corridor System Management Plan (CSMP)?

In November 2006, voters approved Proposition 1B (The Highway Safety, Traffic Reduction, Air Quality, and Port Security Bond Act of 2006). This ballot measure included a funding program to be deposited into the CMIA. For a project to be nominated by a Caltrans district or regional agency, the CMIA guidelines require that project nominations describe how mobility gains of urban corridor capacity improvements would be maintained over time.

The guidelines also stipulate that the CTC will give priority to project nominations that include a CSMP. A CSMP is a comprehensive plan for maintaining the congestion reduction and productivity improvements achieved on a CMIA corridor. CSMPs incorporate all travel modes, including State highways and freeways, parallel and connecting roadways, public transit (bus, bus rapid transit, light rail, intercity rail), carpool/vanpool programs, and bikeways. CSMPs also include intelligent transportation technologies such as ramp metering, coordinated traffic signals, changeable message signs for traveler information, and improved incident management.

This CSMP is the first attempt to integrate the overall concept of system management into Caltrans' planning and decision-making processes for the SR-91 CSMP Corridor. Traditional planning approaches identify localized freeway problem areas and then develop solutions to fix those problems, often by building expensive capital improvement projects. The SR-91 CSMP focuses on the system management approach with greater emphasis on using on-going performance assessments to identify operational strategies that yield higher congestion reduction and productivity benefits relative to the amount of money spent.

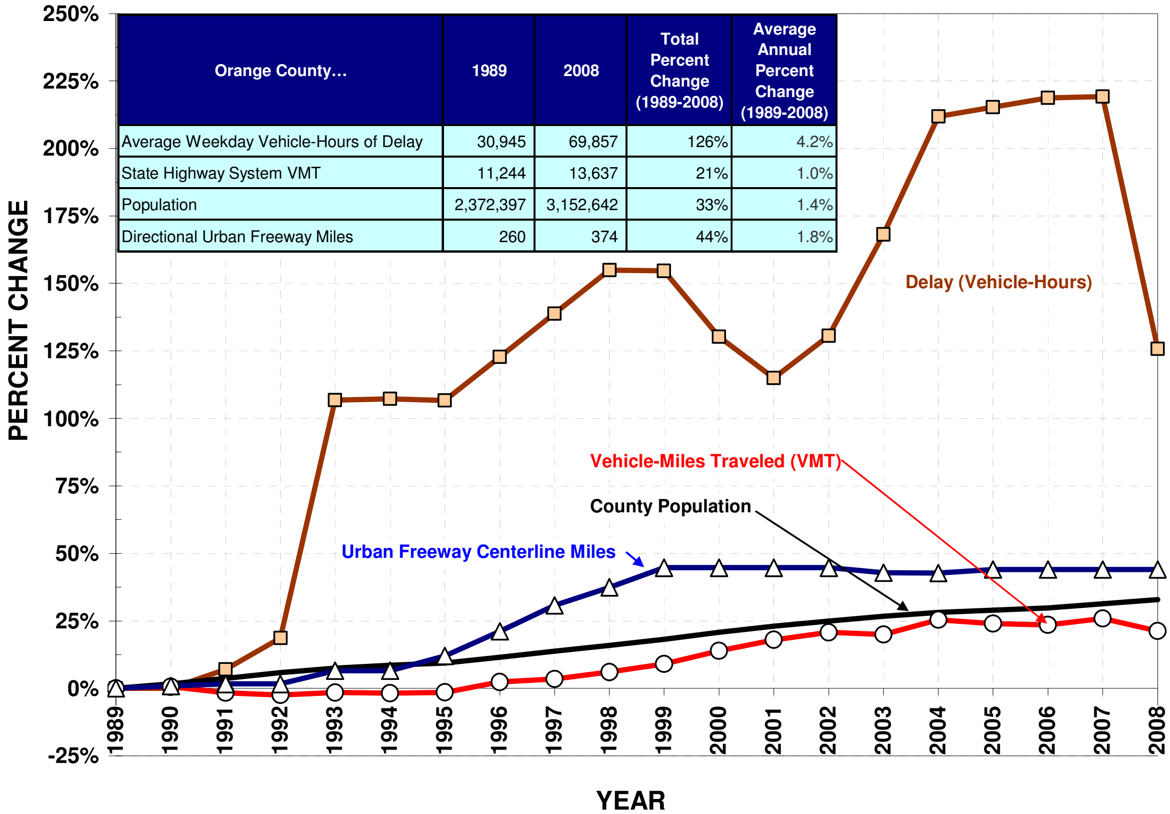
Caltrans develops integrated multimodal projects in balance with community goals, plans, and values. Caltrans seeks and tries to address the safety and mobility needs of bicyclists, pedestrians and transit users in all projects, regardless of funding. Bicycle, pedestrian, and transit travel is facilitated by creating "complete streets" beginning early in system planning and continuing through project delivery, maintenance, and operations. Developing a network of complete streets requires collaboration among all Caltrans functional units and stakeholders. As the first-generation CSMP, this report is focused more on reducing congestion and increasing mobility through capital and operational strategies. Future CSMP work will further address pedestrian, bicycle and transit components and seek to manage and improve the whole network as an interactive system.

What is System Management?

With the rising cost and complexity of construction and right-of-way acquisition, the era of large-scale freeway construction is ending. Compared to the growth of vehicle-miles traveled (VMT) and population, congestion is growing at a much higher rate.

Exhibit 1-1 shows Orange County congestion (measured by average weekday vehicle-hours of recurring delay), VMT, population and urban freeway mileage between 1989 and 2008. Over that 20-year period, congestion grew by more than 125 percent from 1989 levels (just over four percent per year). Over the same period, VMT and population rose by 21 and 33 percent, respectively. Between 1989 and 1999, urban freeway miles grew dramatically, but since then virtually no miles have been added.

Exhibit 1-1: Orange County Growth Trends (1989-2008)

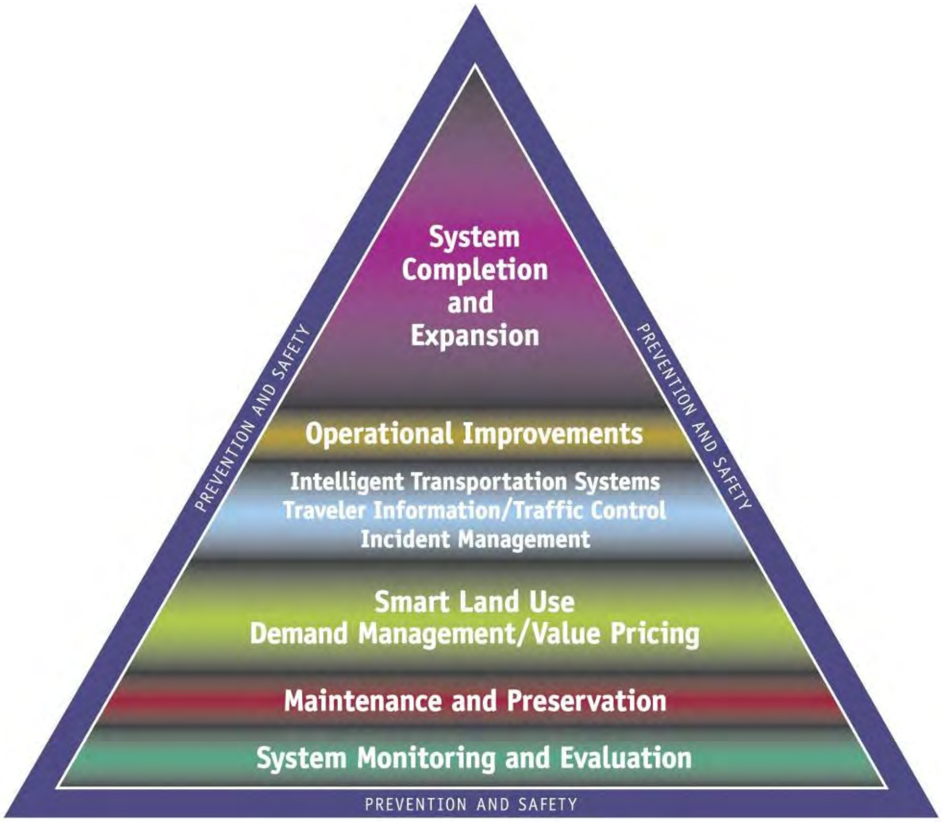


Orange County...	1989	2008	Total Percent Change (1989-2008)	Average Annual Percent Change (1989-2008)
Average Weekday Vehicle-Hours of Delay	30,945	69,857	126%	4.2%
State Highway System VMT	11,244	13,637	21%	1.0%
Population	2,372,397	3,152,642	33%	1.4%
Directional Urban Freeway Miles	260	374	44%	1.8%

Clearly, infrastructure expansion is not keeping pace with demographic and travel trends and is not likely to keep pace in the future. Therefore, if conditions are to improve, or at least not deteriorate as quickly, a new approach to transportation decision making and investment is needed.

Caltrans recognizes this dilemma and has adopted a mission statement that embraces the concept of system management. This mission and its goals are supported by the system management approach illustrated in the System Management pyramid shown in Exhibit 1-2.

Exhibit 1-2: System Management Pyramid



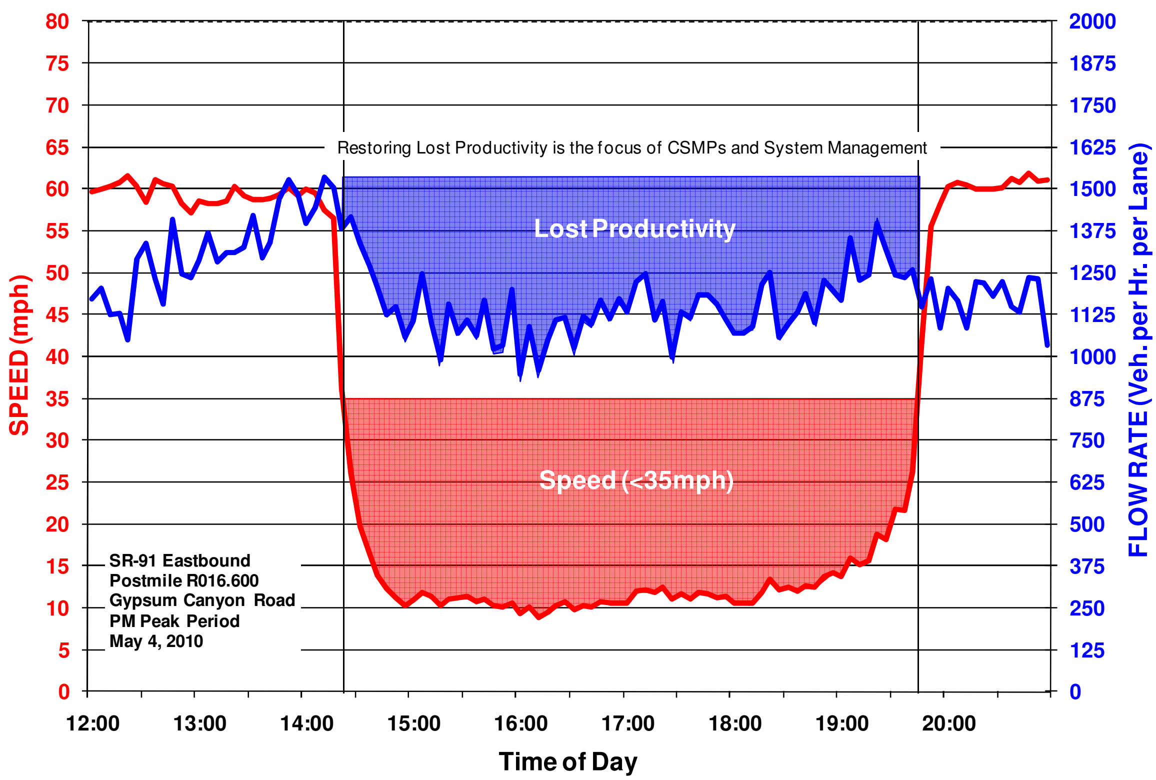
System Management is being touted at the federal, state, regional, and local levels. It addresses both transportation demand and supply to get the best system performance possible. Ideally, Caltrans would develop a regional system management plan that addresses all components of the pyramid for an entire region comprehensively. However, because the system management approach is relatively new, it is prudent to apply it at the corridor level first.

The foundation of system management is monitoring and evaluation (shown as the base of the pyramid). This monitoring is done by comprehensive performance assessment and evaluation. Understanding how a corridor performs and why it performs the way it does is critical to designing appropriate strategies. Section 2 is dedicated to performance assessment. It would be desirable for Caltrans to update this performance assessment every two or three years to ensure that future corridor issues can be identified and addressed before breakdown occurs on the corridor.

A critical goal of system management is to get the most out of the existing system, or maximize system productivity. One would think that a given freeway is most productive during peak commute times. Yet, this is not true for heavy commute corridors. In fact, for Orange County's urban freeways experiencing congestion, the opposite is true. When demand is the highest, the flow breaks down and productivity declines.

Exhibit 1-3 illustrates how congestion leads to lost productivity. The exhibit was created using observed SR-91 data from sensors for a typical spring 2010 afternoon peak period (Tuesday, May 4, 2010). It shows speeds (in red) and flow rates (in blue) on eastbound SR-91 at Gypsum Canyon Road, one of the most congested locations on the corridor.

Exhibit 1-3: Lost Productivity Illustrated on SR-91 Eastbound



Flow rates (measured as vehicle-per-hour-per-lane or vphpl) at Gypsum Canyon Road averaged around 1,500 vphpl between 1:30 PM and 2:30 PM, which is slightly less than the maximum flow rate for a typical peak period. However, flow rates higher than approximately 2,000 vphpl cannot be sustained for a significant time.

Once volumes exceed this maximum rate, traffic breaks down and speeds plummet to below 35 or 45 miles per hour (mph). Rather than being able to accommodate the same number of vehicles, flow rates also drop and vehicles back up, creating what is known as congestion. At the location shown in Exhibit 1-3, throughput drops by an average of nearly 25 percent during the peak period. Since this is a four-lane road, it is as if one full lane were taken away during rush hour. Stated differently, just when the corridor needed the most capacity, it performed in the least productive manner and effectively lost lanes. This is a major cost of congestion that is rarely discussed or understood.

This is lost productivity. Where there is sufficient automatic detection, this loss in throughput can be quantified and presented as “Equivalent Lost-Lane-Miles”. Discussed in more detail later in this report, the productivity losses on eastbound SR-91 exceeded 10.0 lane-miles during the PM peak period in 2009. This means that several hundred million dollars of previous investments on SR-91 were idle when demand was at its highest. It is obvious that Caltrans needs to leverage these past investments to the extent possible. This can be done in large part by operational strategies.

Although still an important strategy, infrastructure expansion (at the top of the pyramid in Exhibit 1-2) cannot be the only strategy for addressing the mobility needs in Orange County. System management must be an important consideration as Caltrans and its partners evaluate the need for facility expansion investments. The system management philosophy begins by defining how the system is performing, understanding why it is performing that way, and then evaluating different strategies, including operations centric strategies, to address deficiencies. Various tools can be used to estimate potential benefits to determine if these benefits are worthy of the costs to implement the strategy.

Stakeholder Involvement

The SR-91 CSMP involved corridor stakeholders including representatives from cities bordering SR-91, the Orange County Transportation Authority (OCTA), and the Southern California Association of Governments (SCAG). Caltrans briefed these stakeholders at critical milestones. Feedback from the stakeholders helped solidify the findings of the performance assessment, bottleneck identification, and causality analysis, given their intimate knowledge of local conditions. Moreover, various stakeholders have provided support and insight, and shared valuable field and project data without which this study would not have been possible.

The stakeholders included representatives from the following organizations:

- OCTA
- SCAG
- City of Anaheim
- City of Buena Park
- City of Fullerton
- City of La Palma
- City of Placentia
- City of Yorba Linda.

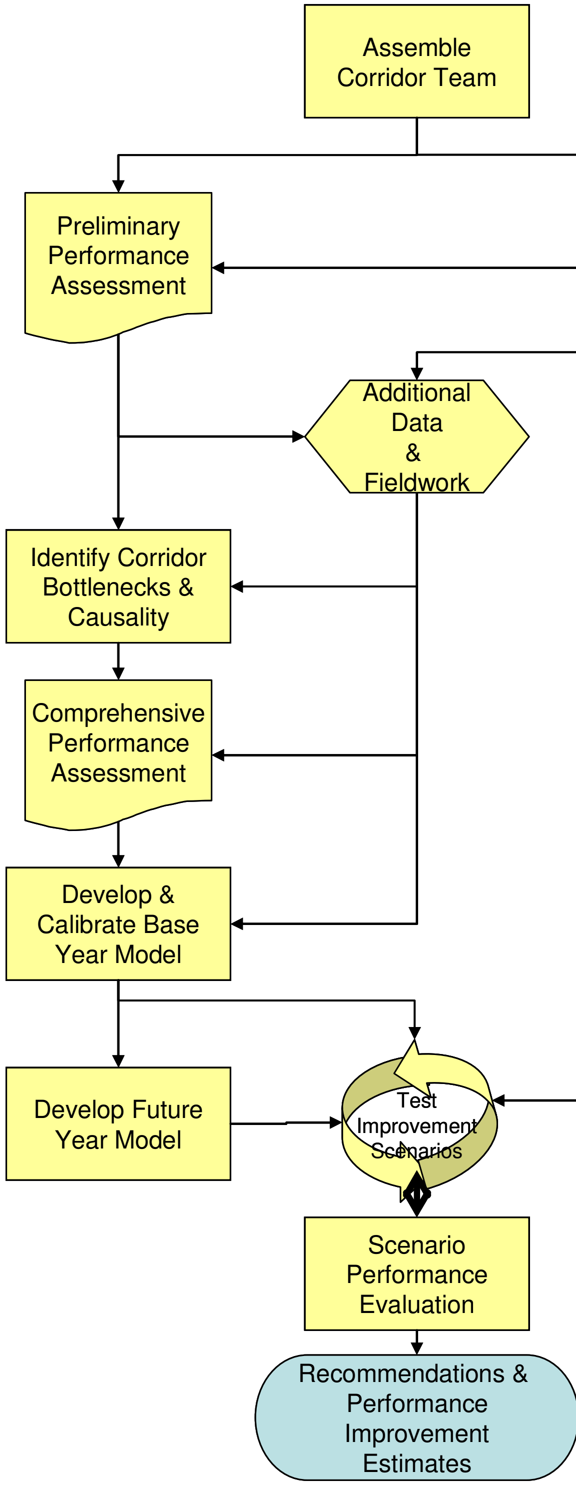
Caltrans would like to thank all of its partners for contributing to this CSMP development process. In addition, the CSMP development provided a venue for tighter coordination between Caltrans planning and operations professionals, which is critical to the success of the system management approach.

Study Approach

The SR-91 CSMP study approach follows system management principles by placing an emphasis on performance monitoring and evaluation (the base of the pyramid in Exhibit 1-2), and on using lower cost operational improvements to maintain system productivity.

Exhibit 1-4 is a flow chart that illustrates this approach. Each step of the approach is described following the chart.

Exhibit 1-4: Study Approach



Assemble Corridor Team

Caltrans District 12 assembled a CSMP Project Development Team, which consists of members from various divisions within Caltrans (Planning, Traffic Operations, Maintenance, and Modeling) as well as representatives from OCTA and SCAG. The CSMP team reviewed project progress and provided continuous feedback throughout the study. Additionally, Caltrans identified along the SR-91 CSMP Corridor cities and other major stakeholders whose input would be needed at critical project junctures (e.g., performance assessments, scenario reviews, and final report). The stakeholders group met several times during the study period to receive local feedback on project status updates and agree on project milestones.

Preliminary Performance Assessment

The Preliminary Performance Assessment Report delivered in June 2008 presented a brief description of the corridor and existing projects along or adjacent to SR-91. It included a corridor-wide performance assessment for four key performance areas: mobility, reliability, safety, and productivity. The assessment also included a preliminary bottleneck location assessment based on readily available existing data and limited field observations.

The results of the Preliminary Performance Assessment were updated and included in the Comprehensive Performance Assessment described below. The results of these two assessments are presented in the Corridor Description and Corridor Performance sections – Sections 2 and 3 of this final report.

For future SR-91 CSMP reporting, the Preliminary Performance Assessment should not be necessary, since its main purpose is to identify data gaps – particularly detection gaps. It is anticipated that these gaps will be addressed with improved automatic detection. Future updates to CSMPs can be made directly to this CSMP report.

Collect Data and Programmed/Planned Project Information

In conjunction with the Preliminary Performance Assessment, the study team reviewed existing studies, plans and other programming documents to assess additional data collection needs for modeling and scenario development. One of the key elements of this study was to identify projects that would be implemented in the short- and long-term timeframes to be included in the TransModeler micro-simulation model developed by the study team.

Details of the projects included in the scenario analysis are discussed in Section 6: Scenario Development and Evaluation.

Additional Data Collection and Fieldwork

The study team identified locations where additional manual traffic counts would be needed to calibrate the 2007 Base Year micro-simulation model, and coordinated the collection of the traffic count data.

The study team conducted several field visits in the summer and fall of 2008 (August 27, September 10, and October 9) to observe peak period traffic conditions and to videotape potential bottleneck locations. This fieldwork will be discussed in Sections 4 and 5: Bottleneck Identification and Causality.

Identify Corridor Bottlenecks and Causality

Building on the Preliminary Performance Assessment and the fieldwork, the study team identified major bottlenecks along the corridor for the AM and PM peak periods. These bottlenecks will be discussed in detail in Section 4 of this report.

Comprehensive Performance Assessment

Once the bottlenecks were identified and the causality of the bottlenecks determined, the study team prepared the Comprehensive Performance Assessment, which was delivered to Caltrans in December 2009. This report built on the Preliminary Performance Assessment and added a discussion of bottleneck causality findings, including performance results for each bottleneck area. It also included corridor-wide performance results updated to reflect 2009 conditions.

Develop and Calibrate Base Year Model

Using the bottleneck areas as the basis for calibration, the study team developed a calibrated 2007 Base Year model for the corridor. This model was calibrated following California and Federal Highway Administration (FHWA) guidelines for model calibration. In addition, the model was evaluated to ensure that each bottleneck area was represented and that travel times and speeds were consistent with observed data. This process required several review iterations by the study team and Caltrans.

Discussion of the calibrated 2007 Base Year model can be found in Section 6: Scenario Development and Evaluation.

Develop Future Year Model

Following the approval of the 2007 Base Year model, the study report developed a 2020 Horizon Year model to be used to test the impacts of short-term programmed projects as well as future operational improvements including the impacts of improved incident management on the corridor.

Discussion of the 2020 Horizon Year model can be found in Section 6: Scenario Development and Evaluation.

Test Improvement Scenarios

The study team developed scenarios that were evaluated using the micro-simulation model. Short-term scenarios included programmed projects that would likely be completed within the next five years along with other operational improvements, such as improved ramp metering. In addition to the short-term evaluations, short-term projects were tested using the 2020 Horizon Year model to assess their long-term impacts.

The study team also developed and tested other scenarios using only the 2020 model. These scenarios included programmed and planned projects that would not be completed within five years of 2007 and would likely experience benefits only in the long term.

Scenario testing results are presented in Section 6: Scenario Development and Evaluation.

Scenario Performance Evaluations

Once scenarios were developed and fully tested, simulation results for each scenario were subjected to a benefit-cost evaluation to determine how much “bang for the buck” each scenario would deliver. The study team performed a detailed benefit-cost assessment using the California Benefit-Cost model (Cal-B/C).

The results of the Benefit-Cost analysis are presented in Section 6: Scenario Development and Evaluation.

Recommendations and Performance Improvement Estimates

The study team developed final recommendations for future operational improvements that could be reasonably expected to maintain the mobility gains achieved by existing programmed and planned projects. Section 7 summarizes these findings.

This report is organized into seven sections (Section 1 is this introduction):

2. *Corridor Description* describes the corridor, including the roadway facility, recent improvements, major interchanges and relative demands at these interchanges, relevant transit services serving freeway travelers, major intermodal facilities around the corridor, special event facilities/trip generators, and an SR-91 origin-destination demand profile from the SCAG regional model.

3. *Corridor Performance and Trends* presents multiple years (2005 to 2009) of performance data for the freeway portion of the SR-91 CSMP Corridor. Statistics are included for the mobility, reliability, safety, and productivity performance measures.

4. *Bottleneck Identification and Performance* identifies bottlenecks, or choke points, on the SR-91 using various sources. This section has performance results for delay, productivity, and safety by major bottleneck area, which allows for the relative prioritization of bottlenecks in terms of their contribution to corridor performance degradation.

5. *Bottleneck Causality Analysis* diagnoses the bottlenecks and identifies the causes of each location through additional data analysis and field observations. This section provides input in selecting projects to address the critical bottlenecks. It also provides a baseline against which the micro-simulation models were validated.

6. *Scenario Development and Evaluation* discusses the scenario development approach and summarizes the expected future performance based on the TransModeler micro-simulation model.

7. *Conclusions and Recommendations* describes the projects and scenarios that were evaluated and recommends a phased implementation of the most promising set of strategies.

The appendices provide project lists for the micro-simulation scenarios and detailed benefit-cost results.

2. CORRIDOR DESCRIPTION

SR-91 runs through Los Angeles, Orange and Riverside Counties. This section describes the subset of SR-91 covered in the Orange County SR-91 CSMP Corridor and summarizes results from the comprehensive corridor performance assessment.

Named the Riverside Freeway, SR-91 links the "Inland Empire" communities in Riverside and San Bernardino Counties to Orange and Los Angeles Counties. In Orange County, SR-91 runs from the Los Angeles County line to the Riverside County line. The Orange County SR-91 CSMP Corridor covers a smaller area. The CSMP corridor extends approximately 19 miles as an east-west route from the I-5 Junction (Postmile R3.6) in Buena Park to the Orange/Riverside County line (Postmile R18.9).

Corridor Roadway Facility

The SR-91 is a six- to eight-lane freeway with a concrete barrier median for most of the CSMP Corridor, with auxiliary lanes along some sections. There is one High Occupancy Vehicle (HOV) lane in each direction of the western portion of the corridor between I-5 and SR-55. The HOV lanes operate as a two-plus vehicle-occupancy facility, 24 hours a day, every day.

A key feature of SR-91 is the *91 Express Lanes* – a ten-mile toll facility in the inner two lanes between SR-55 and the Riverside County line. Opened in 1995, the four-lane facility is the first privately financed toll road in the United States in more than 50 years, the world's first fully-automated toll facility, and the first application of value pricing in the United States. Tolls are paid using a transponder from pre-paid accounts. Reduced tolls are available to vehicles with three or more occupants, as a carpooling incentive.

As shown in Exhibit 2-1, the SR-91 CSMP Corridor passes through Anaheim, Fullerton, Placentia and Yorba Linda, and includes four major freeway-to-freeway interchanges:

- I-5 is a north-south interstate highway serving California from Mexico to Oregon. Regionally, it connects Orange County to San Diego and Los Angeles Counties.
- SR-57 connects SR-22 in the City of Orange to Diamond Bar and other Los Angeles County communities, as well as SR-60, I-10 and I-210 in the north.
- SR-55 provides access between SR-91 and Newport Beach, and also serves the Cities of Irvine, Tustin, Costa Mesa, Santa Ana, Orange and Anaheim.
- SR-241 Eastern Transportation Corridor Toll Road provides access to southern Orange County and serves the communities of Irvine, Lake Forrest, Rancho Santa Margarita and Mission Viejo.

According to Caltrans traffic volumes reported for 2008, the Orange County SR-91 CSMP Corridor carries between 217,000 and 318,000 annual average daily traffic

(AADT). The highest volumes on the corridor occur between Imperial Highway (SR-90) and SR-55. The lowest volumes occur between SR-57 and SR-55.

SR-91 is also a Surface Transportation Assistance Act (STAA) route that allows large trucks to operate on the mainline lanes. According to 2008 truck volumes from Caltrans, trucks comprise 4.5 to 8.7 percent of total daily traffic along the corridor. The heaviest truck volumes occur around SR-57 and State College Boulevard. Truck weigh stations are located in both the eastbound and westbound directions near Weir Canyon and are the only weigh stations in Orange County. Truck volumes are shown in Exhibit 2-2.

Exhibit 2-1: SR-91 CSMP Study Area Map

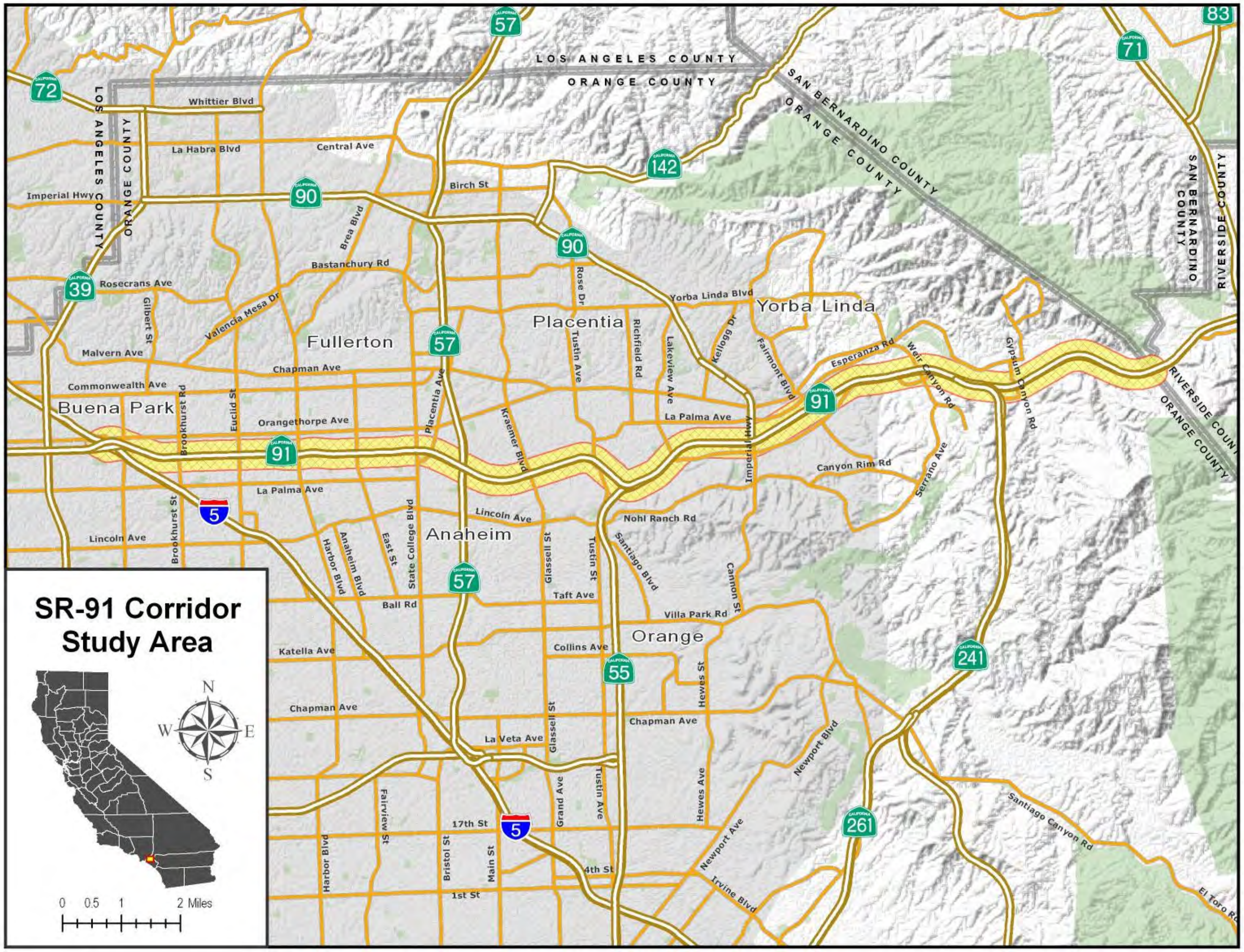
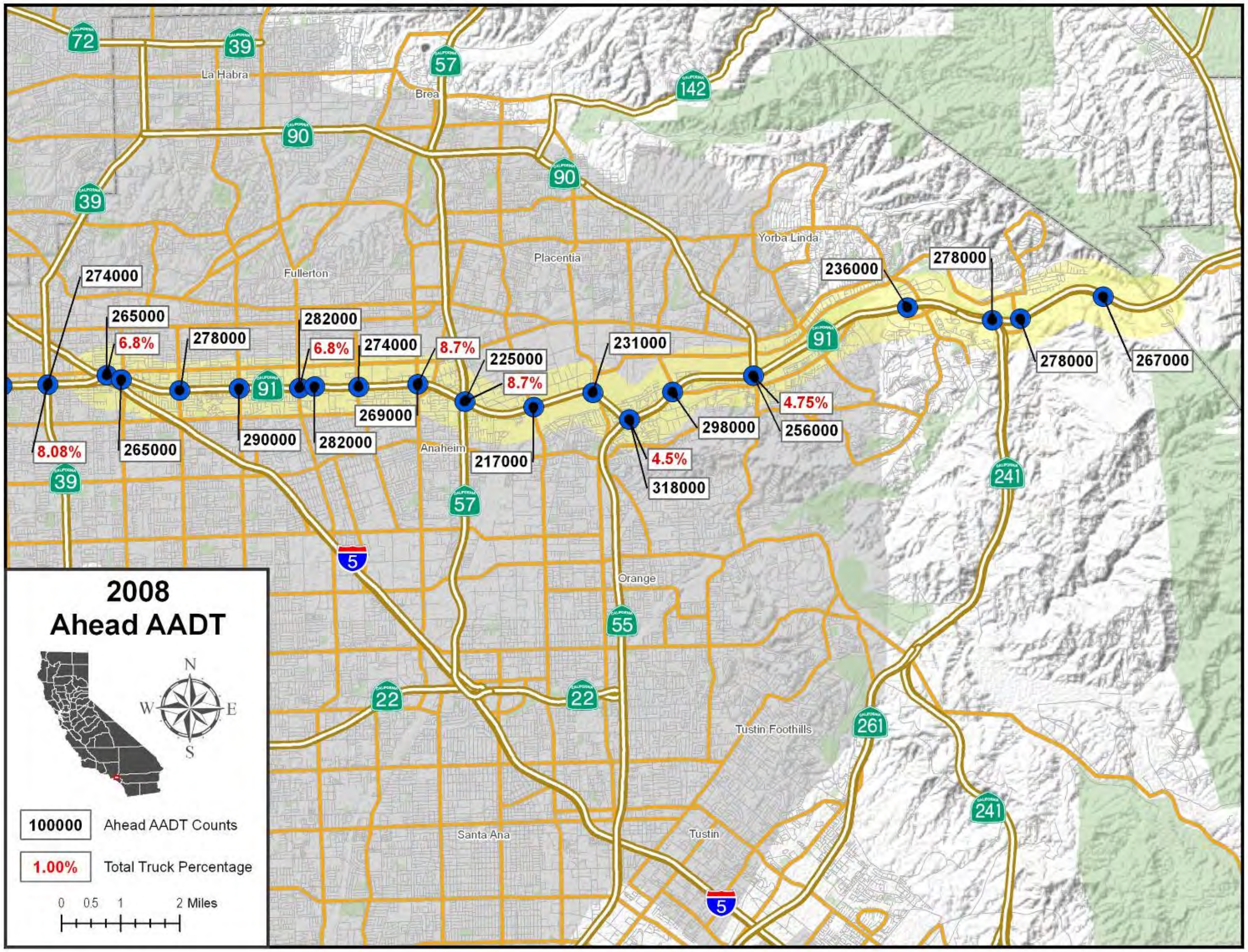


Exhibit 2-2: Major Interchanges, 2008 AADT and Truck Percentages



Source: Caltrans Traffic and Vehicle Data Systems Unit http://www.dot.ca.gov/hq/traffops/saferesr/trafdata/

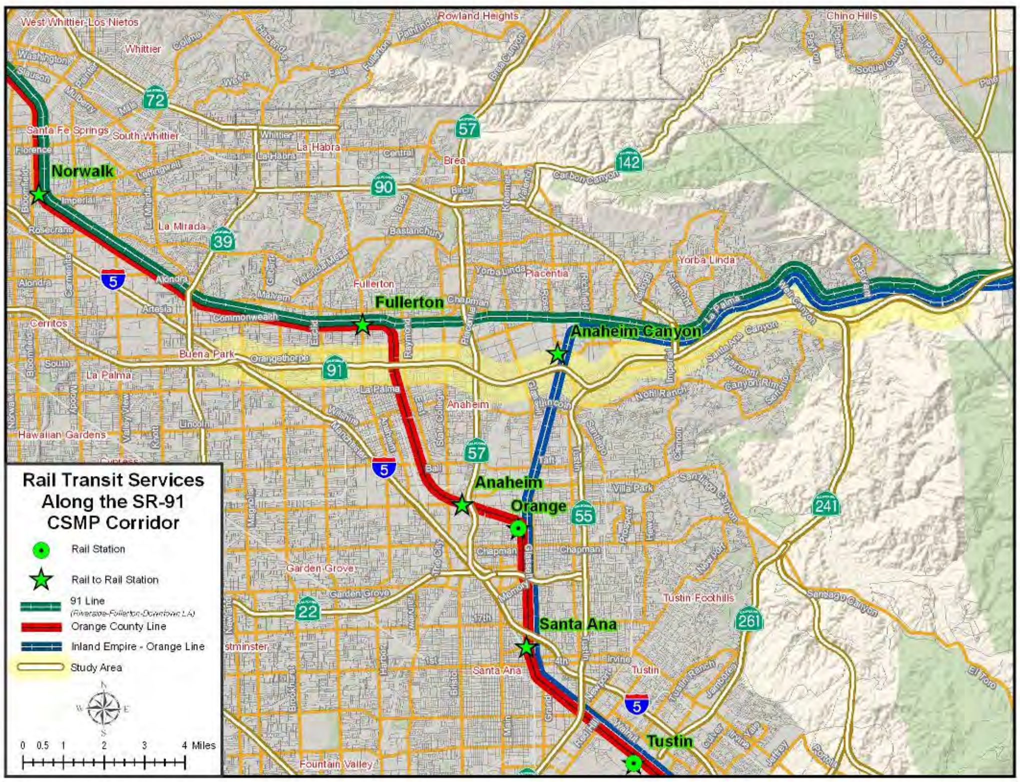
Corridor Transit Services

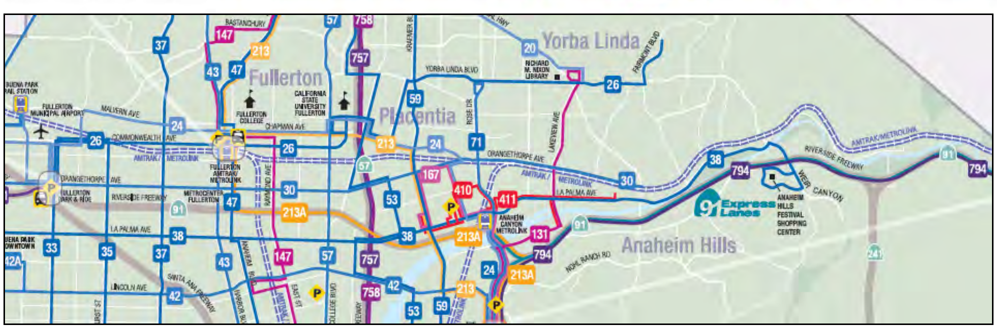
Three major public transportation operators provide service on or near the SR-91:

- Orange County Transportation Authority (OCTA)
- Riverside Transit Agency (RTA)
- Southern California Regional Rail Authority (SCCRA) - Metrolink

Exhibits 2-3 shows the rail and transit services offered along the SR-91 CSMP Corridor.

Exhibit 2-3: SR-91 Corridor Rail and Transit Services





Source: Orange County Transportation Authority (OCTA)

Orange County Transportation Authority (OCTA)

As the primary bus transit provider in Orange County, OCTA provides fixed-route bus and paratransit services throughout Orange County. In addition to several local and express routes that run in the vicinity of the SR-91 CSMP Corridor, as shown in Exhibit 2-3, the following routes operate on or directly adjacent to SR-91:

- *Route 794* operates on SR-91 and SR-71 and connects South Coast Plaza in Costa Mesa and Galleria at Tyler Mall in the City of Riverside. The route also serves the City of Corona in Riverside County.
- *Route 721* is an express route that connects the City of Fullerton to the City of Los Angeles from the Fullerton Park and Ride lot at the western end of the SR-91 CSMP Corridor near the I-5 interchange.
- *Route 213/213A* links the City of Brea to the City of Irvine. Route 213A operates on SR-91 between Lemon Street and SR-55 for one peak hour run during the day. This run travels between the Fullerton Transit Center and the University Research Park at the University of California, Irvine.
- *Route 30* is a local route that operates parallel to SR-91 between the Cities of Cerritos and Anaheim, along Orangethorpe Avenue.
- *Route 38* is a local route that operates parallel to SR-91 between the Cities of Lakewood and Anaheim, along Del Amo Boulevard and La Palma Avenue.

Riverside Transit Agency (RTA)

RTA provides 38 fixed routes and paratransit services in western Riverside County. It provides transit services between communities in Riverside County and Orange County along SR-91:

- *Route 794* operated by OCTA provides service in Riverside County on SR-91 connecting Galleria at Tyler Mall in the City of Riverside and the City of Corona to Orange County. This route terminates at the South Coast Plaza/Costa Mesa area in Orange County.
- *Route 149* operated by RTA travels along SR-91 between the downtown terminal in Riverside to the Village at Orange in Anaheim. It provides both weekday and weekend service.

Southern California Regional Rail Authority (SCRRA) – Metrolink

SCCRA is a joint powers authority that operates the Metrolink regional rail service throughout Southern California. Metrolink commuter rail service stops at 11 stations in Orange County and provides 44 weekday round trips on three lines:

- Inland Empire-Orange County Line provides service from San Bernardino to Oceanside.
- 91 Line provides service Riverside to Los Angeles Union Station, via Fullerton and Buena Park.
- Orange County Line provides service from Los Angeles Union Station to Oceanside.

Inland Empire-Orange County Line connects the City of San Bernardino in San Bernardino County to the City of Oceanside in San Diego County. Along the SR-91 CSMP Corridor, it provides service to the Anaheim Canyon Metrolink Station located at 1039 North Pacificenter Drive in Anaheim, near the intersection of Tustin Avenue and La Palma Avenue (one-quarter mile north of SR-91). There are connecting services to local OCTA bus services including Route 38, which provides local service parallel to SR-91.

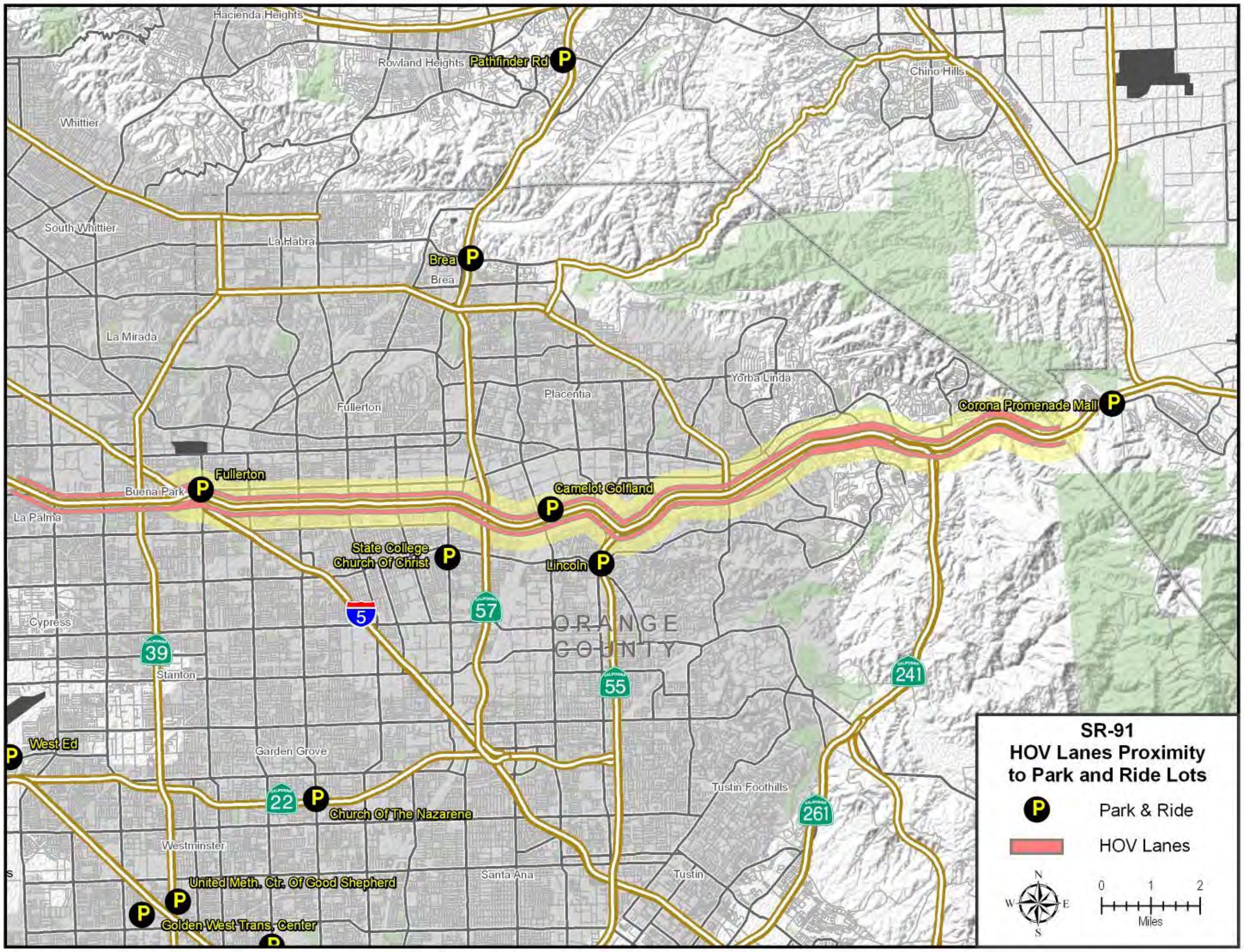
According to the latest ridership statistics provided by SCRRA, this line carries nearly 4,800 weekday passengers with most AM peak period boardings occurring in Riverside County with destinations in Orange County. Ridership between 2006 and 2007 has grown by two percent, according to SCRRA. Over 90 percent of all riders are commuters.

91 Line provides service parallel to SR-91, connecting the City of Riverside to Union Station in downtown Los Angeles. Along the SR-91 CSMP Corridor, this line is accessed at the joint Amtrak/Metrolink station located at the Fullerton Transportation Center on 120 East Santa Fe Avenue, near North Harbor Boulevard just one-mile north of SR-91.

According to the latest ridership statistics provided by SCRRA, this line carries just over 2,300 weekday passengers with most AM peak period boardings occurring in Riverside County. However, a significant percentage of boardings occur in Fullerton near the SR-91 CSMP Corridor. This ridership has declined by 14 percent between 2006 and 2007, according to SCRRA. Over 85 percent of all riders are commuters.

There are several Park and Ride lots that provide commuters access to transit facilities, shown in Exhibit 2-4. The three closest to the corridor are at Fullerton, Camelot, and the Corona Promenade Mall.

Exhibit 2-4: SR-91 Park and Ride Facilities



Intermodal Facilities

There are two airports near SR-91. The first is the Fullerton Municipal Airport, a small general aviation airport adjacent to the I-5 and SR-91 corridors. In 2004-2005, Fullerton Airport had an average aircraft operation of 222 per day.

John Wayne Airport (international airport code "SNA"), is the County's major commercial airport approximately 12 miles south of the SR-91 CSMP Corridor, and is linked directly to SR-91 by SR-55 as shown in Exhibit 2-5. John Wayne Airport hosts air carrier, general aviation, air taxi, military, and air cargo services with 14 commercial and commuter air carriers serving the airport.

Annual enplanement data is shown in Exhibit 2-6. As of 2007, John Wayne Airport recorded the 42nd most enplanements in the United States and is ranked seventh in California, just ahead of Ontario International Airport (ONT).[1] Over the six-year period between 2002 and 2007, the number of passenger boardings grew from just under four million annually to more than 4.9 million in 2007, although this growth has flattened over the past few years. Of course, recent economic challenges indicate that air travel around the country was likely to decline in 2008 and beyond.

In one month alone (September 2007), SNA recorded 782,896 total passengers, including 388,735 enplanements and 394,161 deplanements. In the same month, the airport served 1,967 air cargo tons, of which 1,838 tons were carried by all-cargo carriers. Both FedEx and UPS serve SNA.[2]

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[1] "Passenger Boarding and All-Cargo Data." Federal Aviation Administration. May 2008. Air Carrier Activity Information System (ACAIS). http://www.faa.gov/airports_airtraffic/airports/planning_capacity/passenger_allcargo_stats/passenger/.

[2] Wedge, Jenny. "John Wayne Airport Posts September Statistics (Revised)." *John Wayne Airport News and Facts*. October 11, 2007. John Wayne Airport. 15 May 2008 http://www.ocair.com/newsandfacts/newsreleases/2007/NR-2007-10-11.html.

Exhibit 2-5: John Wayne Airport Map

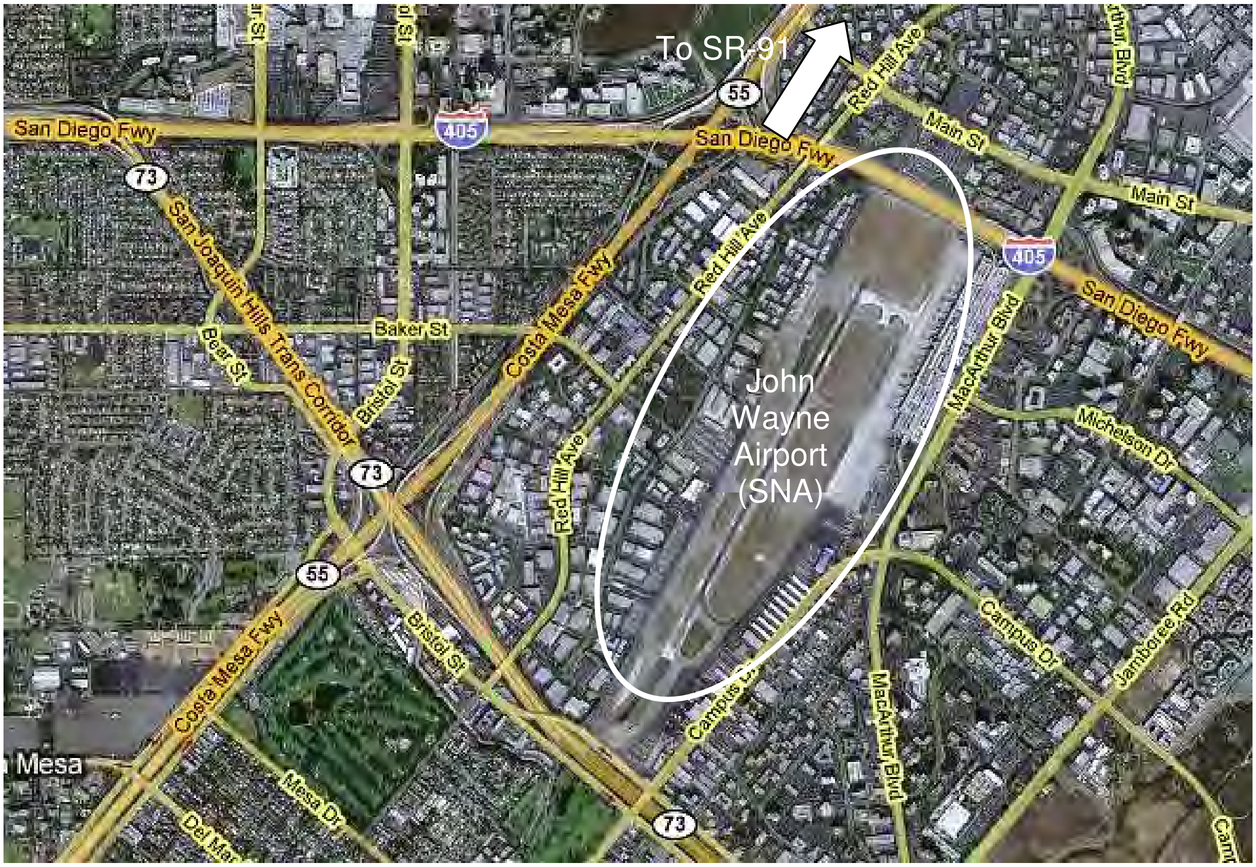


Exhibit 2-6: John Wayne Airport Passenger Boarding Statistics

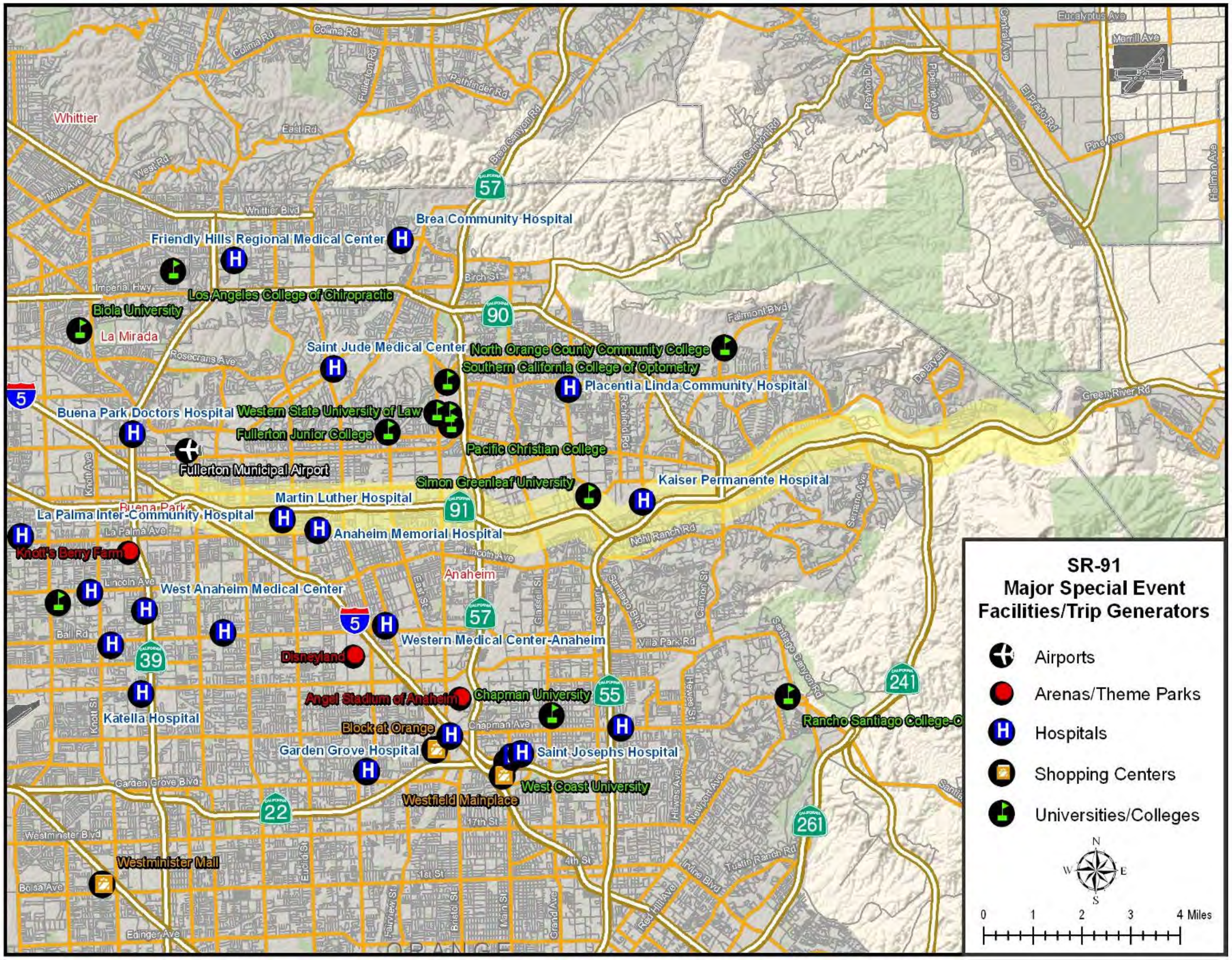
	2002	2003	2004	2005	2006	2007
Passenger Boardings	3,968,978	4,266,083	4,621,107	4,791,786	4,777,896	4,948,846
Difference		297,105	355,024	170,679	(13,890)	170,950
Percent Difference		7.5%	8.3%	3.7%	-0.3%	3.6%

Source: Federal Aviation Administration (FAA) Air Carrier Activity Information System (ACAIS).

Special Event Facilities/Trip Generators

Major special event facilities may generate significant trips. There are a number of these facilities within several miles of the SR-91 CSMP Corridor. The most significant ones are shown in Exhibit 2-7.

Exhibit 2-7: Major Special Event Facilities/Trip Generators Near SR-91



Caltrans

Three miles south of SR-91, on Harbor Boulevard, is the Disneyland Resort and Theme Park, the second busiest amusement park in the world, with an average daily attendance of nearly 40,000 patrons. The Disneyland Resort directly employs over 20,000 people, making it Orange County's largest employer and one of the largest single-site private employers in the state. Knott's Berry Farm is another amusement park situated close to the SR-91. It is located two miles south of the SR-91 on Beach Boulevard in the City of Buena Park and has an average daily attendance of approximately 9,500 patrons.

Three miles south of SR-91 on SR-57 at East Katella Avenue is the Angel Stadium of Anaheim, home of the Los Angeles Angels professional baseball team. The Honda Center arena, home to the professional hockey team the Anaheim Ducks, is co-located there. Other events such as concerts, rodeos, basketball tournaments, and other major performances take place at the Honda Center. Angel Stadium seats over 45,000 fans, and the Honda Center can accommodate between 17,000 and 19,000 people, depending on the event held (sporting or ice skating events accommodate between 17,000 and 17,700 people, while a concert can hold between 18,000 to 19,000). The SR-91 CSMP Corridor is also the main transportation corridor for beach access from the Inland Empire.

There are two major universities/colleges near the SR-91 CSMP Corridor, and other post-secondary and trade schools nearby. California State University Fullerton is about 1.75 miles north of SR-91 on South State College Boulevard adjacent to SR-57 in the City of Fullerton. It is a four-year public university offering Bachelor and Masters Degree programs with an estimated enrollment of just under 36,000 students.

Fullerton College is a two-year college on East Chapman Avenue at North Lemon Street, less than one-half mile north of SR-91. It has nearly 20,000 students. In addition to these two educational facilities, there are a number of secondary, middle and elementary schools within a few miles of the corridor.

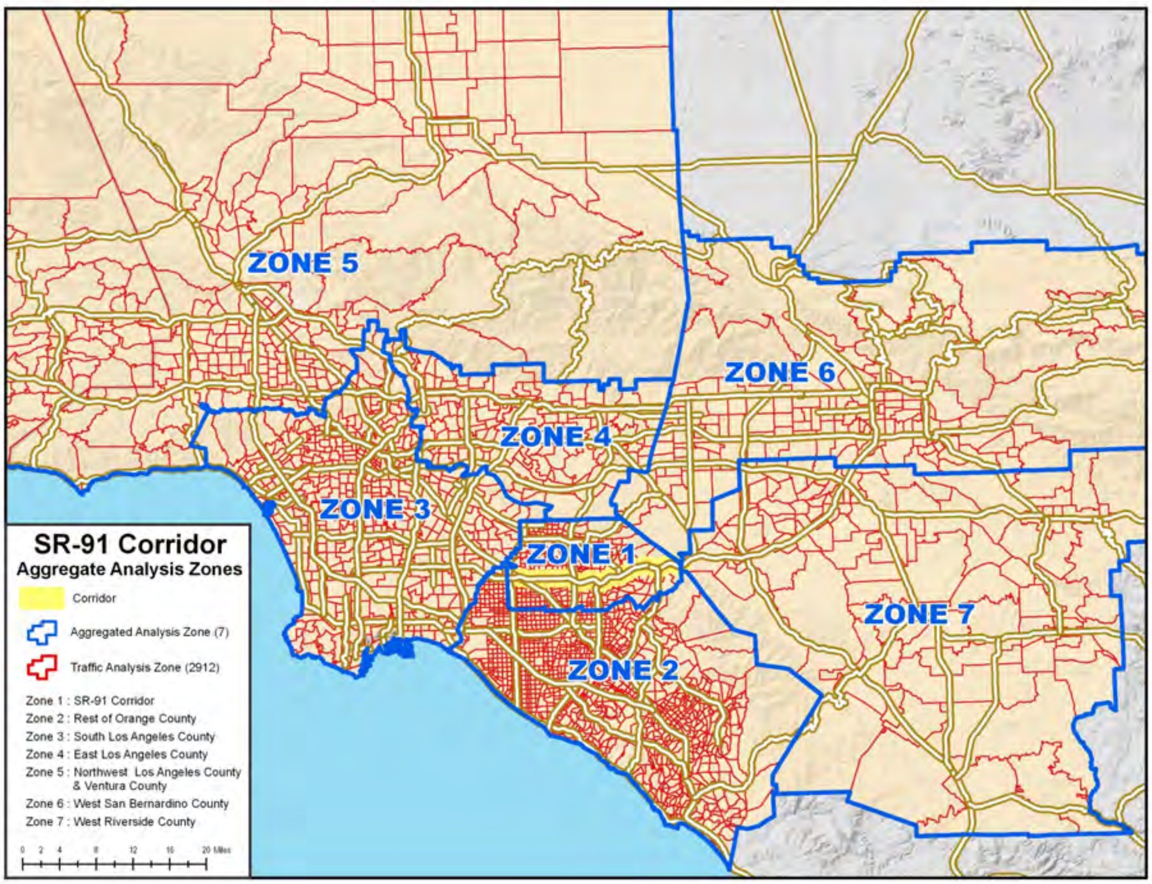
There are also major medical facilities on the corridor. Kaiser Permanente maintains a hospital on West La Palma adjacent to the Anaheim Memorial Medical Center on West La Palma Avenue near North West Street (between North Euclid and South Harbor Streets) about one mile from the nearest SR-91 interchange. Kaiser Permanente is moving from Lakeview to Tustin Avenue.

There are several major shopping centers along freeways connecting with the SR-91 CSMP Corridor, but no major shopping malls are located directly adjacent to the corridor.

Demand Profiles

An analysis was conducted to analyze the origins and destinations using the freeway facility of the SR-91 CSMP Corridor. The analysis relies on OCTA's travel demand model. By selecting the corridor and conducting a "select link analysis", all origins and destinations using the corridor are identified. The origins and destinations are first identified by Traffic Analysis Zone (TAZ). The TAZs are then aggregated into seven aggregate analysis zones as shown in Exhibit 2-8. Note that these aggregated analysis zones were developed by the study team specifically for this analysis, and may not represent official OCTA aggregated analysis zones.

Exhibit 2-8: SR-91 CSMP Demand Profile Aggregated Analysis Zones



Based on this aggregation, demand on the SR-91 CSMP Corridor is summarized by aggregated origin destination zone as shown in Exhibits 2-9 and 2-10 for the AM and PM peak periods respectively. This analysis shows that a significant percentage of trips using the SR-91 represent inter-county trips.

During the AM peak period, only one-third of all trips using the SR-91 CSMP Corridor start and end in Orange County. The remaining trips either originate in Orange County and terminate in another county (27 percent), or originate outside of Orange County and terminate in Orange County (32 percent), or originate and terminate outside of Orange County (eight percent).

During the PM peak period (which experiences around 20 percent more demand than the AM period) the picture is similar. Only 32 percent of trips originate and terminate in Orange County. The remaining trips either originate in Orange County and terminate in another county (31 percent), or originate outside of Orange County and terminate in Orange County (28 percent), or originate and terminate outside of Orange County (nine percent).

Clearly, SR-91 serves a regional, inter-county purpose with more than 65 percent of trips starting or ending outside Orange County.

Exhibit 2-9: AM Peak Origin Destination by Aggregated Analysis Zone

Destination Aggregated Analysis Zone	Origin Aggregated Analysis Zone							
AM Trips	SR91 Corridor	Rest of Orange County	South Los Angeles	East Los Angeles	NW Los Angeles & Ventura	West San Bernardino	West Riverside	Outside Zones
SR91 Corridor	8,743	20,846	9,870	1,832	1,231	2,419	1,356	286
Rest of Orange County	33,459	10,379	35,067	3,375	3,287	5,531	7,382	108
South Los Angeles	9,700	24,132	5,955	545	1,210	790	1,279	431
East Los Angeles	2,375	4,026	820	1	139	0	182	91
NW Los Angeles & Ventura	1,259	2,785	1,317	185	610	276	265	54
West San Bernardino	2,543	6,207	965	1	183	1	254	111
West Riverside	1,550	4,805	1,338	140	278	209	295	88
Outside Zones	154	48	157	26	35	32	32	1

Legend	
(dark green)	Trips Originating and Ending in Orange County
(turquoise)	Trips Originating in Orange County and Destined to Other Counties
(yellow)	Trips Originating Outside of Orange County and Destined to Orange County
(gray)	Trips Originating and Ending Outside of Orange County

Exhibit 2-10: PM Peak Origin Destination by Aggregated Analysis Zone

Destination Aggregated Analysis Zone	Origin Aggregated Analysis Zone							
PM Trips	SR91 Corridor	Rest of Orange County	South Los Angeles	East Los Angeles	NW Los Angeles & Ventura	West San Bernardino	West Riverside	Outside Zones
SR91 Corridor	11,565	38,093	12,707	2,937	2,187	3,273	1,877	204
Rest of Orange County	31,059	14,363	34,264	5,266	6,424	8,300	6,994	82
South Los Angeles	13,515	42,406	8,233	1,078	2,442	1,246	1,783	270
East Los Angeles	2,683	4,491	832	0	469	2	222	46
NW Los Angeles & Ventura	2,128	5,852	2,303	477	1,563	569	516	59
West San Bernardino	3,445	7,164	1,133	1	585	3	316	59
West Riverside	1,817	9,377	1,767	263	515	328	364	69
Outside Zones	370	136	518	102	102	140	116	2

Legend	
(dark green)	Trips Originating and Ending in Orange County
(turquoise)	Trips Originating in Orange County and Destined to Other Counties
(yellow)	Trips Originating Outside of Orange County and Destined to Orange County
(gray)	Trips Originating and Ending Outside of Orange County

3. CORRIDOR PERFORMANCE AND TRENDS

This section summarizes the performance measures used to evaluate the existing conditions of the SR-91 CSMP Corridor. The measures provide a technical basis to describe traffic performance on SR-91 and were used to calibrate the micro-simulation model. Data from mainline (ML) and High Occupancy Vehicle (HOV) facilities were analyzed separately.

Before discussing the performance measures, this section describes the quality of the data used in the analysis. This was done to ensure that the automatic sensor data used for the analysis was sufficiently reliable.

Following the data quality discussion, the following five key performance areas are discussed in detail:

- *Mobility* describes how quickly people and freight move along the corridor.
- *Reliability* captures the relative predictability of travel time along the corridor.
- *Safety* provides an overview of collisions along the corridor.
- *Productivity* quantifies the degree to which traffic inefficiencies at bottlenecks or hot spots reduce flow rates along the corridor
- *Pavement Condition* describes the structural adequacy and ride quality of the pavement.

Data Sources and Detection

The existing available data analyzed for the SR-91 CSMP Corridor include the following sources:

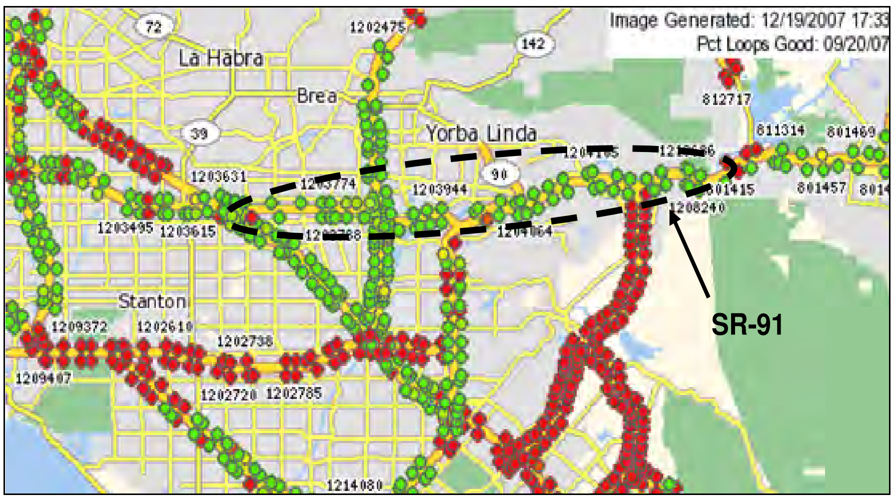
- Caltrans Statewide Highway Congestion Monitoring Program (HICOMP) annual report and data files (2004-2007)
- Caltrans Freeway detector data
- Caltrans District 12 probe vehicle runs (electronic tachometer runs)
- Caltrans Traffic Accident Surveillance and Analysis System (TASAS)
- Signal Timing Plans from the Cities of Anaheim, Fullerton and Yorba Linda
- Traffic study reports (various)
- Aerial photographs (Google Earth) and Caltrans photologs
- Internet (i.e., OCTA website, Metrolink website, SCAG website, etc).

Numerous documents describe these data sources, so they are not discussed in detail in this report. However, given the need for comprehensive and continuous monitoring and evaluation, detection coverage and quality are discussed in more detail.

Freeway Detection Status

Exhibit 3-1 depicts the freeway facility with the detectors in place as of September 20, 2007 (chosen randomly). The exhibit shows that there are many detectors on the mainline, almost all functioning well on that date (based on the green color). Furthermore, it illustrates some seemingly small gaps between detectors at some locations.

Exhibit 3-1: SR-91 Detection Status (September 20, 2007)

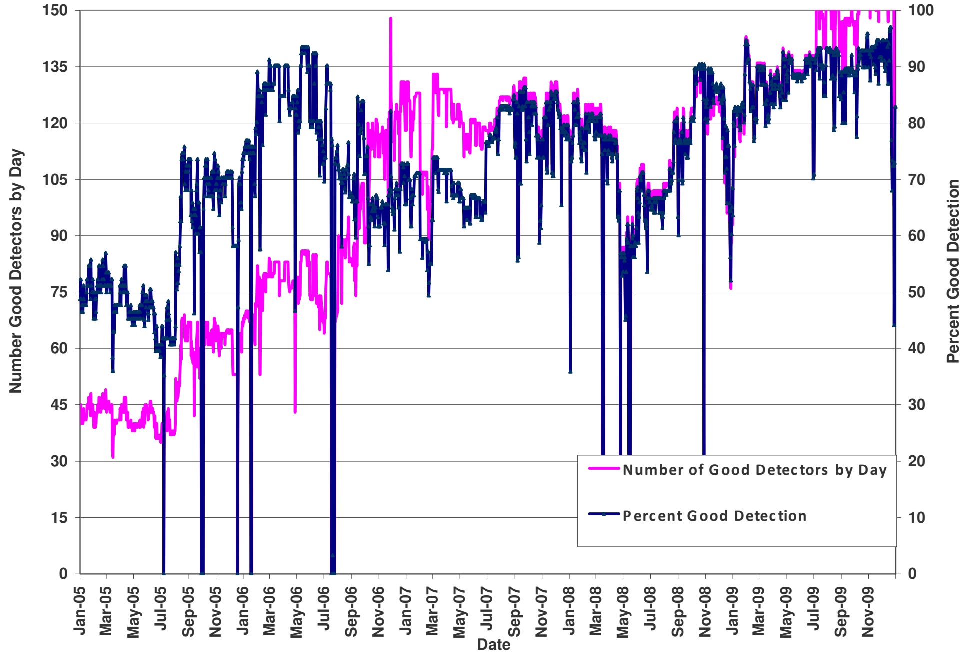


The SR-91 CSMP Corridor stretches approximately 19 miles, from I-5 to the Riverside County line. The analysis of the mainline facility is based on the entire study corridor, whereas the analysis of the HOV facility is based on the nine-mile stretch from I-5 to SR-55. The HOV lane terminates at SR-55 and is replaced by the 91 Express Lanes toll facility.

To see how well the detectors performed over the years covered in the analysis, Exhibits 3-2 and 3-3 show the percentage of good detection on the mainline facility. These include mainline detectors as well as ramp detectors.

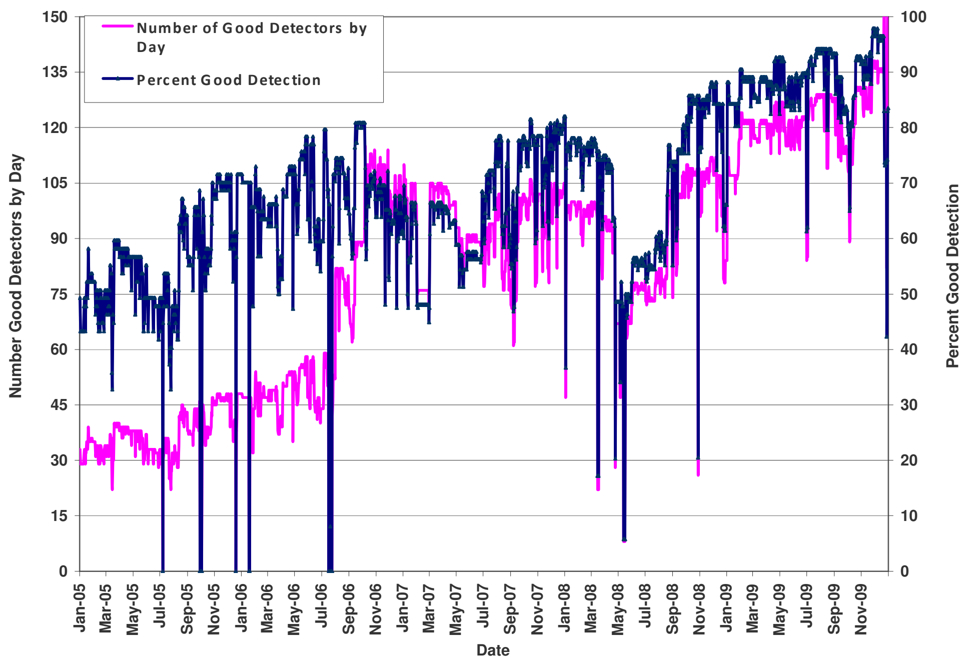
The left y-axis shows the scale used for the number of detectors, while the right y-axis shows the scale used for the percent of good detectors. In both directions of the mainline facility, detection improved overall between 2005 and 2009. In the last quarter of 2007 and 2008, the highest number of good detectors was reported at around 225 detectors in both directions, representing 90 percent of good detection. Furthermore, 2008 and 2009 have been showing steady increases in the number and percentage of good detection. In the second half of 2009, the percentage of good detectors was around 90 percent for both directions.

Exhibit 3-2: Eastbound Mainline Daily Good Detectors (2005-2009)



Source: Caltrans detector data

Exhibit 3-3: Westbound Mainline Daily Good Detectors (2005-2009)

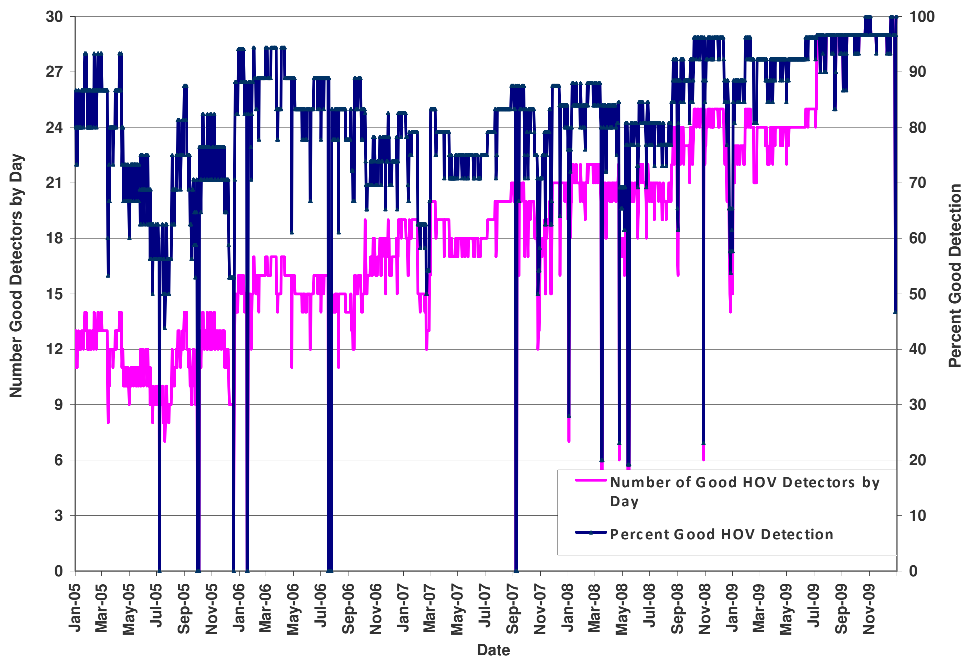


Source: Caltrans detector data

The SR-91 HOV lane extends about nine miles, from I-5 in the west to SR-55 in the east. Exhibits 3-4 and 3-5 illustrate the percentage of good detection on the HOV facility by direction. Similar to the detection pattern along the mainline, the HOV facility also experienced an improvement in detection during the four years of analysis. With the exception of several months in 2005 and 2007, the facility typically had over 70 percent of its detection in good working order, as noted by the blue-colored line. In the second half of 2009, the eastbound direction reported slightly better numbers than the westbound. While the westbound direction reported an average of just below 90 percent of good detectors, the eastbound direction was over 95 percent.

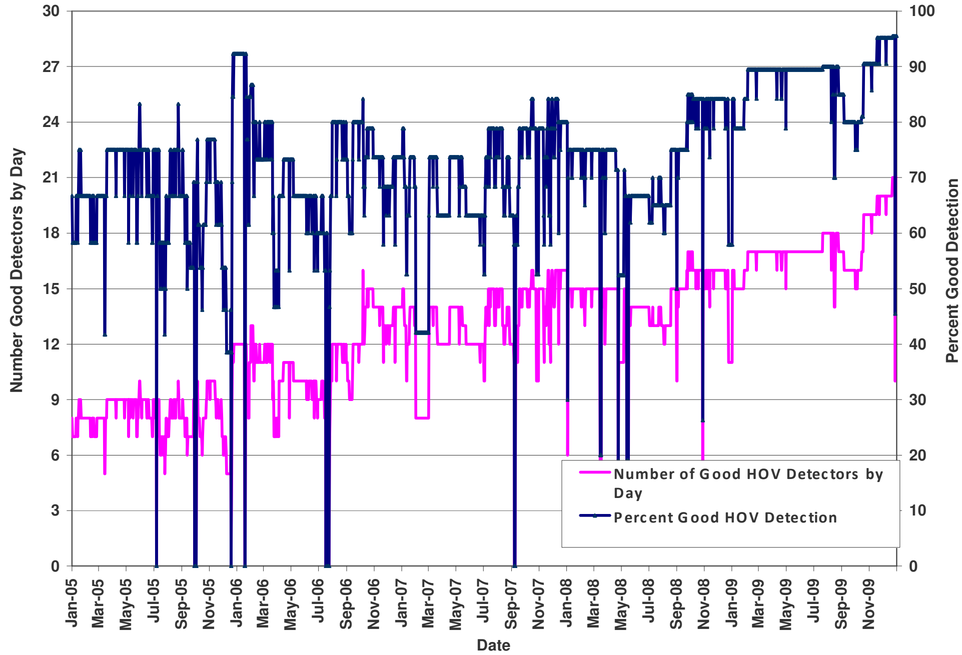
Part of this increase may be attributed to improved maintenance of existing detection. In addition, by comparing detectors in detail, the study team identified several detectors added in 2007. These are shown in Exhibit 3-6.

Exhibit 3-4: Eastbound HOV Daily Good Detectors (2005-2009)



Source: Caltrans detector data

Exhibit 3-5: Westbound HOV Daily Good Detectors (2005-2009)



Source: Caltrans detector data

Exhibit 3-6: SR-91 Detection Added (2007-2009)

VDS	Location	Type	CA PM	Abs PM	Date Online
		EASTBOUND			
1214065	E OF STANTON	HOV	R3	17.739	2/14/2007
1214122	W OF 5	HOV	R3.4	18.139	2/22/2007
1214067	GILBERT	HOV	0.76	19.133	2/14/2007
1213984	PLACENTIA	HOV	5.50	23.873	2/14/2007
1214063	E OF STANTON	Mainline	R3	17.739	2/14/2007
1214118	W OF 5	Mainline	R3.4	18.139	2/22/2007
1213986	PLACENTIA	Mainline	5.50	23.873	2/14/2007
1214119	91E to 5S	Fwy-Fwy	R3.4	18.139	2/22/2007
1214124	91E to 5S HOV	Fwy-Fwy	R3.4	18.139	2/22/2007
1213988	Placentia (EB 91 to SR 57)	Fwy-Fwy	5.5	23.873	2/14/2007
		WESTBOUND			
1214064	E OF STANTON	HOV	R3	17.739	2/14/2007
1214121	W OF 5	HOV	R3.4	18.139	2/22/2007
1214066	GILBERT	HOV	0.76	19.173	2/14/2007
1213983	PLACENTIA	HOV	5.50	23.913	2/14/2007
1203573	BEACH 1	Mainline	R2.4	17.139	5/2/2008
1203604	BEACH 2	Mainline	R2.6	17.339	5/2/2008
1214062	E OF STANTON	Mainline	R3	17.739	2/14/2007
1214117	W OF 5	Mainline	R3.4	18.139	2/22/2007
1213985	PLACENTIA	Mainline	5.50	23.913	2/14/2007
1214120	5N TO 91W	Fwy-Fwy	R3.4	18.14	5/2/2008
1214123	5N TO 91W HOV	Fwy-Fwy	R3.4	18.14	2/22/2007
1213987	Placentia (SB 57 to WB 91)	Fwy-Fwy	5.50	23.91	2/14/2007
1203573	BEACH 1	Mainline	R2.4	17.139	5/2/2008
1203604	BEACH 2	Mainline	R2.6	17.339	5/2/2008

Source: Caltrans detector data

Finally, an analysis of gaps without detection is shown in Exhibit 3-7. Note that there are several segments with lengths over 0.75 miles with detection gaps. These should be considered for deployment of additional detection when funding becomes available.

Exhibit 3-7: SR-91 Detection Gaps

Location		Abs PM		Length (Miles)
From	To	From	To	
EASTBOUND				
Brookhurst	Euclid	19.743	20.773	**1.03**
Euclid	Lemon	20.77	22.28	**1.51**
Tustin	Lakeview 1	26.73	28.45	**1.72**
W of Scales	Weir Cnyn1	31.72	32.8	**1.08**
E of Gypsum	W of Coal	35.39	36.35	**0.96**
WESTBOUND				
Coal	E of Gypsum	36.253	35.457	**0.80**
Weir Cnyn1	W of Scales	32.673	31.762	**0.91**
Lakeview1	Tustin	28.363	26.773	**1.59**
Kraemer 1	La Palma	25.723	24.833	**0.89**
Lemon	Harbor	22.323	21.543	**0.78**
Harbor	Euclid	21.543	20.523	**1.02**
Euclid	Brookhurst	20.523	19.533	**0.99**

Source: Caltrans detector data

Mobility

Mobility describes how well the corridor moves people and freight. The mobility performance measures are both readily measurable and straightforward for documenting current conditions. They can also be forecasted, making them useful for future comparisons. Two primary measures are typically used to quantify mobility: delay and travel time.

Delay

Delay is defined as the total observed travel time less the travel time under non-congested conditions, and is reported as vehicle-hours of delay. Delay can be computed for using the following formula:

$$(\text{Vehicles Affected per Hour})\times(Distance)\times(Duration)\times\left[\frac{1}{(\text{Congested Speed})}-\frac{1}{(\text{Threshold Speed})}\right]$$

In the formula above, the *Vehicles Affected per Hour* value depends on the methodology used. Some methods assume a fixed flow rate (e.g., 2,000 vehicles per hour per lane), while others use a measured or estimated flow rate. The distance is the length under which the congested speed prevails and the duration is the hours of congestion experience below the threshold speed.

The threshold speed can also vary. In general, the threshold speed represents free-flow or some other pre-defined speed. In this CSMP analysis, 60 mph is considered free-flow speed for the corridor, and will be used to calculate delay.

Different reports and studies use other threshold speeds, typically 35 mph (e.g., HICOMP), which is defined here as the "severe congestion" speed threshold, and 45 mph (Federal Highway Administration threshold to define HOV degradation).

The HICOMP annual report discussed in the following section uses the 35 mph threshold speed and assumes 2,000 vehicles per hour per lane as the throughput threshold. Therefore, HICOMP reports on severe delay, while the automatic detector data uses 60 mph and the reported number of vehicles reported by the detectors. Each of these two sources is discussed separately since their results are extremely difficult to compare due to methodological and data collection differences.

Caltrans HICOMP

The HICOMP report has been published annually by Caltrans since 1987.[3] Delay is presented as average daily vehicle-hours of delay (DVHD). The HICOMP report defines delay as travel time in excess of free-flow travel, when speeds dip below 35 mph for 15-minutes or longer.

District 12 collects data for HICOMP using probe vehicle runs for two to four days during the year (ideally, two days of data collection in the spring and two in the fall, though resource constraints often affect the number of runs performed). As discussed later in this section on automatic detector data, congestion levels vary from day to day and depend on any number of factors including accidents, weather, special events, the price of gasoline, and construction activities.

Exhibit 3-8 shows the annual delay for the years 2006 and 2007 during both the AM and PM peak travel period for both directions along the SR-91 CSMP Corridor. As illustrated in Exhibit 3-8, the most significant congestion occurred during the PM peak period in the eastbound direction for both years. In the eastbound direction during the PM peak period, the exhibit shows an increase in congestion from 2006 to 2007 by 27 percent. Congestion in the westbound direction during the PM peak period declined

[3] Located at: http://www.dot.ca.gov/hq/traffops/sysmgtpl/HICOMP/index.htm

from 2006 to 2007, also by 27 percent. For the AM peak period, the exhibit shows that the year 2006 experienced the most congestion in both directions.

Exhibit 3-8: HICOMP Average Daily Vehicle-Hours of Delay (2006-2007)

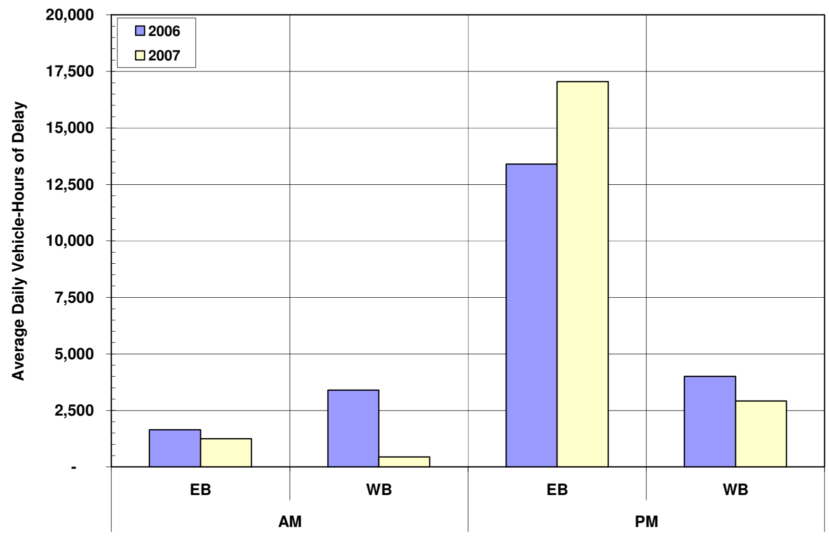


Exhibit 3-9 shows the complete list of congested segments reported by the HICOMP report for the SR-91 CSMP Corridor. "Generalized" congested segments are presented so that segment comparisons can be made from one year to the next since a given congested segment may vary in distance or size from year-to-year or day-to-day. However, it is important to reiterate that these trends are affected by the quality of the data available.

Exhibit 3-9: HICOMP Congested Segments

Period	Dir	Generalized Congested Area	Average Vehicle-Hours of Delay	
			2006	2007
AM	EB	LA County Line to Brookhurst St		
		LA County Line to 0.5 miles e/o Harbor Bl		1,241
		LA County Line to SR-57	1,585	
		Magnolia Av to Brookhurst St		
		Magnolia Ave to State College Bl	56	
		Euclid Av		
		East St/Raymond Av to Acacia St		
		East of SR-57 to Kraemer Bl/Glassell St		
		Tustin Av		
		SR-241 to west of Green River Rd		
	WB	Riverside County Line to 0.2 miles w/o Riverside County Line		
		Riverside County Line to Coal Canyon Rd		
		West of Riverside County Line to Green River Rd	3	
		Imperial Hwy (SR-90) to east of Lakeview Av		
		Imperial Hwy (SR-90) to Magnolia Ave	3,121	
		SR-55 to Raymond Av		310
		Kraemer Bl/Glassell St to LA County Line	272	
		Kraemer Bl/Glassell St to State College Bl		
		Acacia St to East St/Raymond Av		
		0.5 miles e/o Harbor Bl to Knott Ave		125
		Harbor Bl to Euclid Av		
		.	5,037	1,676
PM	EB	LA County Line to Brookhurst St		303
		Magnolia Av to Brookhurst St		
		Brookhurst St		
		Euclid Av		
		Harbor Bl to Kraemer Bl/Glassell St	462	
		East St/Raymond Av to Acacia St		
		Raymond Ave to 0.5 miles east of Lakeview Ave		577
		State College Bl to Tustin Av		
		SR-57 to Tustin Ave	103	
		Imperial Hwy (SR-90) to Riverside County Line	12,833	16,170
	WB	Riverside County Line to SR-241		
		West of SR-241 to west of Weir Canyon Rd		
		Lakeview Av		
		SR-55 to Raymond Av		1,778
		Riverdale Ave to Magnolia Ave	3,693	
		Kraemer Bl/Glassell St to LA County Line	313	
		Frontage Rd to Euclid Av		
		Harbor Blvd to LA County Line		1,132
		PM PEAK PERIOD SUMMARY	17,405	19,960
		TOTAL CORRIDOR CONGESTION	**22,442**	**21,636**

Exhibits 3-10 and 3-11 are maps showing the information from Exhibit 3-9 for the year 2007 during the two peak commute periods, respectively. The approximate locations of the congested segments, the duration of that congestion, and the reported recurrent daily delay are also shown on the maps.

Exhibit 3-10: HICOMP AM Peak Period Congested Segments Map (2007)

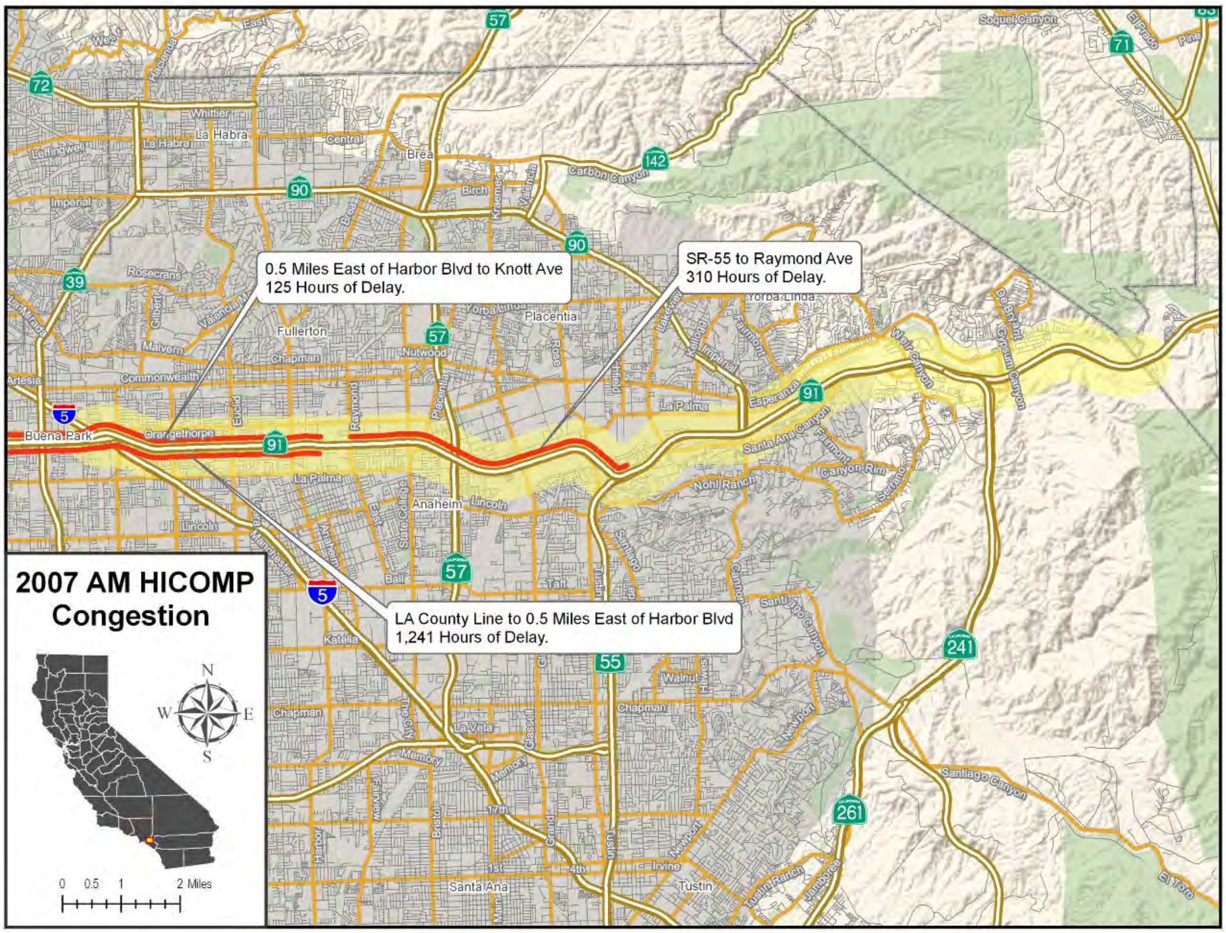
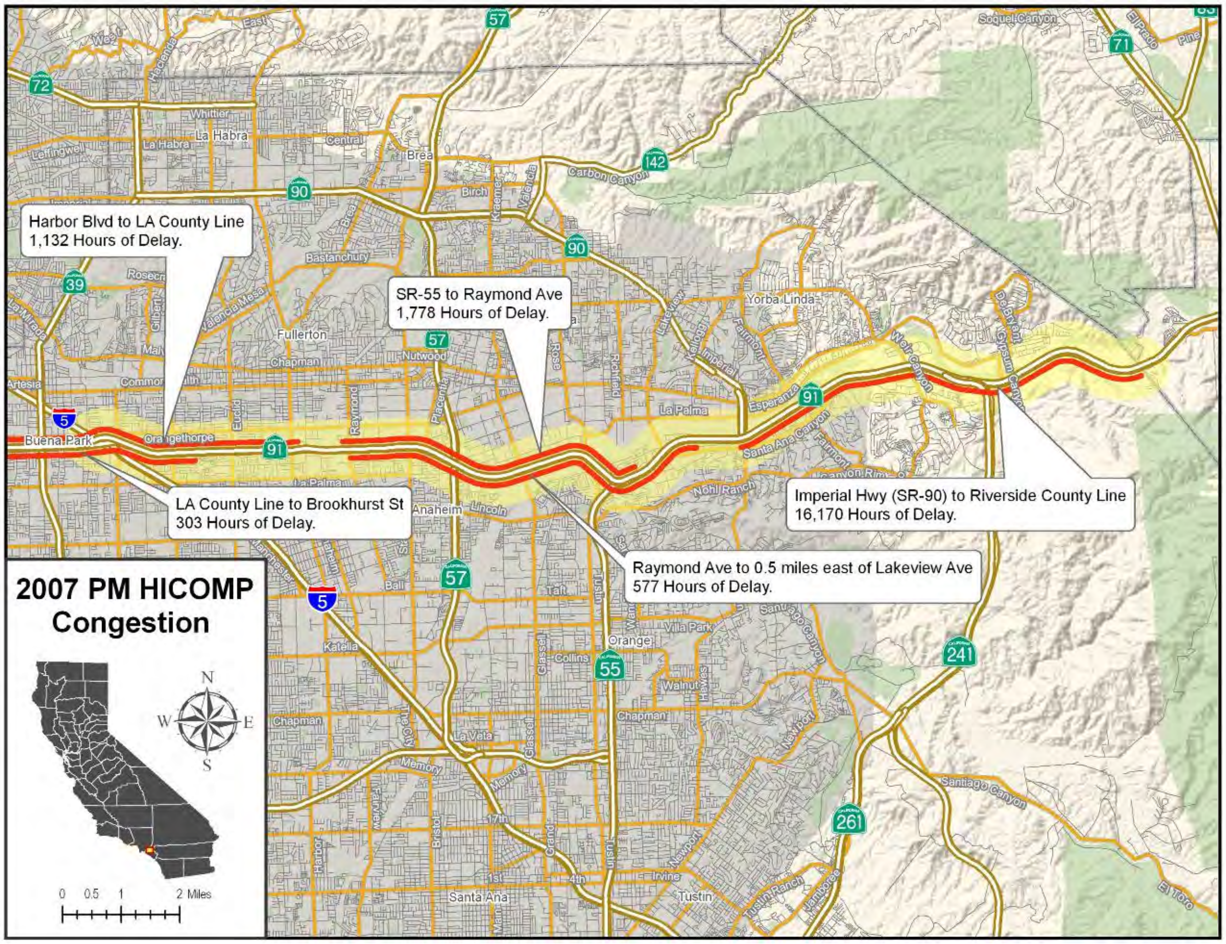


Exhibit 3-11: HICOMP PM Peak Period Congested Segments Map (2007)



Automatic Detector Data

Using freeway detector data discussed in the previous section, delay is computed for each day and summarized in different ways, which is not possible when using probe vehicle data.

Performance assessments were conducted for the four-year period of 2005 to 2008. HICOMP only estimates delay when speeds drop below 35 mph, and it assumes a capacity volume of 2,000 vehicles per hour per lane.

The automatically collected detector data presented here is based on the difference in travel time between reported conditions and the travel time at free-flow measured at 60 miles per hour, applied to the actual output flow volume collected from a vehicle detector station. The total delay by time period for the SR-91 for each direction of the mainline and HOV facilities are shown in Exhibits 3-12 to 3-15. Note that results prior to mid-2007 are based on data from fewer detectors and may be less reliable for analysis.

Total delay along the SR-91 CSMP Corridor was computed for four time periods: AM peak (6:00 AM to 9:00 AM), Midday (9:00 AM to 3:00 PM), PM peak (3:00 PM to 7:00 PM), and evening/early AM (7:00 PM to 6:00 AM).

Exhibits 3-12 and 3-13 show the overall non-holiday, weekday delay for the mainline facility between 2005 and 2009 in the eastbound and westbound directions, respectively. A 90-day moving average line is included to smooth out day-to-day variations and better illustrate seasonal and annual changes in congestion over time.

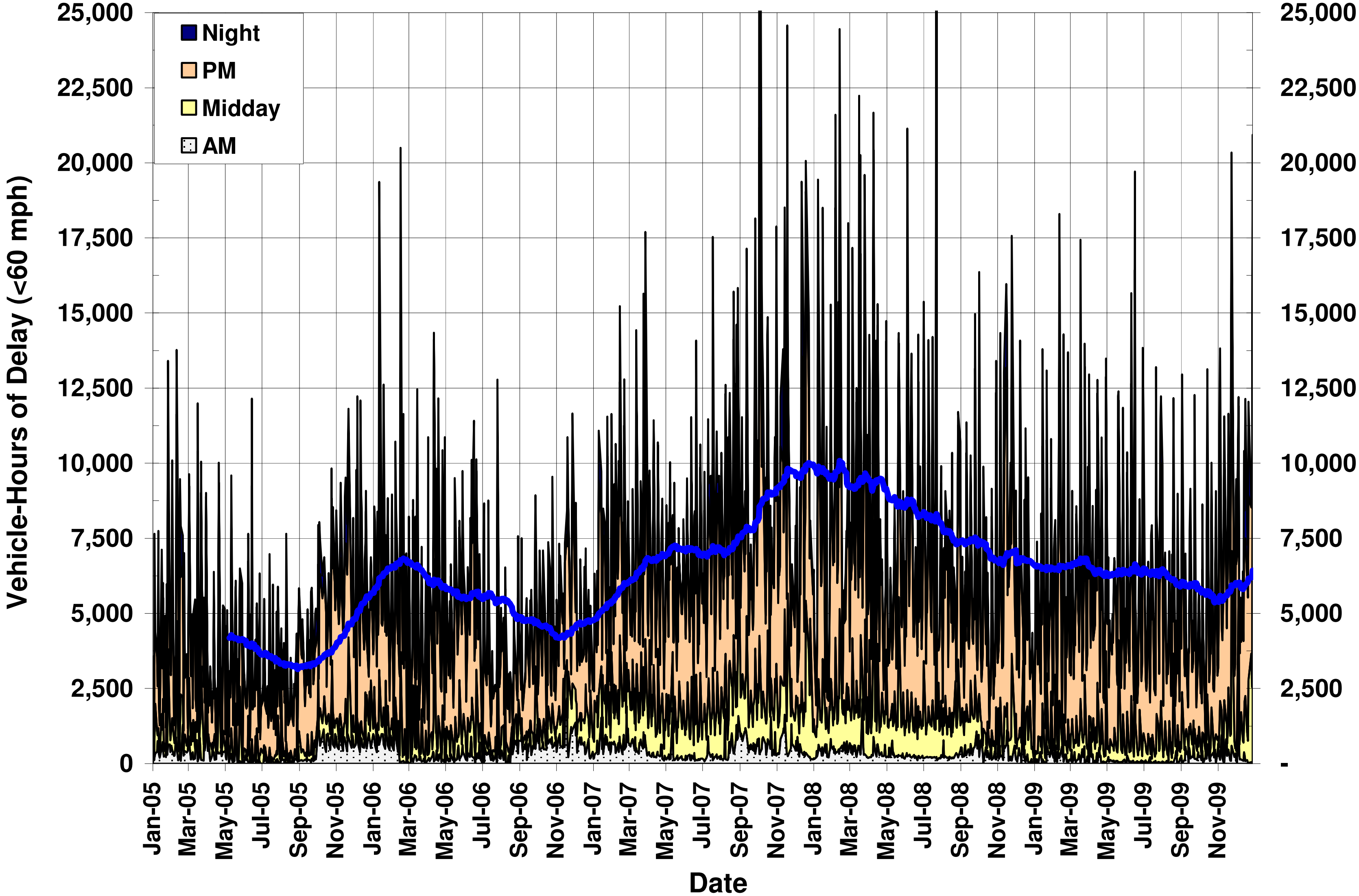
As shown in these exhibits, delay is heaviest in the eastbound direction, similar to the congestion trend shown in the HICOMP report. These exhibits also suggest that delay increased throughout the four years analyzed. In the eastbound direction, daily delay was reported at over 6,000 vehicle-hours in the first quarter of 2006, then surged to 10,000 vehicle-hours at the start of 2008, and finally dropped again to 6,000 vehicle-hours by the end of 2009. This is likely due to a combination of factors, including economic growth and improved detection reliability. In the westbound direction (Exhibit 3-13), daily delay was at about 2,000 vehicle-hours in 2006 before surging to over 6,000 vehicle hours in late 2007 through 2008. The same factors (i.e., economic growth and improved detection reliability) are likely reasons for this increase.

Weekday delay on the HOV facility is depicted by direction in Exhibits 3-14 and 3-15. Both directions of the HOV facility experienced greater delay during the PM peak than the AM peak. In the eastbound direction, delay was most evident from September 2006 to March 2007, where delay peaked at approximately 1,000 vehicle-hours. However, delay remained well below 500 vehicle-hours subsequent to March 2007 and throughout 2009. A similar pattern exists for westbound direction (Exhibit 3-15).

The next set of exhibits provides additional information on delay characteristics and trends. Exhibits 3-16 and 3-17 show the average daily weekday delay by month for the mainline and HOV facilities.

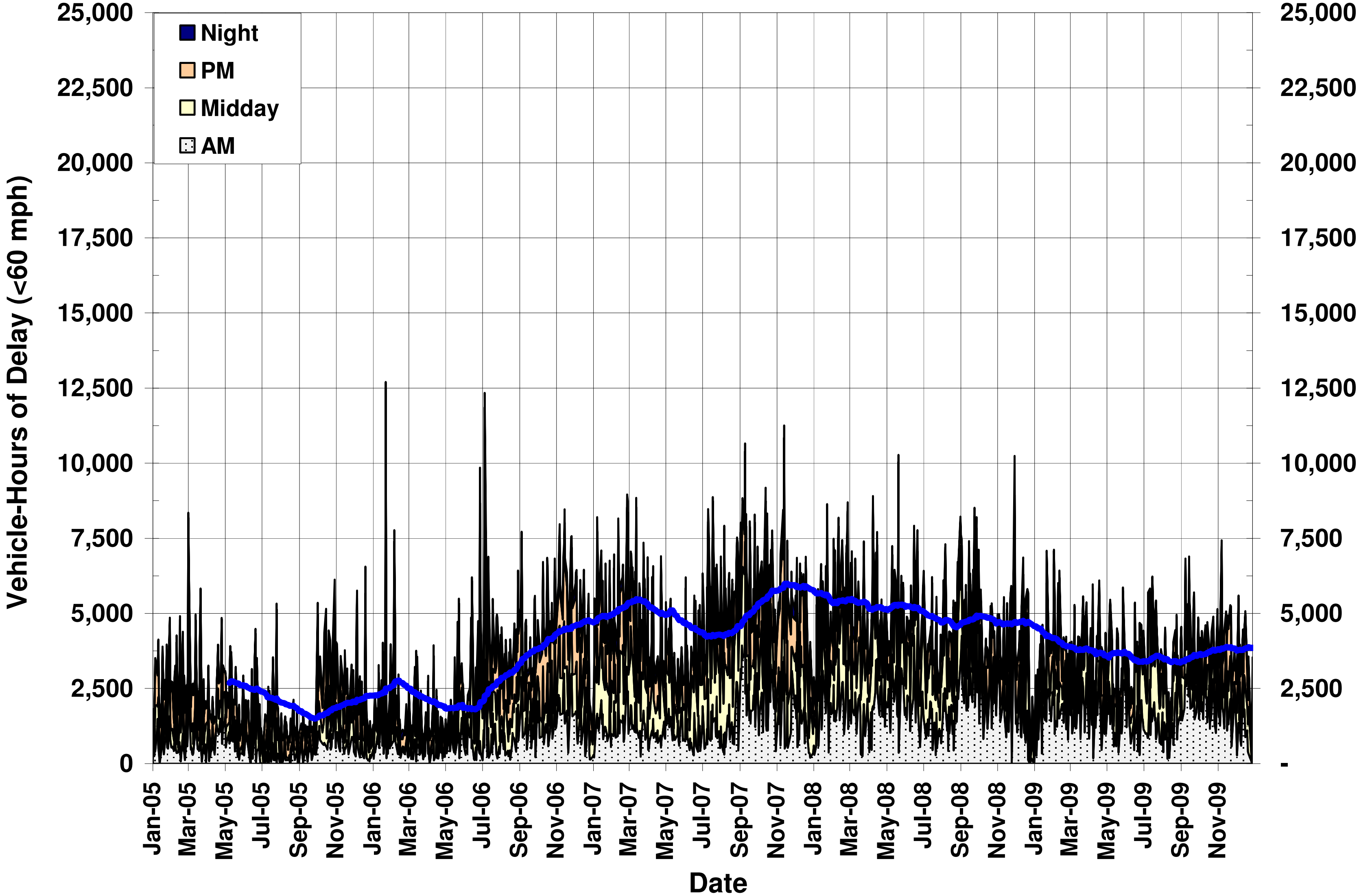
Exhibit 3-16 clearly shows that delay in the eastbound direction of the mainline (blue bars) consistently exceeded delay in the westbound direction (yellow bars). However, Exhibit 3-17 does not show the same trend for the HOV facility. Starting in 2007, delay in the westbound direction of the HOV facility exceeded that of the eastbound.

Exhibit 3-12: Eastbound Mainline Average Daily Delay by Time Period (2005-2009)



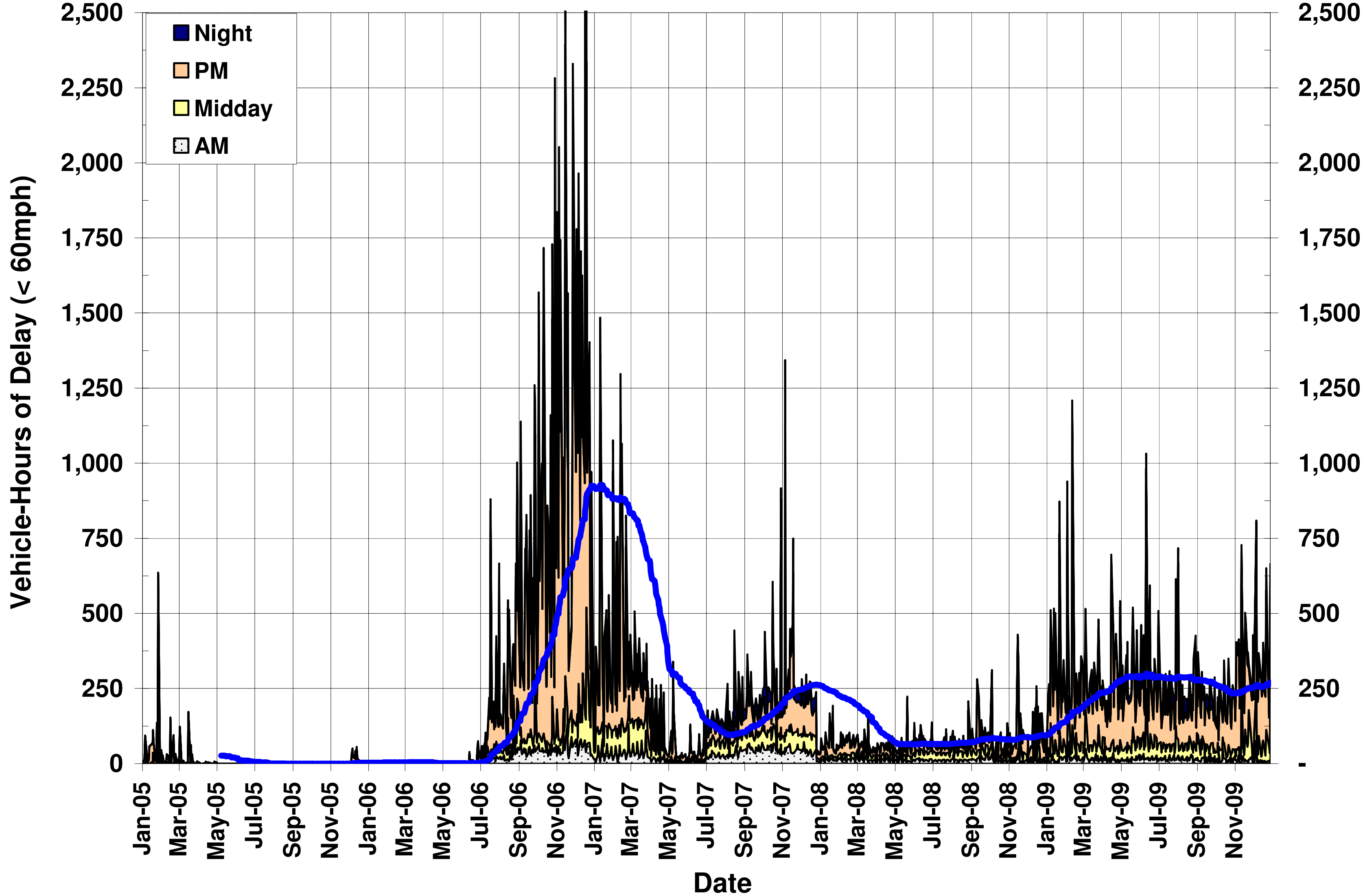
Source: Caltrans detector data

Exhibit 3-13: Westbound Mainline Average Daily Delay by Time Period (2005-2009)



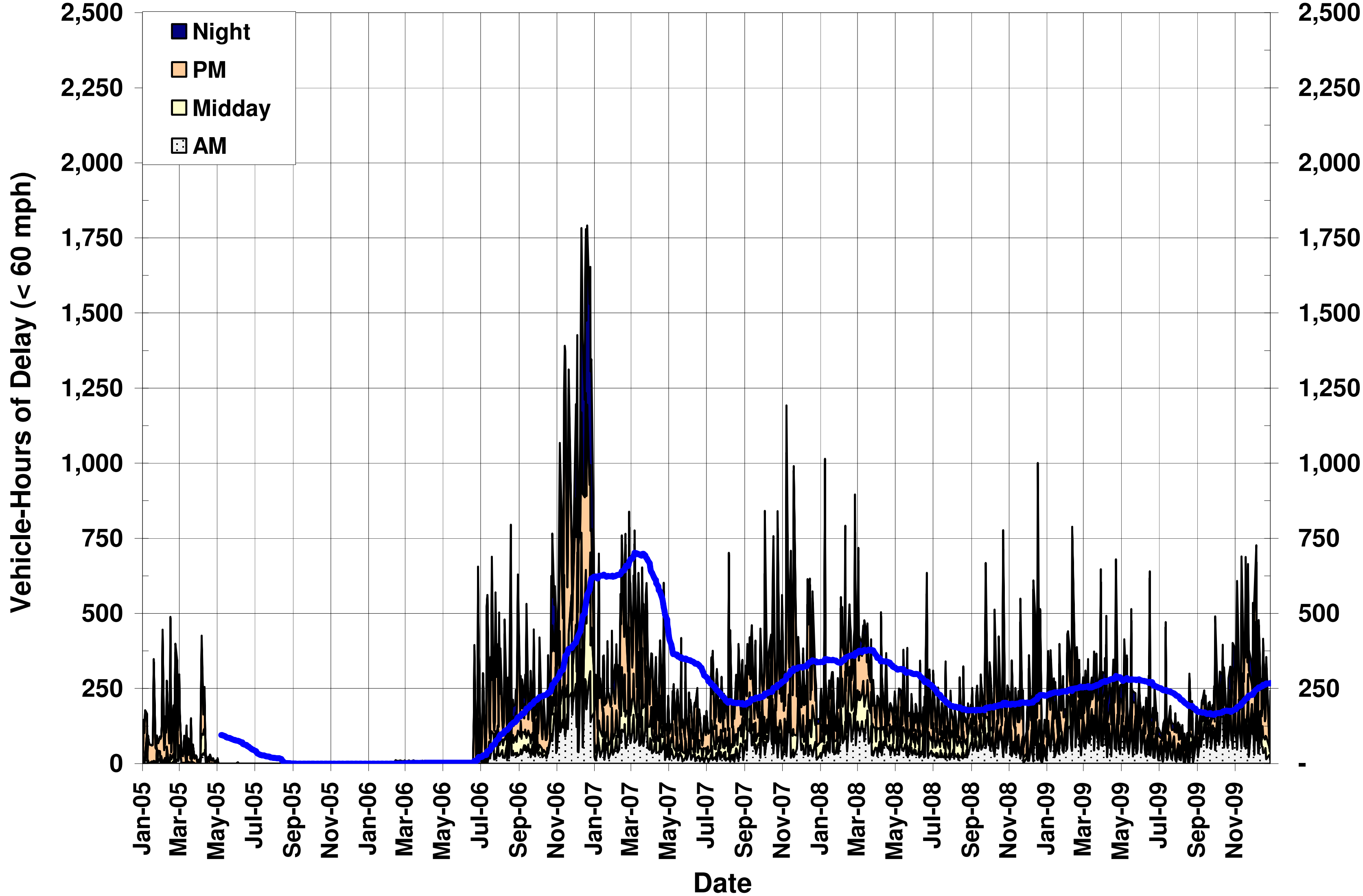
Source: Caltrans detector data

Exhibit 3-14: Eastbound HOV Average Daily Delay by Time Period (2005-2009)



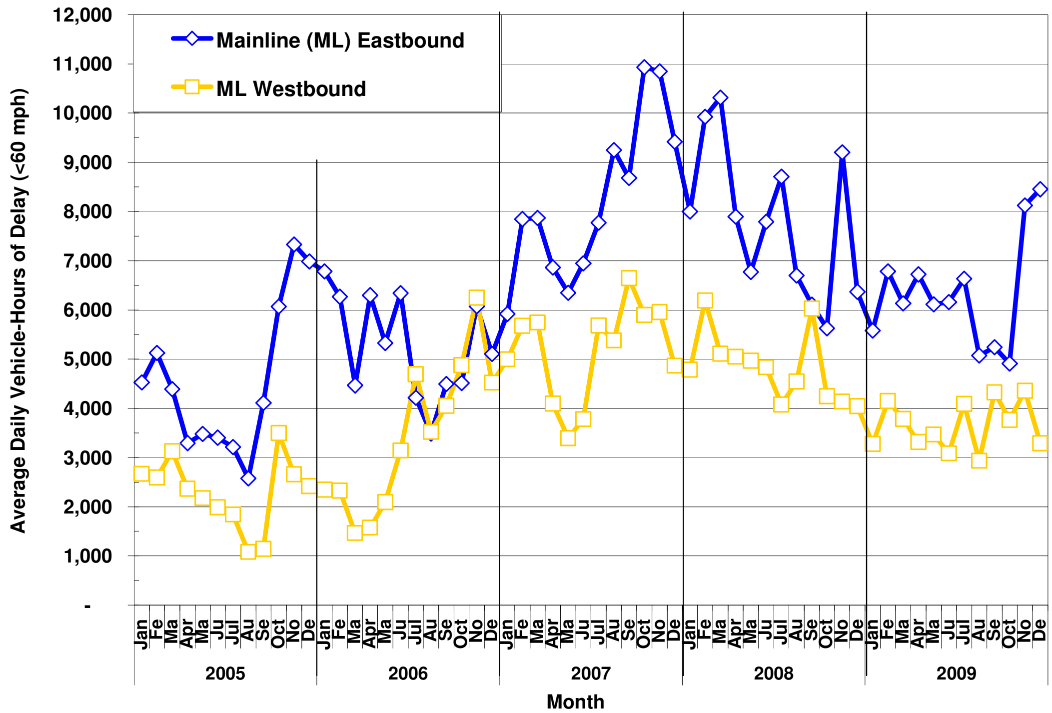
Source: Caltrans detector data

Exhibit 3-15: Westbound HOV Average Daily Delay by Time Period (2005-2009)



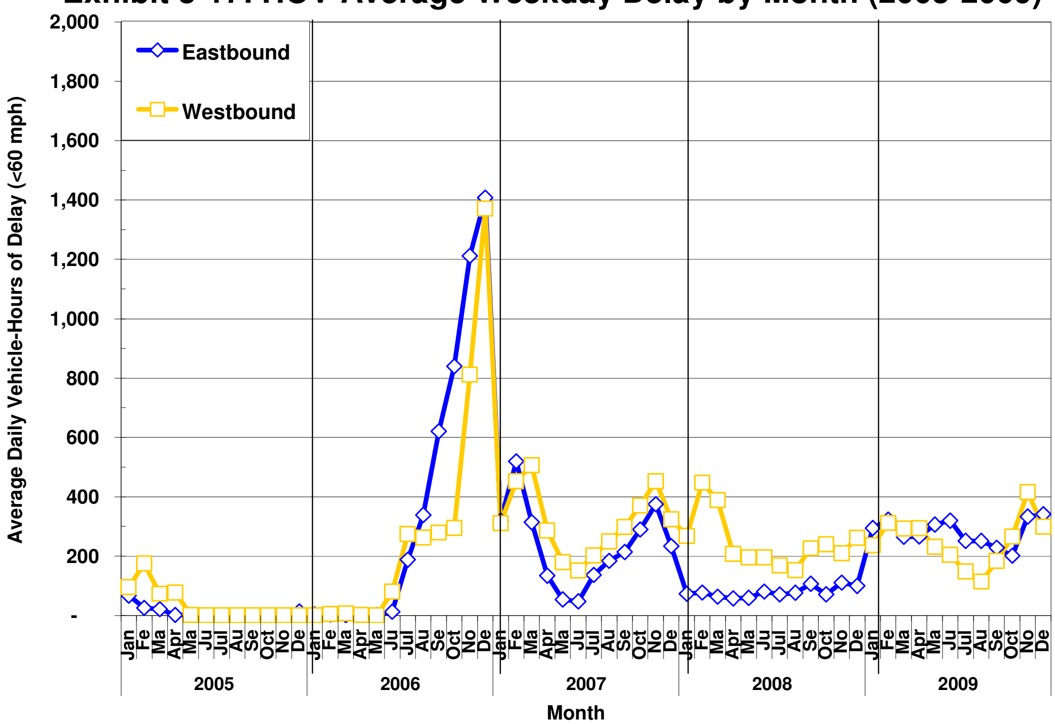
Source: Caltrans detector data

Exhibit 3-16: Mainline Average Weekday Delay by Month (2005-2009)



Source: Caltrans detector data

Exhibit 3-17: HOV Average Weekday Delay by Month (2005-2009)



Source: Caltrans detector data

Delays presented to this point represent the difference in travel time between actual conditions and free flow conditions at 60 mph. This delay can be segmented into two components as shown in Exhibits 3-18 and 3-19:

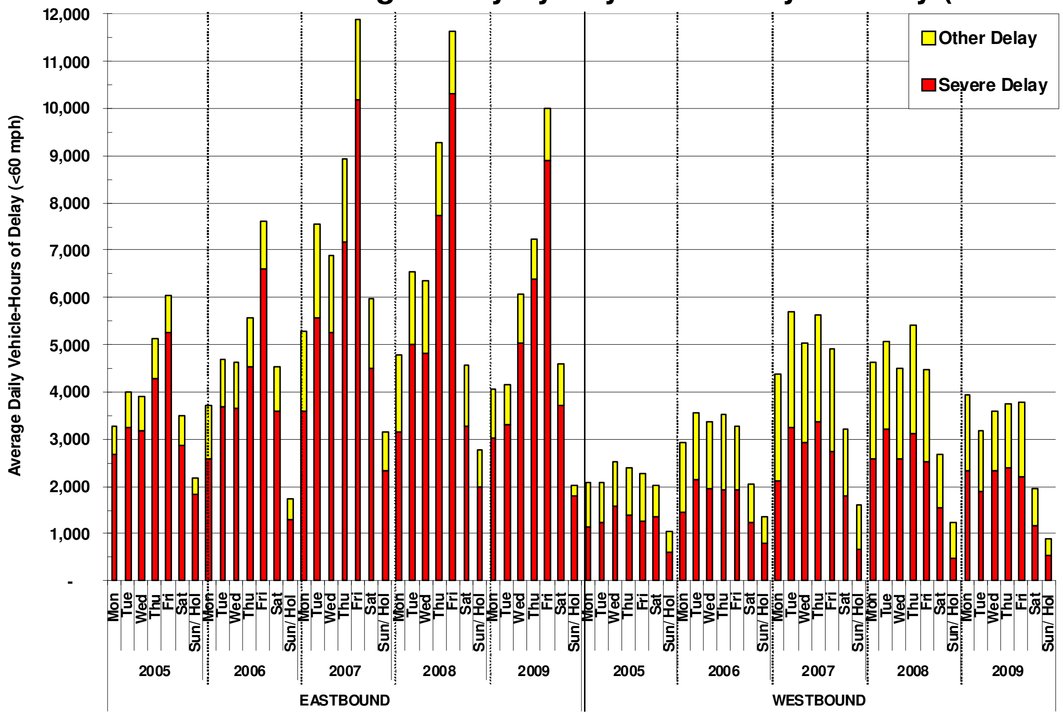
- Severe delay – delay that occurs when speeds are below 35 mph; and
- Other delay – delay that occurs when speeds are between 35 mph and 60 mph.

In Exhibits 3-18 and 3-19, severe delay represents breakdown conditions and is generally the focus of congestion mitigation strategies. "Other" delay represents conditions approaching the breakdown congestion, leaving the breakdown conditions, or areas that do not cause widespread breakdowns, but cause at least temporary slowdowns. Although combating congestion requires the focus on severe congestion, it is important to review "other" congestion and understand its trends. This could allow for proactive intervention before the "other" congestion turns into severe congestion.

Exhibit 3-18 shows that for the mainline facility, severe delay (represented by the red bars) comprised a greater portion of the delay in the eastbound direction than the westbound. In the westbound direction, delay throughout the workweek remained relatively level, whereas delay in eastbound direction increased as the week progressed, peaking on Fridays.

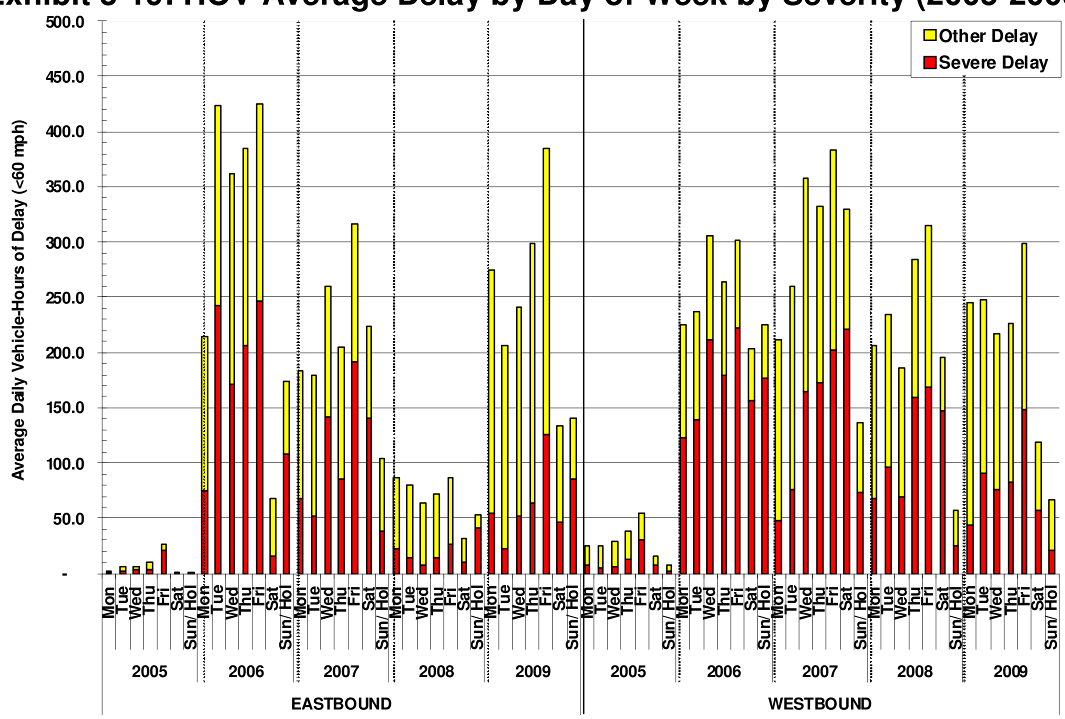
On the HOV facility (Exhibit 3-19), severe delay was more concentrated in the westbound direction than the eastbound, most notably in 2007 and 2008. Delay also peaked on Fridays in both directions of the HOV facility.

Exhibit 3-18: Mainline Average Delay by Day of Week by Severity (2005-2009)



Source: Caltrans detector data

Exhibit 3-19: HOV Average Delay by Day of Week by Severity (2005-2009)

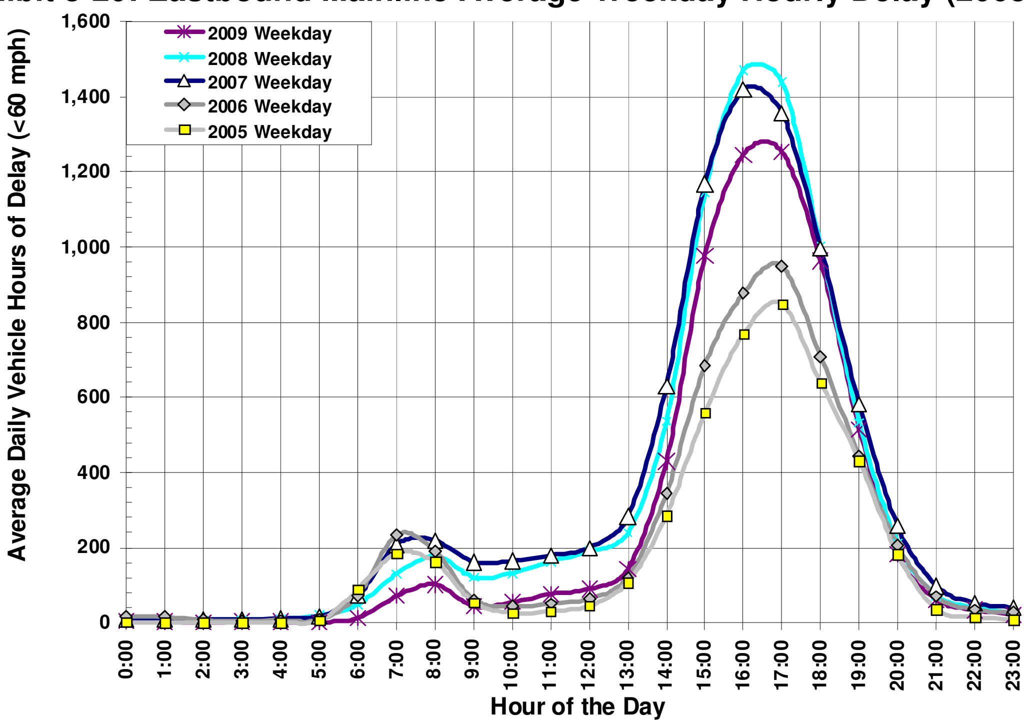


Source: Caltrans detector data

Another way to understand the characteristics of congestion and related delays is shown in Exhibits 3-20 and 3-21, which summarize average weekday hourly delay for the mainline, and Exhibits 3-22 and 3-23, which summarize average weekday hourly delay for HOV facility. These exhibits allow planners and decision makers to understand the trend in peak period delay spiking (greater variance/differences) and peak period spreading (longer duration) by comparing the intensity and duration of the peak congestion. The exhibits highlight several trends on the mainline facility:

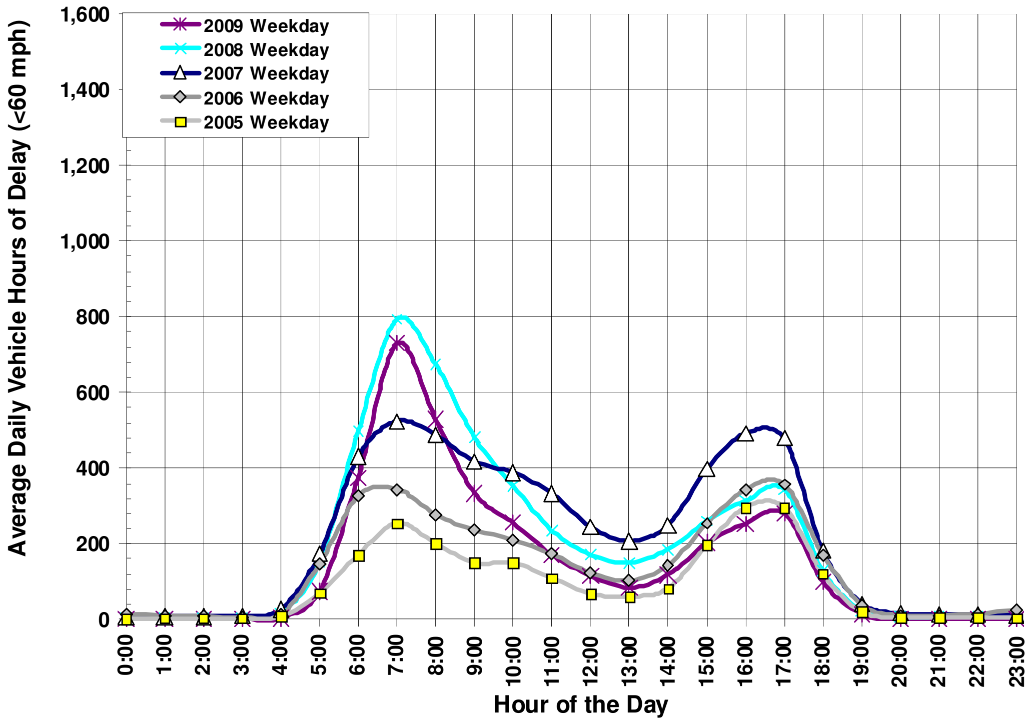
- Delay in the westbound direction peaks during the AM period, while delay peaks in the eastbound direction during the PM period.
- The peak period of delay lasts from 6:00 AM to 9:00 AM and from 3:00 PM to 6:00 PM. The AM peak hour is 7:00 AM, while the PM peak period has two peak hours depending on the year: 4:00 PM or 5:00 PM.
- Delay increased through December 2008, but decreased in 2009. In both directions, peak period congestion nearly doubled between 2005 and 2008, but declined in 2009. Delay is less in the westbound direction
- The eastbound PM peak period started one hour earlier in 2008 than in 2005. In 2009, the eastbound congested period shrank by about one-half hour.
- Although delays are less in the westbound direction, the AM peak grew more pronounced in 2008 and 2009. The AM peak period also expanded.

Exhibit 3-20: Eastbound Mainline Average Weekday Hourly Delay (2005-2009)



Source: Caltrans detector data

Exhibit 3-21: Westbound Mainline Average Weekday Hourly Delay (2005-2009)

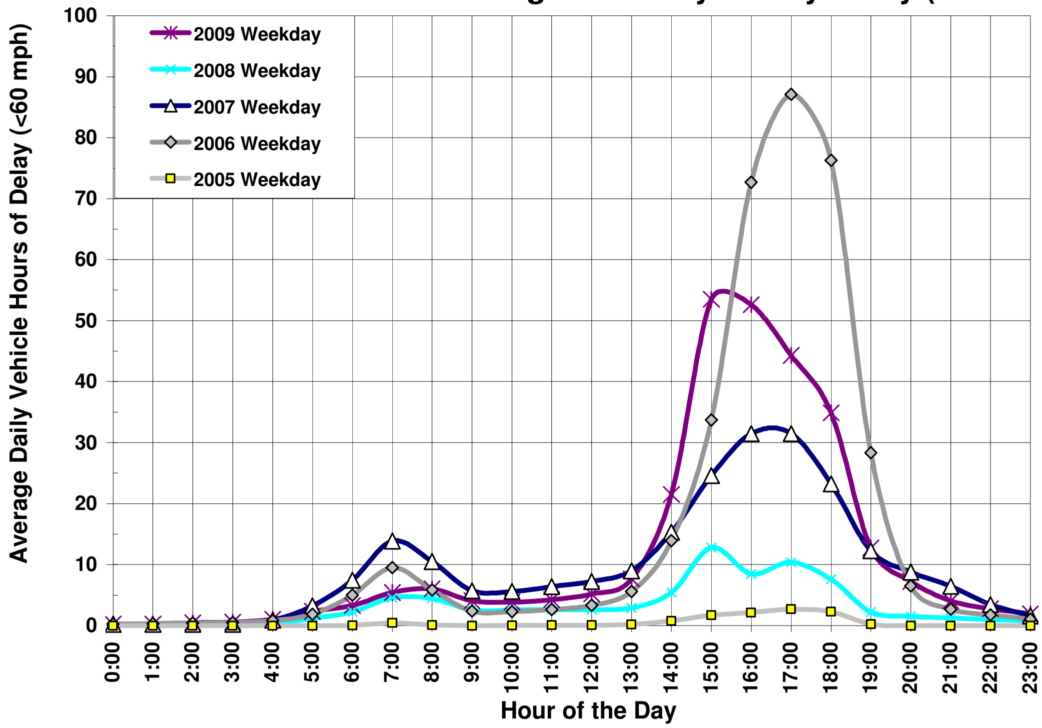


Source: Caltrans detector data

The following trends can be observed on the HOV facility (Exhibits 3-22 and 3-23):

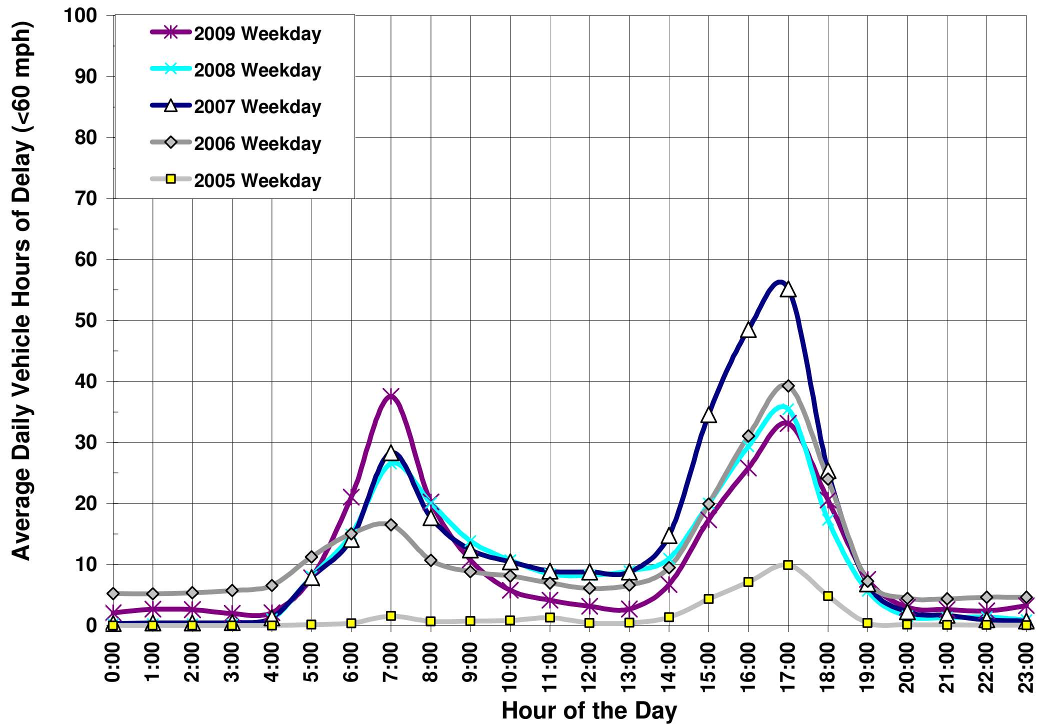
- In the eastbound direction, the PM peak period spanned from 3:00 PM to about 7:00 PM. Delay was greatest in 2006 during the 5:00 PM peak hour with around 90 vehicle-hours.
- In the westbound direction, the PM peak period was more congested than the AM peak period. Delay was greatest in 2007 during the 5:00 PM peak hour. In 2007, the duration of the PM peak hour was longer than the other years, starting at 2:00 PM and ending around 6:00 PM. During the PM peak period, delay in 2008 decreased below 2006 and 2007 levels.
- The AM peak hour in the westbound direction is at 7:00 AM.

Exhibit 3-22: Eastbound HOV Average Weekday Hourly Delay (2005-2009)



Source: Caltrans detector data

Exhibit 3-23: Westbound HOV Average Weekday Hourly Delay (2005-2009)



Source: Caltrans detector data

Travel Time

The travel time measure represents the average time for a vehicle to travel between I-5 and the Riverside County line (a distance of approximately 19 miles on the mainline). The distance measured for HOV lanes is shorter, because HOV lanes extend only nine miles along the SR-91 CSMP Corridor. Caltrans detection data were used to compute and analyze travel times.

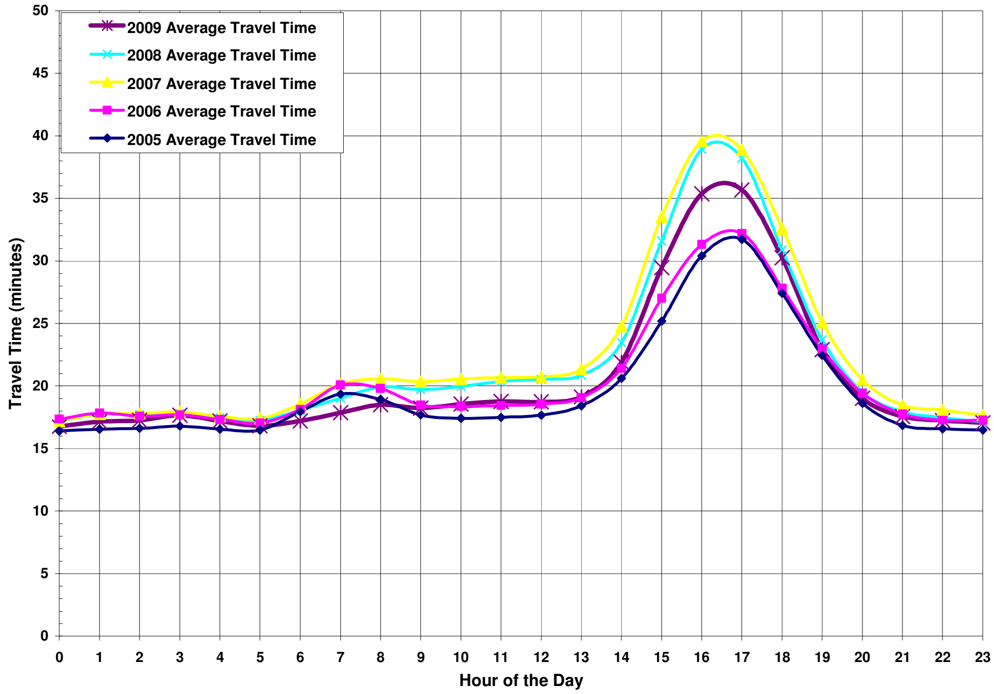
Exhibits 3-24 to 3-25 illustrate the travel times assessed for the mainline facility of the SR-91 CSMP Corridor. As illustrated, the eastbound direction had travel times of approximately 32 to 40 minutes during the PM peak hour, and the westbound direction had travel times of approximately 22 to 25 minutes during the PM peak hour.

In the eastbound direction, travel times remained unchanged in the AM peak hour, while they increased in the PM peak hour (from approximately 32 minutes to 40 minutes between 2005 and 2008). In 2009, PM travel times decreased to 36 minutes.

In the westbound direction, travel times increased in the AM peak hour from approximately 20 minutes to 25 minutes between 2005 and 2008. In contrast, the westbound travel times decreased during the PM peak hour. The travel time in 2008 nearly equaled 2005 and 2006 levels (about 22 minutes).

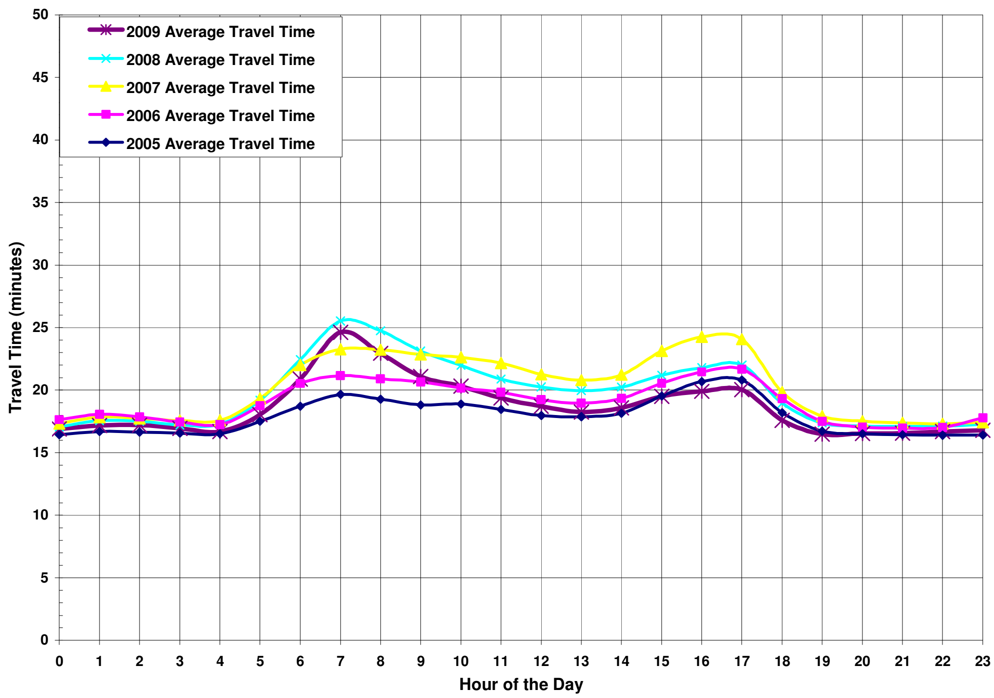
Exhibits 3-26 to 3-27 provide travel times for the HOV facility on the SR-91 CSMP Corridor. Travel times on the HOV facility remained steady in both directions during the four years analyzed. Similar to the mainline, the HOV lane experienced greater delay during the PM peak period in both directions. During the 5:00 PM peak hour in both directions of travel, delay increased from about eight minutes in 2005 to 11 minutes in 2007.

Exhibit 3-24: Eastbound Mainline Travel Time by Time of Day (2005-2009)



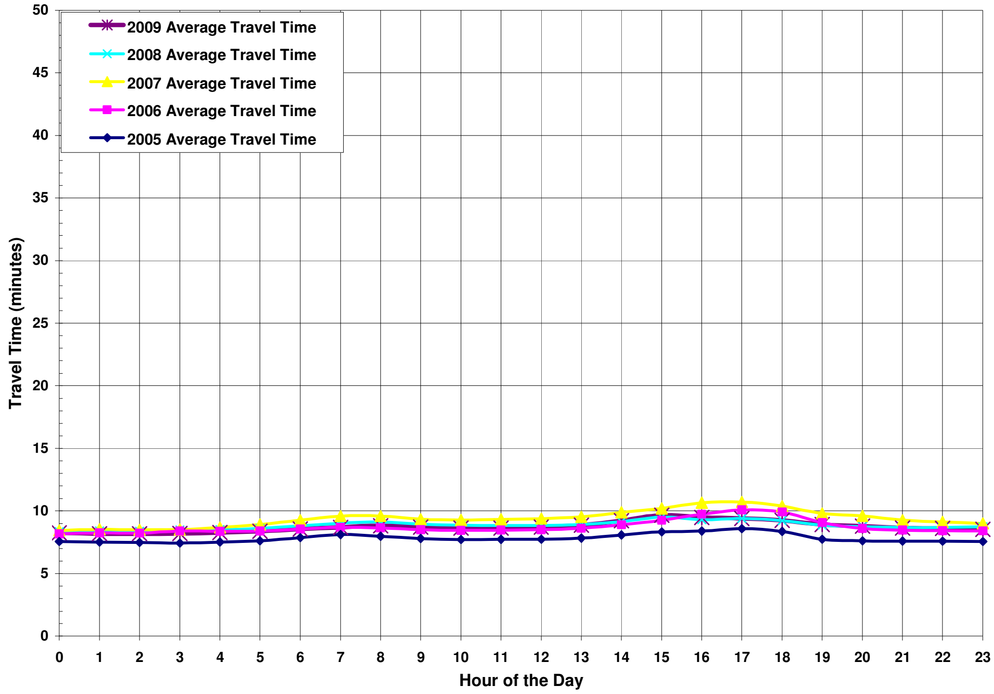
Source: Caltrans detector data

Exhibit 3-25: Westbound Mainline Travel Time by Time of Day (2005-2009)



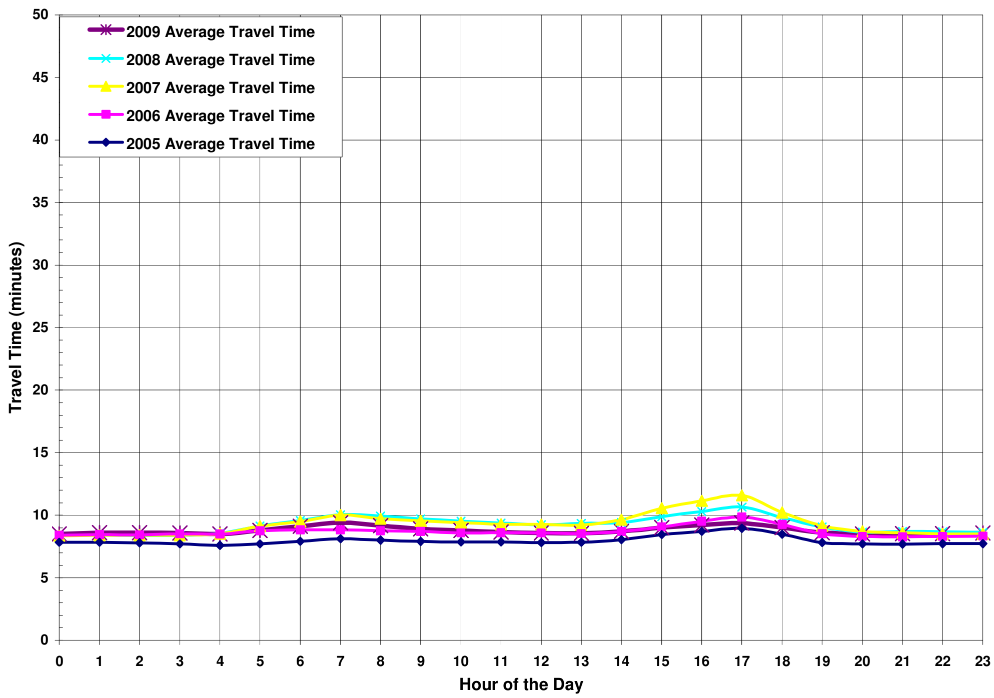
Source: Caltrans detector data

Exhibit 3-26: Eastbound HOV Travel Time by Time of Day (2005-2009)



Source: Caltrans detector data

Exhibit 3-27: Westbound HOV Travel Time by Time of Day (2005-2009)



Source: Caltrans detector data

Reliability

Reliability captures the relative predictability of the public's travel time. Unlike mobility, which measures average delays and travel times, the reliability measure focuses on how much travel time varies from day to day.

Automatic detector data were used to estimate travel time variability by using the 95th percentile travel time—an optimal, desired expected peak travel time at any given day.

Exhibits 3-28 to 3-37 illustrate the variability of travel time along the mainline for weekdays averaged throughout the respective years. The following observations on the mainline facility are worth noting:

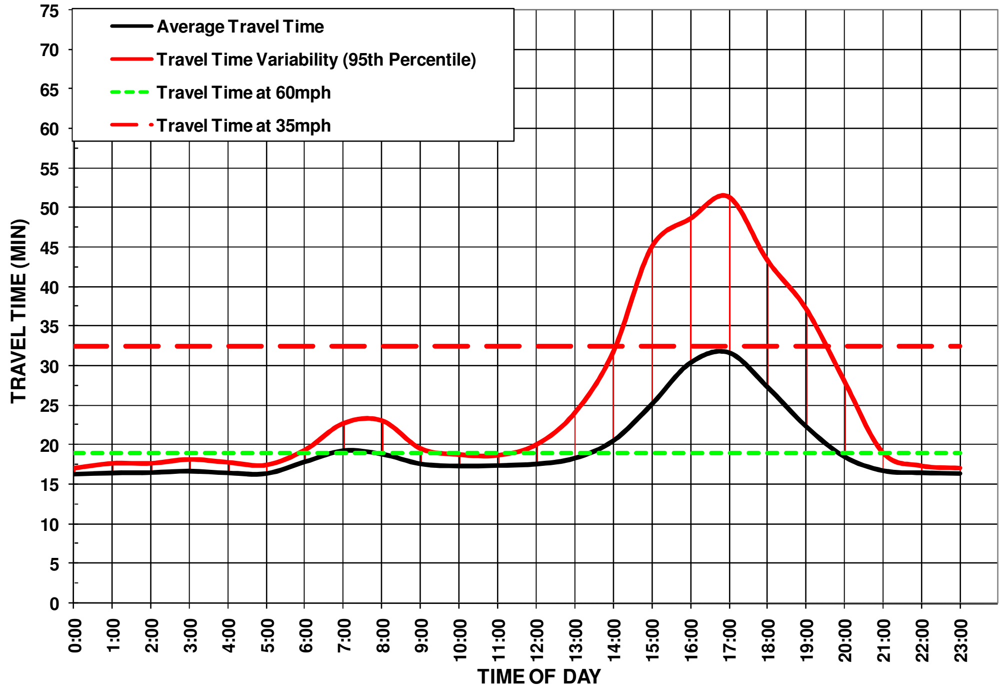
- Variability in the eastbound direction during the PM peak period decreased significantly in 2009. Although the average travel time during the PM peak period is less than 39 minutes, a traveler needs to schedule just below 60 minutes to have a 95 percent likelihood of arriving at the Riverside County line in time. From 2005-2009 reliability had been getting worse every year. Exhibit 3-32 showed that in 2009 reliability was much more promising than the previous year.
- Variability in the westbound direction during the PM peak period decreased in 2008 compared to the prior years from 29 percent in 2007 to 23 percent in 2008.
- For three years, 2003 to 2007, the westbound direction experienced greater travel times during the PM peak period. This changed in 2008 when travel times at 8:00 AM (33 minutes) exceeded travel times in the PM peak (27 minutes).
- Variability in the westbound direction during the AM peak period is more modest. The difference between the average travel time and the 95th percentile travel time is less than 10 minutes.

It is important to keep track of the reliability statistic, in part to evaluate incident management improvement strategies, and in part to gauge the effectiveness of safety projects delivered.

Exhibits 3-38 to 3-47 illustrate the variability of travel time along the HOV facility. The following observations on the HOV facility are worth noting:

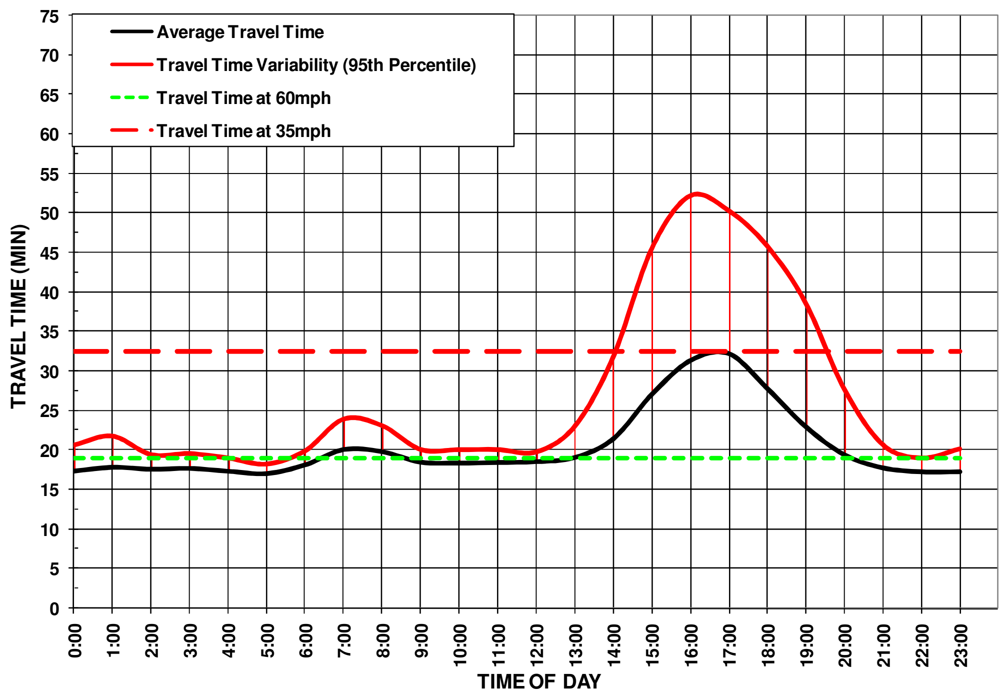
- The 5:00 PM peak hour was the slowest and most unreliable hour in both the eastbound and westbound directions.
- In both directions of travel, 2006 experienced the greatest variability in travel times (40 percent). Variability in travel times decreased since 2006 to 11 percent and 18 percent in the eastbound and westbound directions, respectively, in 2008.
- In 2008 and 2009, the 95th percentile time was ten minutes in both directions.

Exhibit 3-28: Eastbound Mainline Travel Time Variation (2005)



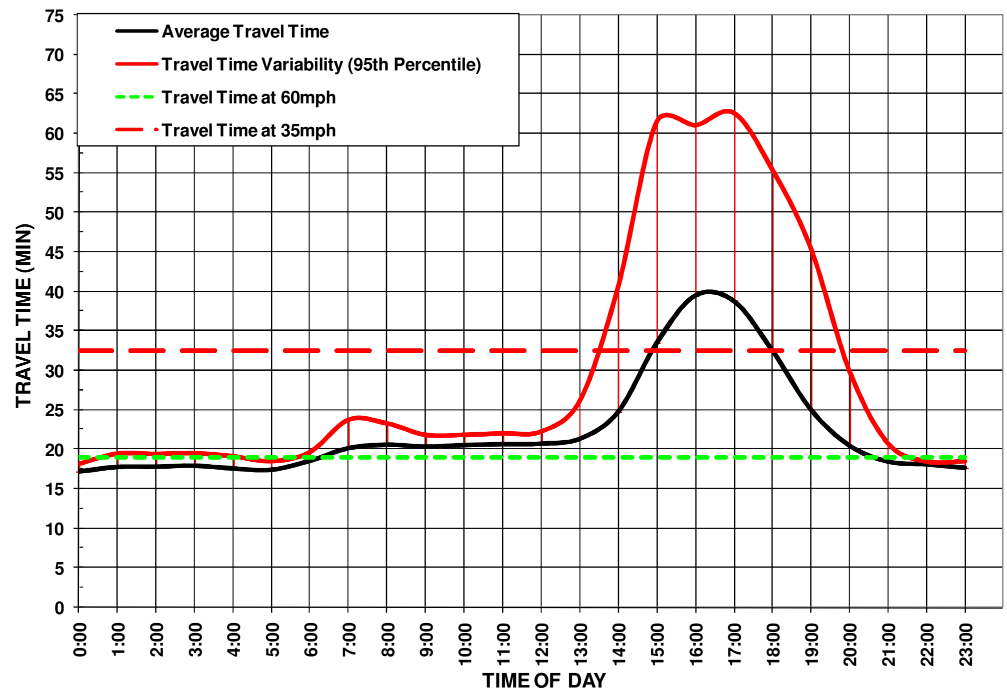
Source: Caltrans detector data

Exhibit 3-29: Eastbound Mainline Travel Time Variation (2006)



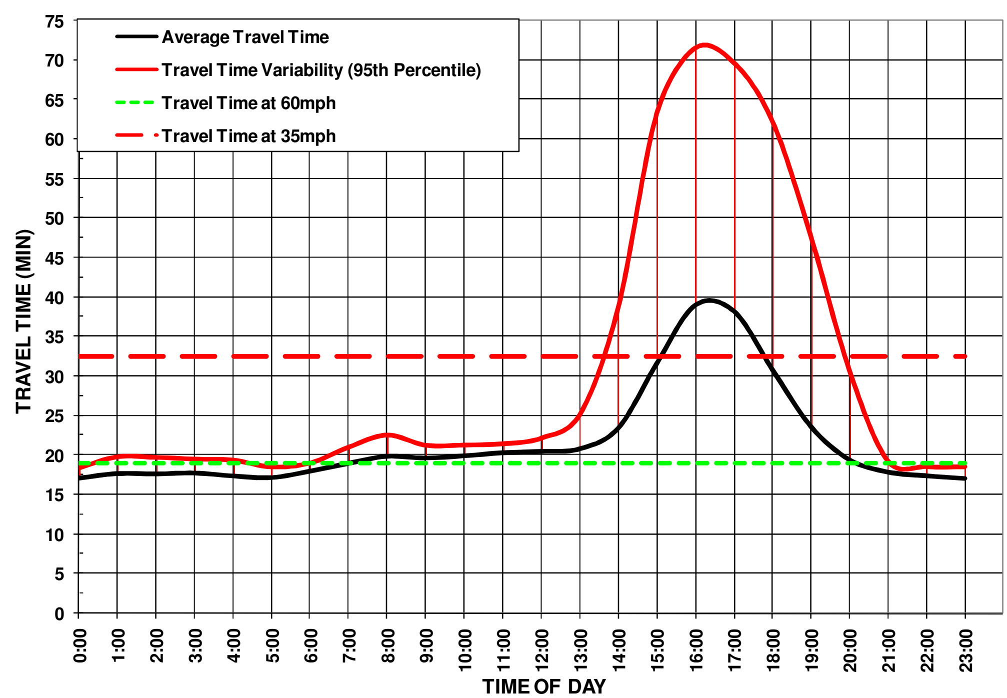
Source: Caltrans detector data

Exhibit 3-30: Eastbound Mainline Travel Time Variation (2007)



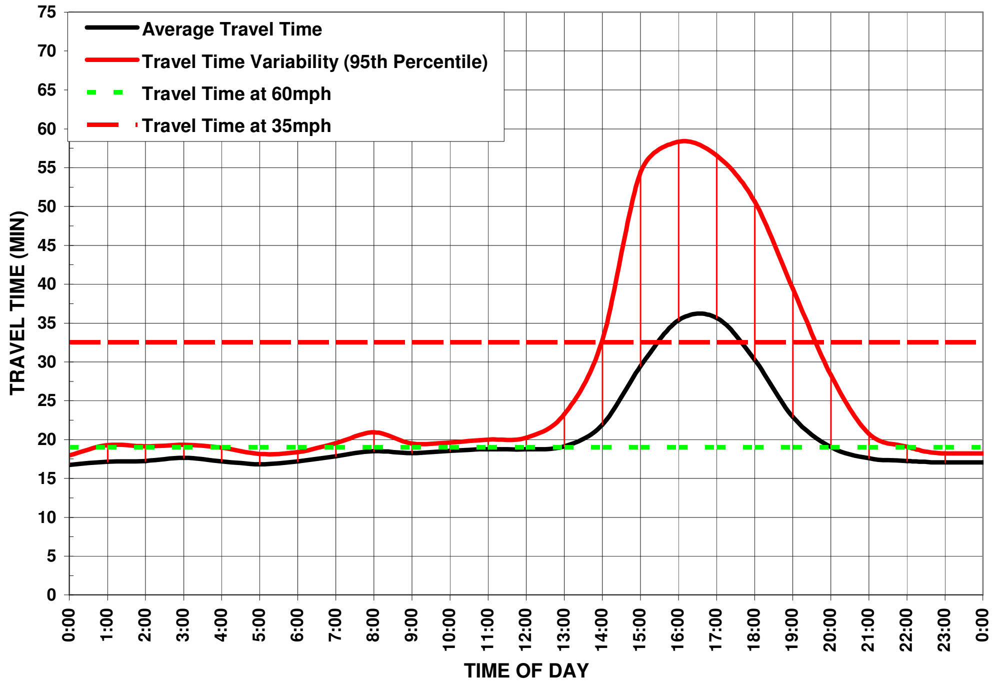
Source: Caltrans detector data

Exhibit 3-31: Eastbound Mainline Travel Time Variation (2008)



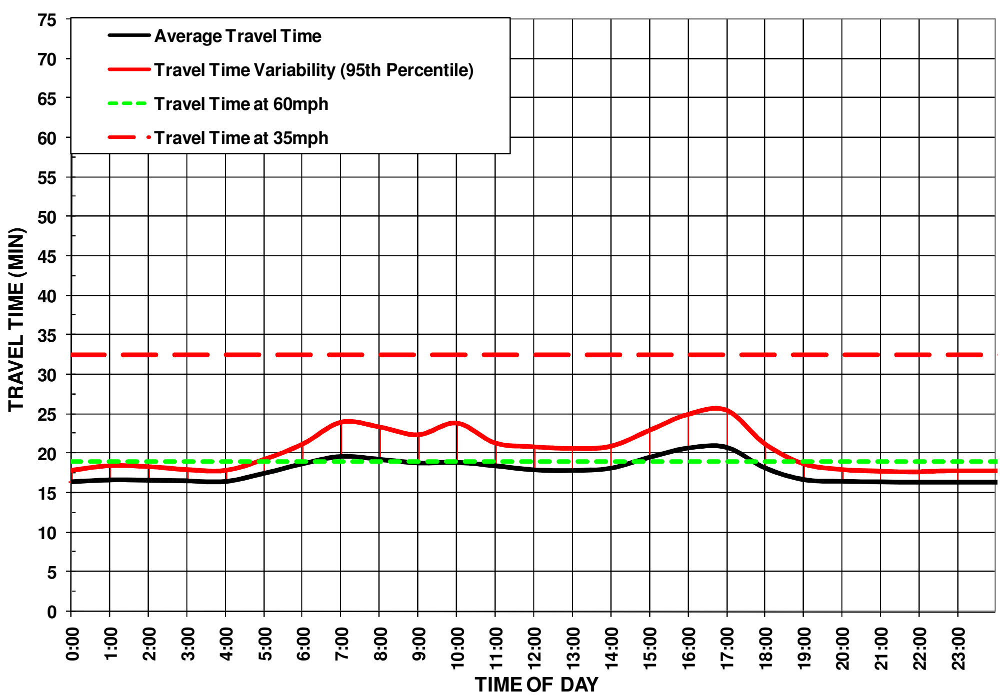
Source: Caltrans detector data

Exhibit 3-32: Eastbound Mainline Travel Time Variation (2009)



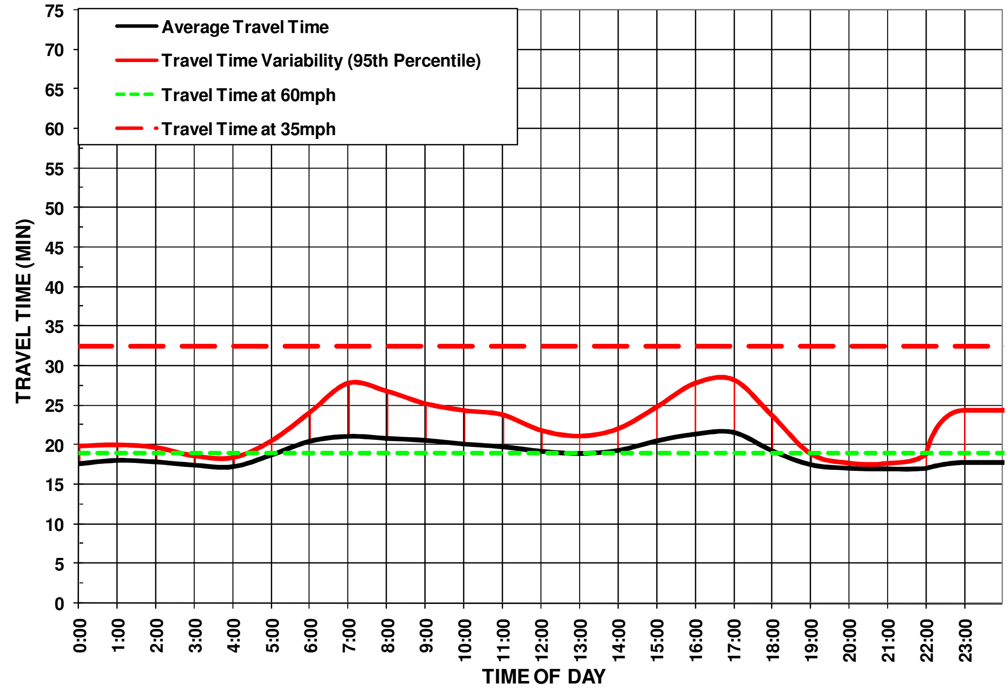
Source: Caltrans detector data

Exhibit 3-33: Westbound Mainline Travel Time Variation (2005)



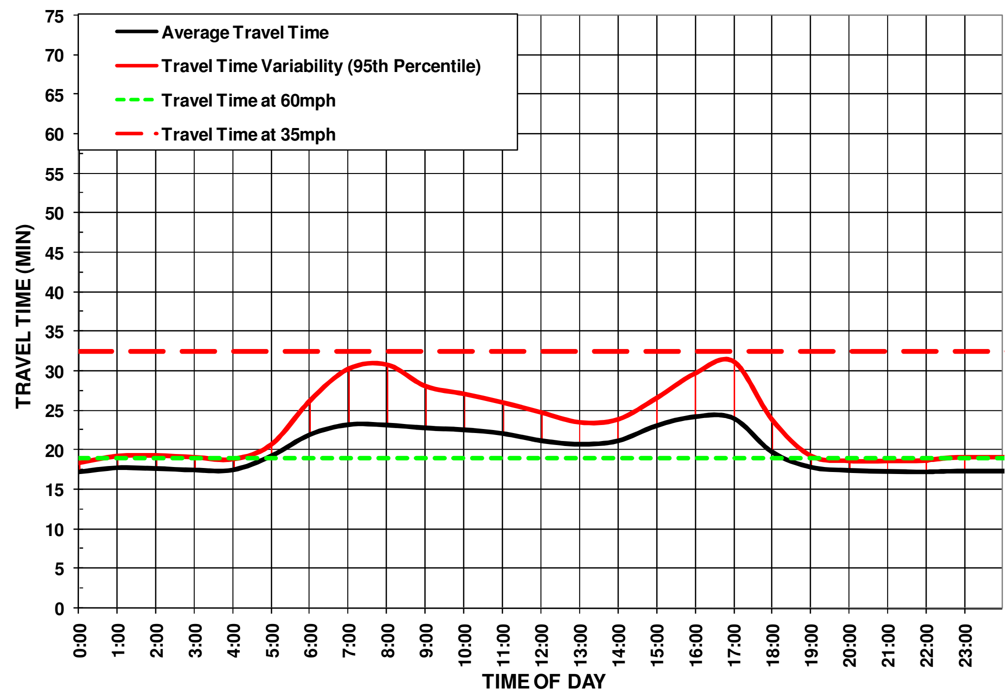
Source: Caltrans detector data

Exhibit 3-34: Westbound Mainline Travel Time Variation (2006)



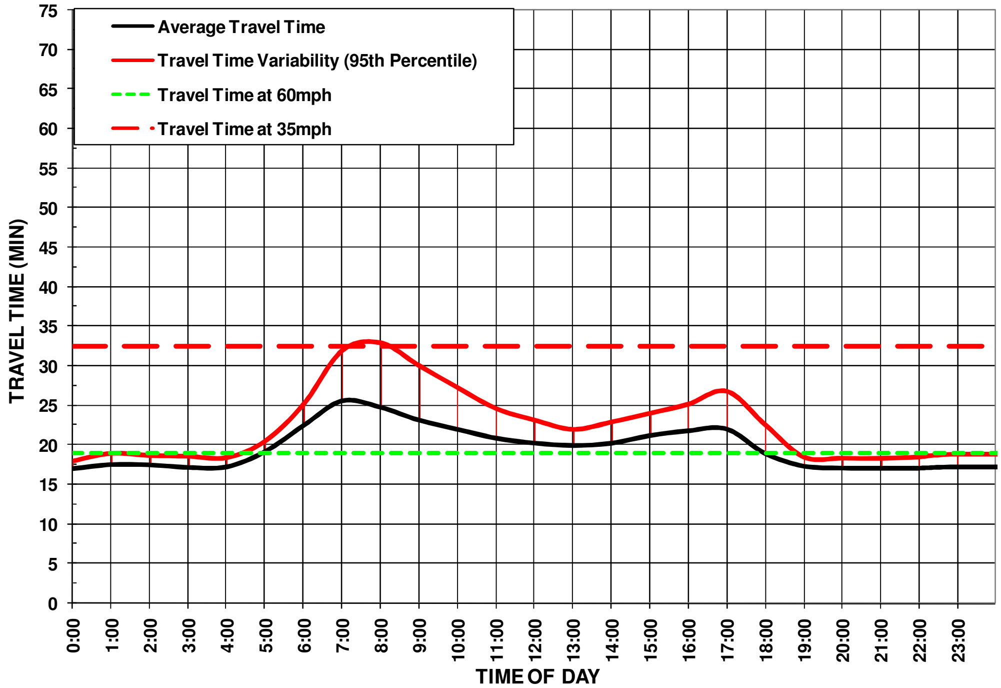
Source: Caltrans detector data

Exhibit 3-35: Westbound Mainline Travel Time Variation (2007)



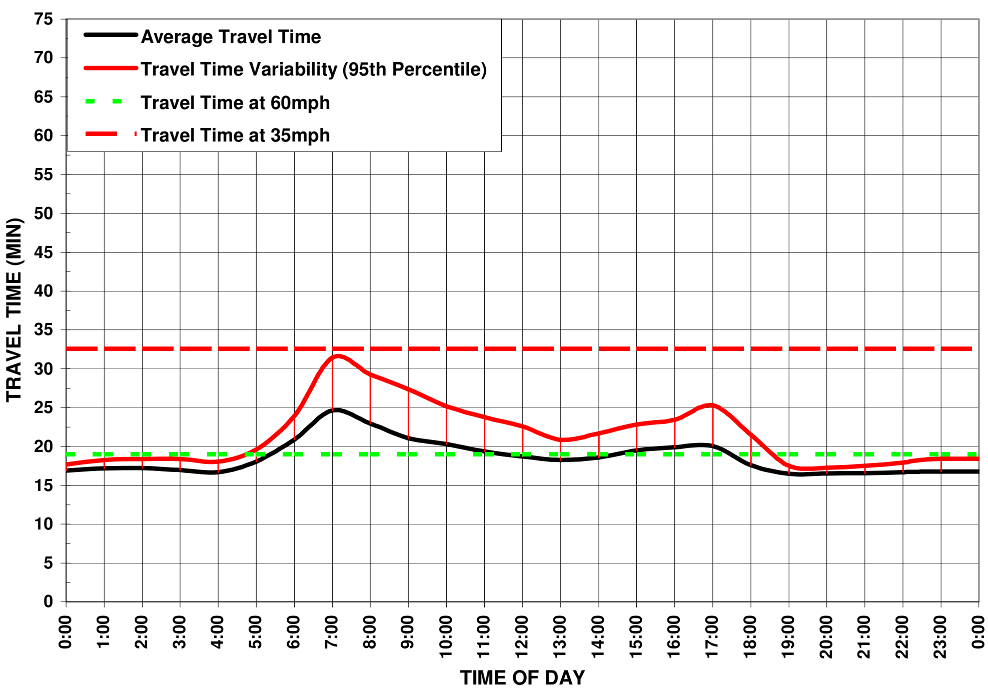
Source: Caltrans detector data

Exhibit 3-36: Westbound Mainline Travel Time Variation (2008)



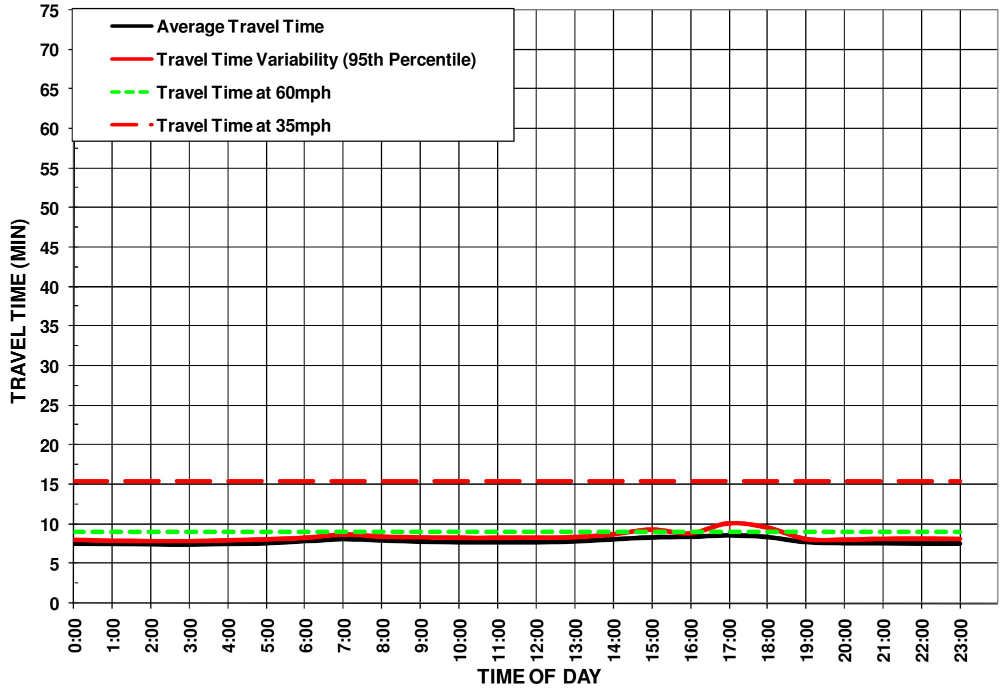
Source: Caltrans detector data

Exhibit 3-37: Westbound Mainline Travel Time Variation (2009)



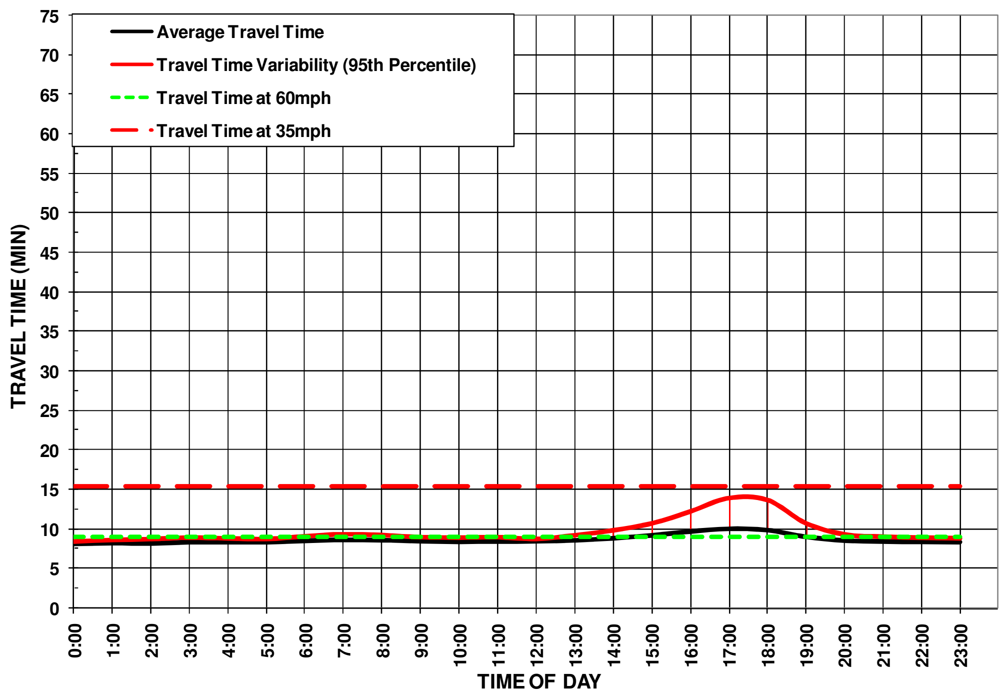
Source: Caltrans detector data

Exhibit 3-38: Eastbound HOV Travel Time Variation (2005)



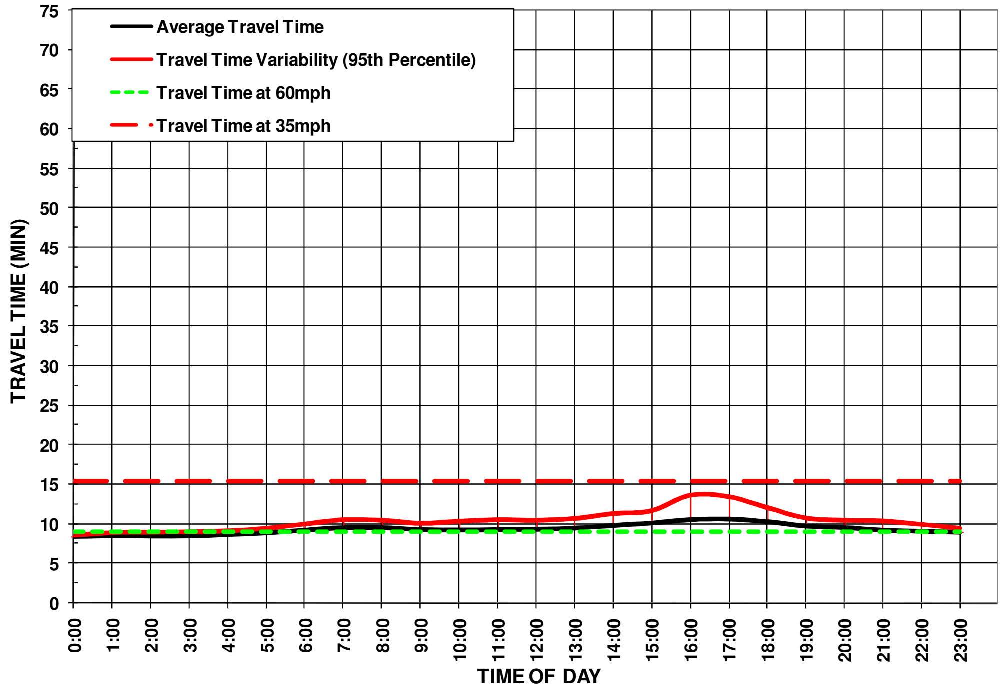
Source: Caltrans detector data

Exhibit 3-39: Eastbound HOV Travel Time Variation (2006)



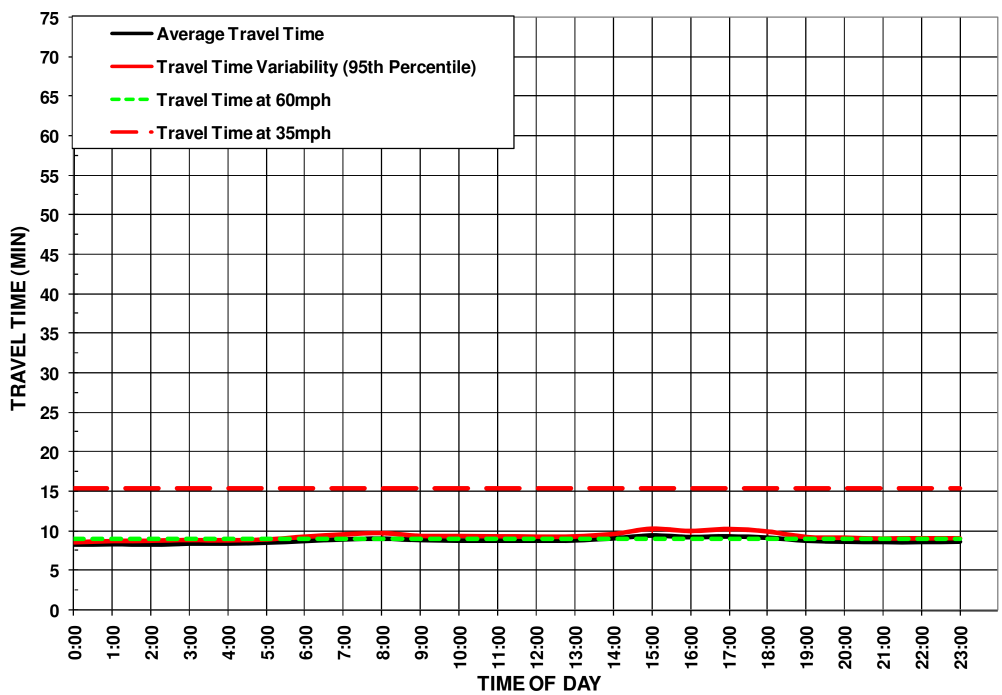
Source: Caltrans detector data

Exhibit 3-40: Eastbound HOV Travel Time Variation (2007)



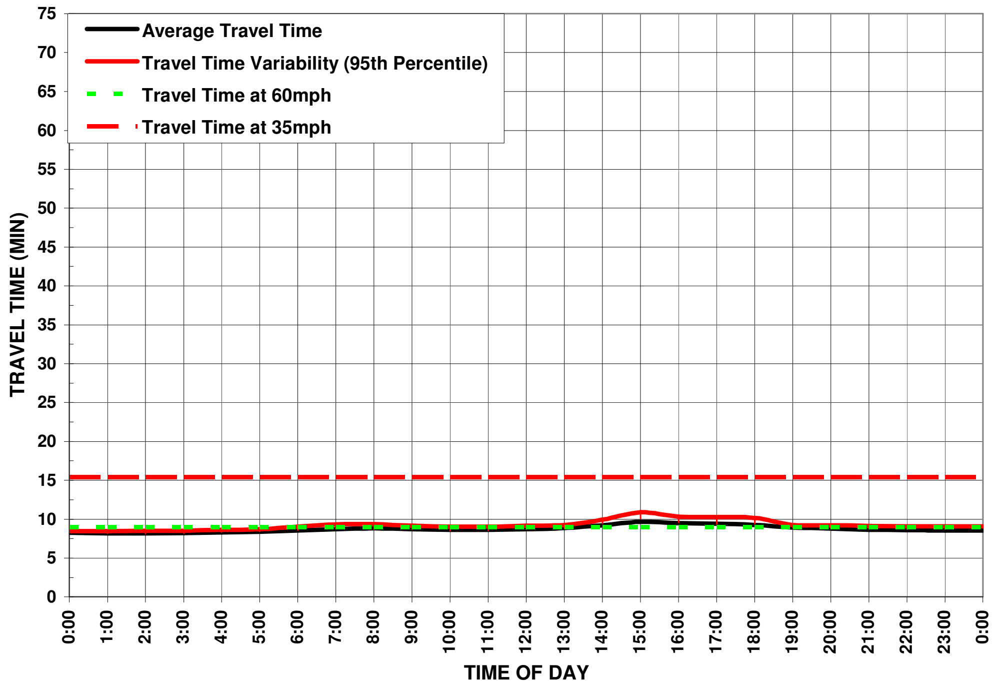
Source: Caltrans detector data

Exhibit 3-41: Eastbound HOV Travel Time Variation (2008)



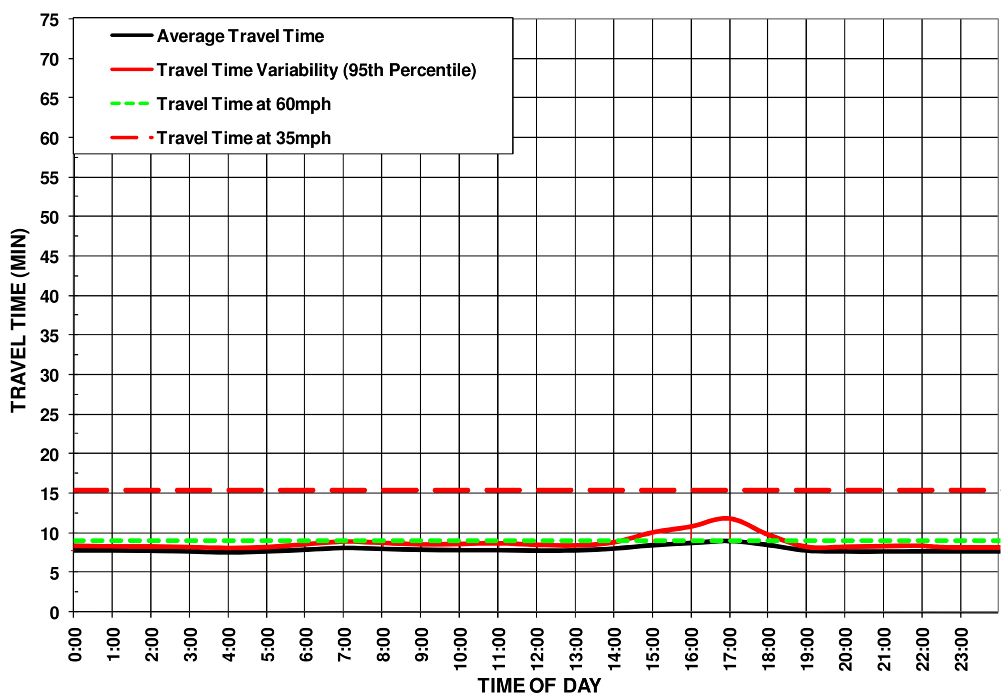
Source: Caltrans detector data

Exhibit 3-42: Eastbound HOV Travel Time Variation (2009)



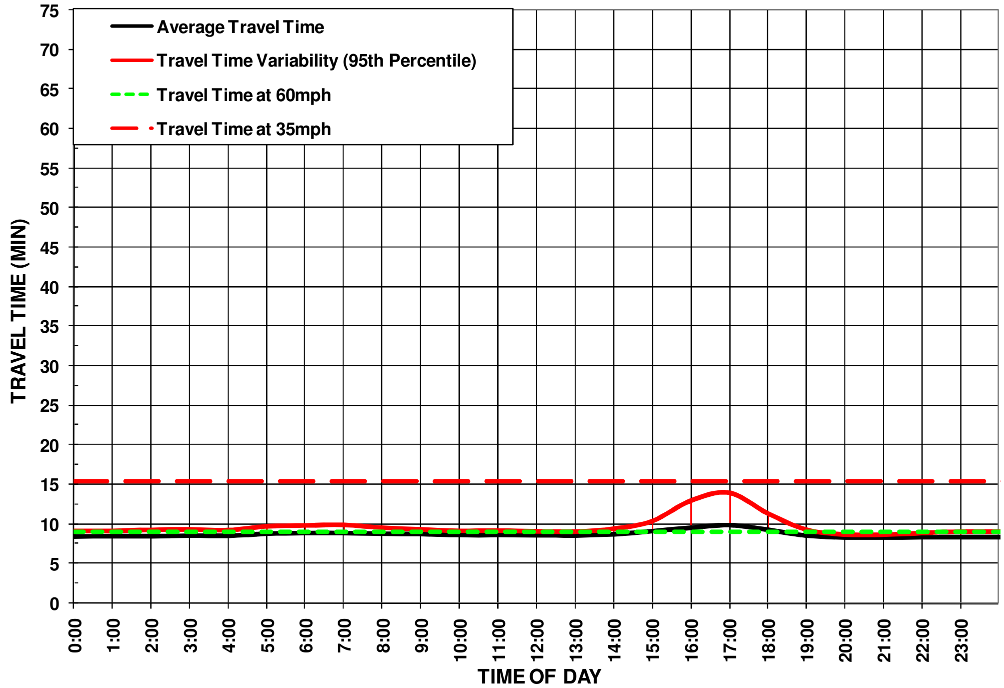
Source: Caltrans detector data

Exhibit 3-43: Westbound HOV Travel Time Variation (2005)



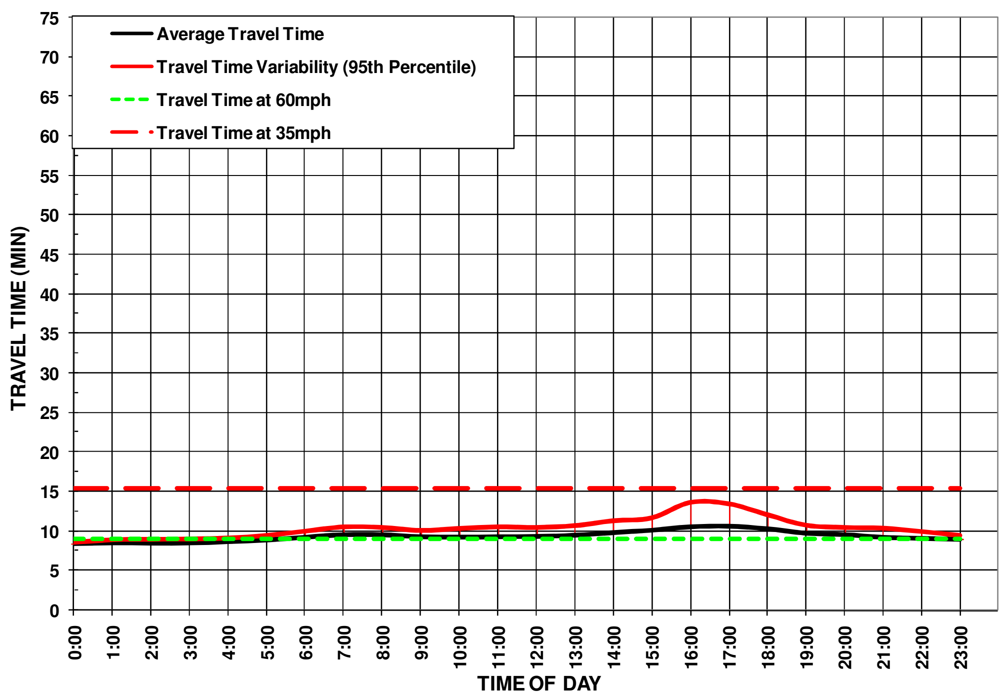
Source: Caltrans detector data

Exhibit 3-44: Westbound HOV Travel Time Variation (2006)



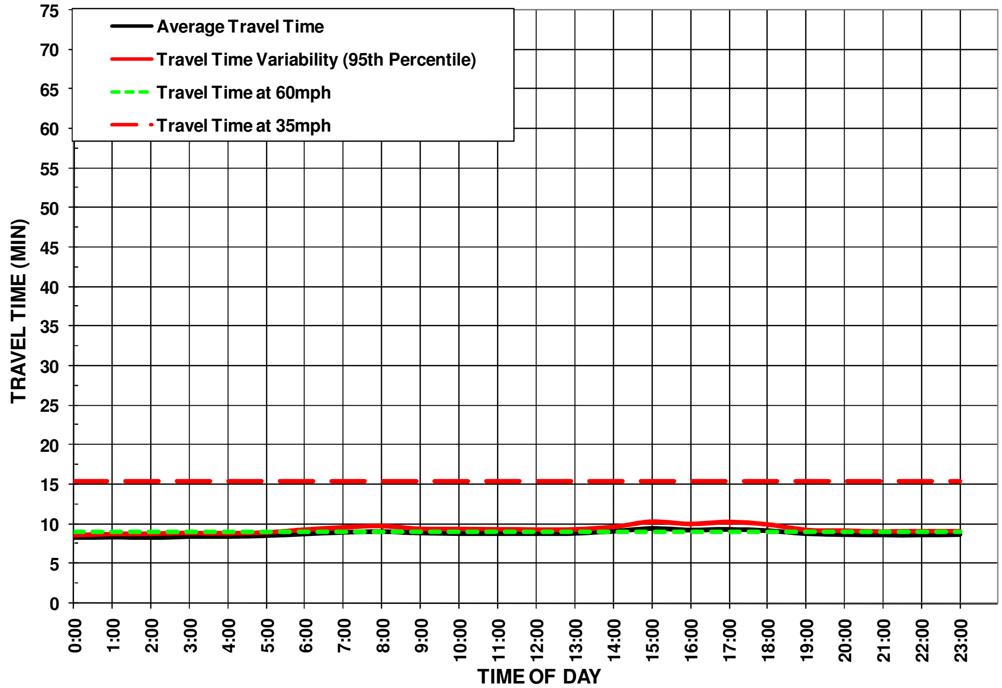
Source: Caltrans detector data

Exhibit 3-45: Westbound HOV Travel Time Variation (2007)



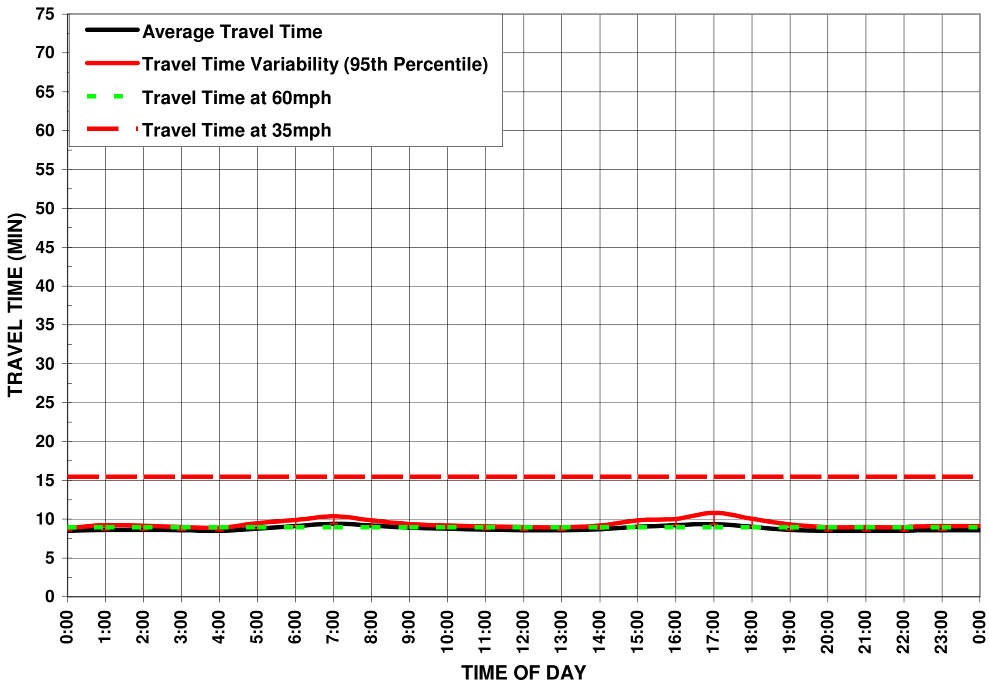
Source: Caltrans detector data

Exhibit 3-46: Westbound HOV Travel Time Variation (2008)



Source: Caltrans detector data

Exhibit 3-47: Westbound HOV Travel Time Variation (2009)



Source: Caltrans detector data

Safety

The adopted performance measures to assess safety involve the number of accidents and the accident rates computed from the Caltrans Traffic Accident Surveillance and Analysis System (TASAS). TASAS is a traffic records system containing an accident database linked to a highway database. The highway database contains descriptive elements of highway segments, intersections and ramps, access control, traffic volumes and other data. TASAS contains specific data for accidents on State Highways. Accidents on non-State Highways are not included (e.g., local streets and roads).

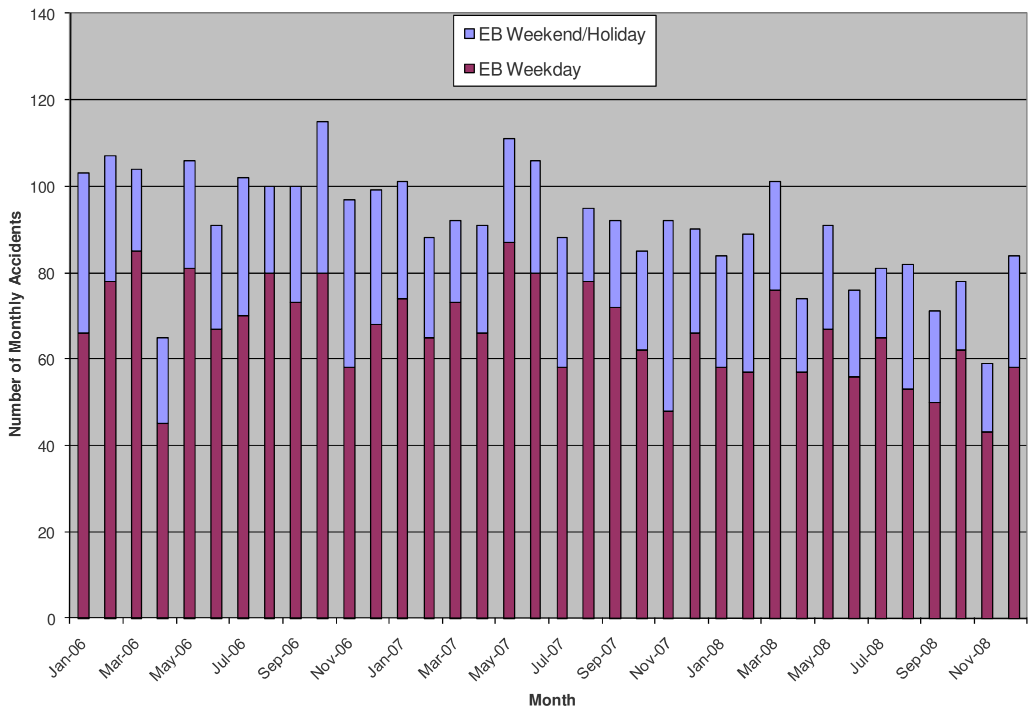
The safety assessment in this report intends to characterize the overall accident history and trends along the SR-91 CSMP Corridor. It also highlights notable accident concentration locations or readily apparent patterns. This report is not intended to replace more detailed safety investigations routinely performed by Caltrans staff.

Exhibits 3-48 and 3-49 illustrate the SR-91 eastbound and westbound accidents by month, respectively. Accidents are reported for the SR-91 CSMP Corridor and not separated by mainline and HOV facility. The latest available three-year data from January 1, 2006 through December 31, 2008 were analyzed and summarized. More recent data are not yet available. Note that TASAS data are comprehensive and do not rely on automatic detection systems.

From 2006 to 2008, westbound SR-91 experienced as many as 118 collisions per month (approximately four per day), while the eastbound direction had up to 110 monthly collisions. It is interesting to note that there were a greater number of collisions in the westbound than the eastbound direction, although the eastbound experienced more congestion each year. In addition, there was a significant increase in total collisions in 2006, which may indicates there was more traffic in 2006 than in prior years. This could validate the 2006 detector-based mobility analysis results. With reduction of congestion and elimination of bottlenecks, these collisions may decrease. Many of the reported accidents were rear-end collisions, which are often indicative of congestion-related incidents. Both directions have shown a decrease in collisions through the end of 2008.

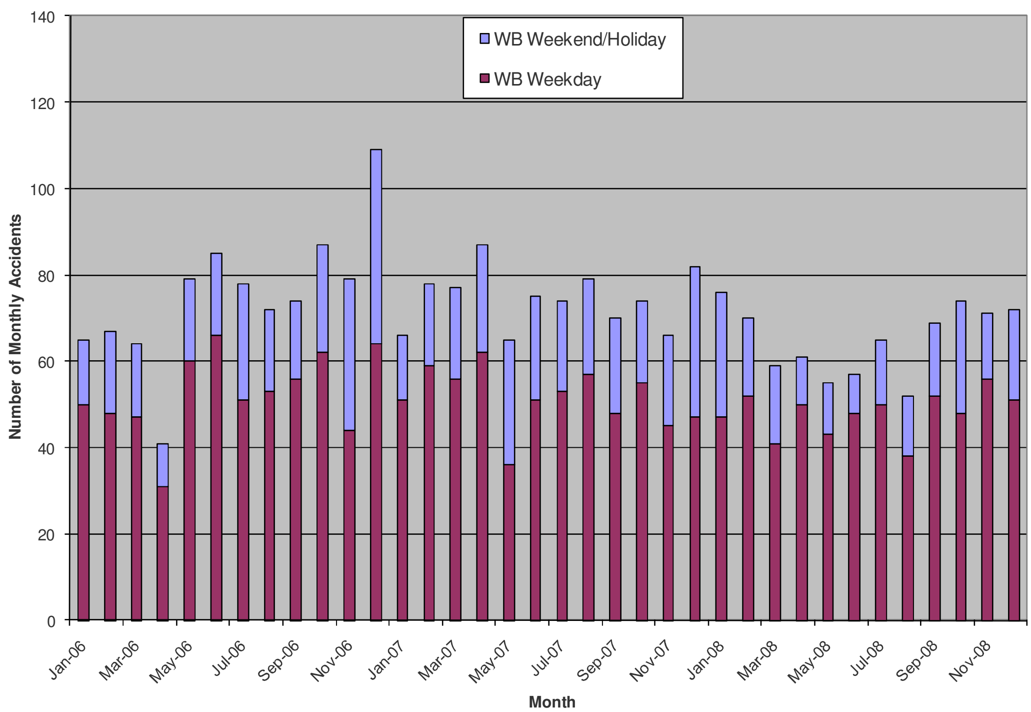
The SR-91 Corridor does not have many parallel routes that offer opportunities for motorists to bypass traffic incidents. To improve travel time reliability, increased incident response could focus on these areas.

Exhibit 3-48: Eastbound Monthly Accidents (2006-2008)



Source: Caltrans TASAS data

Exhibit 3-49: Westbound Monthly Accidents (2006-2008)



Source: Caltrans TASAS data

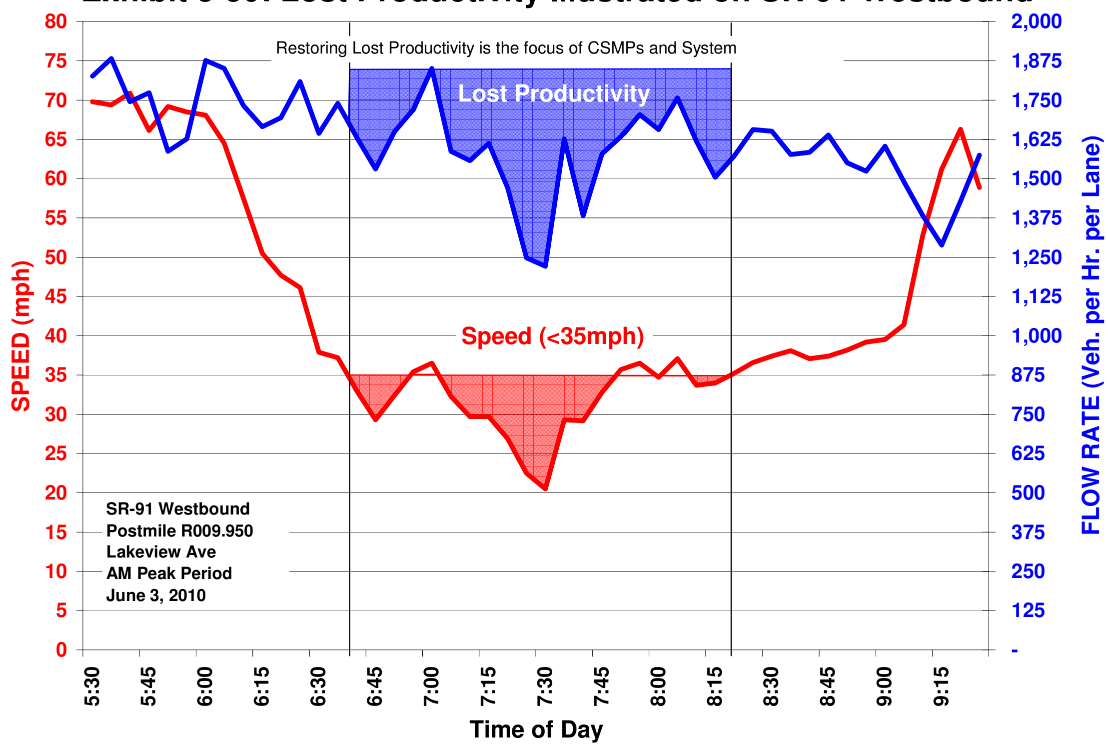
Productivity

Productivity is a system efficiency measure used to analyze the capacity of the SR-91 CSMP Corridor, and is defined as the ratio of output (or service) per unit of input. In the case of transportation, it is the number of people served divided by the level of service provided, or the percent utilization of a facility or mode under peak congested conditions.

For highways, the input to the system is the capacity of the roadway and the output is the number of people or vehicles that can pass through that roadway, and is calculated as the actual volume divided by the theoretical capacity of the highway. Highway productivity is particularly important because where capacity is needed the most, the lowest "production" from the transportation system often occurs.

This loss in productivity example is illustrated in Exhibit 3-50, which is similar to the productivity chart presented in Section 1. As traffic flow increases to the capacity limits of a roadway, speeds decline rapidly and throughput drops dramatically. This loss in throughput is the lost productivity of the system.

Exhibit 3-50: Lost Productivity Illustrated on SR-91 Westbound



There are a few ways to estimate productivity losses. Regardless of the approach, highway productivity calculations require good detection or significant field data collection at congested locations.

One approach is to convert this lost productivity into "equivalent lost lane-miles." These lost lane-miles represent a theoretical level of capacity that would have to be added in order to achieve maximum productivity. For example, losing six lane-miles implies that adding a new lane along a six-mile section of freeway would regain lost productivity. Equivalent lost lane-miles is computed as follows (for congested locations only):

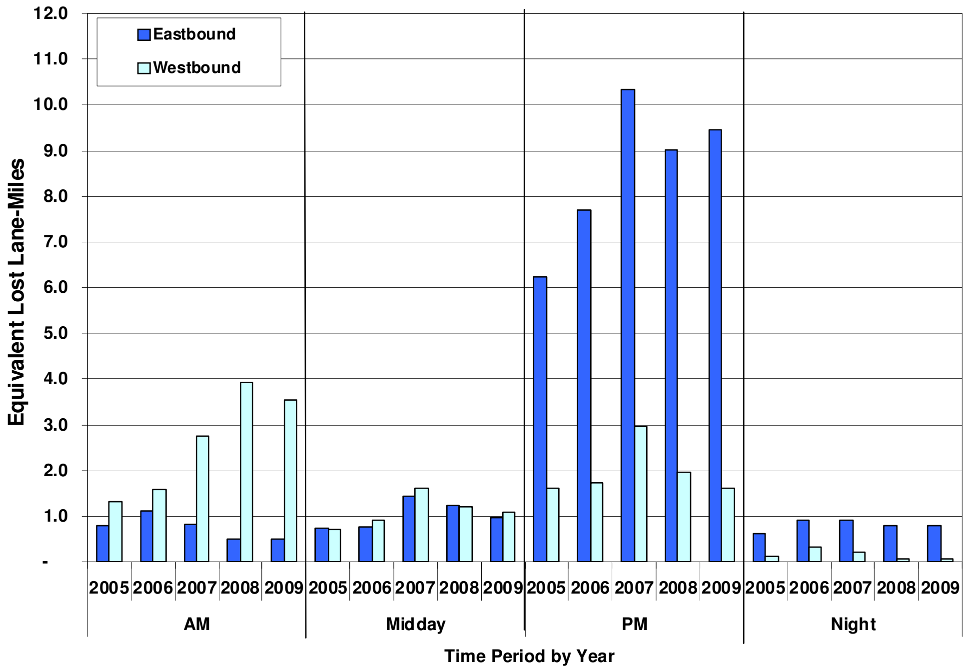
$$LostLaneMiles = \left(1 - \frac{ObservedLaneThroughput}{2000vphpl}\right) \times Lanes \times CongestedLength$$

Exhibits 3-51 and 3-52 summarize the productivity losses on the mainline and HOV facilities from 2005 to 2009. Trends in productivity losses are comparable to the delay trends. The largest losses occurred in the PM peak period in the eastbound direction, which are the time period and direction that experienced the most congestion.

Eastbound PM peak period productivity improved continuously from 2007 to 2008 on the mainline lanes and from 2006 to 2008 on the HOV facility. However, westbound AM peak productivity declined on the mainline during the four years. Express lanes are priced to maximize throughput. Express lanes are managed up to a maximum of 1,600 vphpl and pricing is adjusted to ensure these lanes operate at different flow rates than the mainline.

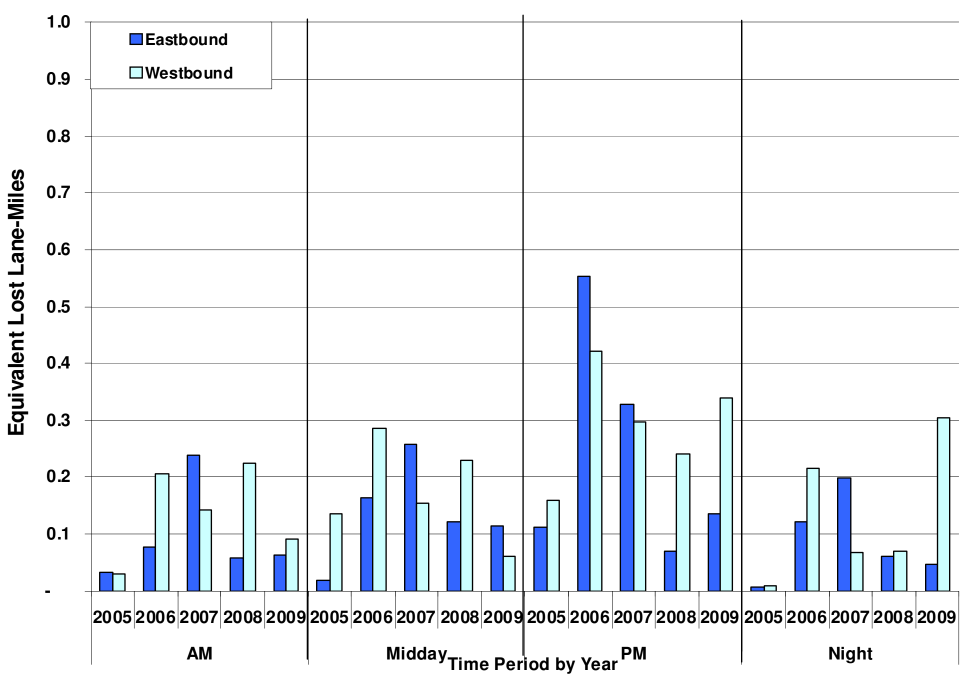
Operational strategies are critical to recovering such productivity losses. These strategies include building new or extending auxiliary lanes, developing more aggressive ramp metering strategies without negatively influencing the arterial network, and improving incident management.

Exhibit 3-51: Mainline Daily Equivalent Lost Lane-Miles by Direction and Time Period (2005-2009)



Source: Caltrans detector data

Exhibit 3-52: HOV Daily Equivalent Lost Lane-Miles by Direction and Time Period (2005-2009)



Source: Caltrans detector data

Pavement Condition

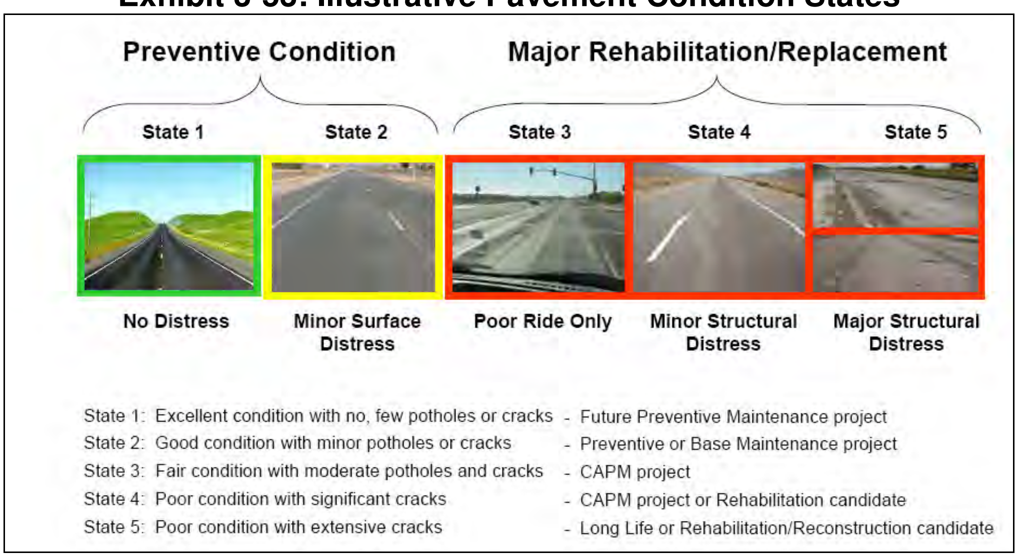
The condition of the roadway pavement (or ride quality) on the SR-91 CSMP Corridor can influence its traffic performance. Rough or poor pavement conditions can decrease the mobility, reliability, safety, and productivity of the corridor, whereas smooth pavement can have the opposite effect. Pavement preservation refers to maintaining the structural adequacy and ride quality of the pavement. It is possible for a roadway section to have structural distress without affecting ride quality. Likewise, a roadway section may exhibit poor ride quality, while the pavement remains structurally adequate.

<u>Pavement Performance Measures</u>

Caltrans conducts an annual Pavement Condition Survey (PCS) that can be used to compute two performance measures: distressed lane-miles and International Roughness Index (IRI). Although Caltrans generally uses distressed lane-miles for external reporting, this report uses the Caltrans data to present results for both measures.

Distressed lane-miles distinguishes among pavement segments that require only preventive maintenance at relatively low costs and segments that require major rehabilitation or replacement at significantly higher costs. All segments that require major rehabilitation or replacement are considered to be distressed. Segments with poor ride quality are also considered to be distressed. Exhibit 3-53 provides an illustration of this distinction. The first two pavement conditions are considered roadway that provides adequate ride quality and is structurally adequate. The remaining three conditions are included in the calculation of distressed lane-miles.

Exhibit 3-53: Illustrative Pavement Condition States



Source: Caltrans Division of Maintenance, 2007 State of the Pavement Report

IRI distinguishes between smooth-riding and rough-riding pavement. The distinction is based on measuring the up and down movement of a vehicle over pavement. When such movement is measured to be 95 inches per mile or less, the pavement is considered good or smooth-riding. When movements are between 95 and 170 inches per mile, the pavement is considered acceptable. Measurements above 170 inches per mile reflect unacceptable or rough-riding conditions.

Existing Pavement Conditions

The most recent pavement condition survey, completed in November 2007, identified 12,998 distressed lane-miles statewide. Unlike prior surveys, the 2007 PCS included pavement field studies for a period longer than a year, due to an update in the data collection methodology. The survey includes data for 23 months from January 2006 to November 2007.

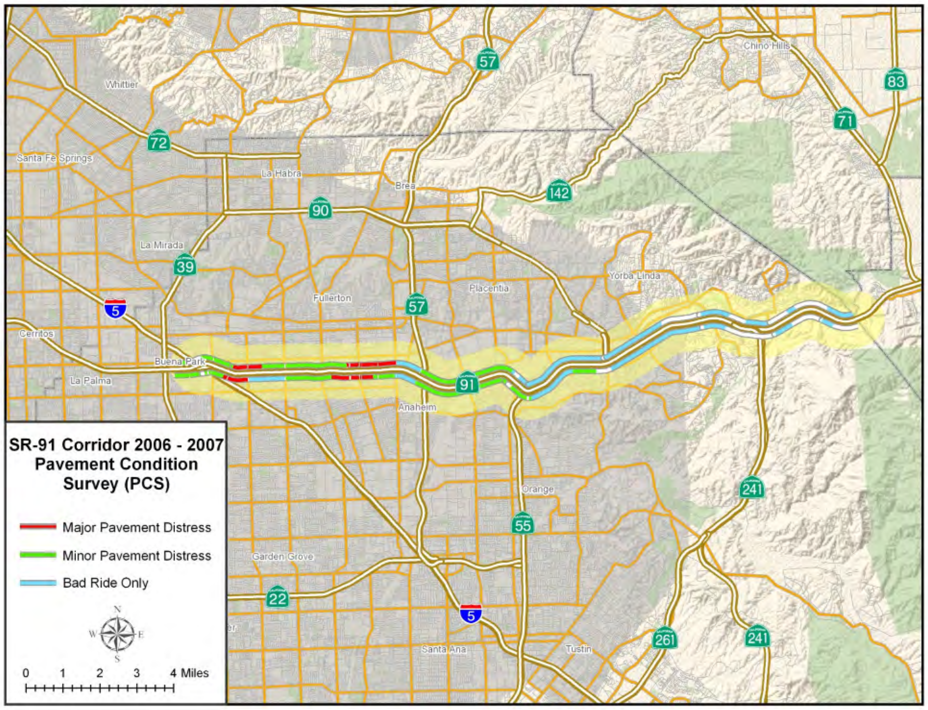
The fieldwork consists of two parts. In the first part, pavement raters visually inspect the pavement surface to assess structural adequacy. In the second part, field staff uses vans with automated profilers to measure ride quality. The 2007 PCS revealed that the majority of distressed pavement was on freeways and expressways (Class 1 roads). This is the result of approximately 56 percent of the State Highway System falling into this road class. As a percentage of total lane-miles for each class, collectors and local roads (Class 3 roads) had the highest amount of distress.

Exhibit 3-54 shows pavement distress along the SR-91 CSMP Corridor according to the 2007 PCS data. The three categories shown in this exhibit represent the three distressed conditions that require major rehabilitation or replacement and were presented earlier in Exhibit 3-53.

In general, pavement on the SR-91 CSMP Corridor is in about the same condition as highways in District 12 as a whole (although the toll roads and recently completed SR-22 have no distressed lane-miles). Most of the SR-91 CSMP Corridor has some kind of distressed conditions, but major pavement distress is limited to the section between I-5 and SR-57. About half of the distressed lane-miles represent minor pavement distress, while about one-third exhibit bad ride quality only.

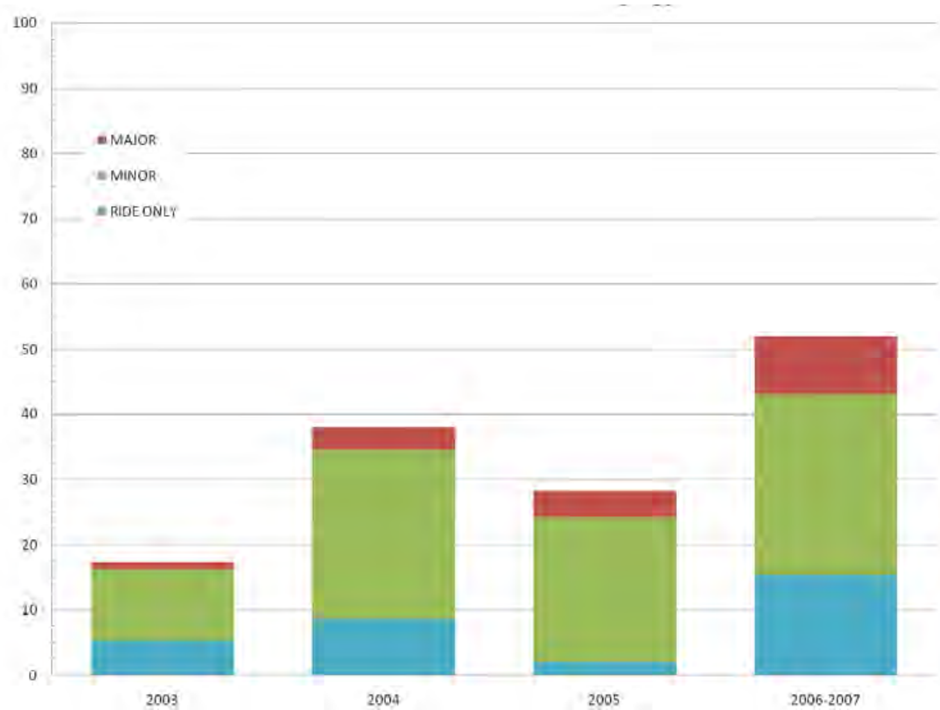
Exhibit 3-55 shows results from prior pavement condition surveys for the SR-91 CSMP Corridor. The total number of distressed lane-miles has generally increased between 2003 and 2006-2007. However, distressed lane-miles did drop and deviate from the trend in 2005. The exhibit also splits the distressed lane-miles by classification. The exhibit shows that the level of distress has stayed roughly even. Although the proportion of major pavement distress has increased slightly, minor pavement distress has been replaced by less severe bad ride only issues. This shift can be seen more clearly in Exhibit 3-56, which shows the percent mix.

Exhibit 3-54: Distressed Lane-Miles (2006-2007)



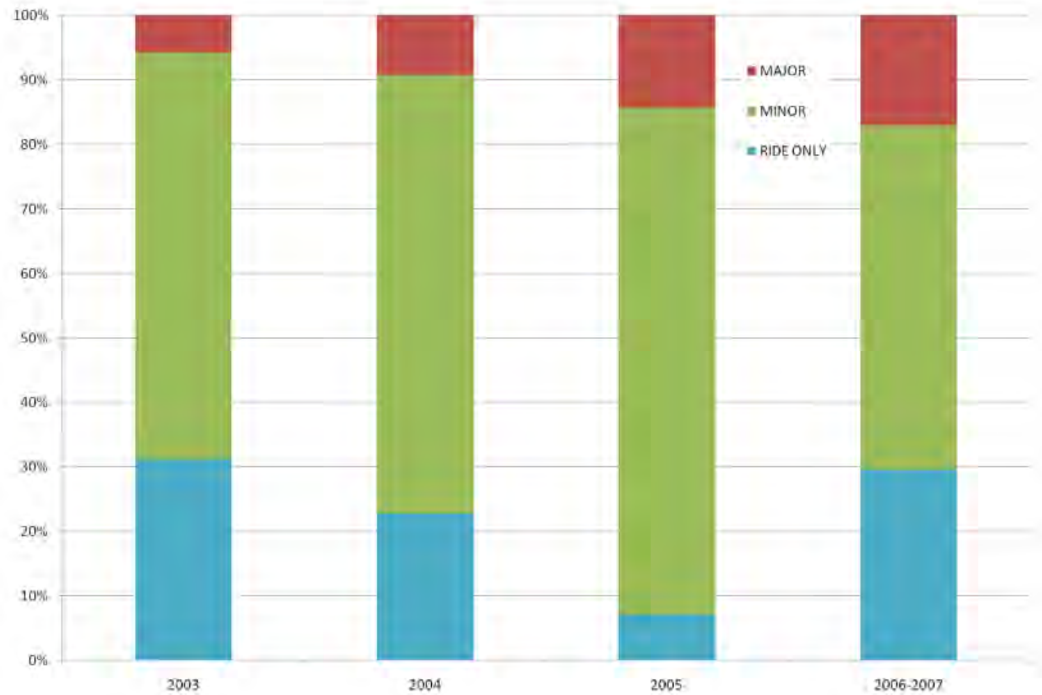
Source: 2007 Pavement Condition Survey data

Exhibit 3-55: Distressed Lane-Mile Trends



Source: 2003 to 2007 Pavement Condition Survey data

Exhibit 3-56: Distressed Lane-Miles by Type of Distress



Source: 2003 to 2007 Pavement Condition Survey data

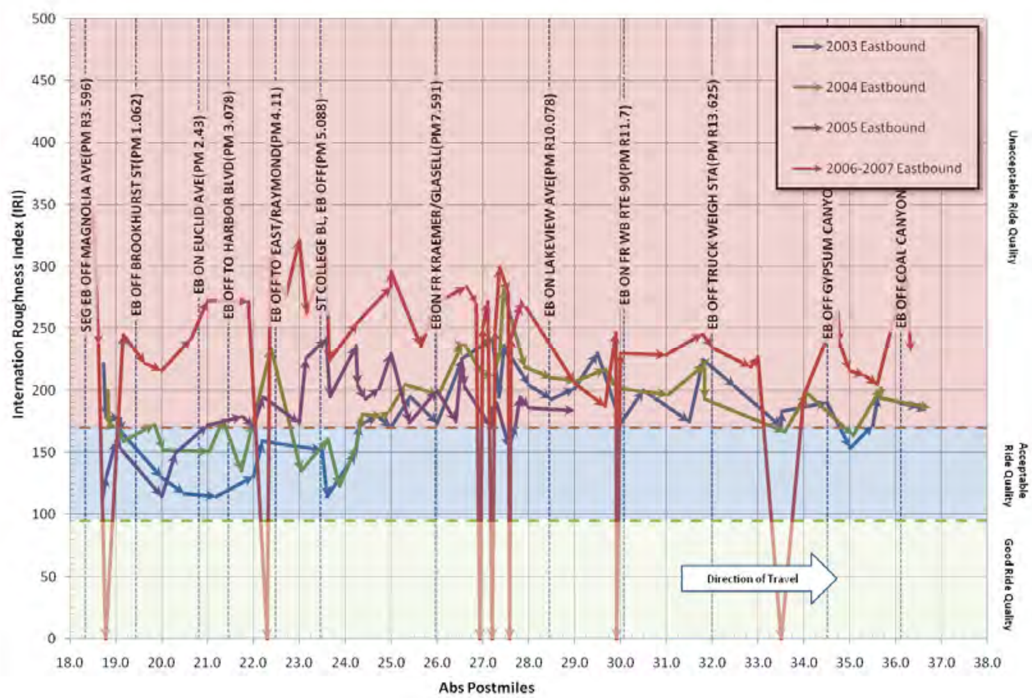
The SR-91 CSMP Corridor comprises roughly 169 lane-miles, of which:

- 49 lane-miles, or 29 percent, are considered to have good pavement conditions (IRI ≤ 95)
- 49 lane-miles, or 29 percent, are considered to have acceptable pavement conditions (95 < IRI ≤ 170)
- 70 lane-miles, or 41 percent, are considered to have unacceptable pavement conditions (IRI > 170).

Exhibits 3-57 and 3-58 present ride conditions based on the IRI measure for the SR-91 CSMP Corridor over the last four pavement surveys. The information is presented by postmile and direction. The exhibits include color-coded bands to indicate the three ride quality categories defined by Caltrans: good ride quality (green), acceptable ride quality (blue), and unacceptable ride quality (red).

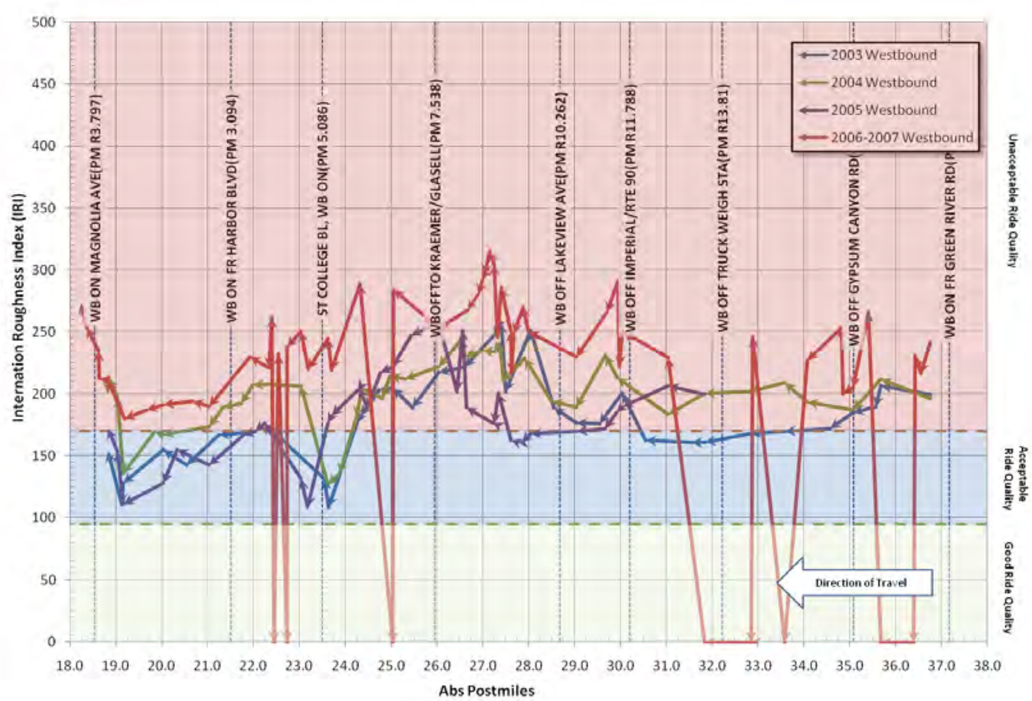
Ride quality worsened considerably between 2005 and the 2006-2007 periods, but this may be due to the 2006-2007 change in data collection methodology. The exhibits show that ride quality is worse in the western section of the corridor, particularly in the eastbound direction.

Exhibit 3-57: Eastbound Pavement International Roughness Index (2003-2007)



Source: 2003 to 2007 Pavement Condition Survey data

Exhibit 3-58: Westbound Pavement International Roughness Index (2003-2007)



Source: 2003 to 2007 Pavement Condition Survey data

4. BOTTLENECK IDENTIFICATION AND PERFORMANCE

Major bottlenecks are the primary cause of congestion and lost productivity. By definition, a bottleneck is a location where traffic demand exceeds the effective carrying capacity of the roadway. In most cases, the cause of a bottleneck relates to a sudden reduction in capacity, such as a lane drop, merging and weaving, driver distractions, a surge in demand, or a combination of factors.

Orange County SR-91 CSMP Corridor bottlenecks were identified and verified during 2008 and 2009 based on a variety of data sources, including State Highway Congestion Monitoring Program (HICOMP) data, Caltrans District 12 probe vehicle runs, automatic detector data, and extensive consultant team field observations and video-taping.

Potential bottleneck locations were initially identified in the Preliminary Performance Assessment report delivered in June 2008. The Comprehensive Performance Assessment delivered in December 2009 presented the results of additional analysis and extensive field observations.

The study team conducted the field observations, videotaping major bottlenecks to document the locations and potential causes of the bottlenecks. These efforts resulted in confirming consistent sets of bottlenecks for both directions of the freeway. Exhibit 4-1 summarizes the bottleneck locations identified in this analysis and their associated delays. The exhibit also shows three bottlenecks indicated by Caltrans, which did not appear until 2009. Caltrans staff indicated that additional bottlenecks likely exist in the westbound direction at Tustin Avenue and the SR-55 On-ramp.

Exhibits 4-2 and 4-3 are maps showing verified bottleneck locations for the AM and PM peak periods.

Exhibit 4-1: SR-91 Bottleneck Locations

Dir	Bottleneck Location	Active Period		Location Postmile
		AM	PM	
Eastbound	Euclid St	✓	✓	2.4
Eastbound	State College Blvd	✓	✓	5.3
Eastbound	SR-57 On	Indicated by Caltrans and did not appear until 2009		
Eastbound	SR-55 Off	Indicated by Caltrans and did not appear until 2009		
Eastbound	SR-90 On	✓	✓	R11.7
Eastbound	Gypsum Canyon Rd On/SR-241	✓	✓	R16.4
Eastbound	Coal Canyon Rd		✓	R17.8
Westbound	Weir Canyon Rd Off	✓	✓	R14.5
Westbound	Truck Weigh Station	✓		R13.3
Westbound	SR-55 Off	✓	✓	R8.9
Westbound	SR-57 Off	Indicated by Caltrans and did not appear until 2009		
Westbound	SR-57 On	✓	✓	6.1
Westbound	State College Blvd	✓	✓	5.1
Westbound	Harbor Blvd	✓	✓	3.1
Westbound	I-5 Off	✓	✓	R3.6

Exhibit 4-2: SR-91 AM Bottleneck Locations

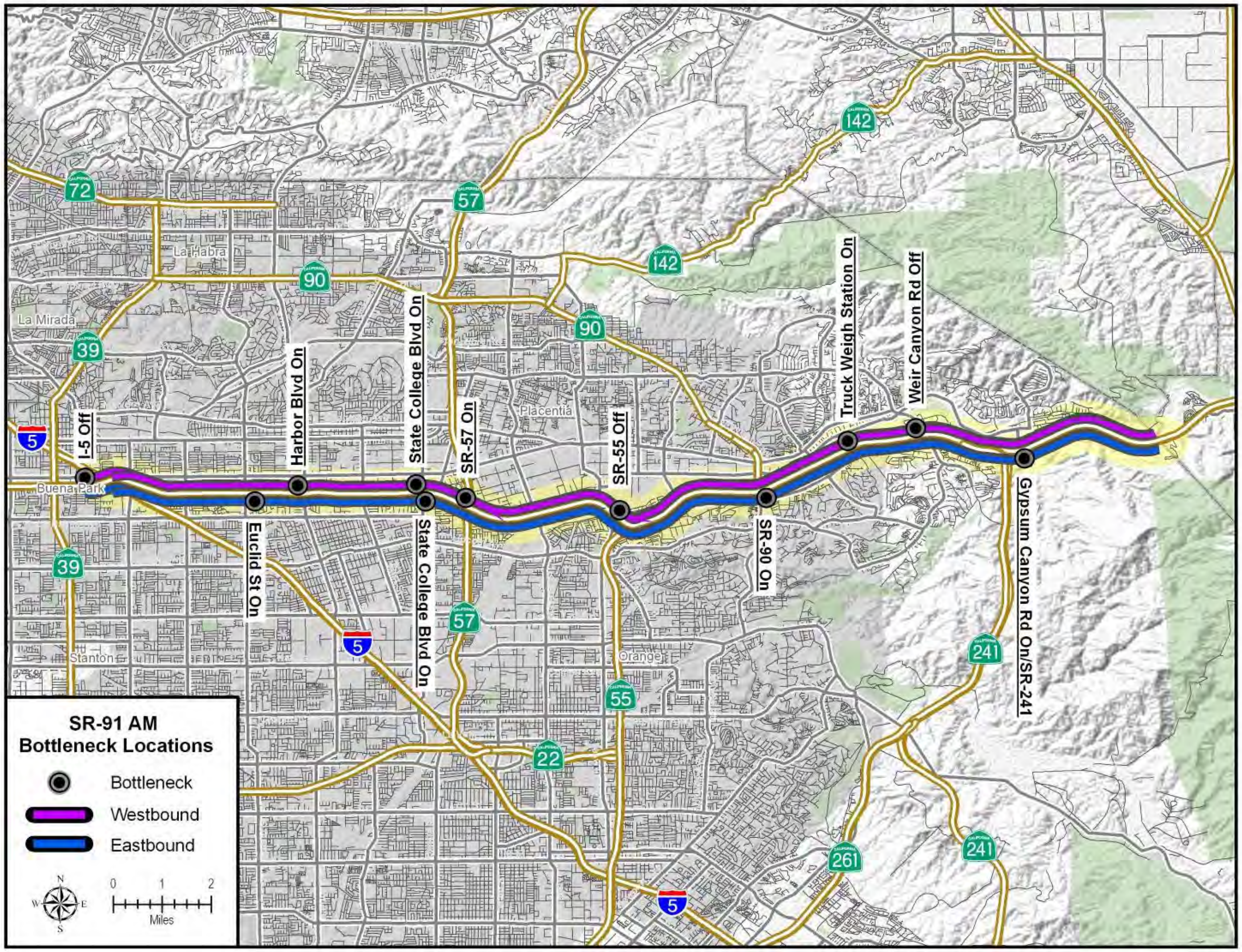
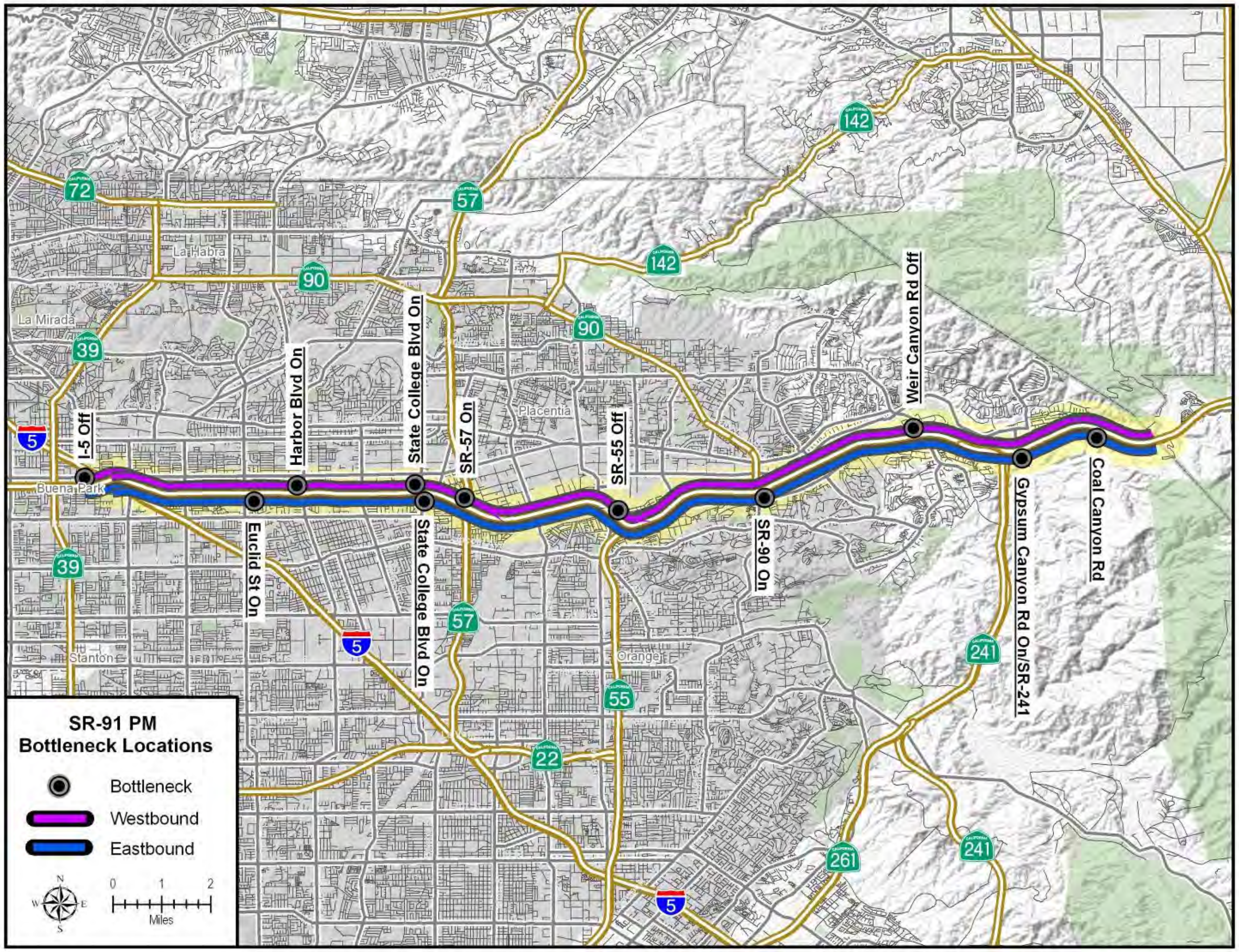


Exhibit 4-3: SR-91 PM Bottleneck Locations



Eastbound Direction Bottlenecks

Starting at I-5 and moving eastbound, the following bottlenecks were verified:

- *Euclid Street* – not directly observable during 2008 field visits.
- *State College Boulevard* – some slowdowns were observed in 2007 around College Boulevard. However, during field observations in 2008, these were not evident. Nevertheless, this bottleneck is included since it may reappear in the future.
- *SR-90 (Imperial Boulevard)* – connector merge bottleneck is not large, but did appear in 2007 data.
- *Gypsum Canyon/SR241* – dual merge creates a consistent bottleneck. The queue from this bottleneck often reaches the SR-90 (Imperial Boulevard) connector.
- *Coal Canyon Road* – the queues of this bottleneck often reach the Gypsum Canyon bottleneck. Note that the Coal Canyon Road Interchange onto SR-91 is not in operation.

Westbound Direction Bottlenecks

Starting at the Riverside County line and moving westbound, the following bottlenecks were verified:

- SR-241 – connector merge bottleneck extends almost to the Weir Canyon Road interchange.
- *Weir Canyon Road* – on-ramp bottleneck extends almost to the Truck Weigh Station.
- *SR-55* – connector off-ramp bottleneck relates to cross-weaving and queuing of vehicles destined to SR-55.
- *SR-57* - connector merge bottleneck extends almost to State College Boulevard.
- Smaller, less relevant bottlenecks from East Street to I-5 – these smaller bottlenecks were not confirmed in recent field visits, but previous data indicated that slowing occurs.

Bottleneck Identification

This section presents the initial bottleneck identification analysis performed as part of the Preliminary Performance Assessment.

A variety of sources was used to identify bottlenecks. They include:

- Caltrans State Highway Congestion Monitoring Program (HICOMP) 2007 report
- Caltrans District 12 probe vehicle runs (electronic tachometer runs)
- Automatic freeway detector data
- Aerial photos (Google Earth) and Caltrans photologs.

State Highway Congestion Monitoring Program

The Caltrans Highway Congestion Monitoring Program (HICOMP) annual report was the first tool used by the study team to identify problem areas. Published annually since 1987, HICOMP attempts to measure "typical" peak period, weekday, and recurring traffic congestion on urban area freeways. HICOMP does not include congestion on other State highways or local surface streets. Non-recurrent congestion such as holiday, maintenance, construction or special-event generated traffic congestion is also not included. HICOMP data are useful for finding general trends and making regional comparisons of freeway performance, but some estimates presented in the report are based on a limited number of observations. Furthermore, HICOMP does not attempt to capture bottleneck locations, but simply report on locations of likely recurrent congestion.

Using the 2007 HICOMP data, potential problem areas were initially identified. As illustrated in Exhibit 4-4 and 4-5, the downstream end of congested segments were initially considered bottleneck areas in the westbound direction (shown with blue circles) and in the eastbound direction (shown with red circles).

Exhibit 4-4: HICOMP AM Congestion Map with Potential Bottlenecks (2007)

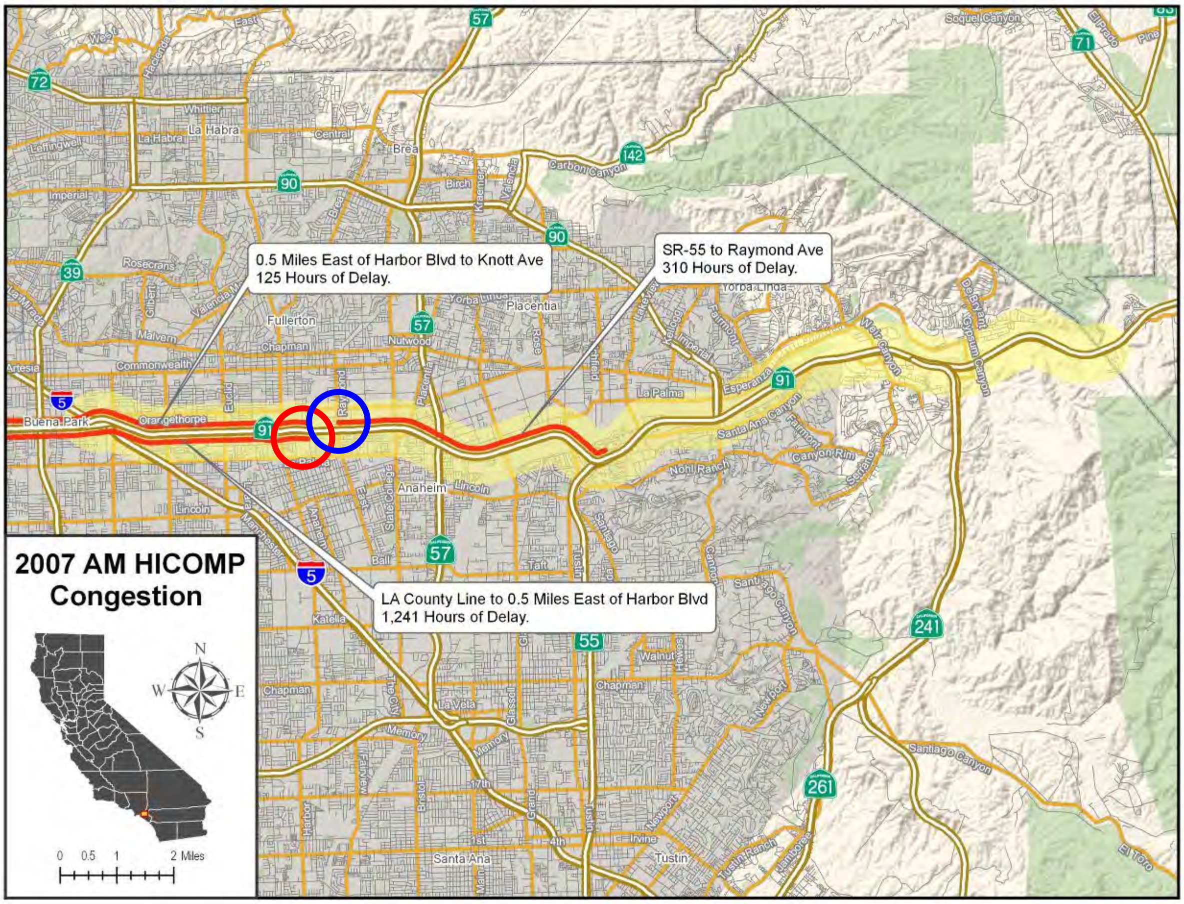
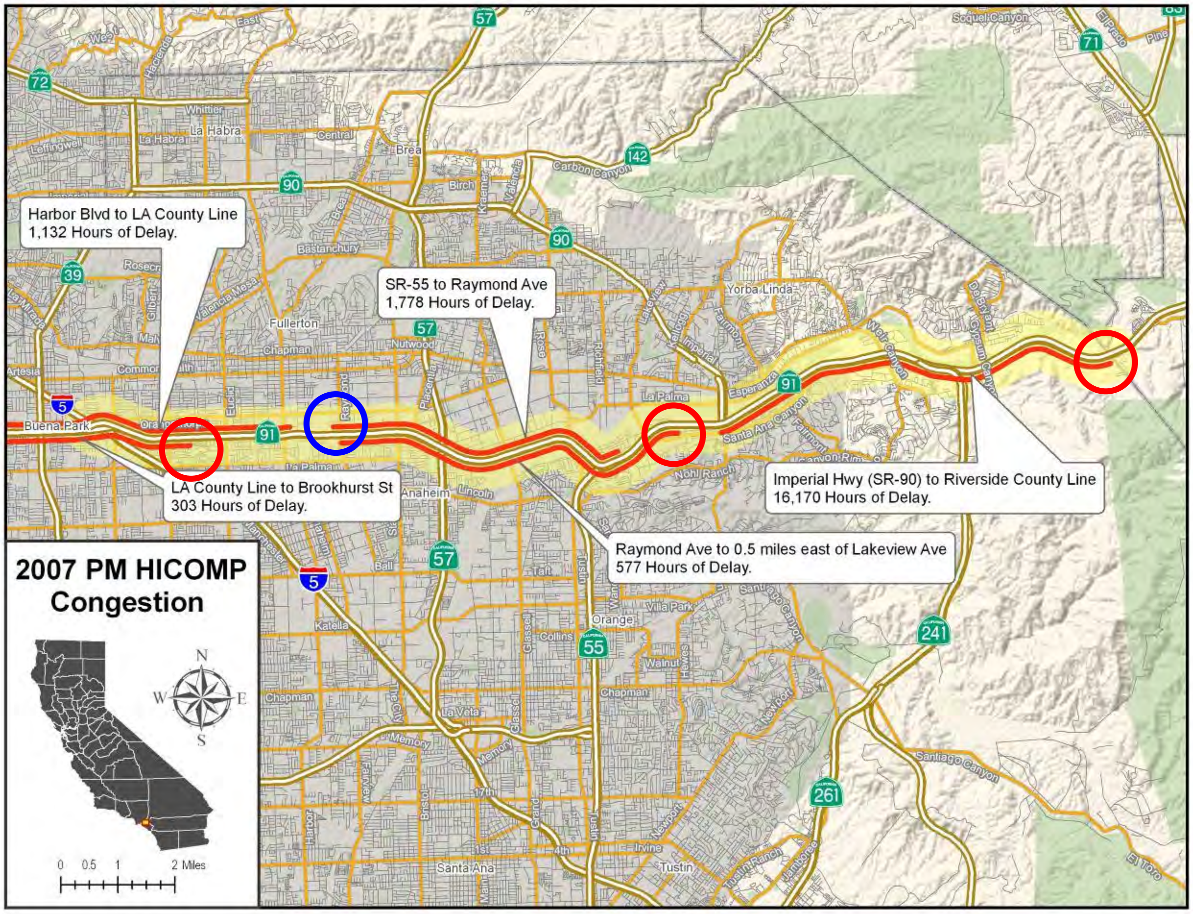


Exhibit 4-5: HICOMP PM Congestion Map with Potential Bottlenecks (2007)



Probe Vehicle Runs

The probe vehicle runs (electronic tachometer runs) provide speed plots across the SR-91 CSMP Corridor at various departure times. A vehicle equipped with an electronic (GPS or tachograph) device is driven along the corridor at various departure times, typically in a middle lane, during the peak period, at regular, 20- to 30-minute intervals. Actual speeds are recorded as the vehicle traverses the corridor. Bottlenecks can be found at the end of a slow congested speed location where speeds pick up to 30 mph to 50 mph.

Caltrans District 12 collected probe vehicle run data in March 2006 for the SR-91 freeway from the Los Angeles County line to the Riverside County line. The probe runs were broken into three separate segments from the Los Angeles County line (Carmenita Road) to East Street, East Street to Imperial Highway, and Imperial Highway to the

Riverside County line (Green River Road). For each segment, runs were conducted from approximately 6:00 AM to 10:00 AM and 3:00 PM to 7:30 PM.

Exhibit 4-6 presents the SR-91 eastbound AM and PM probe vehicle runs from 7:00 AM to 9:00 AM and from 4:00 PM to 6:00 PM. These data were collected on separate days in March 2006. As indicated, there are slow speeds (congestion) and bottlenecks evident in both the AM and PM peak period hours in the eastbound direction. These potential bottleneck locations are highlighted in the exhibit.

Similar to Exhibit 4-6, Exhibit 4-7 shows the westbound AM and PM probe vehicle runs from 7:00 AM to 9:00 AM and from 4:00 PM to 6:00 PM. These data were collected on separate days in March 2006 as well. Both peak periods show bottlenecks as outlined in the exhibit.

Exhibit 4-6: Eastbound Sample Probe Vehicle Runs (March 2006)

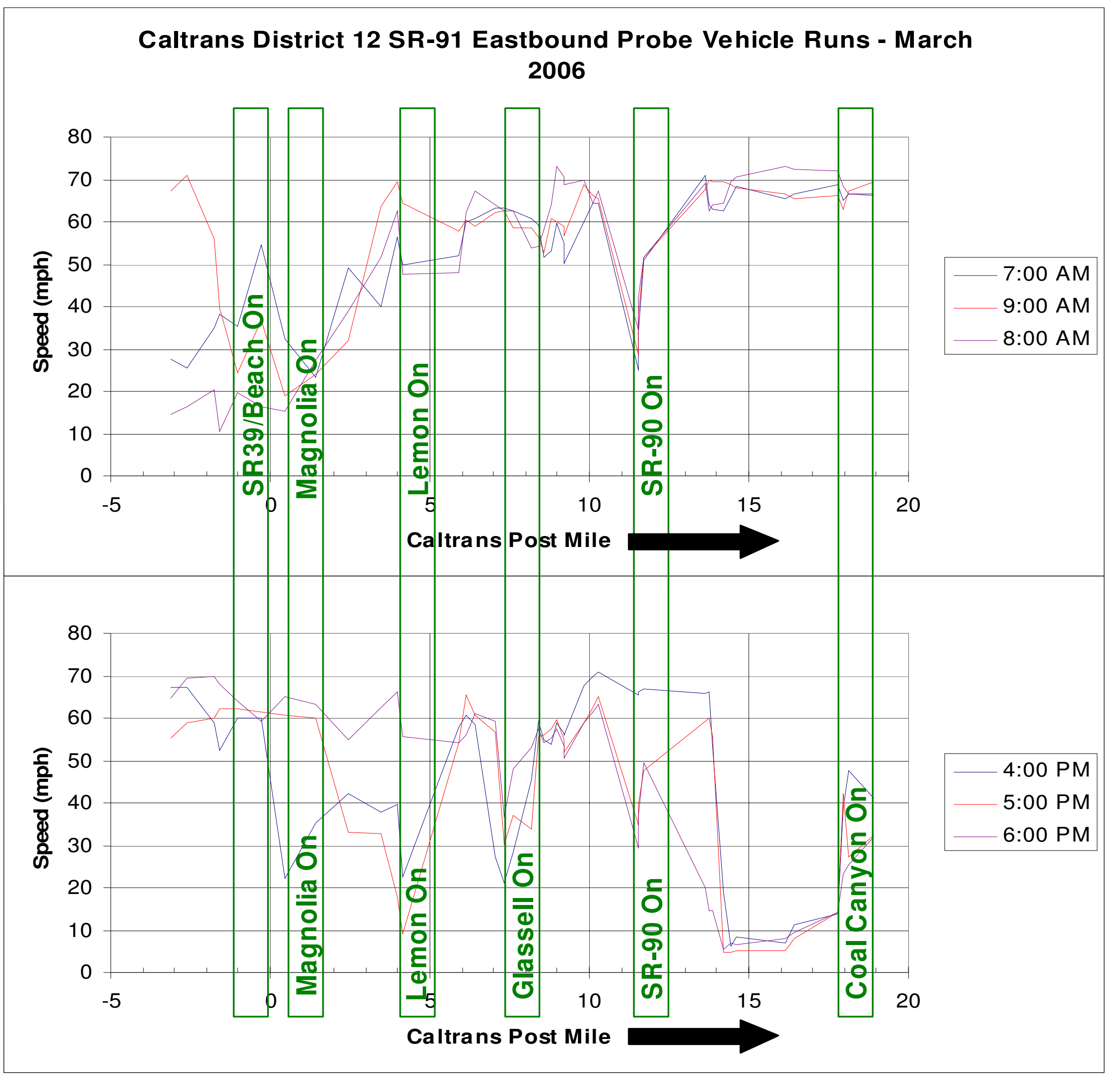
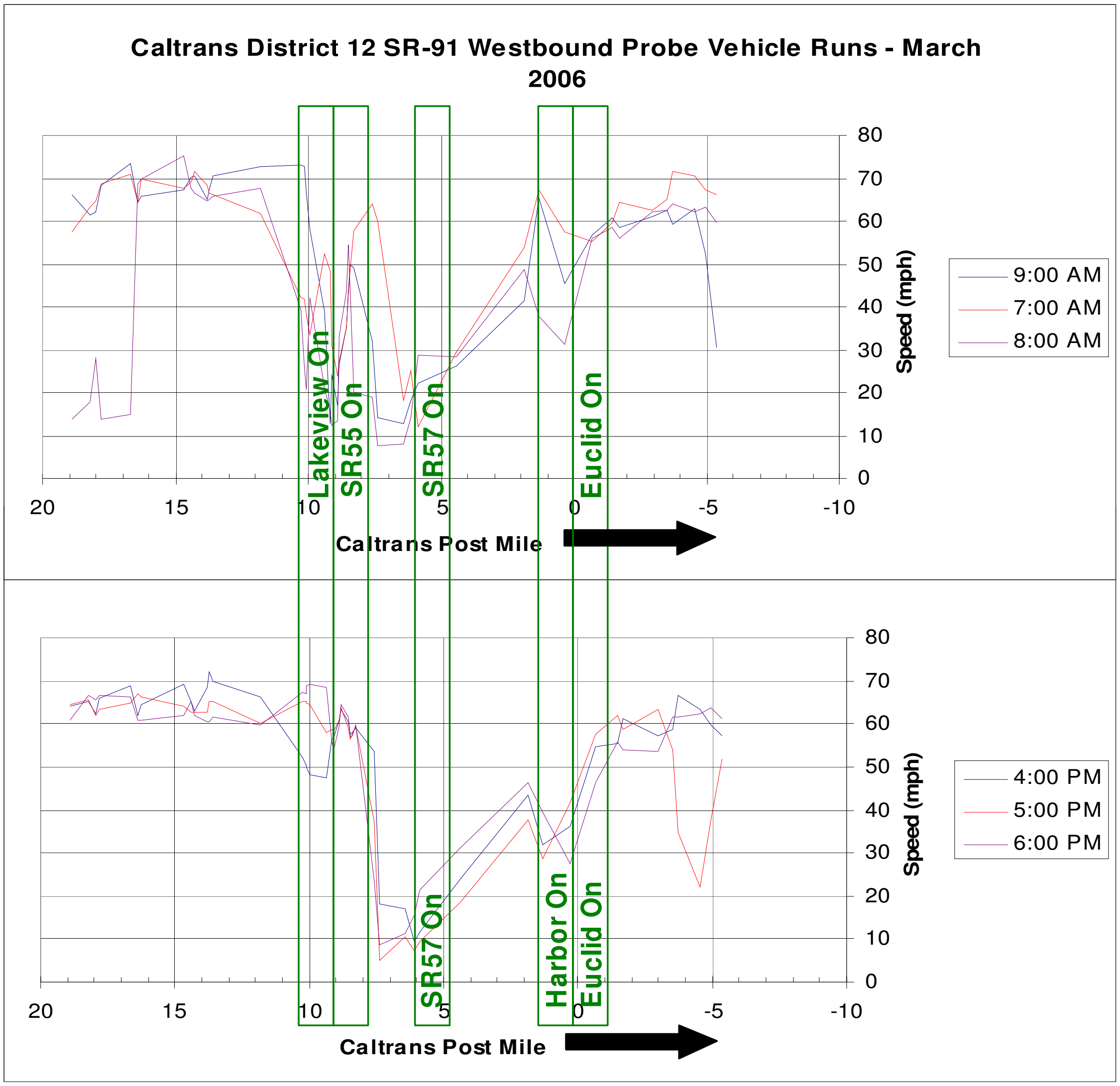


Exhibit 4-7: Westbound Sample Probe Vehicle Runs (March 2006)



Note: Negative Postmile represents Los Angeles County segment Postmile for continuous presentation.

Automatic Detector Data

The third source used to identify potential bottlenecks prior to the in-depth field visits was to review speed contour and speed profile plots from automatic detectors. The study team downloaded detector data to conduct this analysis.

Speed contour plots show speeds for every detector location for every five-minute period throughout the day. The resulting plot shows the location, extent, and duration of congestion.

Speed profile plots are very similar to probe vehicle run graphs. Unlike the probe vehicle runs, however, each speed plot has the same time across the corridor. For example, an 8:00 AM plot includes the speed at one end of the corridor at 8:00 AM and the speed at the other end of the corridor at 8:00 AM. With probe vehicle runs, the end time, or time at the end of the corridor is the departure time plus the actual travel time. Despite this difference, they both identify similar problem areas. These speed plots are then compiled at every five minutes and presented in speed contour plots.

Eastbound SR-91 Detector Analysis

Speed contour and profile plots were analyzed for different weekdays in September and October 2007. "Long-contour" weekday plots for each quarter of 2007 were also reviewed to identify "typical" conditions.

Exhibits 4-8 through 4-11 illustrate the speed contour plots used to analyze eastbound SR-91 (traffic moving left to right on the plot). Along the vertical axis is the time from 4:00 AM to 8:00 PM. Along the horizontal axis is the corridor segment from the Riverside County line (Green River Road) to the Los Angeles County line (Carmenita Avenue).

Exhibit 4-8: Eastbound Speed Contour Plots (September 2007)

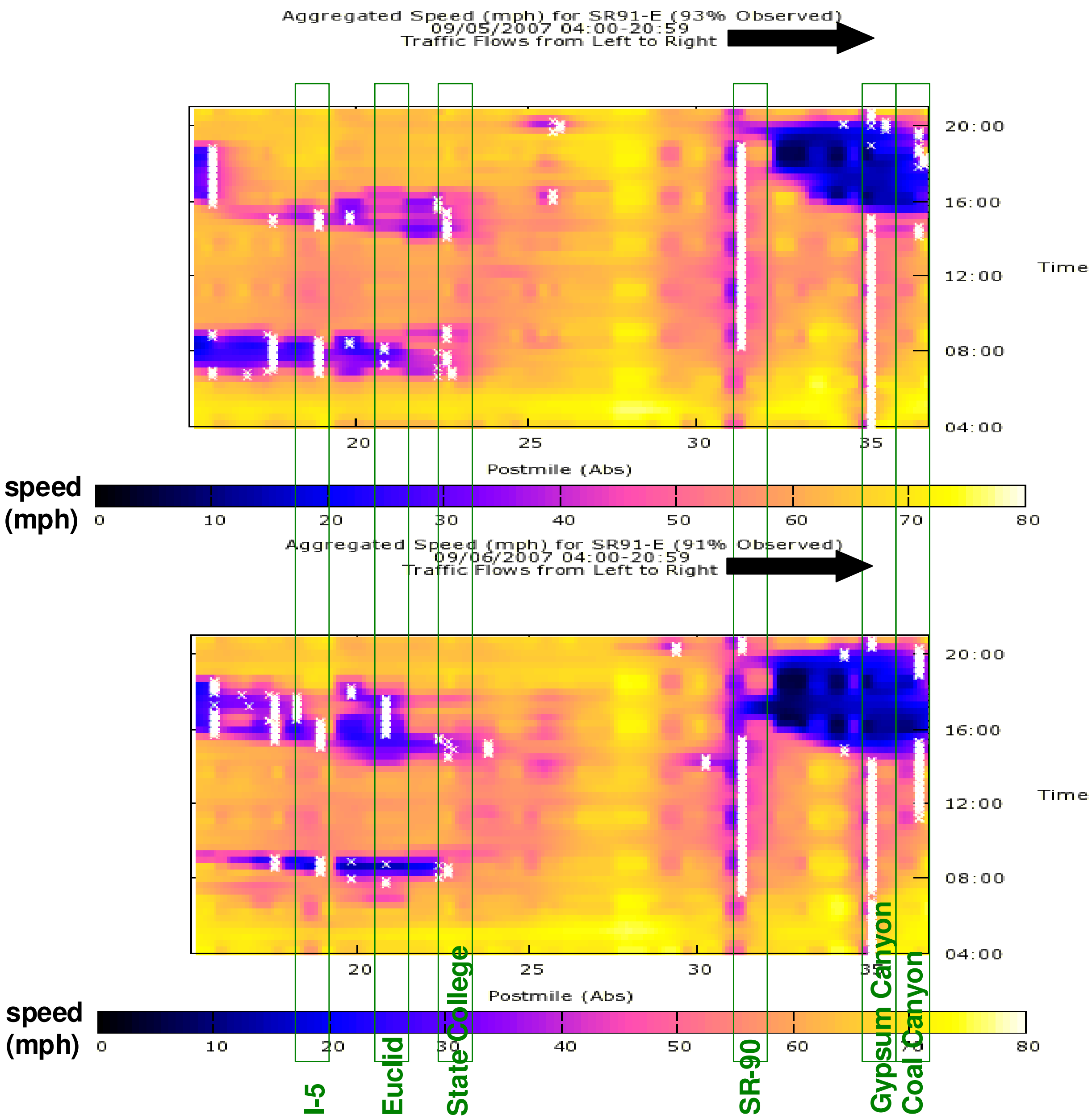


Exhibit 4-9: Eastbound Speed Profile Plots (September 2007)

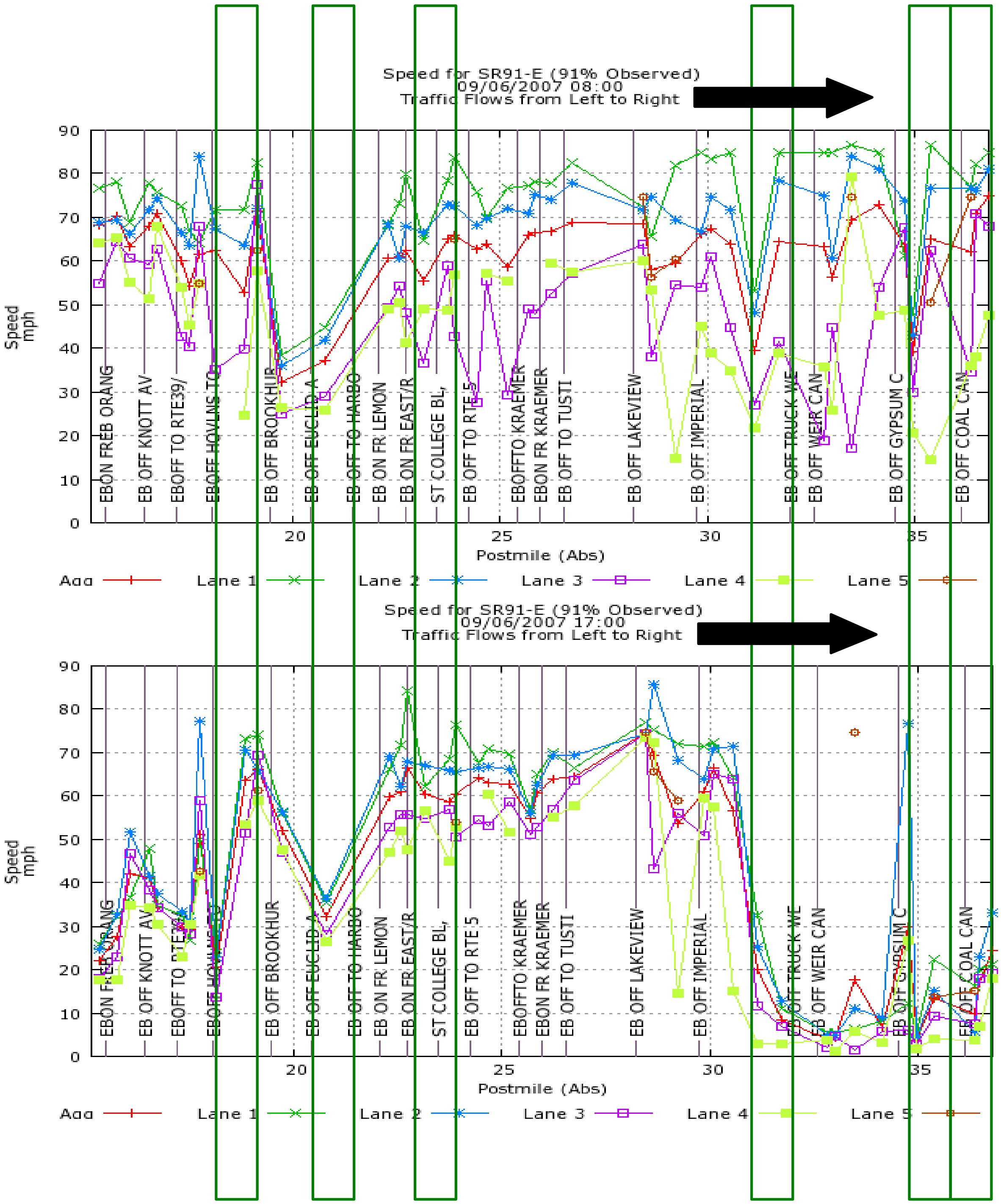


Exhibit 4-10: Eastbound Speed Contour Plots (October 2007)

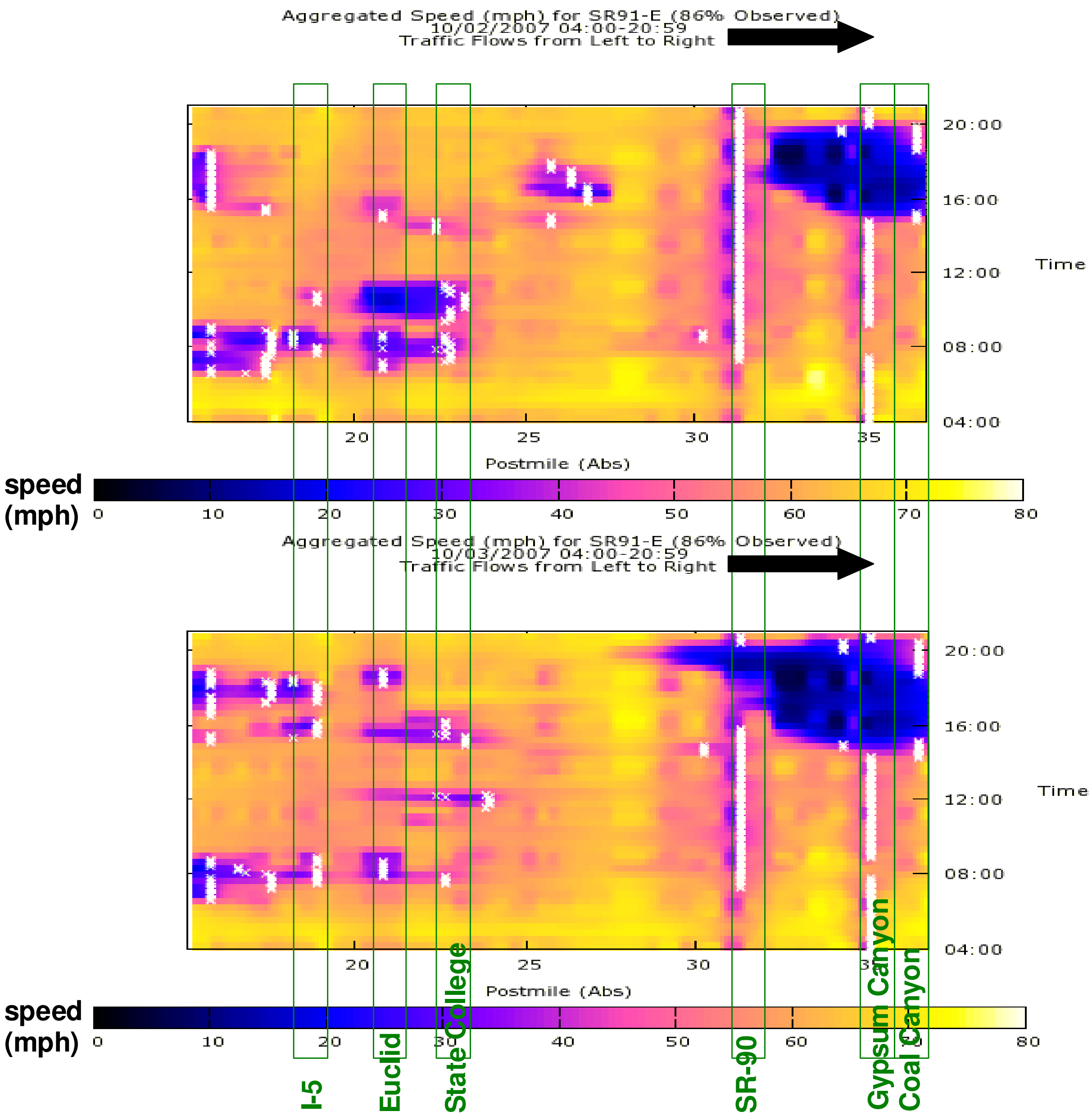
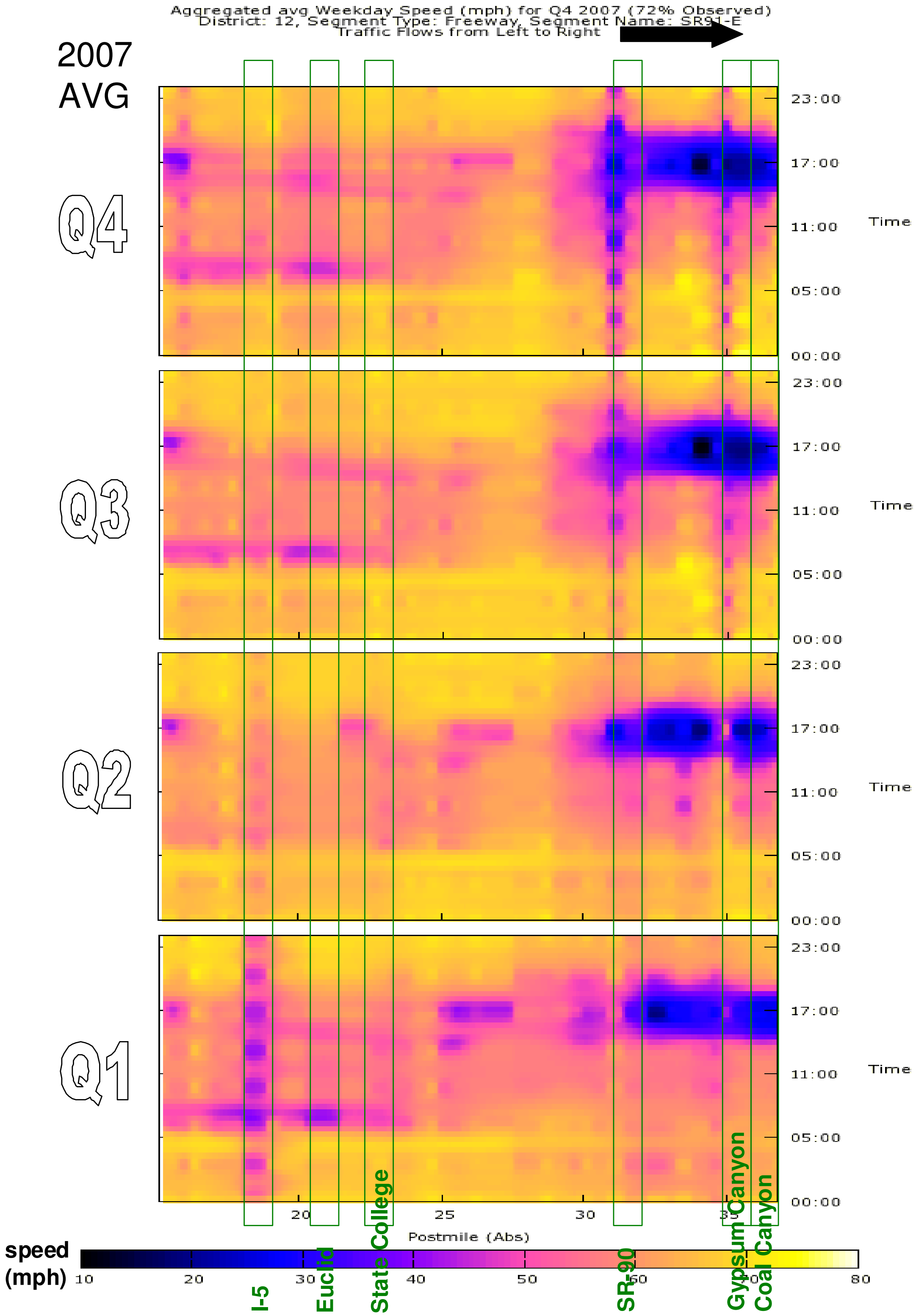


Exhibit 4-11: Eastbound Speed Long Contours (2007 Quarterly Averages)



Westbound SR-91 Detector Analysis

Exhibit 4-12 shows speed contour plots for Tuesday, October 2, 2007 and Wednesday, October 3, 2007. The plots attempt to represent a "typical" weekday to help identify common bottleneck locations and resulting congestion in the westbound direction. The sample days had observed or "good" detection data of at least 89 percent, which the study team believed to provide reasonably reliable congestion estimates.

The vertical axis shows the time of day from 4:00 AM to 8:00 PM. The horizontal axis is the SR-91 CSMP Corridor segment from Green River Road to Carmenita Avenue. The varying colors represent the average speeds corresponding to the legend at the bottom of the chart - the darker the shade of "blue" the slower the speed, with the darker areas representing bottleneck areas. From this plot, one can see the location of the bottleneck, the extent of the resulting queue, the duration of the congestion, and some indication of the magnitude of congestion experience (the darker the color, the more congested the location).

Exhibit 4-13 is the speed profile plots on Wednesday, October 3, 2007. These plots also attempt to represent a typical weekday to help identify bottleneck locations and congestion formed from them at a particular time in the day, in this case at 8:00 AM in the morning and 5:00 PM in the evening.

In addition to the two days in October 2007, additional days were analyzed. Exhibit 4-14 is the speed contour plot of the November 2007 weekdays. The same bottleneck locations are identified on each of the two different sample days, indicating a reoccurring pattern of the bottleneck locations.

In addition to multiple days, larger quarterly averages were also analyzed. Exhibit 4-15 illustrates the weekday averages by each quarter of 2007. These "long contours" tend to smooth out extreme variations in traffic congestion caused by incidents or other variables. Again, the quarterly averages reveal the same bottleneck locations.

Exhibit 4-12: Westbound Speed Contour Plots (October 2007)

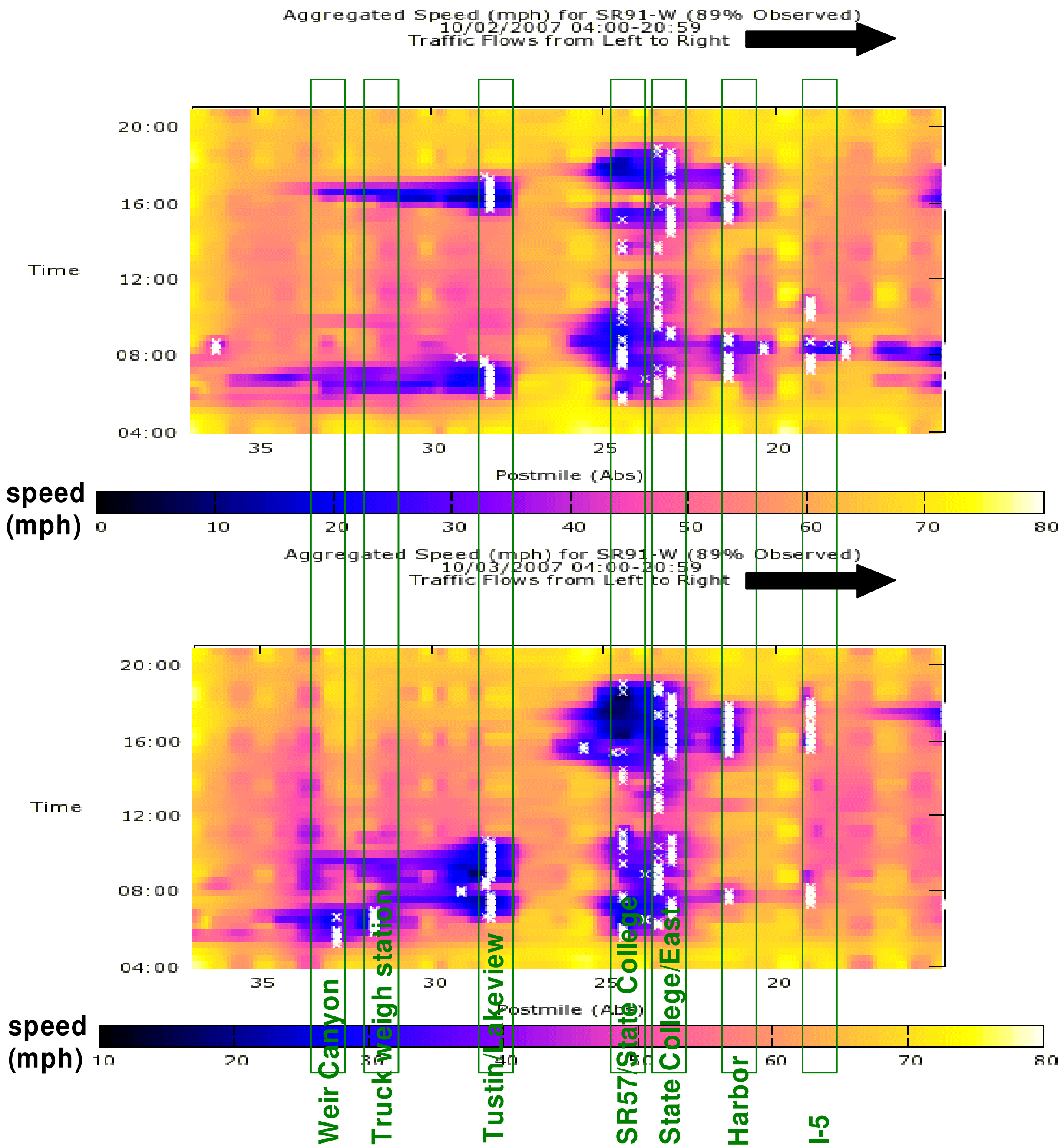


Exhibit 4-13: Westbound Speed Profile Plots (October 2007)

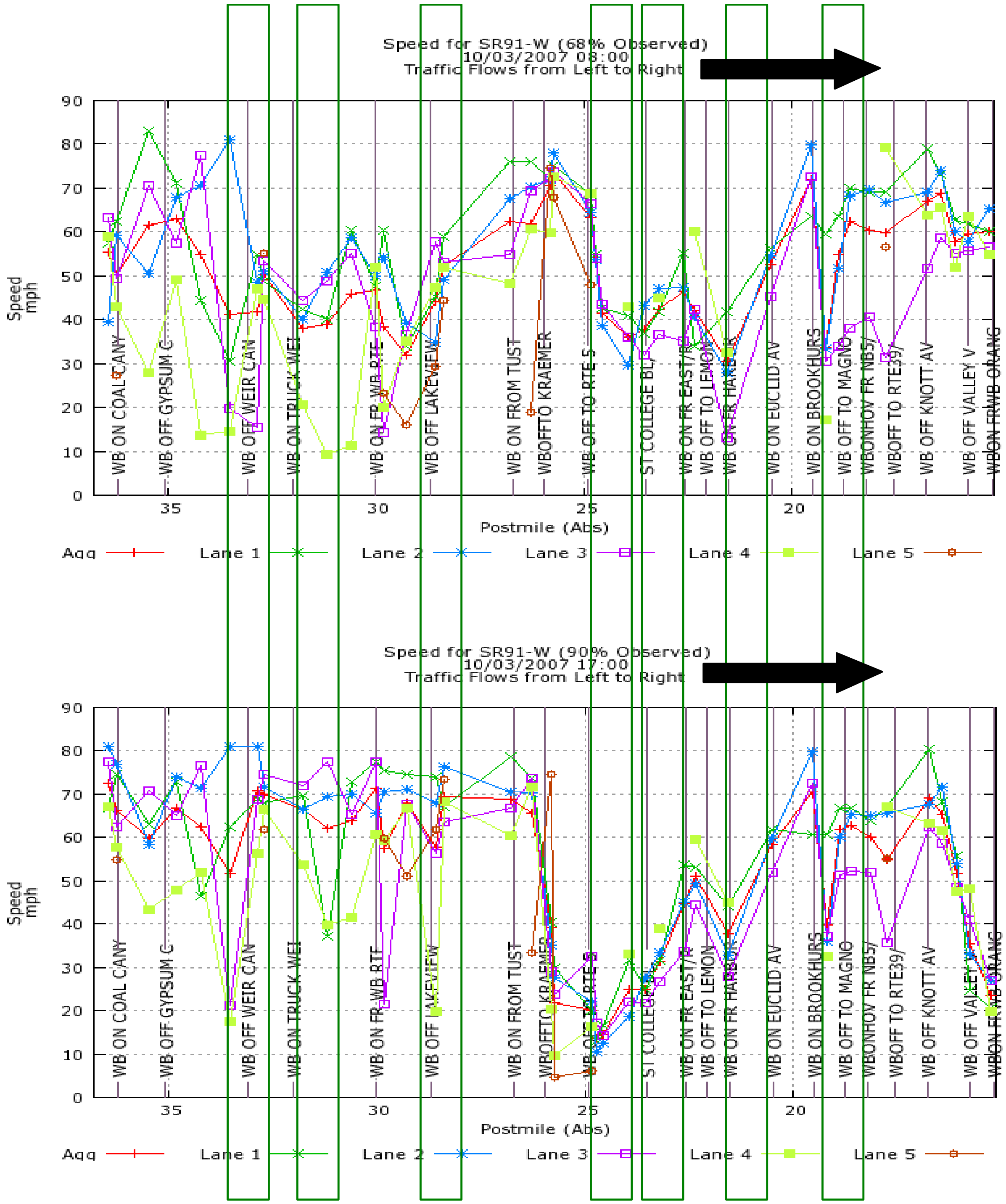


Exhibit 4-14: Westbound Speed Contour Plots (November 2007)

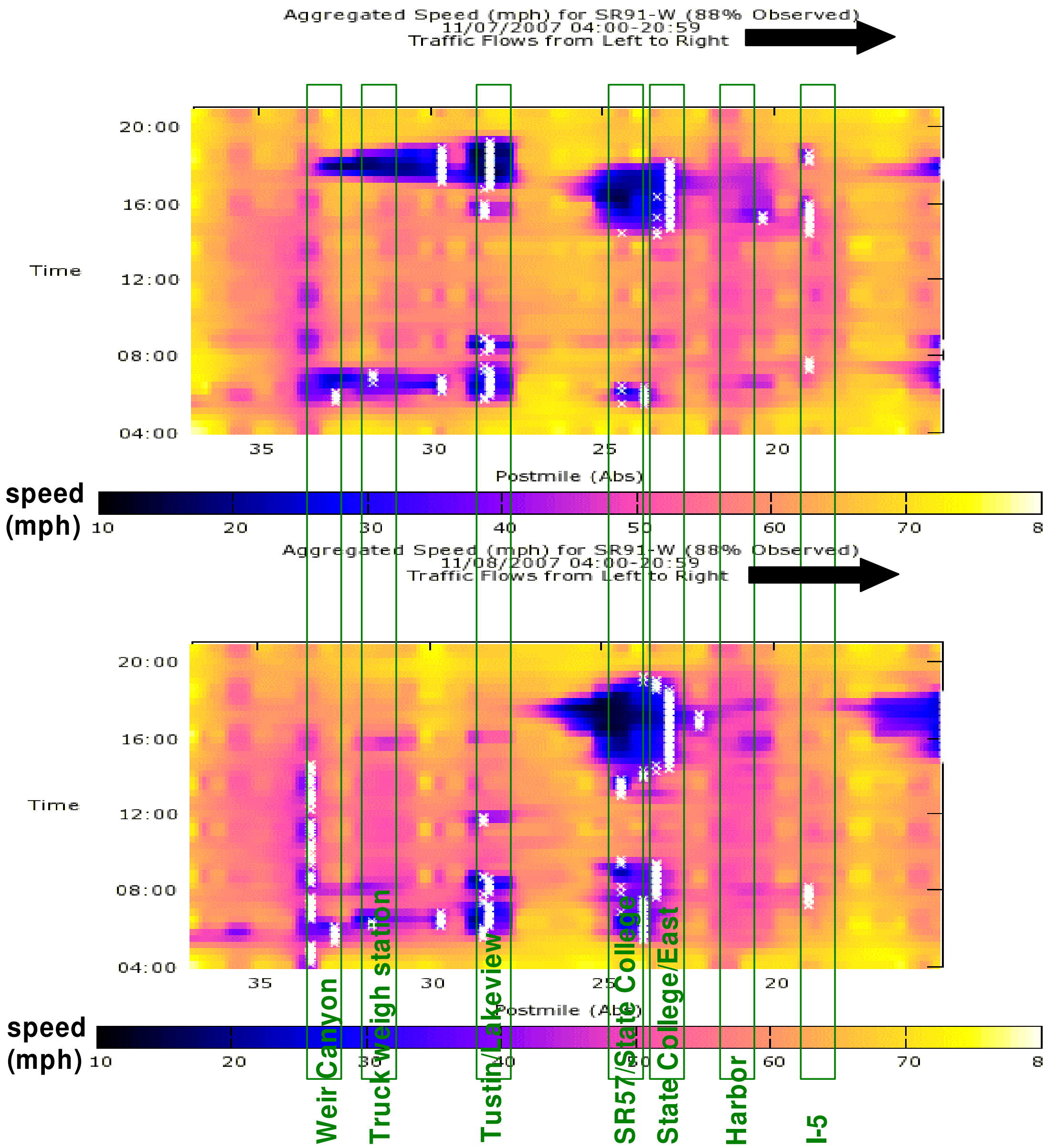
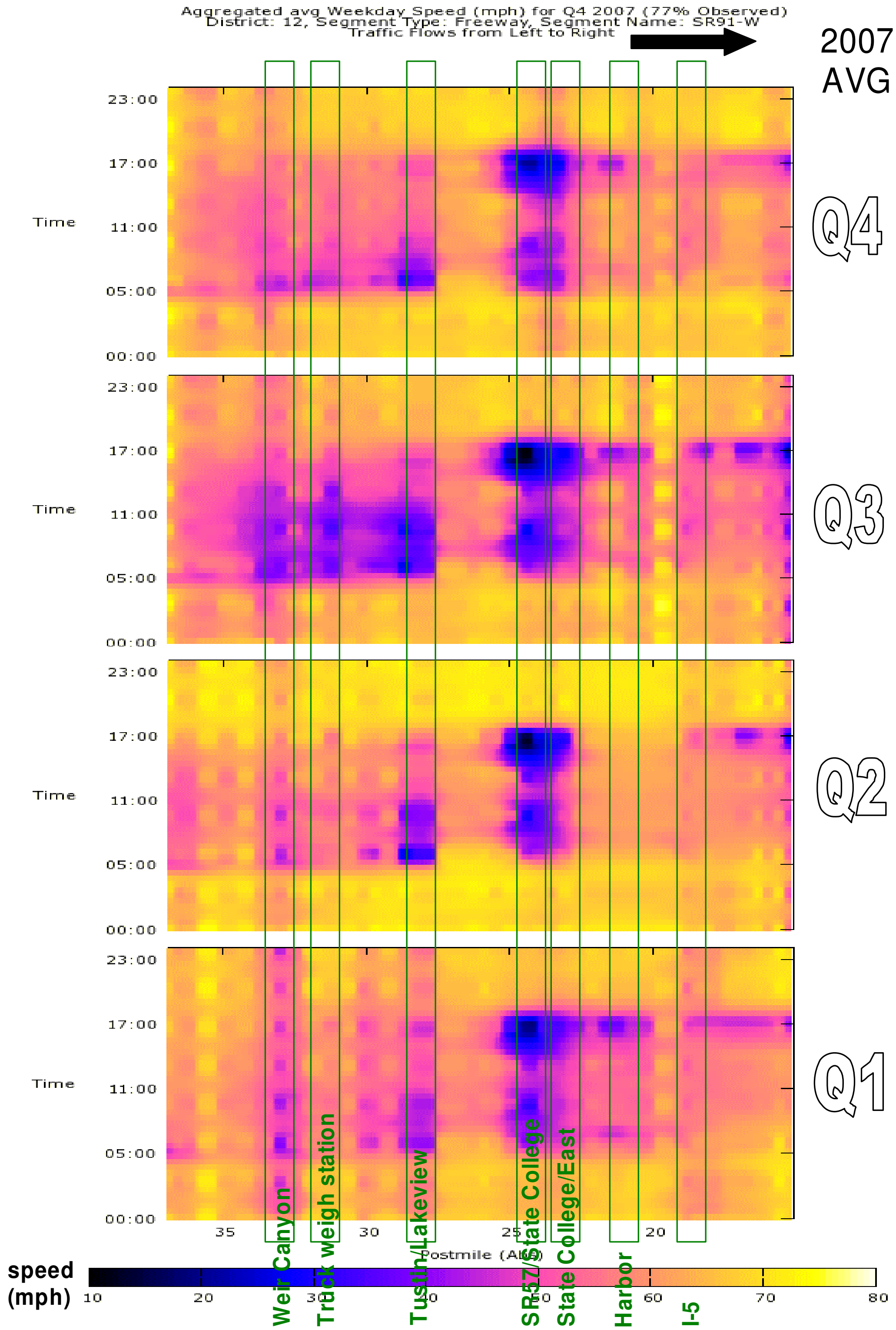


Exhibit 4-15: Westbound Speed Long Contours (2007 Quarterly Averages)



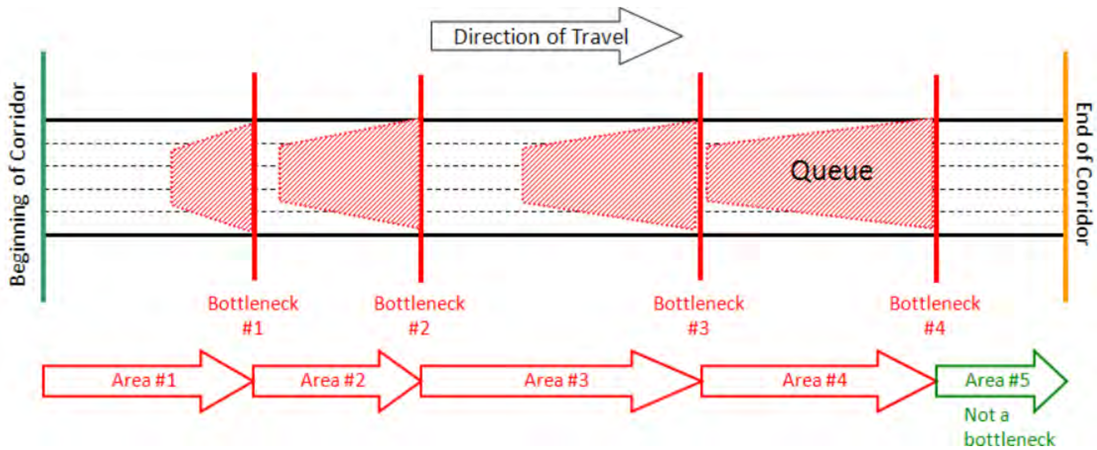
Bottleneck Area Analysis

Once the bottlenecks were identified, the corridor was divided into "bottleneck areas." Bottleneck areas represent segments that are defined by one major bottleneck (or a number of smaller ones). By segmenting the corridor into these bottleneck areas, the performance statistics presented earlier for the entire corridor in Section 3 of this report can be segmented by bottleneck area. This way, the relative contribution of each bottleneck area to the degradation of the corridor performance can be gauged. Performance statistics that lend themselves to such segmentation include:

- Delay
- Productivity
- Safety.

The analysis of bottleneck areas is based on 2007 data (when available) and limited to the mainline facility due to the limited detection available on the HOV facility. Based on this approach, the SR-91 CSMP Corridor comprises several bottleneck areas, which differ by direction. Exhibit 4-16 illustrates the general concept of bottleneck areas in one direction. The red lines in the exhibit represent the bottleneck locations and the arrows represent the bottleneck areas.

Exhibit 4-16: Bottleneck Areas Illustrated



Dividing the SR-91 CSMP Corridor into bottleneck areas makes it easier to compare the various segments of the freeway with each other. Based on the above, the verified bottlenecks shown in Exhibit 4-1 are shown again in Exhibit 4-17 with the associated bottleneck areas. The additional bottlenecks indicated by Caltrans, which did not appear until 2009 are not included and were not used to divide the corridor into bottleneck areas.

Exhibit 4-17: SR-91 Bottleneck Locations and Areas

Dir	Bottleneck Location	Bottleneck Area	Active Period AM	Active Period PM	From Postmile Abs	From Postmile CA	To Postmile Abs	To Postmile CA	Distance (miles)
EASTBOUND	Euclid St	I-5 to Euclid St	✓	✓	18.3	R3.6	20.7	2.4	2.4
	State College Blvd	Euclid St to State College Blvd	✓	✓	20.7	2.4	23.7	5.3	3.0
	SR-90 (Imperial Blvd)	State College Blvd to SR-90 (Imperial Blvd) On	✓	✓	23.7	5.3	30.0	R11.7	6.3
	Gypsum Canyon Rd/ SR-241	SR-90 On to Gypsum Canyon Rd On/SR-241	✓	✓	30.0	R11.7	34.7	R16.4	4.7
	Coal Canyon Rd	Gypsum Canyon Rd On/ SR-241 to Coal Canyon Rd		✓	34.7	R16.4	36.2	R17.8	1.5
	Not a bottleneck location	Coal Canyon Rd to ORA/RIV Co. Line	n/a		36.2	R17.8	37.3	R18.9	1.1
WESTBOUND	Weir Canyon Rd Off	ORA/RIV Co. Line to Weir Canyon Rd Off	✓	✓	37.3	R18.9	32.9	R14.5	4.4
	Truck Weigh Station	Weir Canyon Rd Off to Truck Weigh Station	✓		32.9	R14.5	31.7	R13.3	1.2
	SR-55	Truck Weigh Station to SR-55 Off	✓	✓	31.7	R13.3	27.2	R8.9	4.5
	SR-57	SR-55 Off to SR-57 On	✓	✓	27.2	R8.9	24.4	6.1	2.8
	State College Blvd	SR-57 On to State College Blvd	✓	✓	24.4	6.1	23.5	5.1	0.9
	Harbor Blvd	State College Blvd to Harbor Blvd	✓	✓	23.5	5.1	21.5	3.1	2.0
	I-5	Harbor Blvd to I-5 Off	✓	✓	21.5	3.1	18.3	R3.6	3.2

This section uses the previously discussed performance measures of mobility, safety, and productivity to evaluate each bottleneck area. The results from this bottleneck analysis reveal which segments of the SR-91 CSMP Corridor should be prioritized for improvements.

Mobility by Bottleneck Area

Mobility describes how efficiently the SR-91 CSMP Corridor moves vehicles. Vehicle-hours of delay measured at 60 mph were calculated for each segment. The results reveal the areas of the corridor that experience the worst mobility.

Exhibits 4-18 and 4-20 show the delay experienced by each bottleneck area. In the eastbound direction, the delay during the AM peak is noticeably less than the PM peak with all segments of the corridor experiencing less than 100,000 annual vehicle-hours of delay. During the PM peak, the segment between SR-90 to Gypsum Canyon Road/SR-241 experienced over half of the corridor's delay at slightly under 600,000 vehicle-hours of delay. In the westbound direction, the segment between the Truck Weigh Station to SR-55 experienced the greatest delay with 44 percent of the corridor's delay during the AM peak. During the PM peak, the segment between SR-55 to SR-57 experienced the greatest delay with 39 percent of the corridor's delay.

Exhibits 4-19 and 4-21 have been normalized to reflect delay per lane-mile. The delay calculated for each bottleneck area was divided by the total lane-miles for each bottleneck area to obtain delay per lane-mile. The results of these exhibits differ from Exhibits 4-18 and 4-20. In the eastbound direction, Gypsum Canyon/SR-241 to Coal Canyon Road had the highest delay per lane-mile during the PM peak, while delay per lane-mile for each bottleneck area remained relatively similar to Exhibit 4-18 during the AM peak. In the westbound direction, the segment from Weir Canyon Road to the Truck Weigh Station experienced the highest delay per lane-mile during the AM peak, while the segment from SR-57 to State College Boulevard experienced the highest delay during the PM peak.

Exhibit 4-18: Eastbound Annual Vehicle-Hours of Delay (2007)

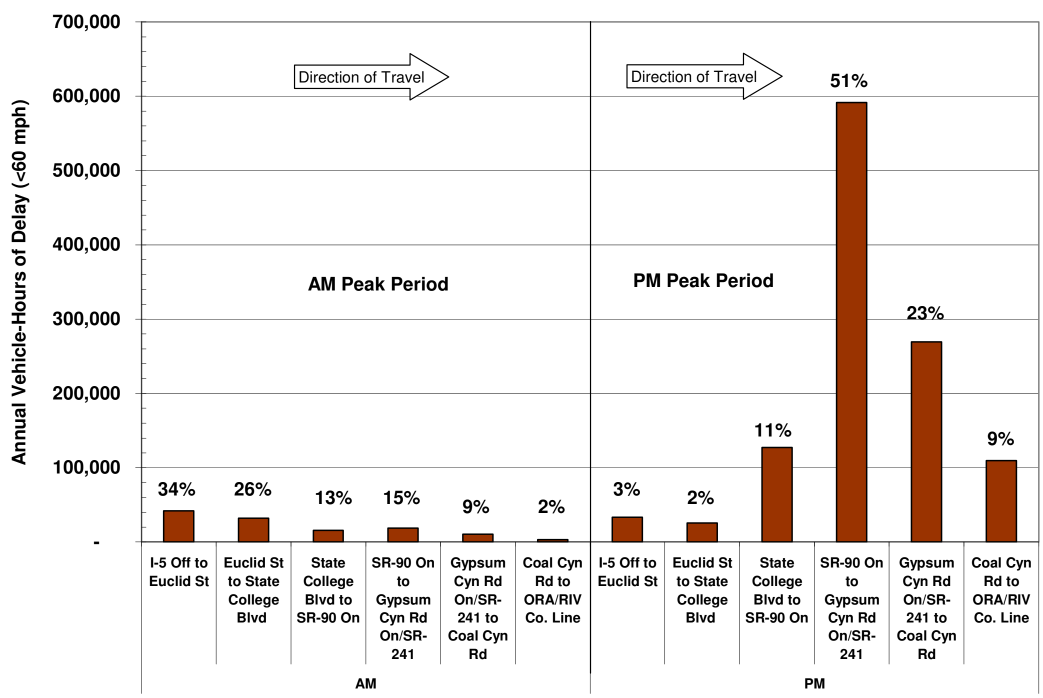


Exhibit 4-19: Eastbound Delay per Lane-Mile (2007)

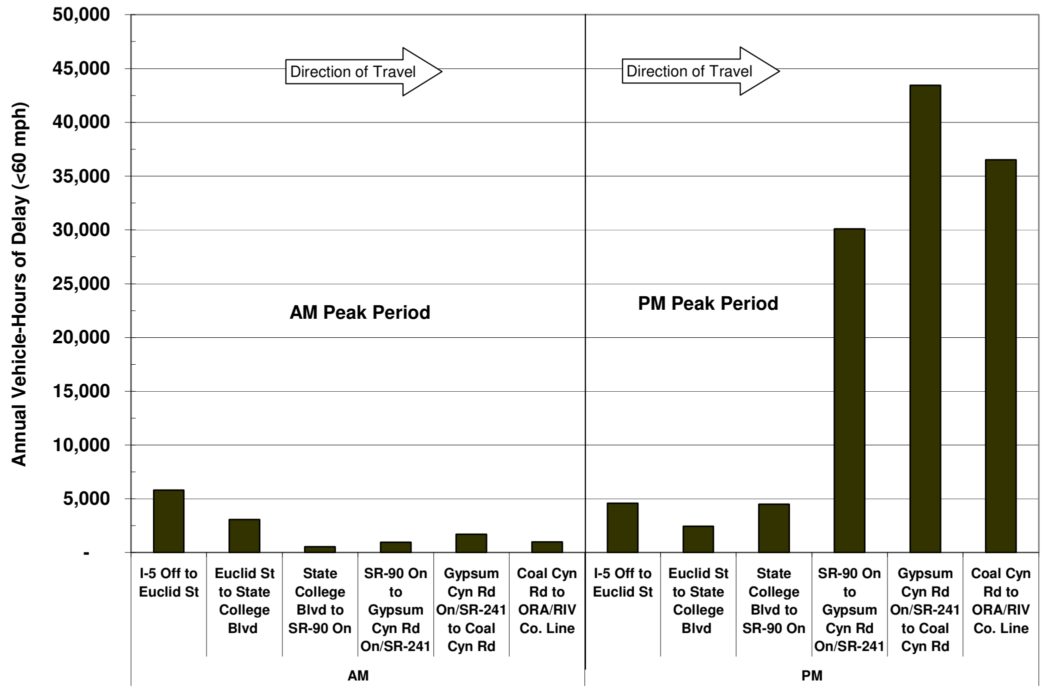


Exhibit 4-20: Westbound Annual Vehicle-Hours of Delay (2007)

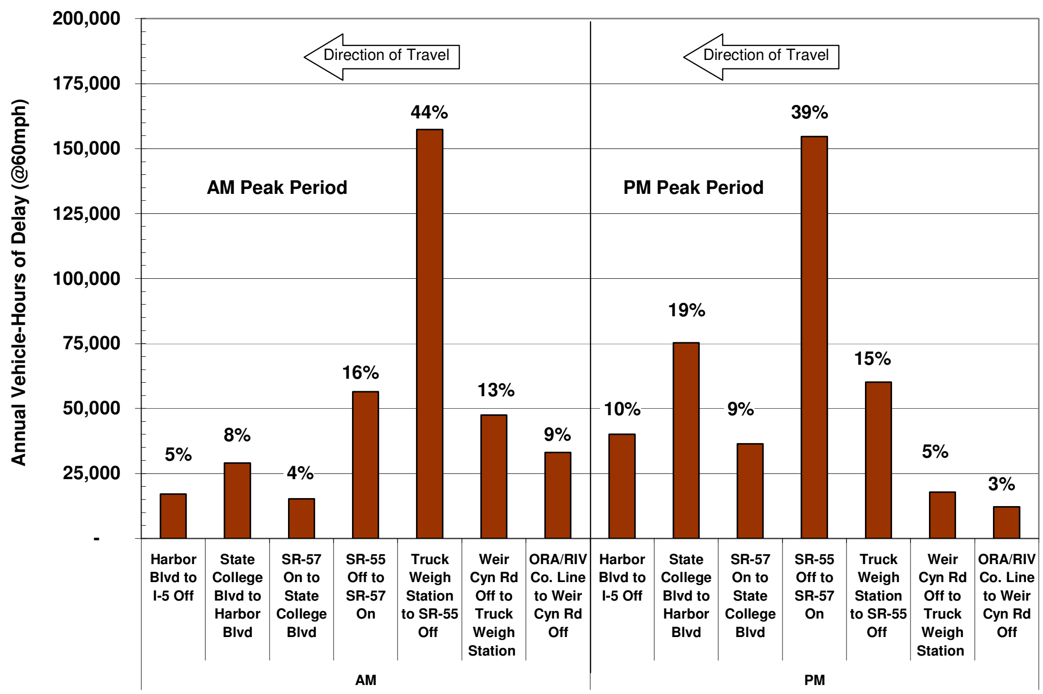
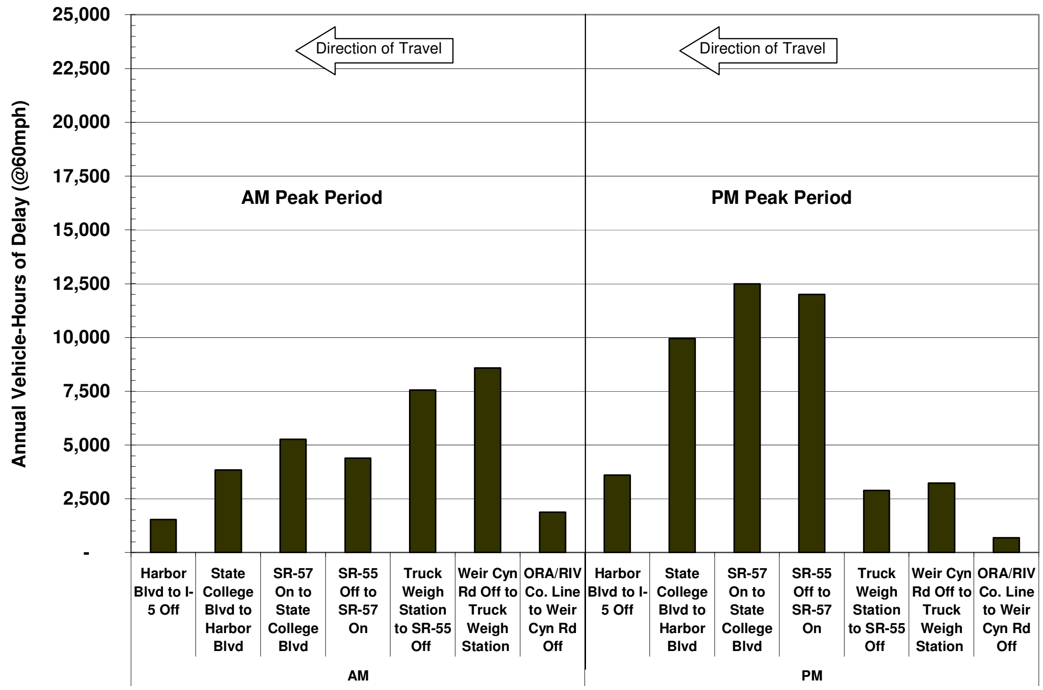


Exhibit 4-21: Westbound Delay per Lane-Mile (2007)

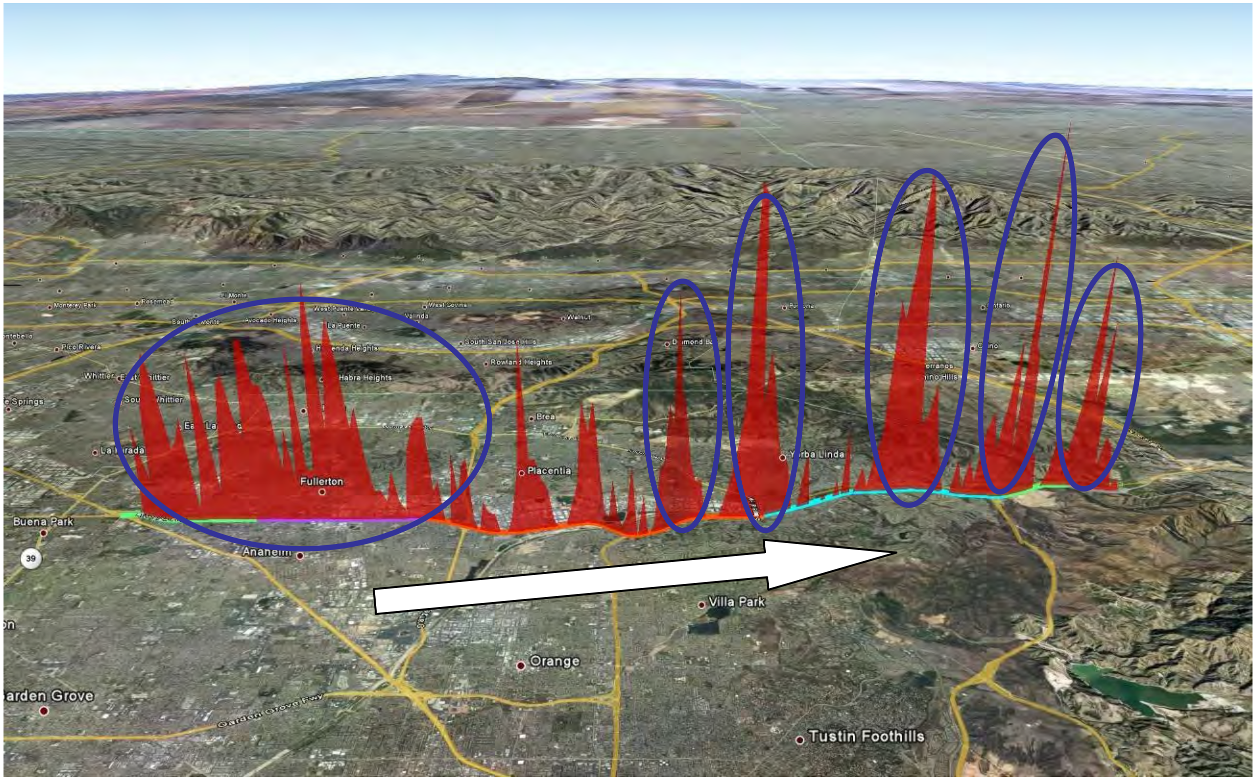


Safety by Bottleneck Area

Exhibit 4-22 shows the location of all collisions plotted along the SR-91 CSMP Corridor in the eastbound direction. The color-coding along the corridor shows the extent of each bottleneck area. The spikes show the total number of collisions (fatality, injury, and property damage only) occurring within 0.1 mile segments during 2006. The highest spike corresponds to roughly 27 collisions in a single 0.1-mile location. The size of the spikes is a function of how collisions are grouped. If the data were grouped in 0.2-mile segments, the spikes would be higher.

As Exhibit 4-22 shows, a large group of collisions occurs near Fullerton between I-5 and SR-57. Other groupings occur at the curve near Lakeview Avenue, at the SR-90 (Imperial Highway) interchange, near Yorba Linda Boulevard, at the SR-241 interchange, and at the curve east of SR-241. In many cases, a spike in the number of collisions occurs in the same location as a bottleneck. For example, a spike occurs at the SR-90 (Imperial Highway), which is also a bottleneck. This is shown as the transition from the red to the light blue area in Exhibit 4-22.

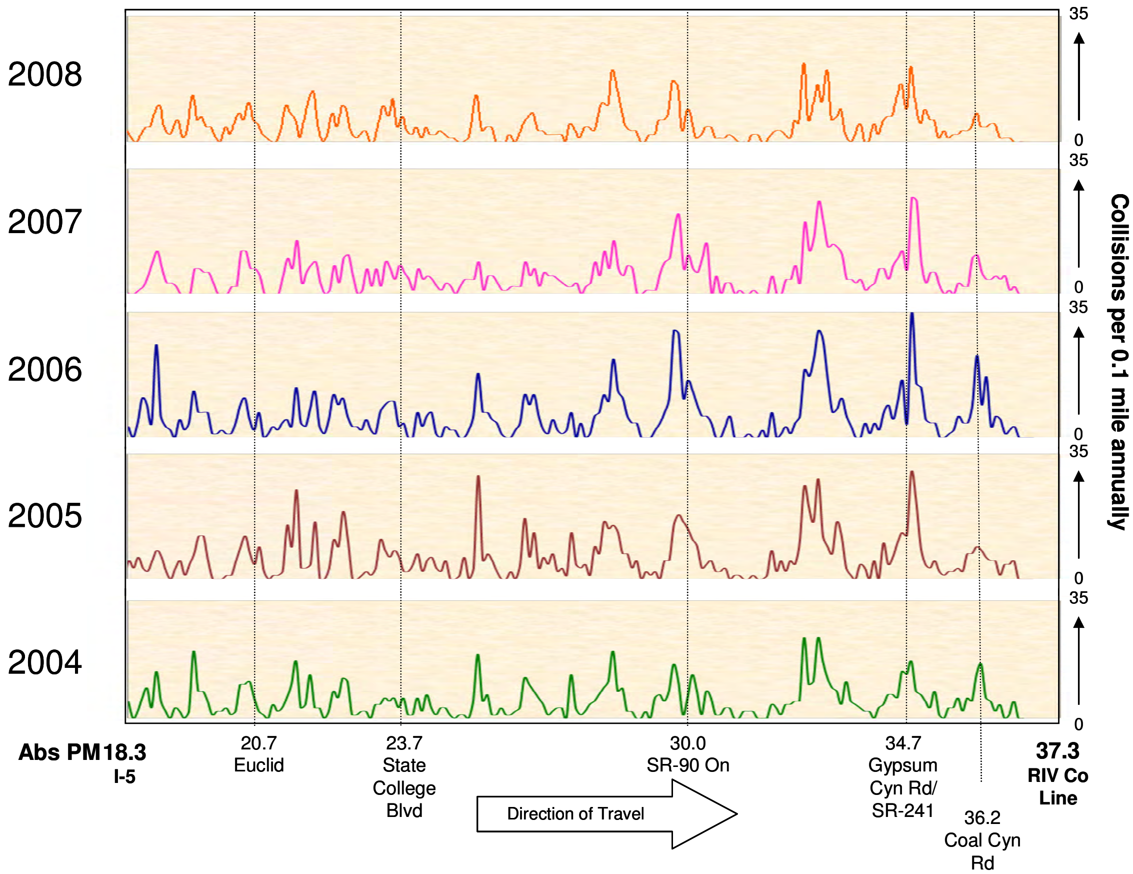
Exhibit 4-22: Eastbound Location of Collisions (2007)



Source: TASAS data

Exhibit 4-23 shows that the pattern of collisions has stayed fairly consistent from one year to the next with a general decline in collisions in 2008 from prior years, particularly near SR-90 and Gypsum Canyon Road.

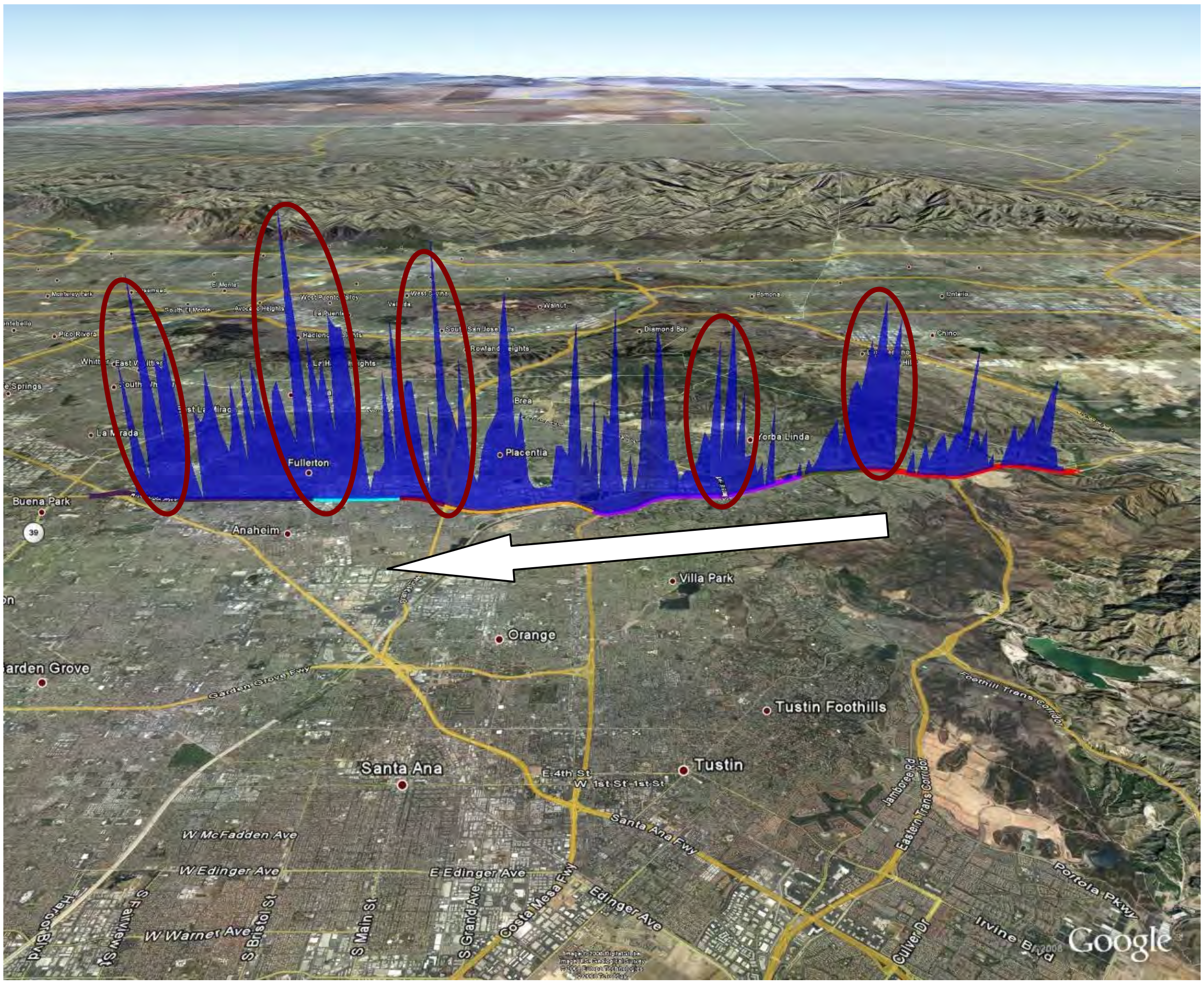
Exhibit 4-23: Eastbound Collisions by Bottleneck Location (2004-2008)



Source: TASAS data

Exhibit 4-24 shows similar collision data for the westbound direction. The largest spike corresponds roughly to 22 collisions per 0.1 miles. The patterns in the westbound direction are similar to those in the eastbound direction.

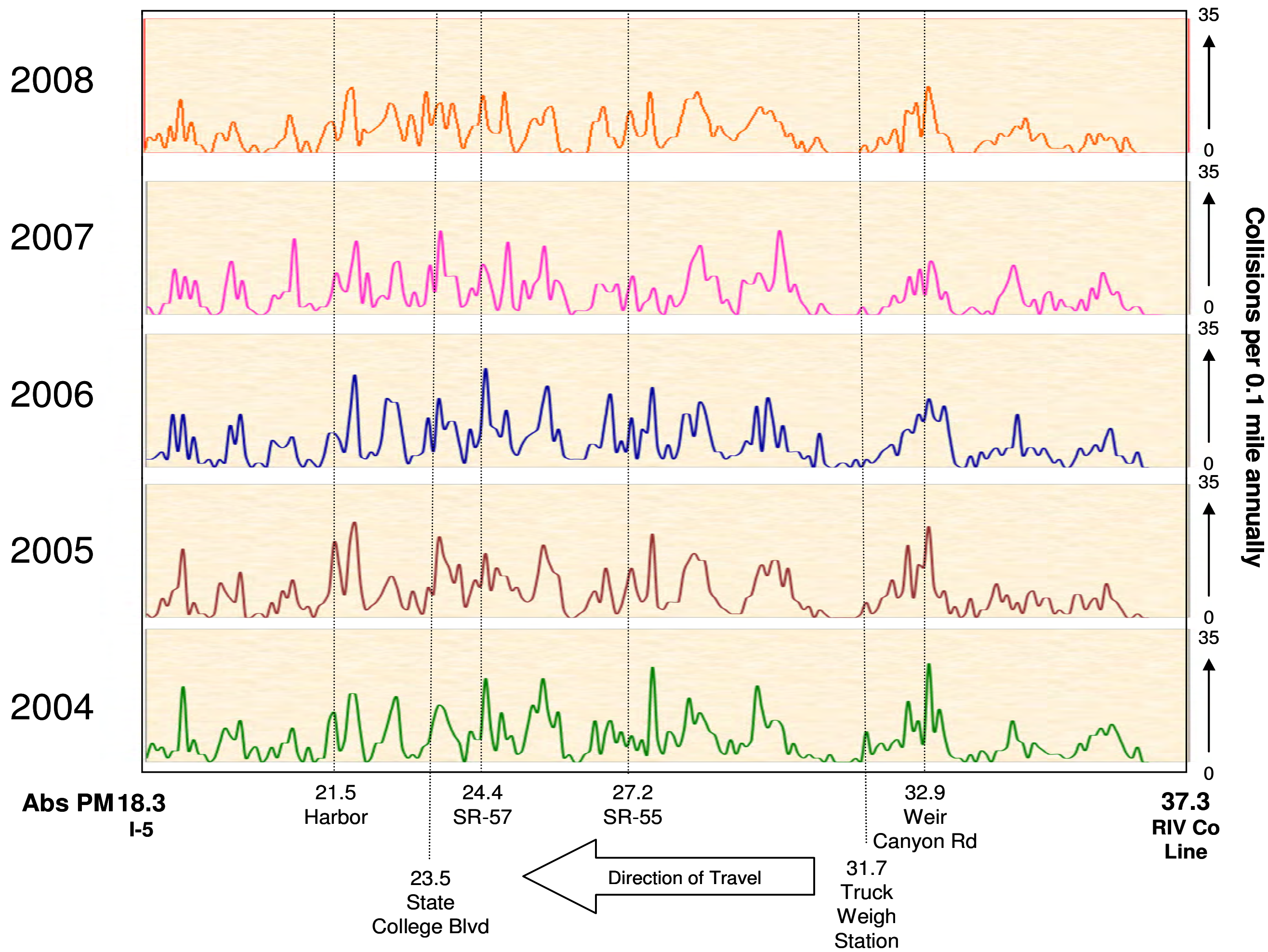
Exhibit 4-24: Westbound Location of Collisions (2007)



Source: TASAS data

Exhibit 4-25 shows the trend for the westbound direction since 2004. As the exhibit shows, the pattern of collisions has been fairly steady from one year to the next. The number of collisions has decreased between I-5 and SR-57 throughout the five-year period.

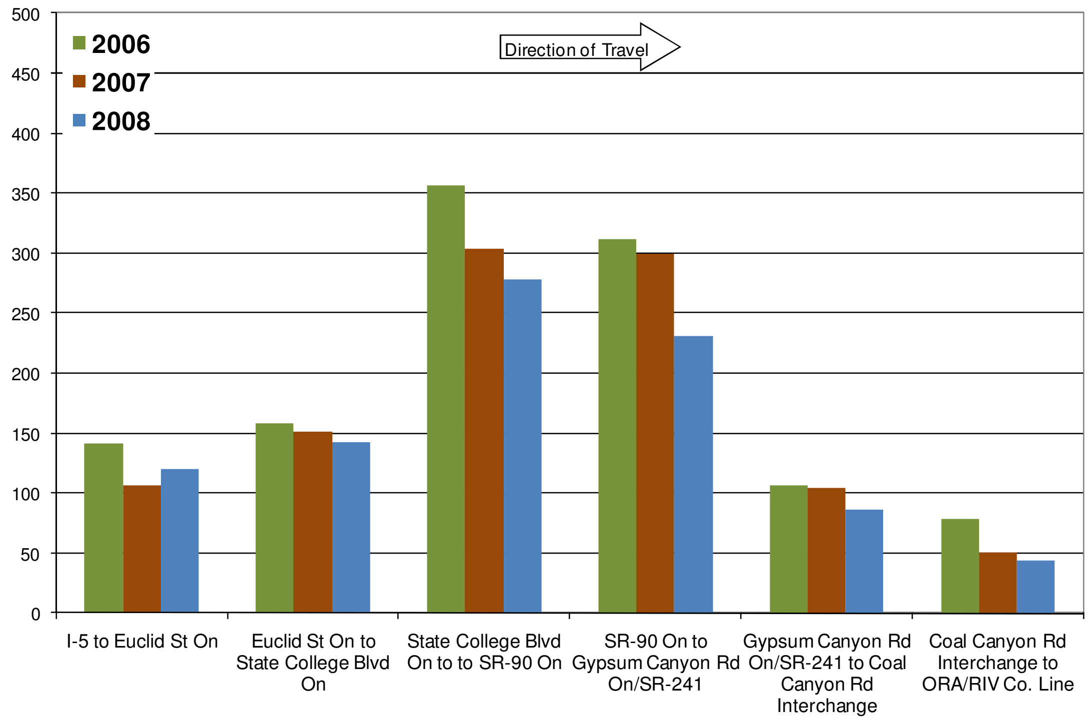
Exhibit 4-25: Westbound Collisions by Bottleneck Location (2004-2008)



Source: TASAS data

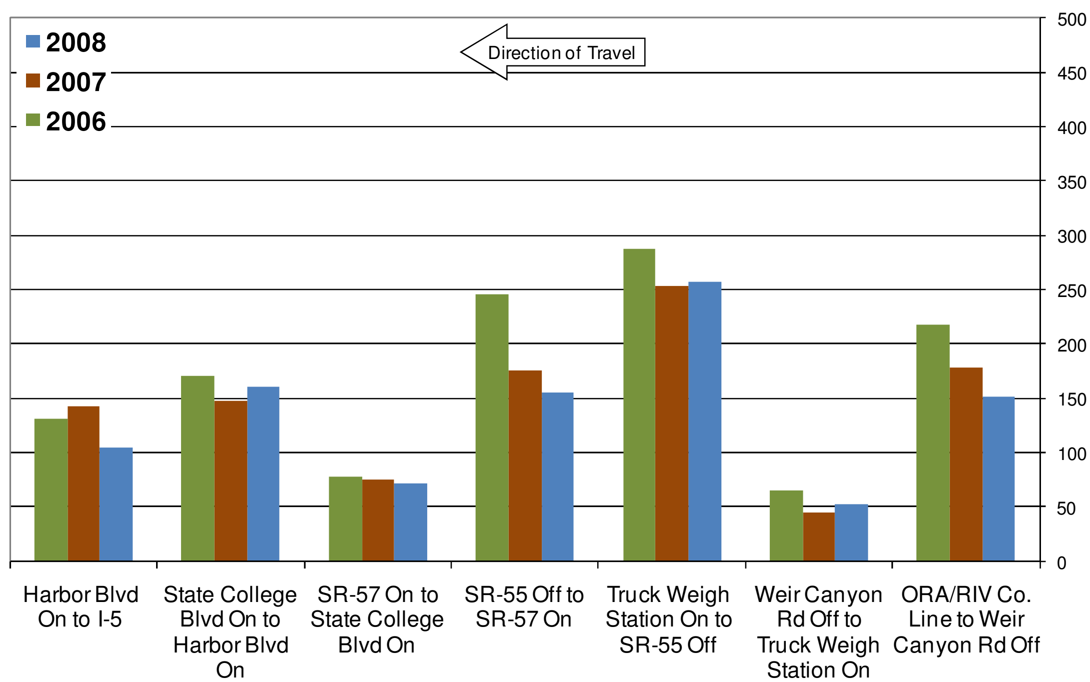
Exhibits 4-26 and 4-27 summarize the total number of accidents reported in TASAS by bottleneck area. The bars show the total annual number of accidents that occurred in 2006, 2007, and 2008, the latest three years available in TASAS. The number of accidents generally declined in each bottleneck area throughout the three years. The areas that experienced higher accidents generally correspond to the areas that experienced high levels of delay. This is true for the westbound segment from the Truck Weigh Station to SR-55, which experienced the greatest delay and number of accidents compared to any other westbound segment.

Exhibit 4-26: Eastbound Total Accidents (2006-2008)



Source: TASAS data

Exhibit 4-27: Westbound Total Accidents (2005–2008)



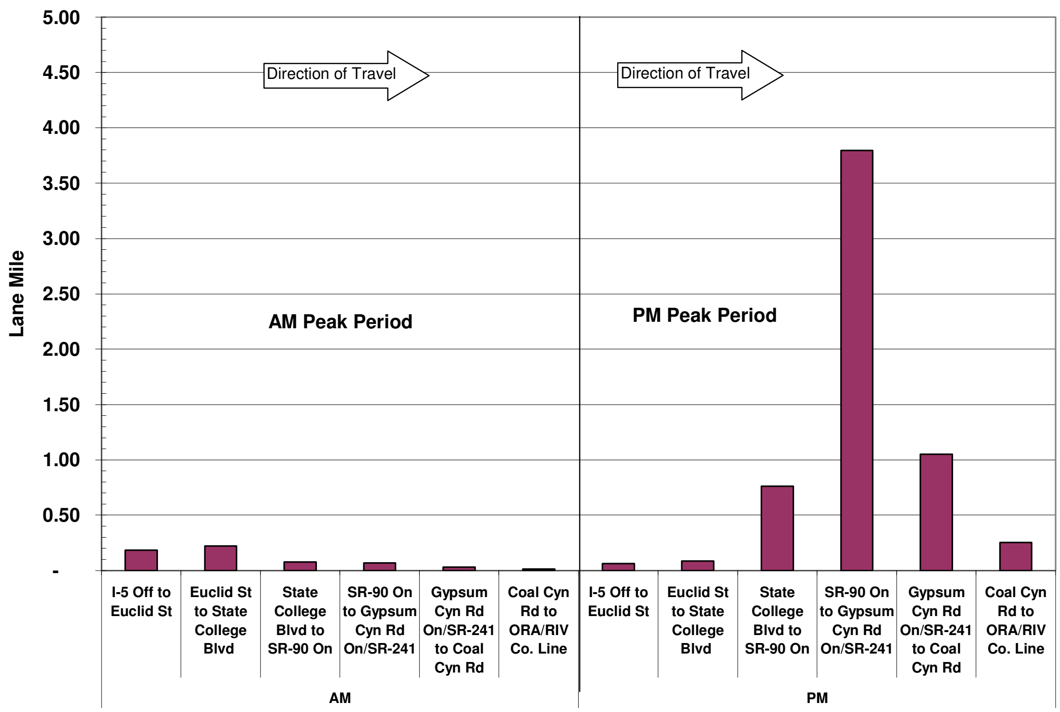
Source: TASAS data

Productivity by Bottleneck Area

As previously discussed in Section 3, the productivity of a corridor is defined as the percent utilization of a facility or mode under peak conditions. Productivity is measured by calculating the lost productivity of the corridor and converting it into "lost lane-miles." These lost lane-miles represent a theoretical level of capacity that would have to be added in order to achieve maximum productivity.

Exhibits 4-28 and 4-29 show the productivity losses for both directions of the SR-91 CSMP Corridor. In the eastbound direction, the segment from SR-90 to Gypsum Canyon Rd On/SR-241 had the worst productivity of any segment on the corridor. It experienced a productivity loss of 3.8 lane-miles during the PM peak. During the AM peak, the eastbound direction experienced relatively high productivity with all segments of the corridor experiencing less than a quarter-mile of productivity loss.

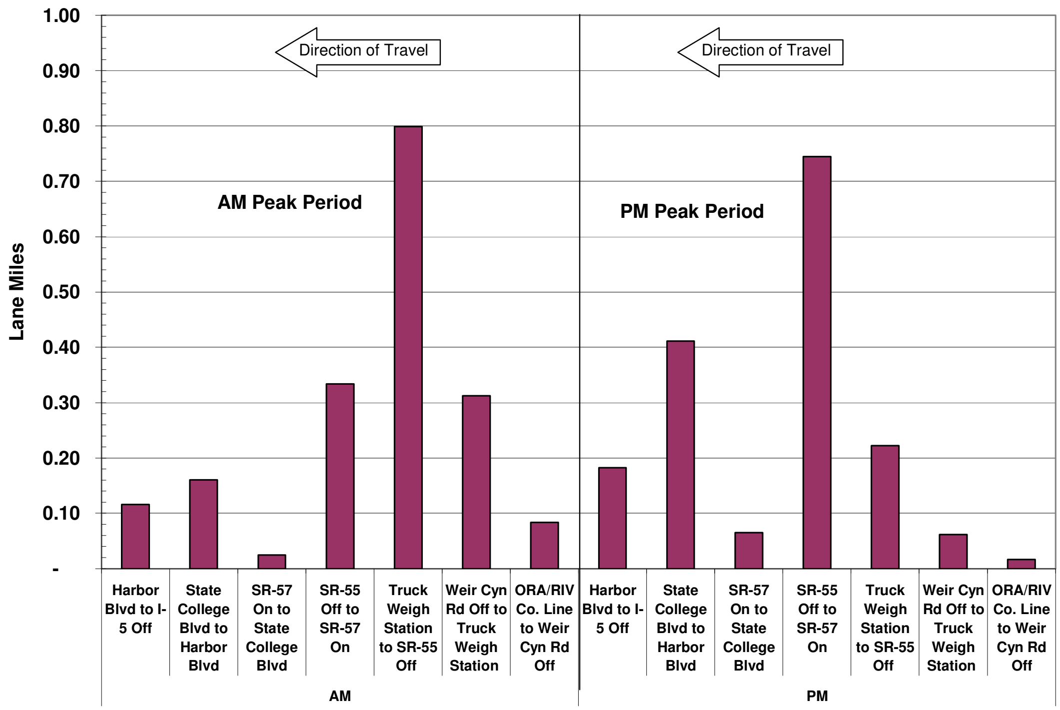
Exhibit 4-28: Eastbound Lost Lane-Miles (2007)



In the westbound direction, the segment from the Truck Weigh Station to SR-55 experienced the greatest productivity loss (0.8 mile) during the AM peak, while the segment from SR-55 to SR-57 experienced the highest productivity loss (0.74 mile) during the PM peak.

The segments of the corridor with the highest productivity losses coincide with the segments that experience the greatest annual vehicle-hours of delay.

Exhibit 4-29: Westbound Lost Lane-Miles (2007)



5. BOTTLENECK CAUSALITY ANALYSIS

This section details the causes of the major bottlenecks verified in Section 4 of this report (see Exhibits 4-1 and 4-17 for reference). The three bottlenecks indicated by Caltrans, which did not appear until 2009, are not included in the causality analysis.

Major bottlenecks are the primary cause of traffic congestion and lost productivity. It is important to verify the precise location and causes of each major bottleneck to develop appropriate, low cost, operational improvements to maintain corridor mobility.

The location of each major bottleneck was verified by multiple field observations on separate days as discussed in Section 4 of this final report. The causes of each major bottleneck were also identified by field observations and additional traffic data analysis. For the SR-91 CSMP Corridor, field observations were conducted by the project consultant team on August 27, 2008 (Wednesday), September 10, 2008 (Wednesday), and October 9, 2008 (Thursday) during the AM and PM peak hours.

By definition, a bottleneck is a location where traffic demand exceeds the capacity of the roadway facility. The cause of a bottleneck is typically related to a sudden reduction in capacity, such as a physical loss when a lane drop occurs or when heavy merging and weaving take place at major on- and off-ramps. Other variables that can cause reductions in capacity include weather or driver distractions. On the demand side, surges in demand can be larger than a roadway can accommodate. In many cases, it is a combination of increased demand and capacity reductions.

Eastbound Bottleneck Causality

As discussed in Section 4 above, five bottlenecks were verified in the eastbound direction on the SR-91 CSMP Corridor:

- Euclid Street
- State College Boulevard
- SR-90 (Imperial Boulevard)
- Gypsum Canyon Road/SR-241
- Coal Canyon Road.

Caltrans staff indicated that additional bottlenecks likely exist in the eastbound direction at the SR-57 on-ramp and the SR-55 off-ramp. The eastbound bottlenecks and congestion occur in both AM and PM peak hours (with the exception of the Coal Canyon Road bottleneck, which occurs only in the PM peak period). The following is a summary of the eastbound bottlenecks and the identified causes.

I-5 to State College Boulevard

Several bottlenecks were identified from the data analysis between I-5 and State College Boulevard (Abs PM=18.06/23.8; Cal PM=R3.3/5.4), notably at I-5/Magnolia Avenue, Euclid Street, Harbor Boulevard/Lemon Street, and State College Boulevard.

However, none of these bottlenecks was observed in the recent field visits. This could be from the reduction in the overall travel demand in recent years caused by the economic downturn. As a result, the actual bottleneck locations could not be verified or causes determined, from the field observations.

State College Boulevard to SR-90 On-Ramp

Bottlenecks were also identified from between State College Boulevard and SR-90 (Imperial Highway) on-ramp (Abs PM=23.8/30.1; Cal PM=5.4/R11.7), notably at the SR-57, Glassell Street, and SR-90 (Imperial Highway) interchanges. However, none of these bottlenecks was observed in the recent field visits.

Exhibit 5-1 is an aerial photograph of the eastbound SR-91 mainline at the SR-90, Imperial Highway interchange. As shown, two consecutive on-ramps from the Imperial Highway merges onto the freeway mainline. Although the volumes are fairly low at below 700 vph for the two ramps combined, the consecutive merges are likely to cause the freeway speeds to be reduced. Some slowdown and queuing also were noticed at the SR-57 connector off-ramp, causing the speed of the outer lanes to slow.

Exhibit 5-1: Eastbound SR-91 at SR-90 (Imperial Highway) On-Ramp

Gypsum Canyon Road/SR-241 On-Ramp to Coal Canyon Road

Exhibit 5-2 is an aerial photograph of the eastbound SR-91 mainline at Gypsum Canyon Road/SR-241 (Abs PM=34.8/36.1; Cal PM=R16.5/R17.8). As shown, traffic from Gypsum Canyon Road merges into the freeway mainline via consecutive ramps. The merging volume exceeds 1,200 vph. Just past the consecutive ramps is the northbound SR-241 to eastbound SR-91 connector on-ramp. It is a two-lane connector that merges into one new mainline lane. This connector carries over 2,000 vph during the PM peak hours. The effects of the heavy consecutive ramp merging and additional demand are compounded by the long steep grade as shown on Exhibit 5-3. The photo also shows the mainline traffic congestion and the ramp merging from Gypsum Canyon Road on-ramps, followed by the SR-241 connector traffic.

The bottleneck from the Gypsum Canyon Road on-ramps merging and the bottleneck from the heavy additional demand from the SR-241 connector on-ramp are hidden in the congestion queue by the third major bottleneck at the crest of the mountain terrain approaching the Coal Canyon Road interchange, where the outside lane (new lane from SR-241 connector on-ramp) is dropped. Exhibit 5-4 illustrates this location. The next downstream bottleneck is beyond Green River Road interchange and into Riverside County.

Exhibit 5-2: Eastbound SR-91 at Gypsum Canyon Road/SR-241 On-Ramp

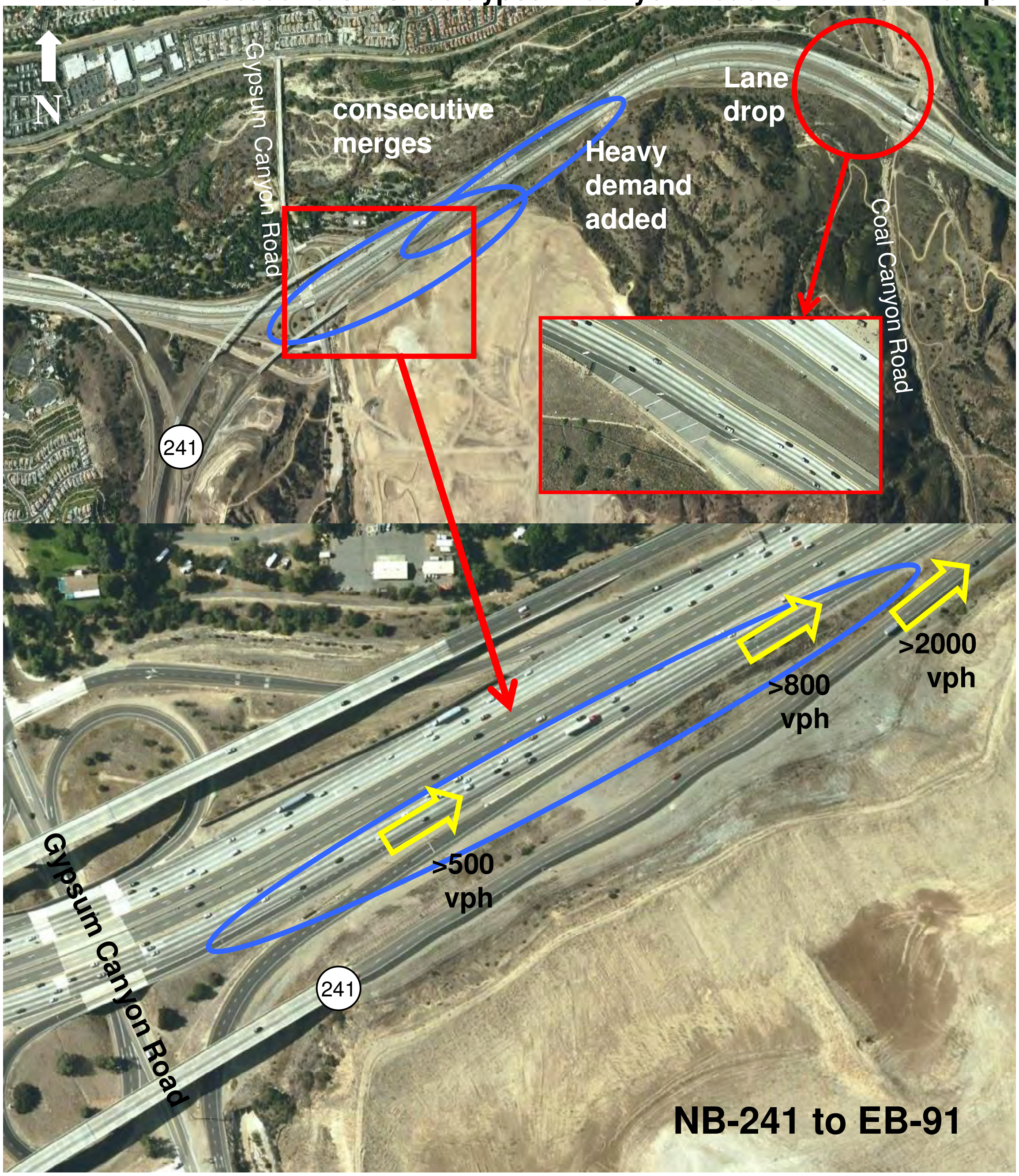


Exhibit 5-3: Eastbound SR-91 at Gypsum Canyon Road/SR-241 On-Ramp

Exhibit 5-4: Eastbound Approaching Coal Canyon Road

Westbound Bottleneck Causality

Major westbound bottlenecks and congestion often occur during both the AM and PM peak hours. Minor bottlenecks, however, typically occur during AM peak hours.

From Section 4, the following westbound bottlenecks were verified:

- Weir Canyon Road Off-ramp
- Truck Weigh Station
- SR-55
- SR-57
- State College Boulevard
- Harbor Boulevard
- I-5.

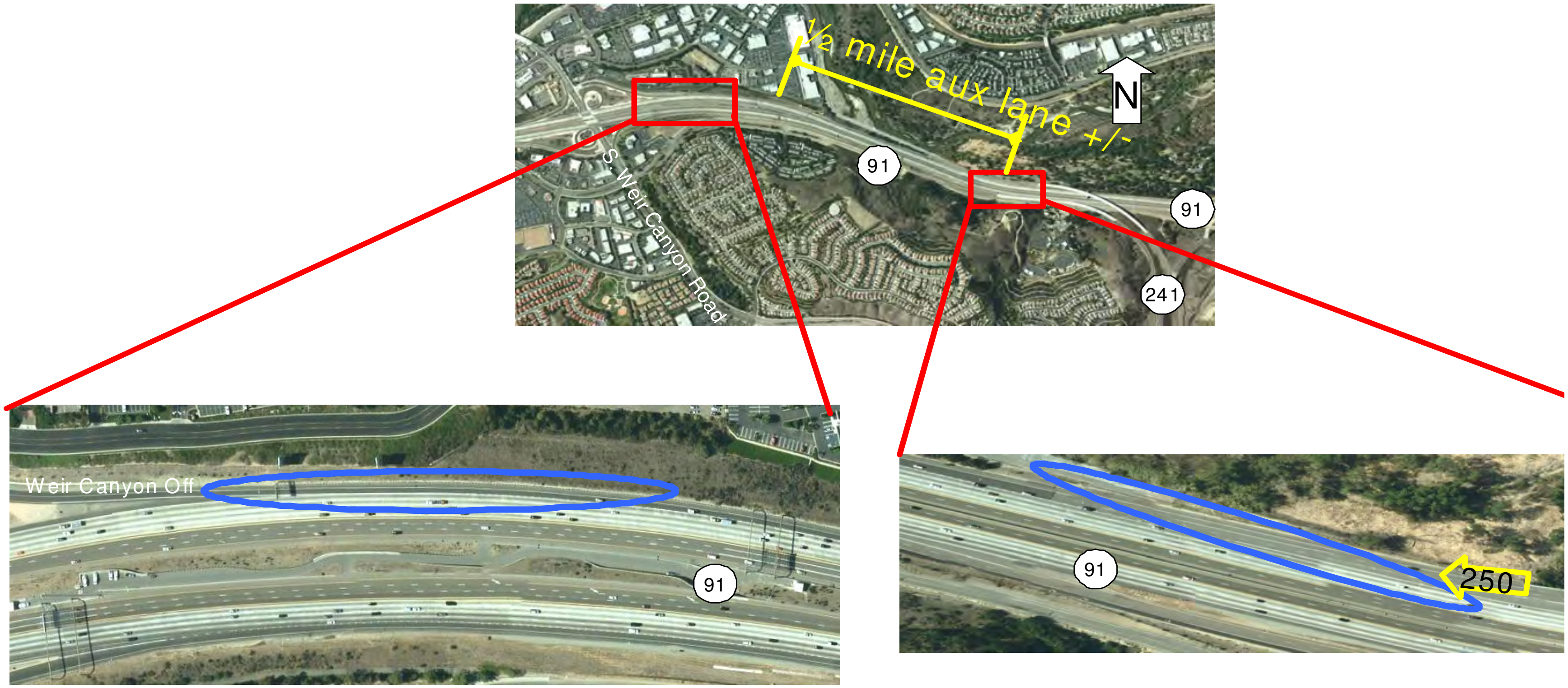
Caltrans staff indicated that additional bottlenecks likely exist in the westbound direction at Tustin Avenue, the SR-57 off-ramp, and the SR-55 on-ramp. The following is a summary of the westbound verified bottlenecks and their identified causes.

<u>SR-241 On-Ramp to Weir Canyon Road Off-Ramp</u>

Exhibit 5-5 are aerial photographs of the westbound SR-91 mainline approaching Weir Canyon Road off-ramp (Abs PM=34.1/33.1; Cal PM=R15.7/R14.7). Traffic from the northbound SR-241 traffic merges into the westbound SR 91 mainline traffic. The primary cause of this bottleneck is the traffic from the SR-241 on-ramp and the loss of over half-mile auxiliary lane at the Weir Canyon Road off-ramp. The bottom photographs in Exhibit 5-5 show the two-lane connector that merges into one auxiliary lane (at the bottom right of the page) and the very long—over 3,400 feet—auxiliary lane that ends at the Weir Canyon Road off-ramp (at the bottom left of the page).

Typically, the outer lanes are most affected and have slower speeds. Recent counts conducted in June of 2008 indicate that the NB-241 to WB-91 connector on-ramp volumes are about 250 vehicles in the AM peak hour and over 800 in the PM peak hour. Typically, this bottleneck and congestion occurs in the very early AM hours between 5:00 AM and 6:30 AM when the mainline volume is near 8,000 vehicles per hour (vph) or 2,000 vph per lane.

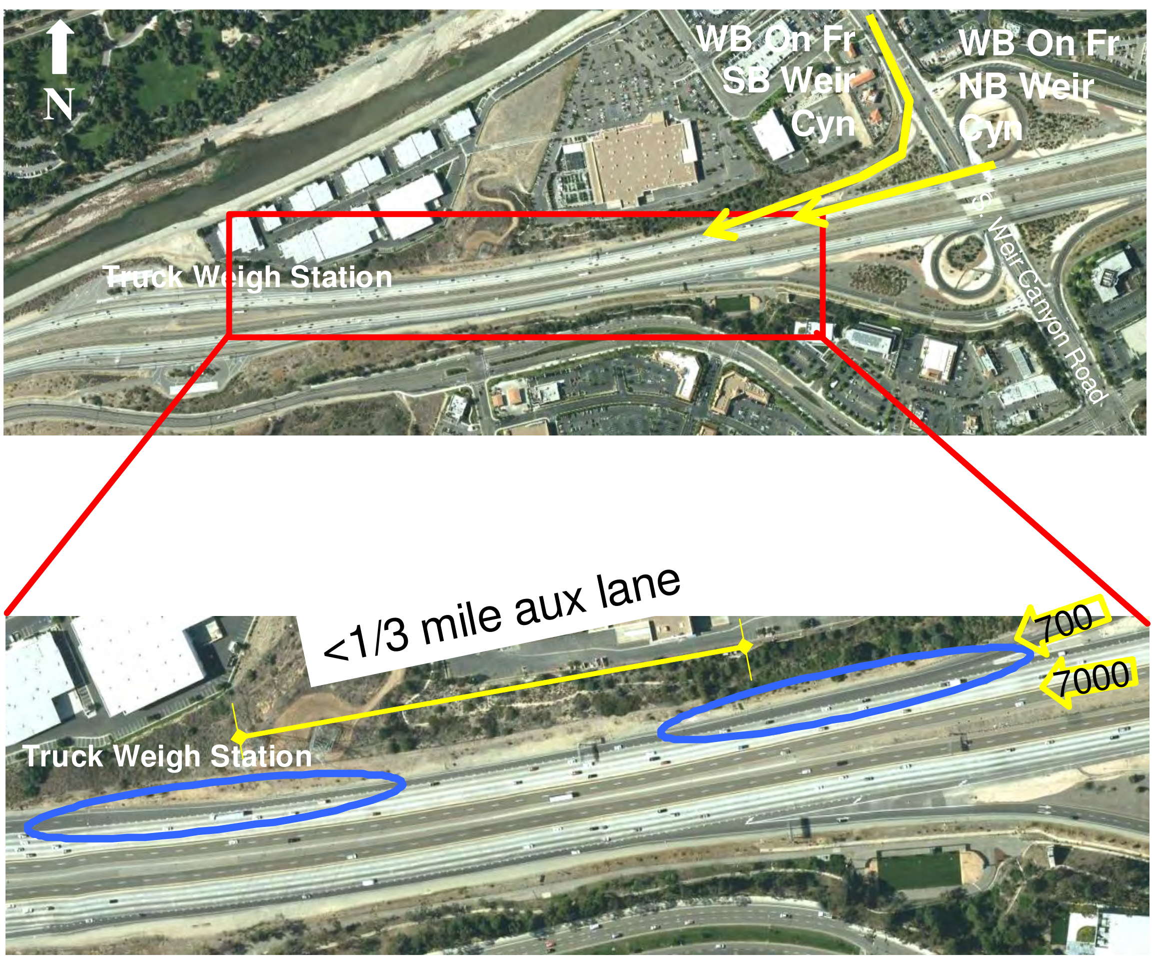
Exhibit 5-5: Westbound SR-91 at SR 241/Weir Canyon Road Interchange



Weir Canyon Road On-Ramp to Truck Weigh Station

Exhibit 5-6 is aerial photographs of the westbound SR-91 mainline between Weir Canyon Road and the Truck Weigh Station (Abs PM=32.0/30.2; Cal PM=13.6/R11.8). There are two on-ramps from Weir Canyon Road that merge into one auxiliary lane that ends at the weigh station. The primary cause of this bottleneck is the heavy traffic from the Weir Canyon on-ramps merging into the freeway traffic, nearly 1,400 vph combined while mainline volume exceeds 7,000 vph during the peak hours. The auxiliary lane (approximately 2,000 feet in length) helps to diffuse the merging, but on many occasions, the mainline cannot accommodate the additional demand during the peak hours. Ramp metering is less effective here since the ramp metering location for each ramp is too far up the ramp. As a result, platoons occur as the traffic from the two ramps merge down the auxiliary lane.

Exhibit 5-6: Westbound SR-91 at Truck Weigh Station Interchange



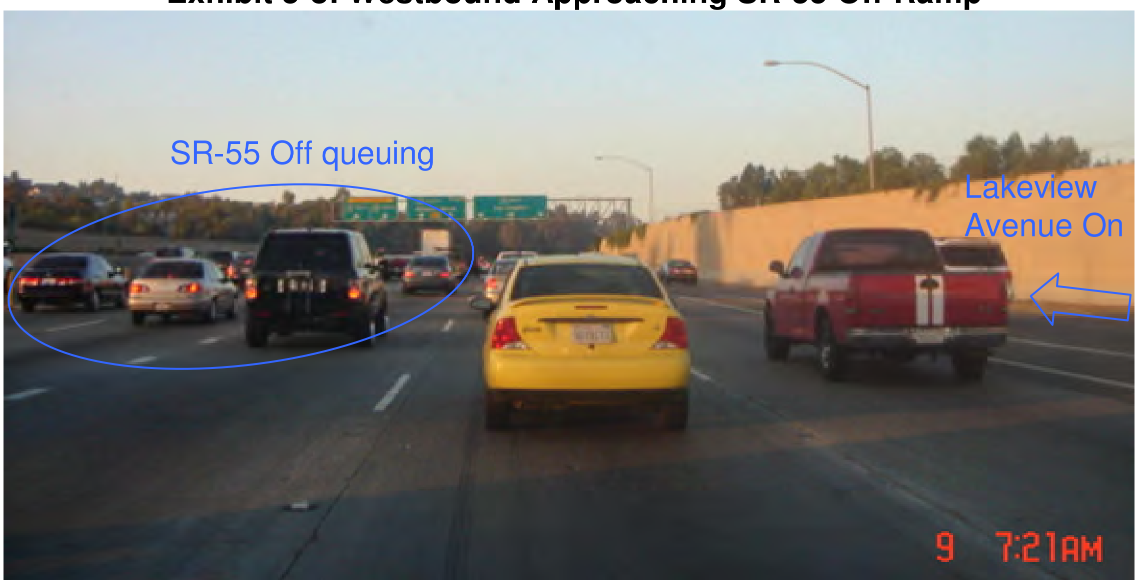
Lakeview Avenue On-Ramp to SR-55 Off-Ramp

Exhibit 5-7 shows aerial photographs of the westbound SR-91 mainline between Lakeview Avenue on-ramp and the SR-55 connector off-ramp (Abs PM=27.5/27.3; Cal PM=9.1/8.9). As indicated, the five-lane mainline splits into two lanes to southbound SR-55 to the left and three lanes continuing on westbound SR-91 to the right.

Exhibit 5-7: Westbound SR-91 at SR-55 Off-Ramp

Extensive queuing from the SR-55 connector off-ramp and cross-weaving from the Lakeview Avenue on-ramp to the SR-55 connector off-ramp were noticed in the field observations during the AM and PM peak hours. The queuing from the SR-55 connector off-ramp caused blockage of the SR-91 through-lanes with vehicles trying to squeeze into the queued traffic. The queuing often extended past the Lakeview Avenue on-ramp. The Lakeview Avenue on-ramps exceed 1,100 vph combined during both AM and PM peak hours. The SR-55 connector off-ramp exceeds 1,200 vph during the peak hours. Exhibit 5-8 is a photograph of the SR-55 connector off-ramp approach during the AM peak, illustrating the queuing.

Exhibit 5-8: Westbound Approaching SR-55 Off-Ramp



SR-57 On-Ramp to State College Boulevard

Exhibit 5-9 shows aerial photographs of the consecutive SR-57 connector on-ramps to westbound SR-91 (Abs PM=24.2/23.8); Cal PM=5.8/5.4). The northbound SR-57 to westbound SR-91 is a tight loop ramp that merges into the outside lane (lane 3). Due to the short radius of the loop ramp, vehicles are traveling at slow speeds when merging into the mainline lane, forcing the mainline speeds to slow down.

Based on the field observations, platoon merging was frequent from this ramp. Just past this merge point, the southbound SR-57 connector on-ramp enters the auxiliary lane, approximately 1,500 feet long, to State College Boulevard off-ramp. Essentially, all of the SR-57 connector traffic enters the westbound SR-91 mainline.

During the peak hours when the mainline traffic flow is near capacity, the additional demand from the two connector ramps overloads the mainline, causing the freeway flow to break down and form the bottleneck. Mainline volumes to the east of the SR-57 interchange is over 6,000 vph (2,000 vph per lane) during the peak hours, before congestion begins, and over 7,000 vph (2,300 vph per lane) through the traffic congestion. The two consecutive SR-57 connector on-ramp volumes reach over 1,700 vph combined during the peak hours.

This bottleneck and congestion occurs during the both the AM and PM peak hours. Exhibit 5-10 illustrates the platoon merging from the two consecutive connector ramps. Due to the slow speeds and density of the traffic flow, the traffic congestion does not recover until past the crest of the uphill grade at State College Boulevard interchange. Exhibit 5-11 provides photos that illustrate the short relief past the SR-57 on-ramp bottleneck and reforming of the congestion until past the State College Boulevard overcrossing.

Exhibit 5-9: Westbound SR-91 at SR-57 On-Ramp

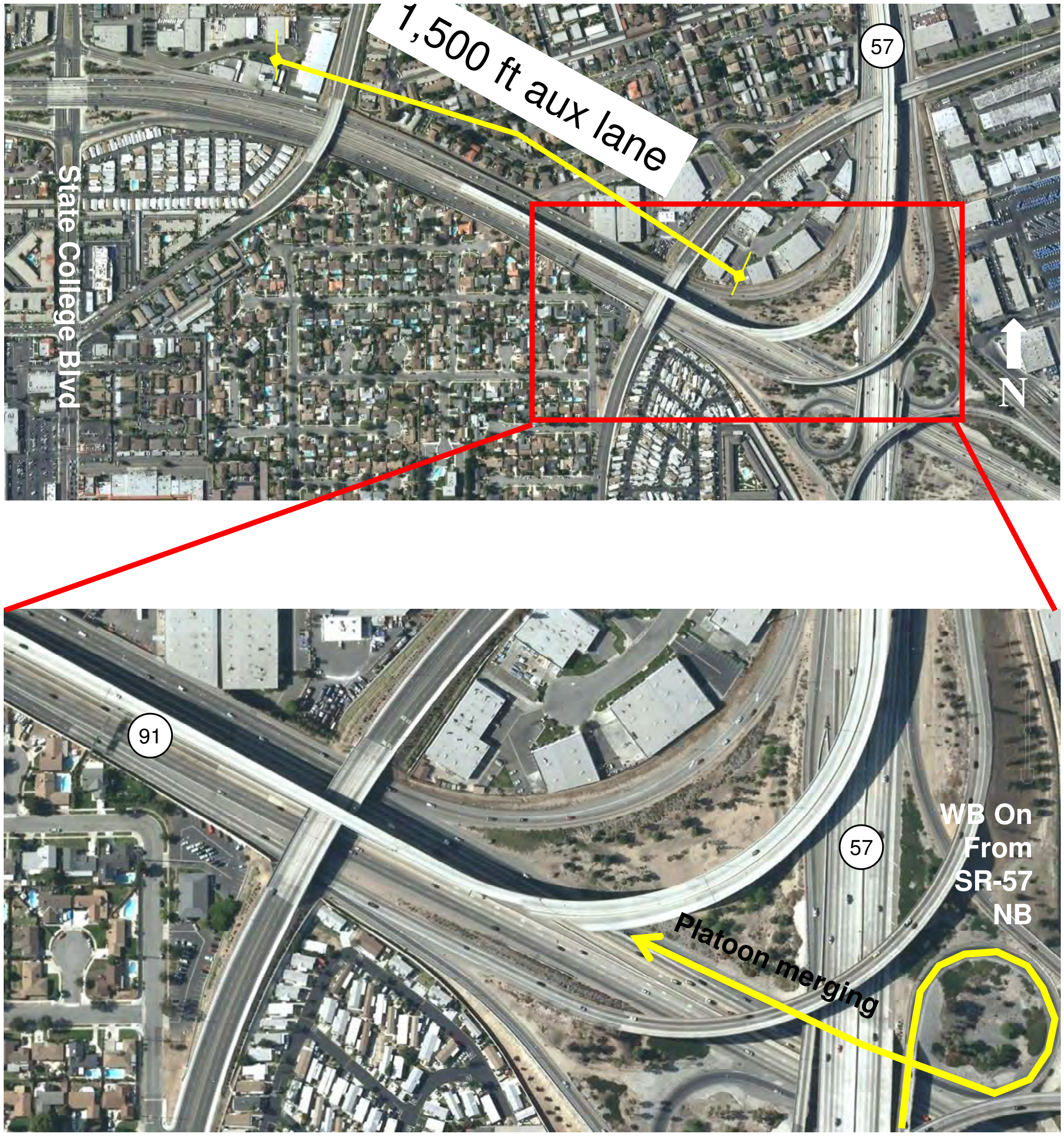
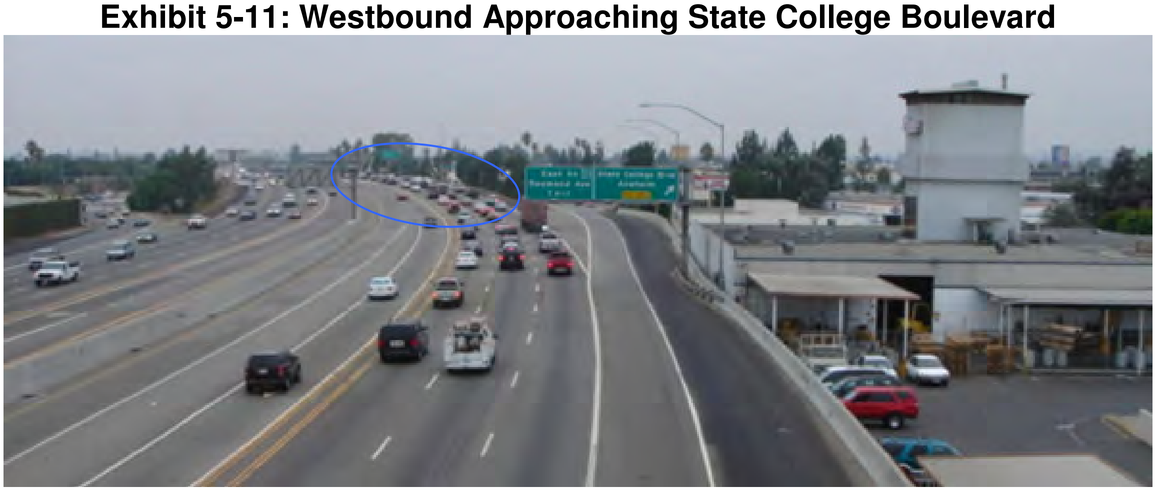


Exhibit 5-10: Westbound SR-91 at SR-57 On-Ramp

Exhibit 5-11: Westbound Approaching State College Boulevard



East Street to I-5

Several bottlenecks were identified from the data analysis between East Street and I-5 interchange, notably at Harbor Boulevard (Abs PM=20.8; Cal PM=2.4), Euclid Street (Abs PM=19.8, Cal PM=1.4) and Brookhurst Road/I-5 Off (Abs PM=19.0; Cal PM=0.5). However, none of these bottlenecks was observed in the recent field visits. Still, reduced speeds to 45 mph or slightly less were observed at the Harbor Boulevard, Euclid Street, and Brookhurst Road interchanges, primarily due to the changes in the vertical grade (rolling hills) over and under the interchanges that reduces sight distance. When mainline flows are at their peak through this segment, it is likely that minor bottlenecks are formed due to the slower speeds. The ramp traffic at these interchanges did not seem to adversely affect the mainline speeds.

6. SCENARIO DEVELOPMENT AND EVALUATION

Fully understanding how a corridor performs and why it performs that certain way sets the foundation for evaluating potential solutions. Several steps were required to develop and evaluate improvements, including:

- Developing traffic models for 2007 base-year and 2020 long-term demand
- Combining projects in a logical manner for modeling and testing
- Evaluating model outputs and summarizing results
- Conducting benefit-cost assessments of scenarios.

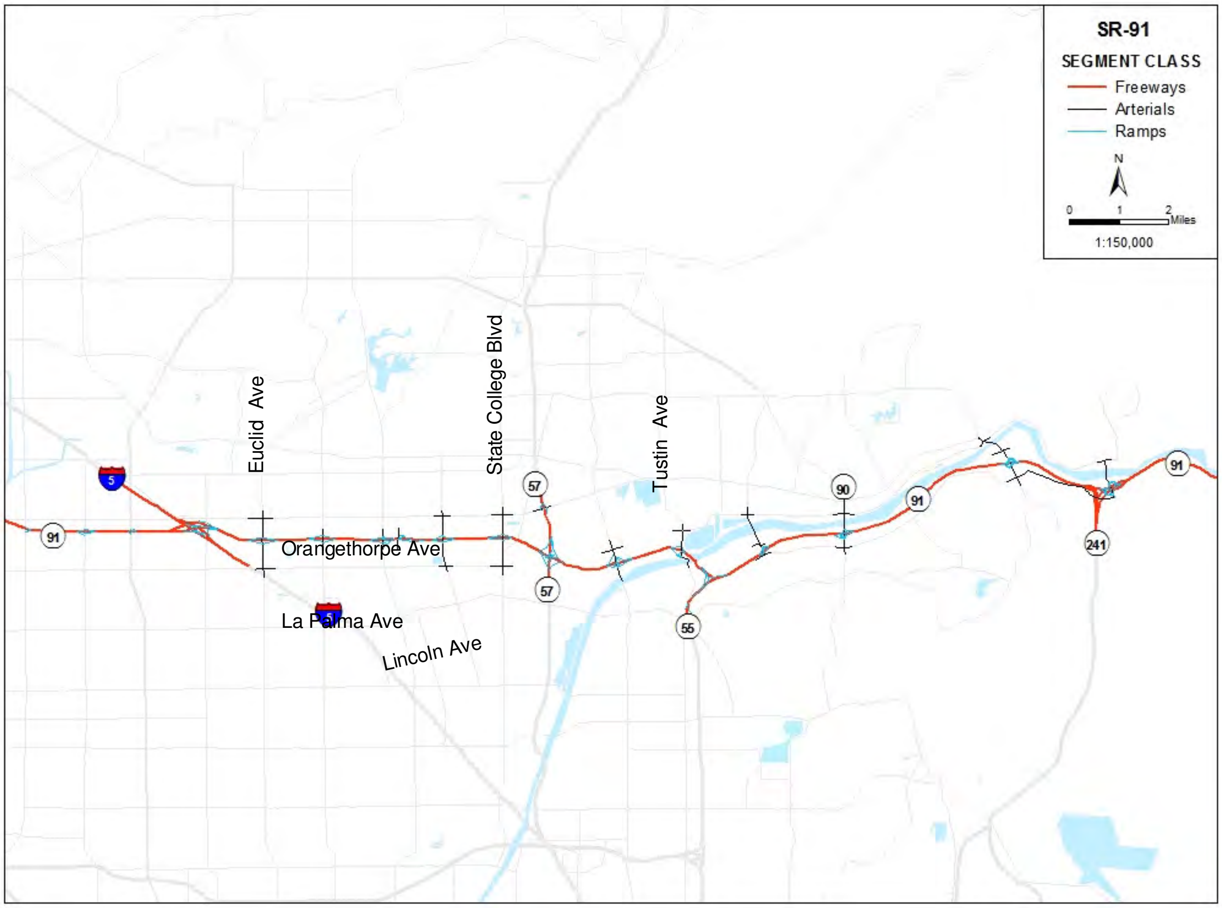
Traffic Model Development

The study team developed a traffic model using the Caliper TransModeler micro-simulation software. It is important to note that micro-simulation models are complex to develop and calibrate for a large urban corridor such as the SR-91 CSMP Corridor. However, it is one of few tools capable of providing reasonable approximations of bottleneck formation and queue development. Therefore, such tools help quantify the impacts of operational strategies, which traditional travel demand models cannot.

Exhibit 6-1 shows the corridor roadway network included in the model. All freeway interchanges were included as well as on-ramps and off-ramps along the SR-91 CSMP Corridor. The study team calibrated the base year model against the actual 2007 conditions presented earlier. This effort required several submittal and review cycles until the model reasonably matched bottleneck locations and relative severity. After acceptance of the base year model, the team developed a model with 2020 demands extrapolated from the 2030 Orange County Transportation Authority's (OCTA) travel demand model. Caltrans and the study team agreed to 2020 as the Horizon Year since micro-simulation modeling captures operational strategies, but is typically suited for the short- to medium-term forecasting. Note that latent demand over and beyond the OCTA forecast demand was not accounted for in the analysis.

These two models were then used to evaluate different scenarios (combinations of projects) to quantify the associated congestion relief benefits and to compare the project costs against their benefits.

Exhibit 6-1: SR-91 Micro-Simulation Model Network



Scenario Development Framework

The study team developed a framework for combining projects into scenarios for evaluation. It would be desirable to evaluate every possible combination of projects, but this would have entailed thousands of model runs. Instead, the team combined projects based on a number of factors, including:

- Projects fully programmed and funded were combined separately from projects that were not.
- Whenever possible, expansion projects were not combined with operational strategies in order to delineate differences between types of improvements.
- Short-term projects (delivered by 2015) were used to develop scenarios tested with both the 2007 and 2020 models.
- Long-term projects (delivered after 2015, but before or by 2020) were used to develop scenarios tested with the 2020 model only.

The study team assumed that projects developed before 2015 could reasonably be evaluated using the 2007 base year model. The 2020 forecast year for the SR-91 CSMP Corridor was consistent with the origin-destination matrices in the OCTA regional travel demand model.

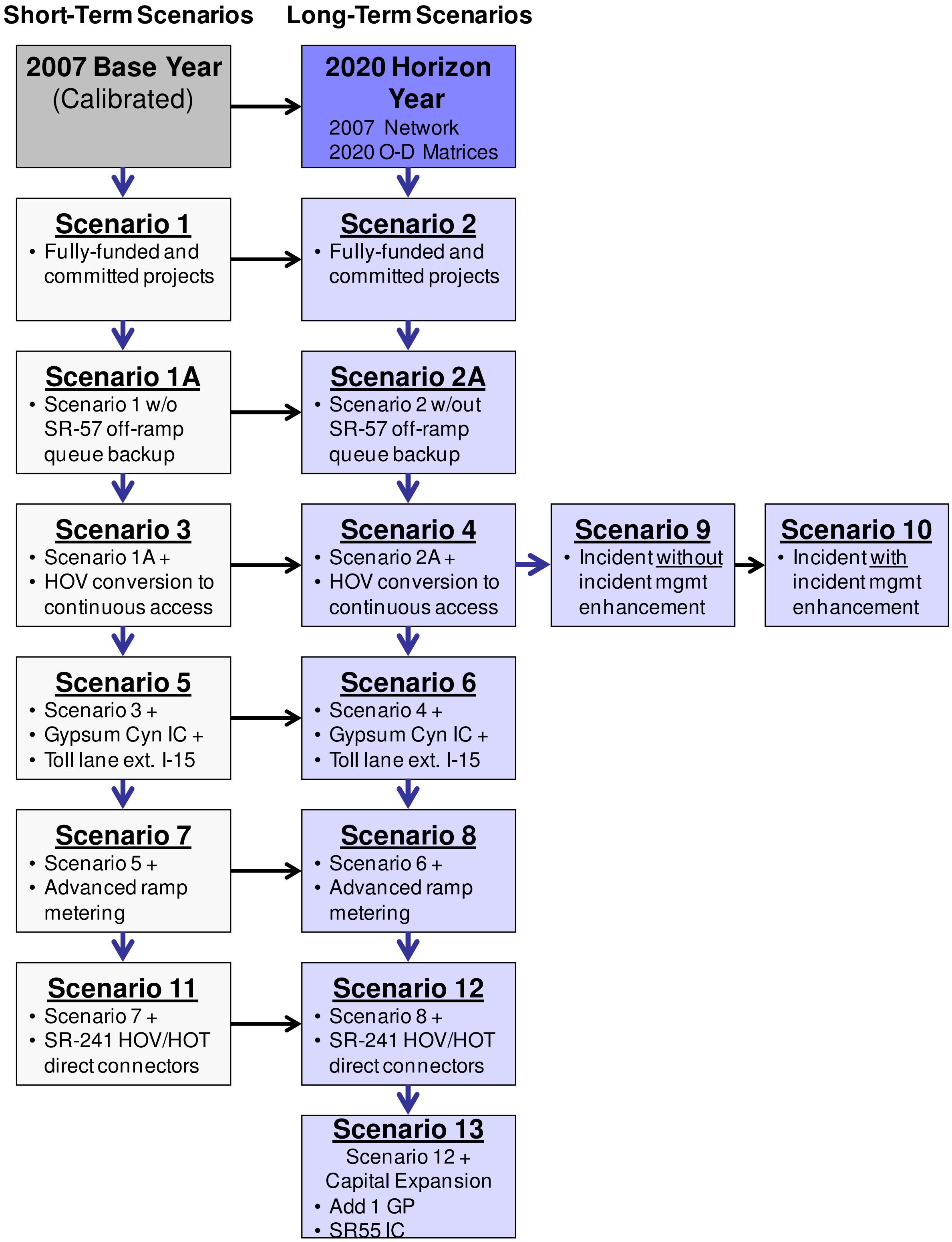
When OCTA updates its travel demand model and when SCAG updates its Regional Transportation Plan (RTP), they may wish to update the micro-simulation model with revised demand projections.

Project lists used to develop scenarios were from the Regional Transportation Improvement Program (RTIP), the RTP, Measure M2, SR-91 Implementation Plan, Transportation Corridor Agencies (TCA) improvements, Riverside County Transportation Commission (RCTC) improvements, and other sources (such as special studies). The study team eliminated projects that do not directly affect mobility. For instance, sound wall, landscaping, or minor arterial improvement projects were eliminated because micro-simulation models cannot evaluate them. Appendix A provides project lists used in developing the micro-simulation scenarios.

Scenario testing performed for the SR-91 CSMP differs from traditional alternatives evaluations or Environmental Impact Reports (EIRs). Traditional alternatives evaluations or EIRs focus on identifying alternative solutions to address current or projected corridor problems, so each alternative is evaluated separately and results among competing alternatives are compared, resulting in a locally preferred alternative. In contrast, for the SR-91 CSMP, scenarios build on each other. A scenario contains the projects from the previous scenario plus one or more projects as long as the incremental scenario results show an acceptable level of performance improvement. This incremental scenario evaluation approach is important because CSMPs are new and often compared with alternatives studies.

Exhibit 6-2 summarizes the approach used and scenarios tested. It also provides a general description of the projects included in the 2007 and 2020 micro-simulation runs.

Exhibit 6-2: Micro-Simulation Modeling Approach



Exhibits 6-3 and 6-4 show the delay results for all the 2007 scenarios evaluated for the AM and PM peak periods, respectively. Exhibits 6-5 and 6-6 show similar results for scenarios evaluated using the 2020 horizon year model. The percentages shown in the exhibits indicate the difference in delay between the current scenario and the previous scenario (e.g., Percent Change = (Current Scenario – Previous Scenario) / Previous Scenario). Impacts of strategies differ based on a number of factors such as traffic flow conditions, ramp storage, bottleneck locations, and levels of congestion.

For each scenario, the modeling team added the proposed improvements, conducted multiple model runs, and produced composite results by facility type (i.e., mainline, HOV, arterials, and ramps) and vehicle type (SOV, HOV, and trucks) as well as speed contour diagrams. The study team reviewed incremental steps in detail to ensure they were consistent with general traffic engineering principles.

A traffic report with all the model output details is available under separate cover.

Exhibit 6-3: AM Peak Micro-Simulation Delay Results by Scenario (2007)

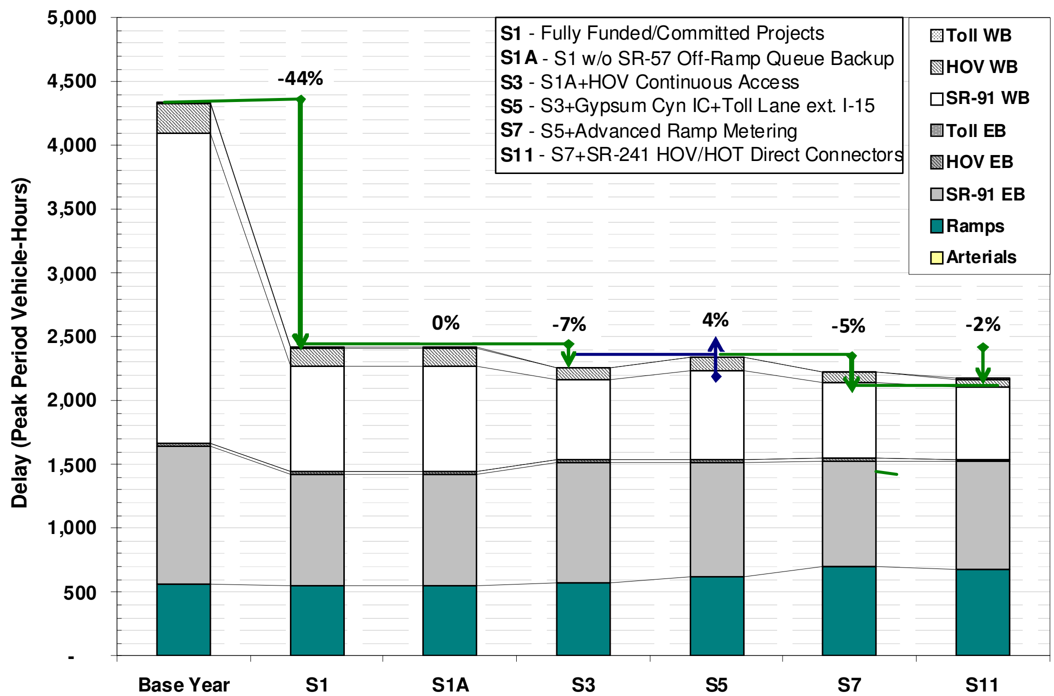


Exhibit 6-4: PM Peak Micro-Simulation Delay Results by Scenario (2007)

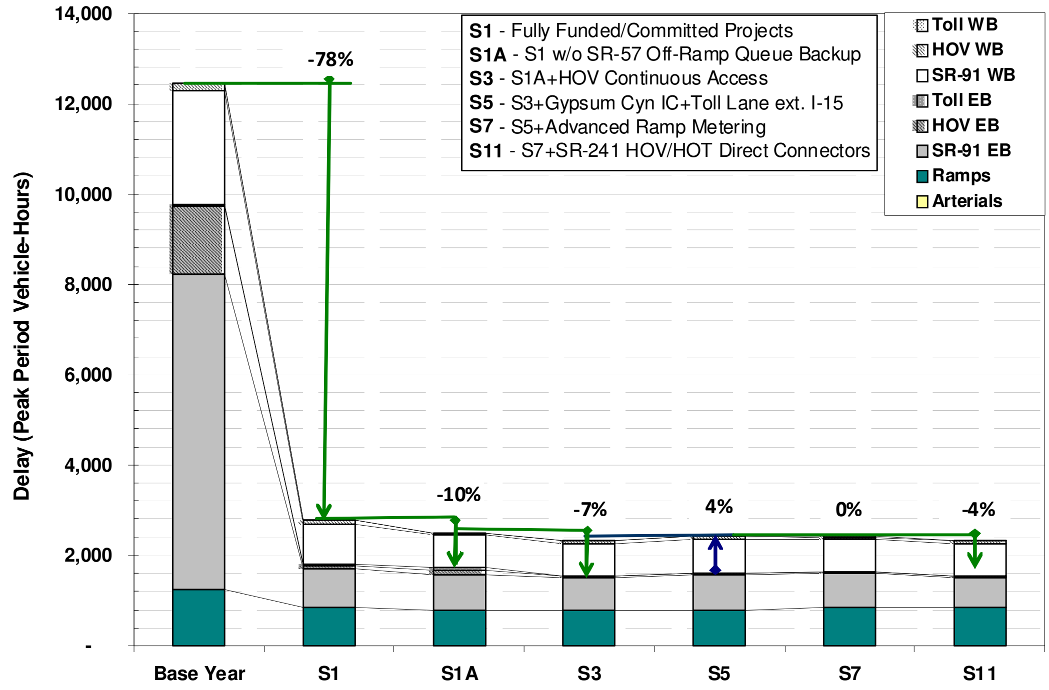


Exhibit 6-5: AM Peak Micro-Simulation Delay by Scenario (2020)

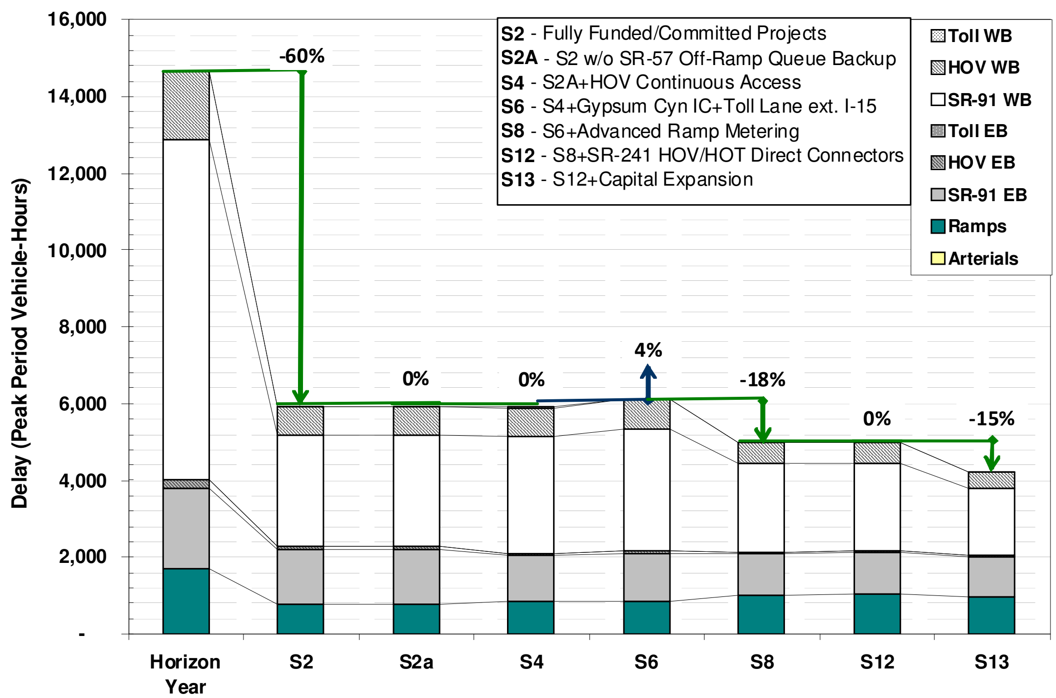
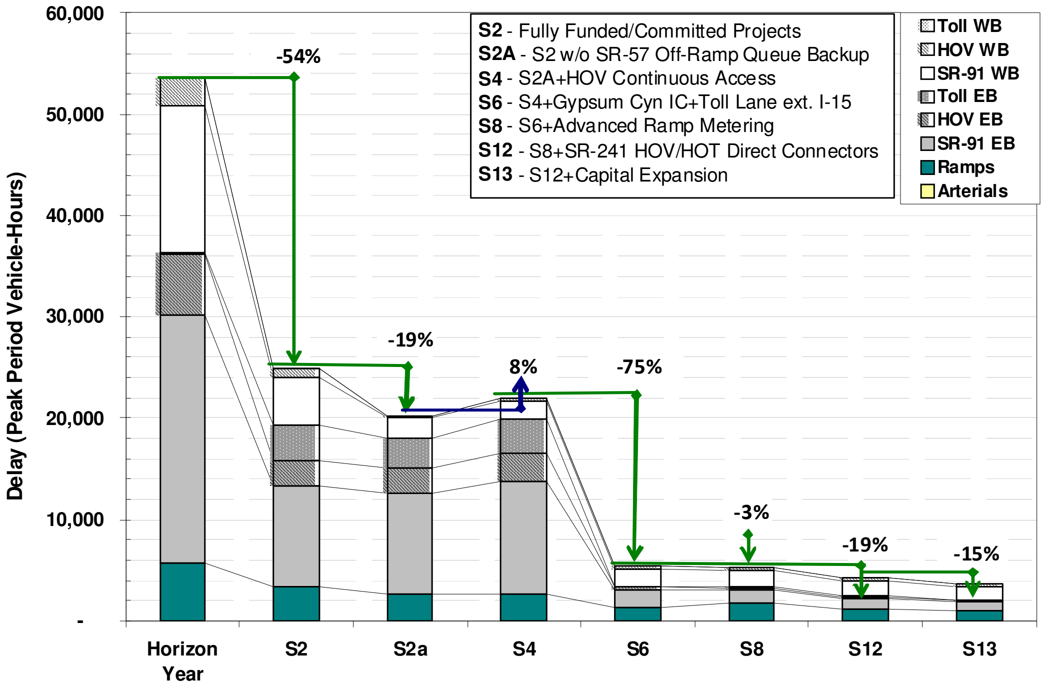


Exhibit 6-6: PM Peak Micro-Simulation Delay by Scenario (2020)



Exhibits 6-7 to 6-10 show the delay results by corridor segments (current bottleneck areas) and peak period for all 2007 scenarios. Exhibits 6-11 to 6-14 show similar results for all 2020 scenarios.

Exhibit 6-7: Eastbound AM Delay Results by Scenario and Bottleneck Area (2007)

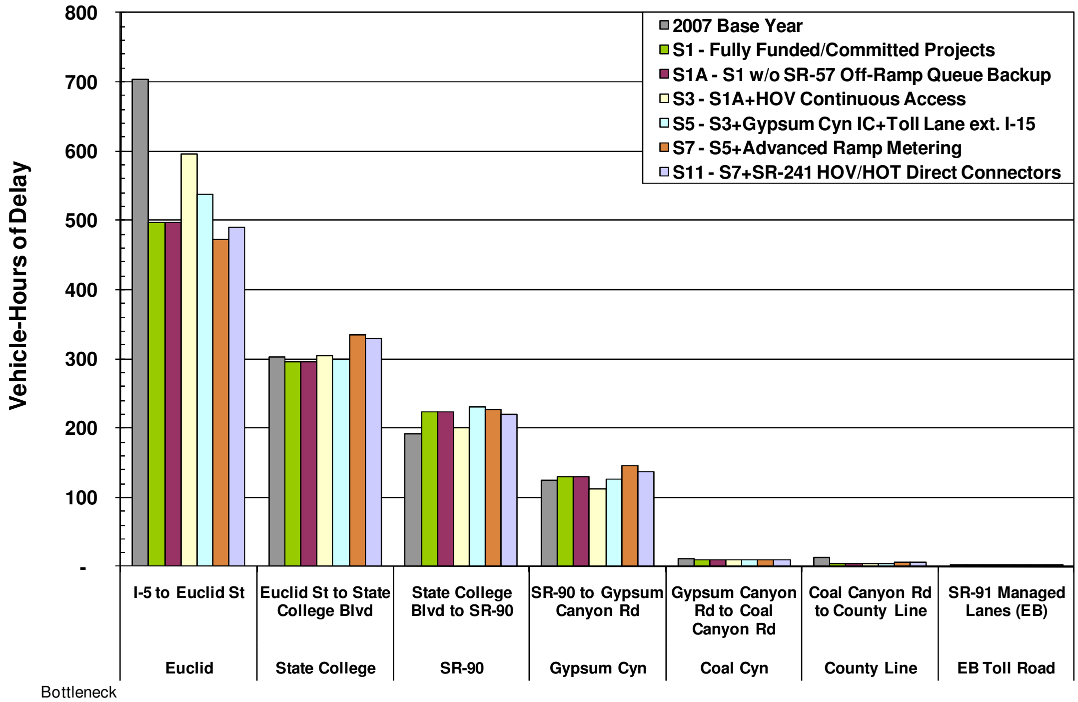


Exhibit 6-8: Eastbound PM Delay Results by Scenario and Bottleneck Area (2007)

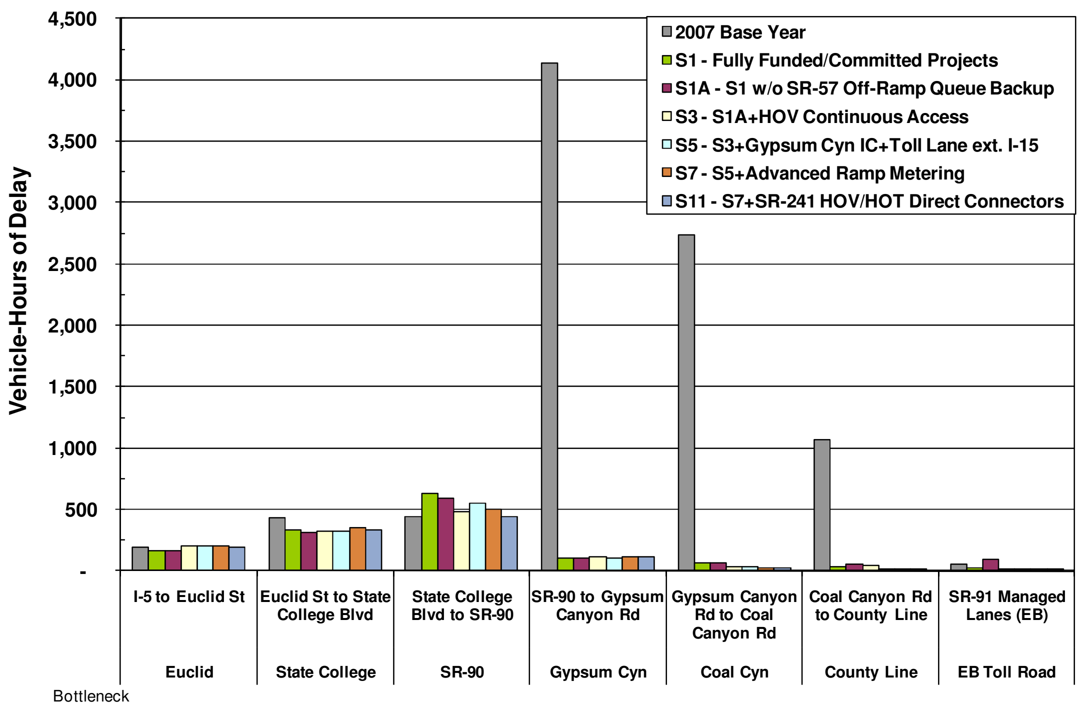


Exhibit 6-9: Westbound AM Delay Results by Scenario and Bottleneck Area (2007)

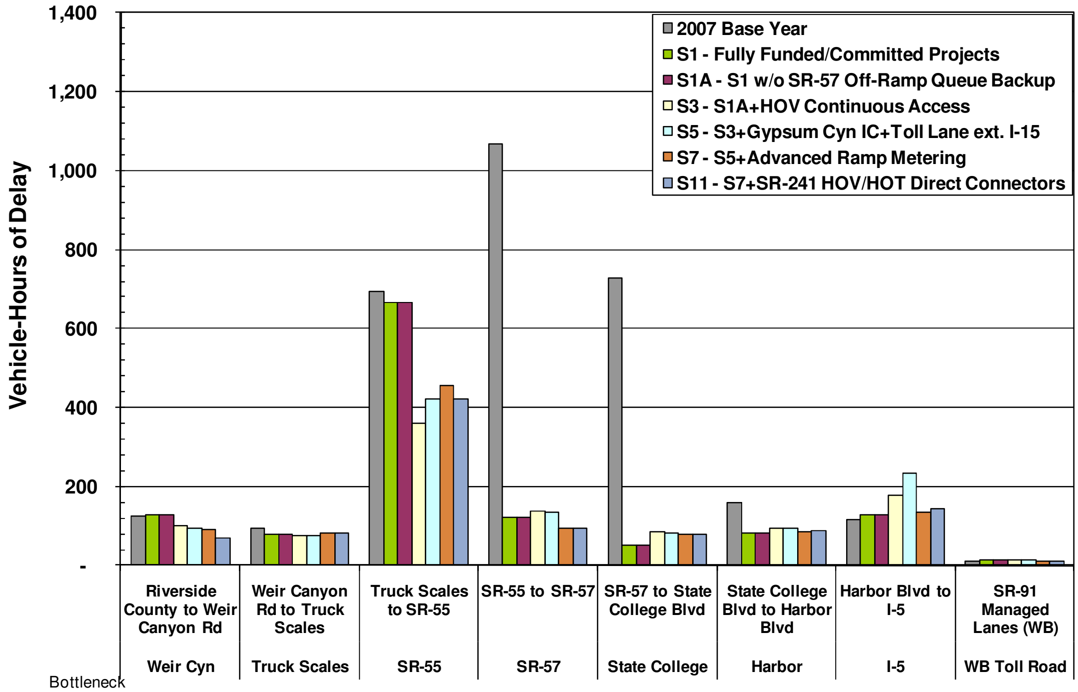


Exhibit 6-10: Westbound PM Delay Results by Scenario and Bottleneck Area (2007)

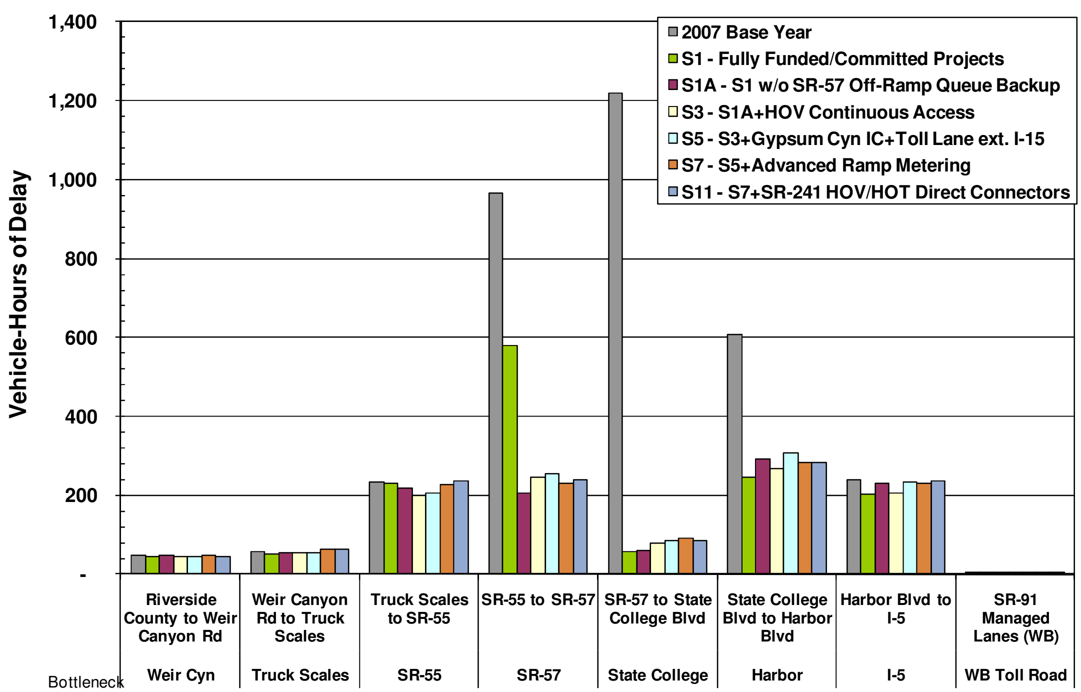


Exhibit 6-11: Eastbound AM Delay Results by Scenario and Bottleneck Area (2020)

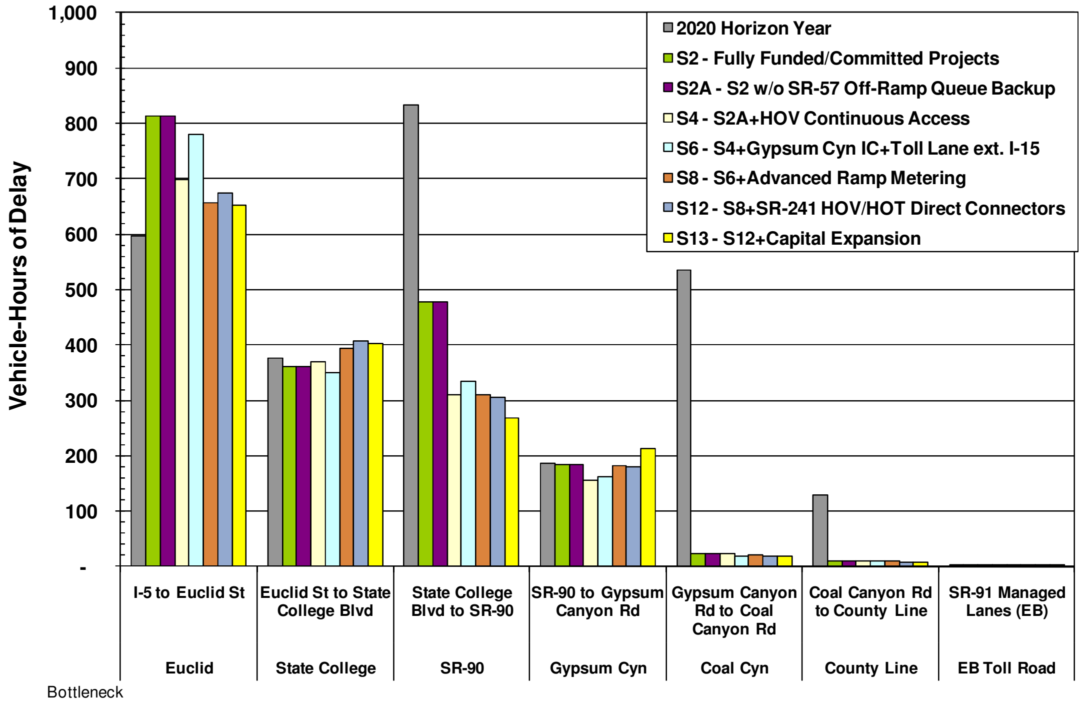


Exhibit 6-12: Eastbound PM Delay Results by Scenario and Bottleneck Area (2020)

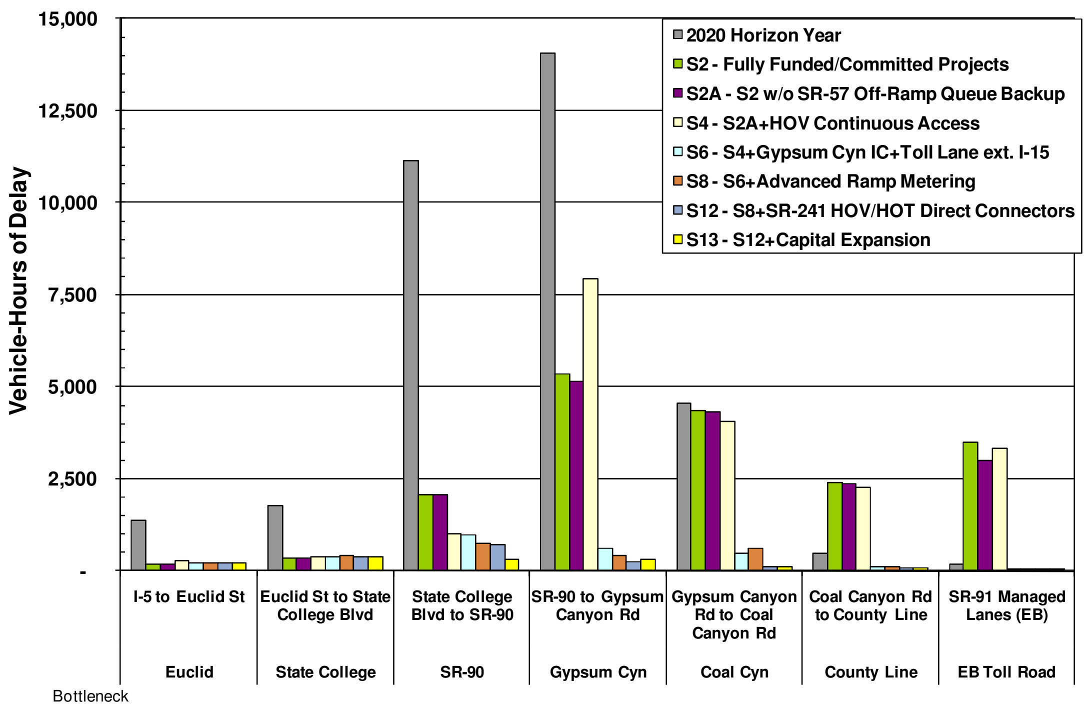


Exhibit 6-13: Westbound AM Delay Results by Scenario and Bottleneck Area (2020)

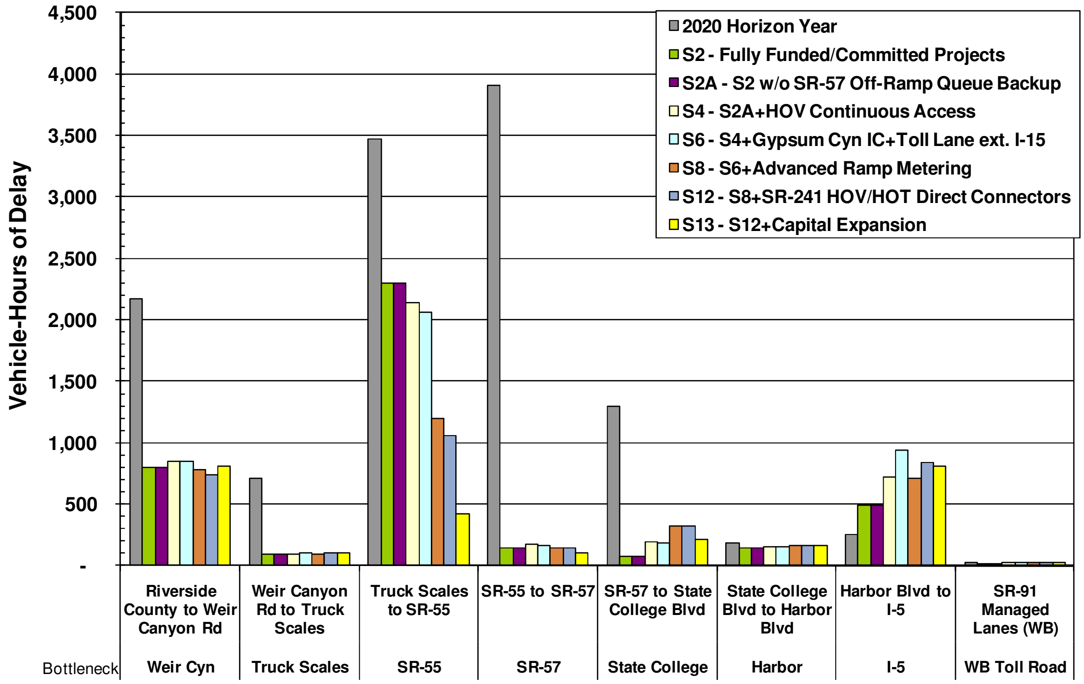
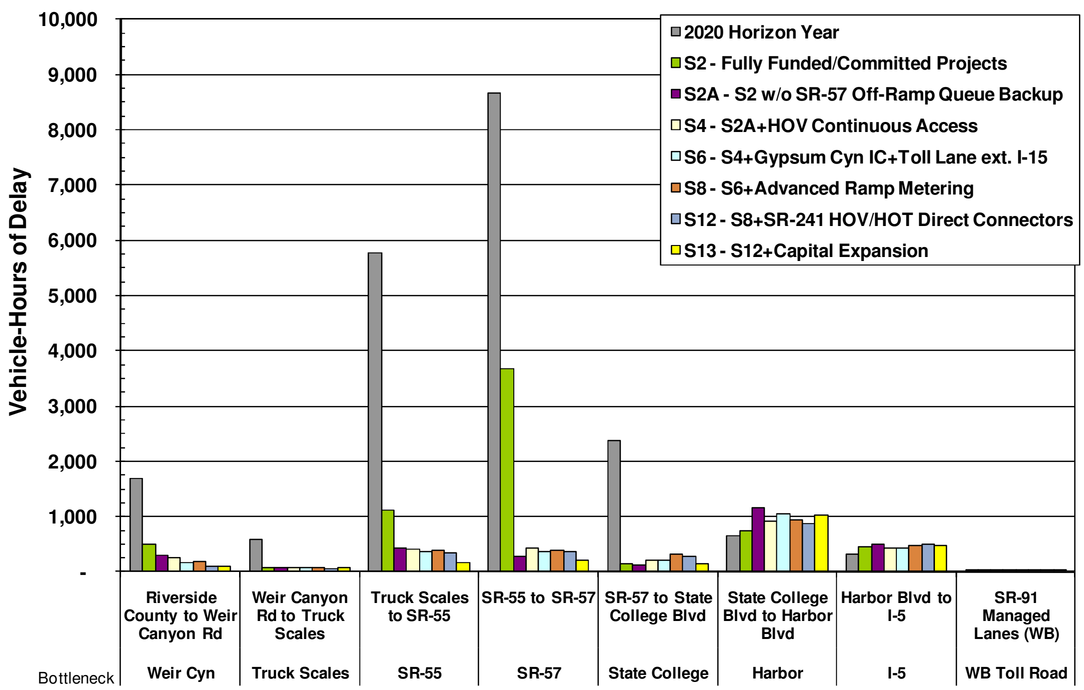


Exhibit 6-14: Westbound PM Delay Results by Scenario and Bottleneck Area (2020)



The following describes the findings for each scenario tested and reviewed by the study team.

2007 Base Year and 2020 "Do Minimum" Horizon Year

Absent any physical improvements, the modeling team estimates that by 2020, total delay (mainline, HOV, ramps, and arterials) will increase by more than 400 percent compared to 2007 (from a total of around 17,000 vehicle-hours daily to nearly 69,000 vehicle-hours). Demand may continue to increase beyond 2020 and may require further study. As described below, the programmed projects lead to significant decreases in congestion. The improved mobility on the corridor accounts for more than a 50-percent reduction in delay.

Scenarios 1 and 2 (Fully Funded and Committed Projects)

The first two scenarios include fully funded and programmed projects that are both expansion and operations-related. These projects are slated for completion by 2015 and include:

- Connecting the existing auxiliary lane through interchanges on westbound SR-91 between SR-57 and I-5 with its elements
- Extending a lane and reconstructing the auxiliary lane on westbound SR-91 from SR-55 through the Tustin interchange
- Adding an eastbound lane between SR-241 and SR-71, and improving the northbound SR-71 connector from SR-91 to a standard one lane and shoulder width (CMIA project)
- Adding one lane in each direction – SR-55 connector to SR-241 in Anaheim, from east of SR-55 connector to east of Weir Canyon Road (CMIA project)
- Re-striping southbound Lakeview Avenue to provide 1.5 right-turn lanes to westbound SR-91 on-ramp
- Widening and improving Tustin Avenue between SR-91 and La Palma Avenue (city development mitigation project)
- Widening northbound SR-241 to both directions of SR-91 from three to four lanes (two in each direction).

The 2007 model estimates that the programmed projects will reduce delay on the corridor by approximately 44 percent in the AM peak period and by 78 percent in the PM peak period. In total, this scenario estimates a reduction of nearly 12,000 vehicle-hours of daily (AM and PM peak period) delay. In the westbound direction, the majority of the delay reduction occurs during the AM peak period from SR-55 to State College Boulevard. In the eastbound direction, the largest mobility improvements occur during the PM peak period from Gypsum Canyon Road to Coal Canyon Road.

The 2020 model estimates that the same projects will reduce delay on the corridor by approximately 60 percent in the AM peak period and 54 percent in the PM peak period, for a total daily reduction of over 38,000 vehicle-hours delay.

These scenarios include CMIA projects that will produce significant corridor operational and mobility benefits. Reductions in daily delay are well over 50 percent in both directions and on every type of corridor facility (mainline, HOV lanes, ramps, and arterials).

Scenarios 1A and 2A (Programmed Projects without SR-57 Off-Ramp Queue Backup)

During the early stages of testing, the study team realized that improvements on SR-57 led to mobility benefits on SR-91 and vice versa. The team needed to isolate such benefits and assign them to the appropriate corridor. For instance, improvements on SR-91 will reduce backups on the connector from southbound SR-57 to westbound SR-91. These delay benefits do not relate to improvements on SR-57. Conversely, improvements on SR-57 also lead to delay reductions on SR-91.

In order to assign benefits correctly, the team evaluated two sets of scenarios related to the programmed projects listed above. The first set (Scenarios 1 and 2) maintained the queue backups from westbound SR-91 to northbound SR-57 connector. The second set (Scenarios 1A and 2A) relieved these backups with the improvements on the SR-57 CSMP Corridor. The difference between the benefits of these two sets of scenarios belongs to the SR-57 CSMP Corridor. The team used the same approach with the SR-57 model (developed for the SR-57 CSMP) to delineate the benefits associated with SR-91 improvements that affect SR-57.

The results of the scenarios run in the SR-91 model were applied to the SR-57 CSMP. In addition, the study team assumed that the SR-57 improvements that relieve the queue backup onto SR-91 would occur prior to all subsequent SR-91 improvement scenarios.

Scenarios 3 and 4 (HOV Lane Conversion to Continuous Access)

Scenarios 3 and 4 build on Scenarios 1A and 2A by adding a project to convert the existing buffer-separated HOV and limited access HOV to a full-time continuous access HOV facility. The study team tested Scenarios 3 and 4 with the 2007 and 2020 models, respectively. Caltrans may revisit the modeling once the full details of the continuous access design are finalized.

The 2007 model estimates that this project would produce a delay reduction of approximately seven percent in the AM peak period and seven percent in the PM peak period. The 2020 model, however, estimates that Scenario 4 would result in an increase in delay by as much as eight percent in the PM peak period. The model shows that this is due to the HOV conversion exacerbating an eastbound bottleneck downstream at Gypsum Canyon. The project improves operations upstream in the eastbound direction and allows traffic to move downstream faster. This higher demand compounds the bottleneck at Gypsum Canyon and results in a higher overall delay. It is only when this bottleneck is relieved (in Scenarios 5 and 6) that the continuous HOV access project will produce an overall net positive result.

Scenarios 5 and 6 (Planned Short-Range Implementation Projects)

Scenarios 5 and 6 build on Scenarios 3 and 4 by adding planned short-range implementation projects. These projects include:

- Widening Gypsum Canyon Road from two to four lanes; adding Class II on-road bike lanes; adding a multi-use trail and sidewalk on west side of roadway; modifying an existing entrance ramp; and reconstructing and signalizing the eastbound SR-91 exit ramp intersection
- Extending the toll lane to east of I-15 (a component of Project No. 7 of the 2009 Implementation Plan and Project No. 4 of the 2010 Implementation Plan).

With the widening and toll extension of the SR-91 Express Lanes to I-15, traffic flows would increase in the westbound direction from east of I-15. This increased traffic would result in an increase in overall delay in both the AM and PM peak period by about four percent.

However, while the 2020 model estimates that the AM peak period also results in overall increase in delay by about four percent, this delay is more than made up for by a significant reduction in delay (reduction of over 75 percent or over 12,000 vehicle-hours delay) in the PM peak period. This reduction occurs almost entirely in the eastbound direction from Imperial Highway to the Riverside County line. This result should be expected with the toll lane extension eastbound to I-15.

Scenarios 7 and 8 (Advanced Ramp Metering System with Connector Metering)

Scenarios 7 and 8 build on Scenarios 5 and 6 by adding an advanced ramp metering system, such as dynamic or adaptive ramp metering with connector metering and queue control. Queue control ensures that traffic flow does not exceed the capacity of the connector at the following locations:

- SB-57 to WB-91 (widen connector to three lanes of storage)
- NB-57 to EB-91 (widen connector to two lanes of storage)
- NB-55 to WB-91 (no widening)
- NB-241 to WB-91 (no widening)
- NB-241 to EB-91 (no widening at maximum allowable rate to flow)
- SB-5 to EB-91 (no widening)
- NB-5 to WB-91 (no widening)
- Meter all HOV bypass ramps.

The 2007 model estimates that this project would produce a delay reduction of approximately five percent in the AM peak period and minimal impact in the PM peak period. The 2020 model estimates that advanced ramp metering would reduce delay by as much as 18 percent in the AM peak period (with the largest mobility improvements from Truck Scales to SR-55) and three percent in the PM peak period. Ramp metering has less impact on the PM peak period because there is very little freeway congestion.

Note that there are various types of advanced ramp metering systems deployed around the world, including the System-Wide Adaptive Ramp Metering System (SWARM) tested on the Los Angeles I-210 freeway corridor. For the SR-91 modeling purposes, the Asservissement Lineaire d'Entrée Autoroutiere (ALINEA) system was tested as proxy for any advanced ramp metering system, as its algorithm for the model was readily available. It is, however, not necessarily recommended that ALINEA be deployed but rather some type of advanced ramp metering system that would produce similar, if not better results.

Scenarios 9 and 10 (Enhanced Incident Management System)

The study team tested two incident scenarios built upon the Scenario 4 network to evaluate non-recurrent delay reductions resulting from enhanced incident management strategies. In the first scenario (Scenario 9), a collision incident with one outside lane closure was simulated in the westbound direction in the AM peak period model and in the eastbound direction in the PM peak period model. The incident simulation location and duration were selected based on review of the 2010 actual incident data, at one of the high-frequency incident locations.

The following are the scenario details:

- Westbound AM Peak Period starting at 7:00 AM, close outermost mainline lane for 35 minutes at postmile R10.2 (west of Lakeview Avenue)
- Eastbound PM Peak Period starting at 4:00 PM, close outermost mainline lane for 35 minutes at postmile R18.8 (at Green River).

This scenario represents a typical, moderate incident at one location during each peak direction period. Data suggest that incidents vary significantly in terms of impact and duration. Some incidents last hundreds of minutes, some close multiple lanes, and some occur at multiple locations simultaneously. There are also numerous minor incidents lasting only a few minutes without lane closures, yet still resulting in congestion. In addition, there are many incidents occurring during off-peak hours.

Based on actual Caltrans incident management data, it is estimated that an enhanced incident management system could reduce a 35-minute incident by about 10 minutes. An enhanced incident management system would entail upgrading or enhancing the current Caltrans incident management system to include deployment of intelligent transportation system (ITS) field devices, central control/communications software, communications medium (i.e. fiber optic lines), advanced traveler information system, and/or freeway service patrol (FSP) program to reduce incident detection, verification, response, and clearance times.

In the second scenario (Scenario 10), the study team simulated the same collisions with a 10-minute reduction in duration to determine the benefits of an enhanced incident management system.

The 2020 model results indicate that deployment of such a system could eliminate approximately 1,500 vehicle-hours delay in the eastbound direction and nearly 3,500 vehicle-hours of delay in the westbound direction using 2020 demand. As shown in Exhibits 6-15 and 6-16, these results reflect benefits during the peak direction period. Additional benefits would be realized during off-peak hours and in the off-peak direction.

Exhibit 6-15: AM Delay Results for Enhanced Incident Management (2020)

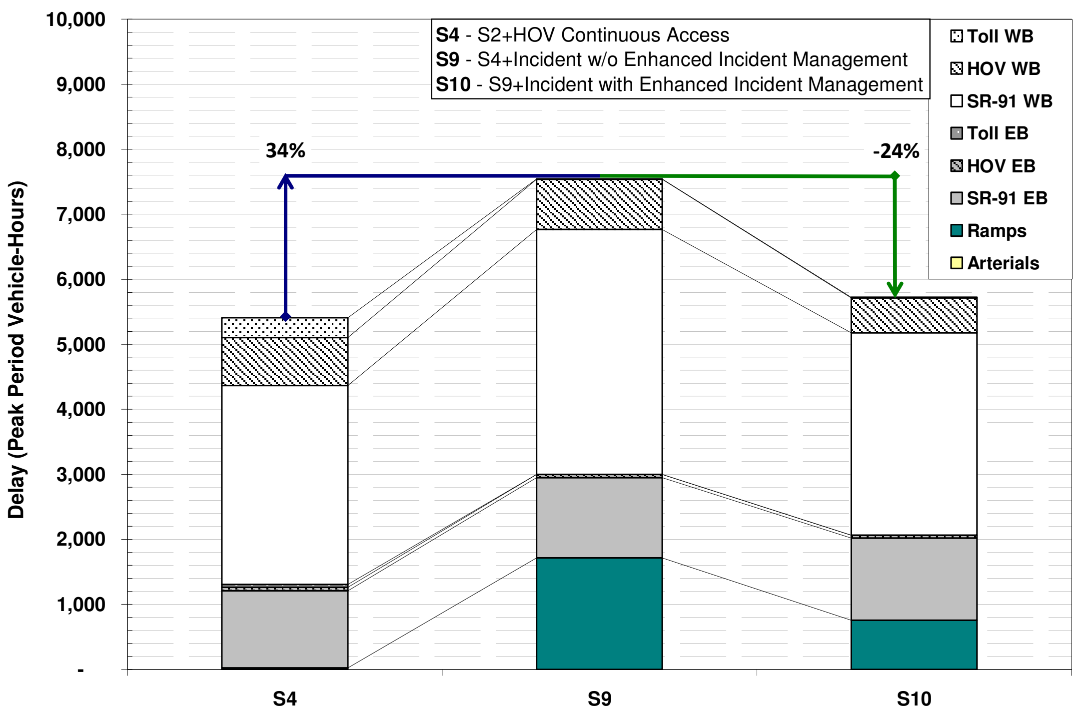
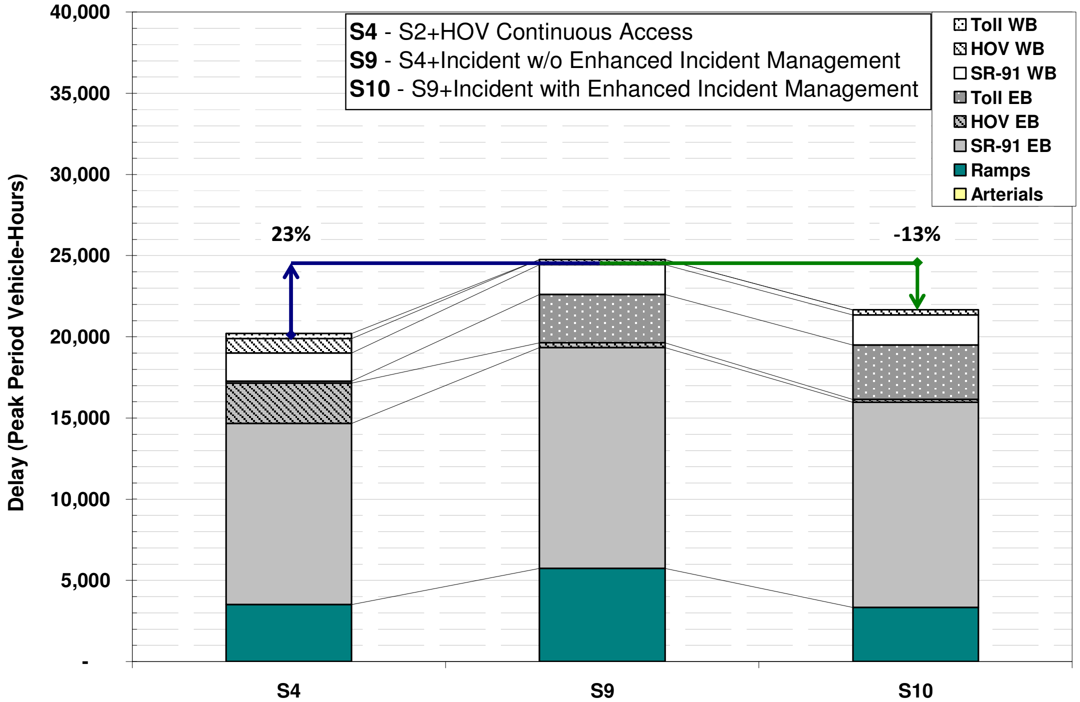


Exhibit 6-16: PM Delay Results for Enhanced Incident Management (2020)



Scenarios 11 and 12 (Direct HOV/HOT Connectors)

Scenarios 11 and 12 build on Scenarios 7 and 8 and include a planned project to add direct HOV/HOT connectors at:

- Northbound SR-241 to eastbound SR-91
- Westbound SR-91 to southbound SR-241.

The 2007 model estimates that this project would reduce delay by about two percent in the AM peak period and four percent in the PM peak period.

The 2020 model estimates that Scenario 12 would result in reduction in delay by as much as 19 percent in the PM peak period with minimal impact in the AM peak period.

Scenario 13 (Planned Long-Range Capital Expansion)

Scenario 13 builds on Scenarios 12 by adding the following planned, long-range capital expansion projects:

- Adding one general purpose lane in each direction from SR-57 to SR-55

- Reconstructing the SR-55 interchange, re-striping existing lanes, modifying the SR-55 connectors to SR-91, and adding a flyover connector from WB SR-91 to SB SR-55.

The 2020 model estimates that this project would produce a delay reduction of approximately 15 percent in the AM peak period and 15 percent in the PM peak period. This is a total reduction in delay of about 3,000 vehicle-hours.

Post Scenario 13 Conditions

By 2020, with the inclusion of projects from Scenario 1 to Scenario 13, the model reveals some residual congestion remains to be addressed with future improvements. According to the model results, the total remaining delay on the corridor is less than 10,000 daily vehicle-hours with no bottleneck area segment exceeding 1,000 vehicle-hours in either direction during either peak period.

Benefit-Cost Analysis

Following an in-depth review of the model results, the study team developed a benefit-cost analysis for each scenario. The benefit-cost results represent the incremental benefits over the incremental costs of a given scenario.

The study team used the California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C) developed by Caltrans to estimate benefits in three key areas: travel time savings, vehicle operating cost savings, and emission reduction savings. The results are conservative since this analysis does not capture benefits after the 20-year lifecycle or other benefits, such as the reduction in congestion beyond the peak periods and improvement in transit travel times.

Project costs were obtained from various sources, including the RTIP, OCTA's Long Range Plan (LRP), and Caltrans project planning. Costs for the advanced ramp and connector ramp metering include widening to accommodate the connector meters within the State's right-of-way, but not the acquisition of new right-of-way. A benefit-cost ratio (B/C) greater than 1 means that a scenario's projects return benefits greater than they cost to construct or implement. It is important to consider the total benefits that a project brings.

Exhibit 6-17 illustrates typical benefit-cost ratios for different project types. Large capital expansion improvements generally produce low benefit-cost ratios because the costs are so high. Conversely, transportation management strategies such as ramp metering produce high benefit-cost ratios given their low costs. The benefit-cost analysis for the SR-91 CSMP Corridor is summarized in Exhibit 6-18.

Exhibit 6-17: Benefit-Cost Ratios for Typical Projects

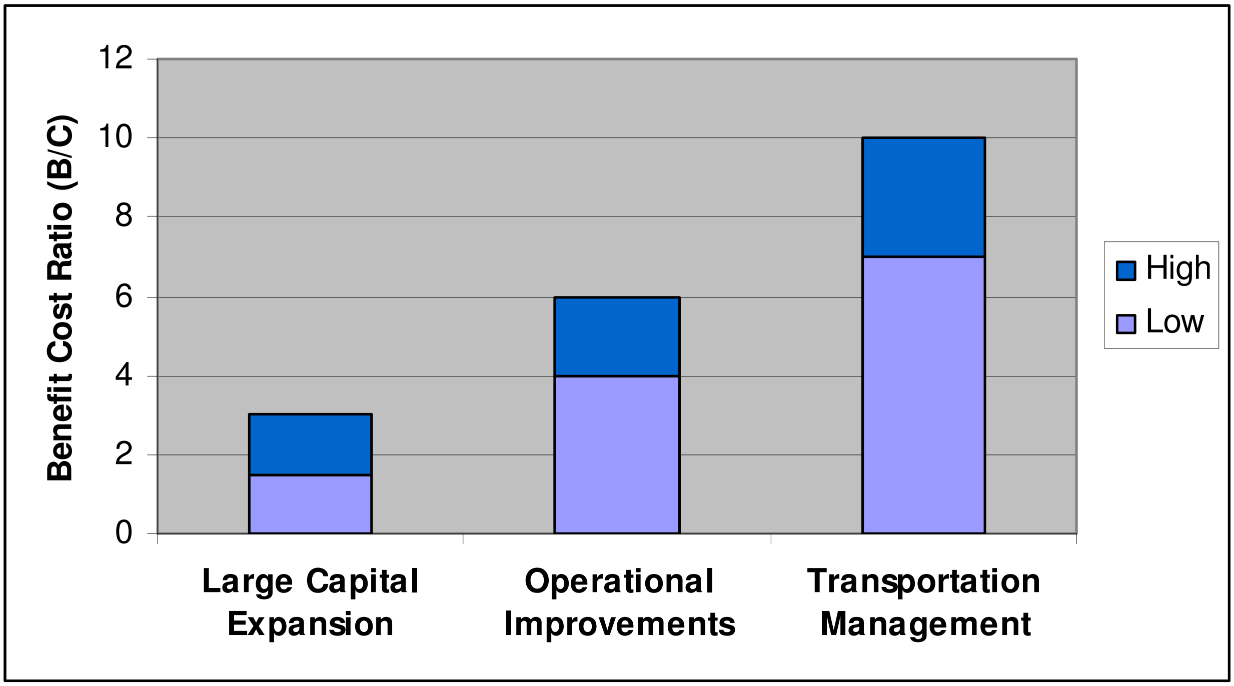
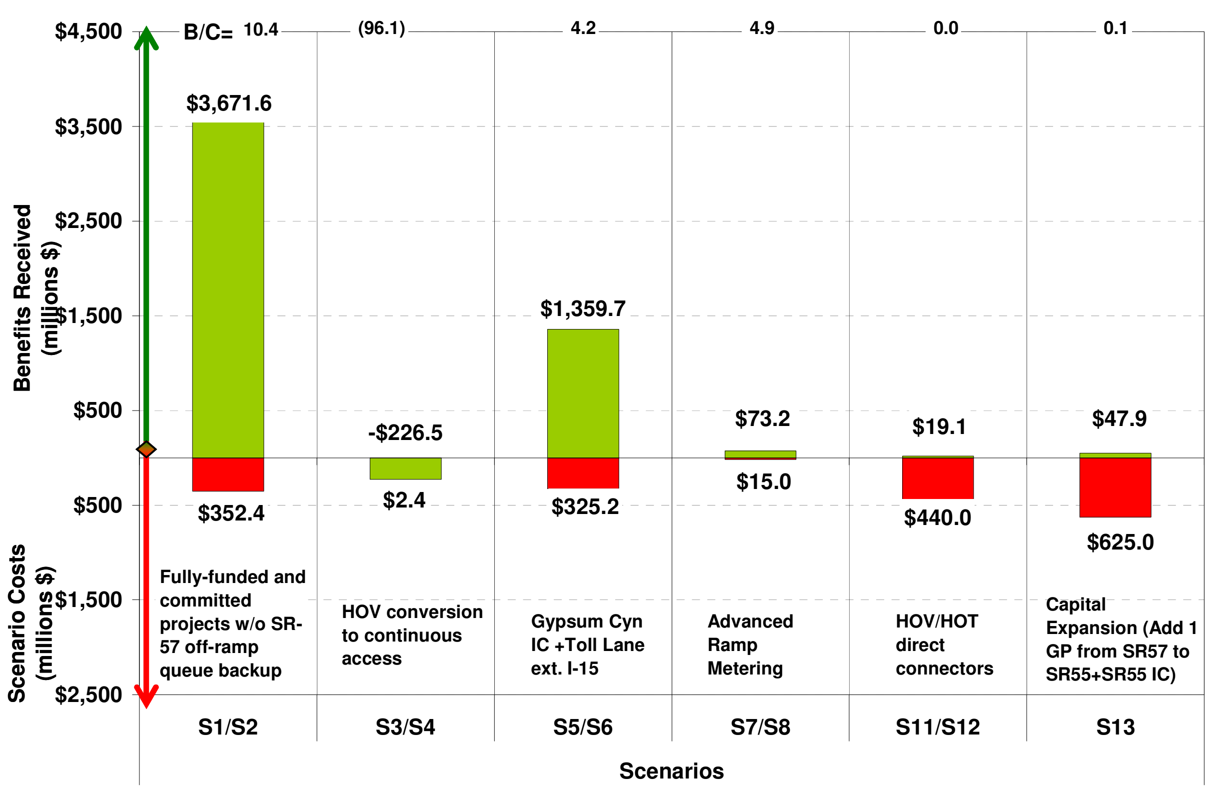


Exhibit 6-18: Scenario Benefit/Cost (B/C) Results



The benefit-cost findings for each scenario are as follows:

- Scenarios 1 and 2 (completed or fully funded programmed projects) produce a high benefit-cost ratio of over 10:1.
- Scenarios 3 and 4 (HOV lane conversion to continuous access) produce a benefit-cost ratio of less than 1, but the full benefits appear in later scenarios after the Gypsum Canyon bottleneck is relieved.
- Scenarios 5 and 6 (planned short-range implementation projects) produce a benefit-cost ratio of over 4:1. The benefit-cost ratio is lowered by the high cost of the toll lane extension.
- Scenarios 7 and 8 (advanced ramp metering with connector metering) produce a benefit-cost ratio of nearly 5:1.
- Scenarios 11 and 12 (direct HOV/HOT connectors) produces a low ratio of below 1, due mainly to the high cost and benefits limited to a point location in the corridor. Consistent with standard benefit-cost methodology, toll revenue is not included in the benefit-cost calculation.
- Scenario 13 (capital expansion project) produces a low benefit-cost of less than 1, mainly due to a high cost and limited benefits. There is very little noticeable congestion by year 2020 for the projects to address. Demand may continue to increase beyond 2020 and require further study.
- The benefit-cost ratio of all the scenarios combined is about 3:1. If all the projects are delivered at current cost estimates, the public will get three dollars of benefits for each dollar expended. In current dollars, costs add to around $1.8 billion whereas the benefits are estimated to be almost $5.0 billion.
- The projects also alleviate greenhouse gas (GHG) emissions by over 3.3 million tons over 20 years, averaging nearly 165,000 tons reduced per year. The emissions reductions are estimated in Cal-B/C using data from the California Air Resources Board (CARB) Emissions Factors (EMFAC) model.

Detailed benefit-cost results can be found in Appendix B.

7. CONCLUSIONS AND RECOMMENDATIONS

This section summarizes the conclusions and recommendations based on the analysis presented. Many of these conclusions are based on the micro-simulation model results. The model was developed based on the best data available at the time. After a thorough and careful review of each incremental step and analysis, the study team believes that both the calibration and the scenario results are reasonable and allow for more informed decision-making.

However, caution should always be used when making decisions based on modeling alone. Engineering and professional judgment and experience, among other technical factors, should be taken into consideration in making the most effective project decisions that affect millions, if not billions, of dollars in investment. Project decisions are based on a combination of regional and inter-regional plans and needs, regional and local acceptance for the project, availability of funding, planning and engineering requirements.

Based on the results, the study team offers the following conclusions and recommendations:

- Although the costs of completed or programmed and committed projects (including CMIA) in Scenarios 1 and 2 are high at over $350 million combined, the model results indicate that benefits could outweigh costs by over 10:1 with benefits exceeding $3.5 billion over a 20-year lifecycle. These projects produce significant returns on investment.
- The benefit-cost ratios for Scenarios 3 to 13 range from low to moderate. Low-cost improvements, such as advanced ramp metering with connector metering, seem to show relatively reasonable investment results. Other improvements may need to consider other factors.
- Enhanced incident management shows promise. Over the course of a year, the delay savings could be substantial when both peak and off-peak benefits are considered.

Exhibits 7-1 and 7-2 show speed contour maps for the SR-91 mainline in the 2020 "Do Minimum" Horizon Year with the growth in congestion before any improvements. Exhibits 7-3 and 7-4 show the speed contour maps produced by the model for the mainline at the conclusion of Scenario 13, the final scenario tested. Other speed contour maps are in the traffic report. Exhibits 7-3 and 7-4 show the last remaining residual congestion and bottleneck locations. There is very little congestion by year 2020 after all of the scenarios are implemented. Only a small amount of congestion at Gypsum Canyon on-ramp remains in the eastbound direction in the PM peak period. Westbound, three AM period congested locations remain at Gypsum Canyon Road, State College Boulevard, and Brookhurst Street. Since the CSMP horizon year model is for 2020, further study or other methodology may be needed to assess the benefits of addressing demand beyond 2020.

Exhibit 7-1: Eastbound PM Peak Model Speed Contours Before Improvements (2020)

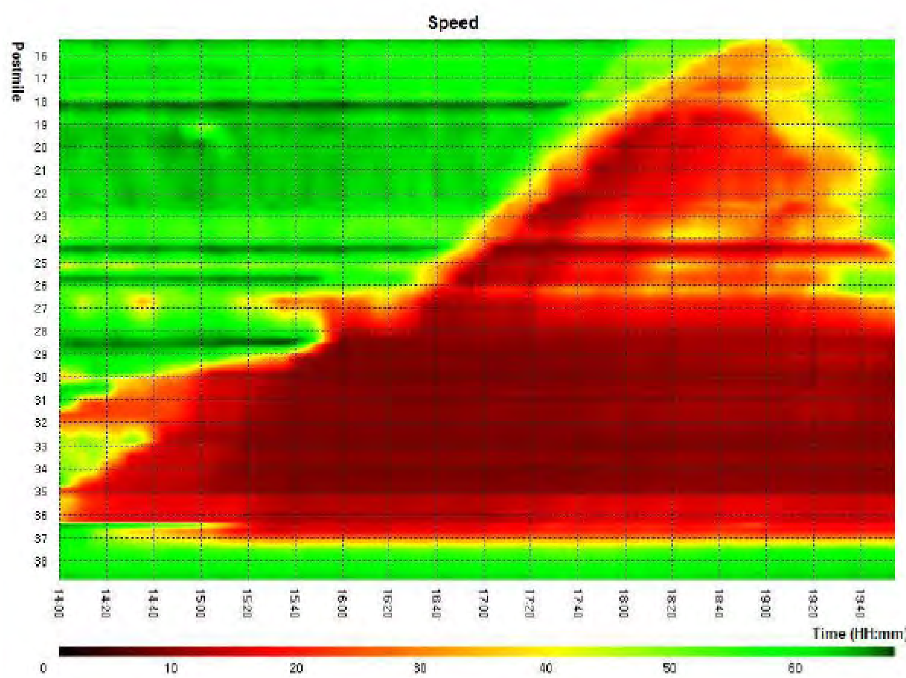


Exhibit 7-2: Westbound AM Peak Model Speed Contours Before Improvements (2020)

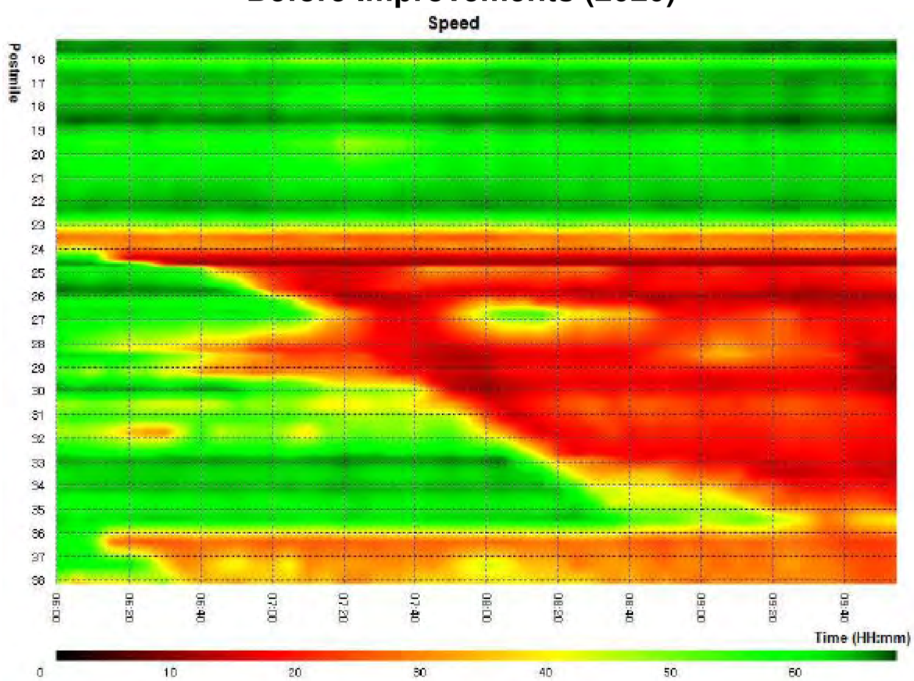


Exhibit 7-3: Eastbound PM Peak Model Speed Contours After Improvements (2020)

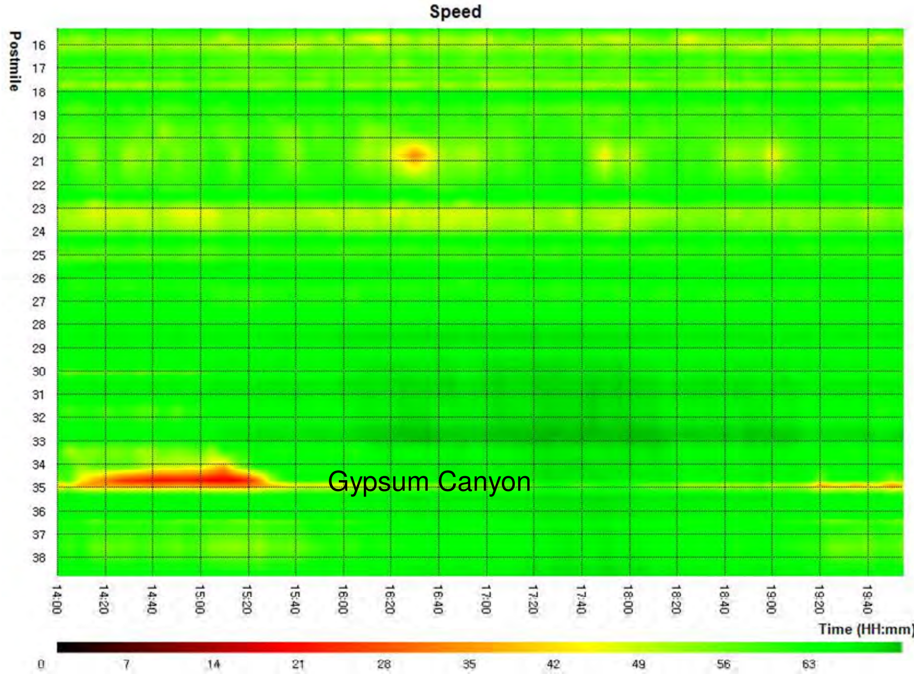
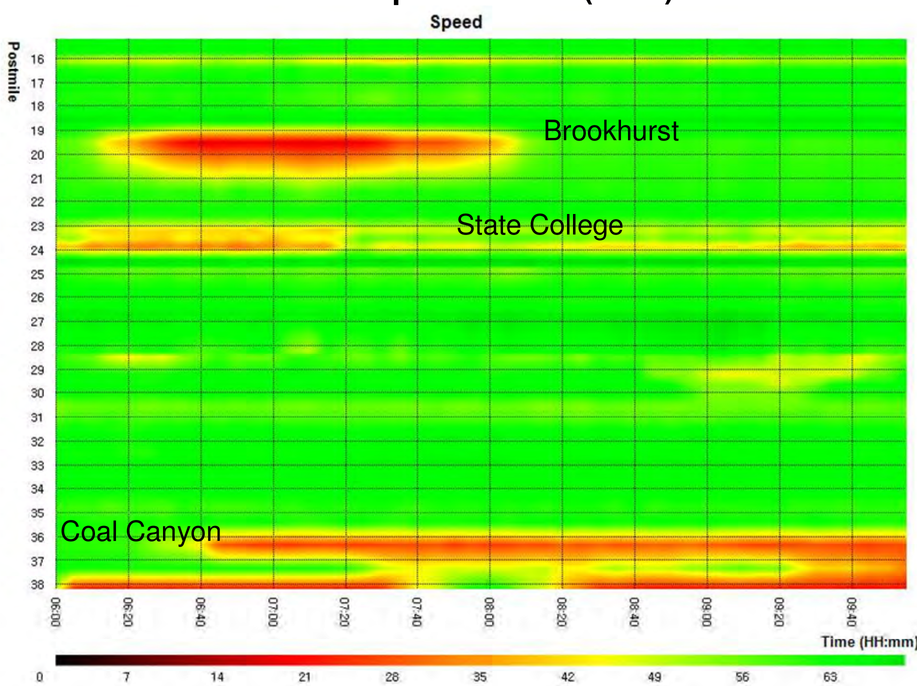


Exhibit 7-4: Westbound AM Peak Model Speed Contours After Improvements (2020)



This is the first-generation CSMP for the SR-91 corridor. It is important to emphasize that CSMPs should be updated, on a regular basis, if possible. This is particularly important since traffic conditions and patterns can differ from current projections. After projects are delivered, it is also useful to compare actual results with estimated ones in this document so that models can be further improved as appropriate.

CSMPs, or some variation, should become the normal course of business that includes detailed performance assessments, an in-depth understanding of the reasons for performance deterioration, and an analytical framework that allows for evaluating complementary operational strategies that maximize system productivity.

Appendix A: Project List for Micro-Simulation Scenarios

Scenario	Proj ID	Improvement	Lead Agency	Expected Compl Date	Source	Est Total Proj Cost (in 1,000s)
1 (2007-1) 2 (2020-1)	ORA000822 EA 0C5700	Connect existing auxiliary lane through interchanges on WB SR-91 between SR-57 and I-5 with its elements	OCTA	2014	06 & 08 TIP CMIA	$ 73,400
	ORA000821 EA 0C560	SR-91 WB (SR-55 through Tustin IC) extend lane and reconstruct aux lane	CALTRANS	2015	2008 TIP CMIA	$ 91,434
	ORA120336 EA 0G0400	SR-91 EB lane addition between SR-241 & SR-71, & improve NB SR-71 connector from SR-91 to std one lane and shoulder width	CALTRANS	2010 (4/22 PDT mtg)	06 & 08 TIP CMIA	$ 59,500
	ORA030601 EA 0G3300	Widening - Rte 55 connector to SR-241 in Anaheim, from east of route 55 connector to east of Weir Canyon road. Add one lane in each direction	CALTRANS	2014	06 & 08 TIP	$ 128,000
	EA 0L330	Restripe SB Lakeview Ave to provide 1.5 R to WB SR-91 on-ramp (Caltrans Minor B)	CALTRANS	2010		$ 30
	D12 Added	Tustin Ave Improvement/widening btwn SR-91 and La Palma Ave (Cost will not be included in this scenario since it is a mitigation project paid for by Kaiser)	ANAHEIM			$ -
	EA 0G0111	Widen NB SR-241 to both dir SR-91 from 3 to 4 lanes (2 WB and 2 EB) [Cost will not be included in this scenario]	CALTRANS	Completed		$ -
1A (2007-1A) 2A (2020-1A)	Same as Scenarios 1 and 2 except with Speed Control to isolate benefits					

Scenario	Proj ID	Improvement	Lead Agency	Expected Compl Date	Source	Est Total Proj Cost (in 1,000s)
3 (2007-2) 4 (2020-2)	EA 0J450K	Convert existing buffer-separated ingress/egress access HOV facility to continuous access	CALTRANS		PSR	$ 2,356
5 (2007-3) 6 (2020-3)	ORA000815 EA 0H470	SR-91/Gypsum Cyn Rd IC: Widen Gypsum Cyn Rd from 2 to 4 lanes. Add Class II on-road bike lanes; add multi-use trail and sidewalk on west side of roadway. This will require modification of existing entrance ramp to Gypsum. SR-91 connections are unchanged, the EB SR-91 exit ramp intersection will be reconstructed and signalized.	ANAHEIM	2014	2008 RTP	$ 5,200
	D12 Added	Toll lane extension to I-15 (a component of Project No. 7 of the 2009 Impl Plan, No. 4 of 2010 Plan)	RCTC	2015	09 Impl Plan 2008 RTIP	$ 320,000
7 (2007-4) 8 (2020-4)	Proposed (SMG)	Adaptive ramp metering with queue control			Proposed	$ 15,000
	D12 Added	Fwy to Fwy connector ramp metering at: - SB-57 to WB-91 (w/queue control) – widen connector to 3 lanes of storage - NB-57 to EB-91 (w/qc) – widen connector to 2 lanes of storage - NB-55 to WB-91 (w/qc) – no widening - NB-241 to WB-91 (w/qc) – no widening - NB-241 to EB-91 (w/qc) – no widening (at maximum allowable rate to flow, 3 cars per green per lane if you can) - SB-5 to EB-91 (w/qc) – no widening - NB-5 to WB-91 (w/qc) – no widening			Proposed	
	D12 Added	Meter HOV bypass ramps				
9 (2020-5) 10 (2020-6) -Builds on Sc 4	Proposed (SMG)	**Enhanced Incident Management System** (incident clearance time reduction from current and with improvements)				

Scenario	Proj ID	Improvement	Lead Agency	Expected Compl Date	Source	Est Total Proj Cost (in 1,000s)
11 (2007-5) 12 (2020-7)	2T01135	HOV/HOT Connector: NB SR-241 to EB SR-91, WB SR-91 to SB SR-241 (1 lane each direction). Status: currently in legislature	OCTA	2015 (4/22 PDT mtg)	2008 RTP; 09 Impl Plan	$ 440,000
13 (2020-8)	2M0727	Improve IC at SR-55: reconstruct IC, re-stripe existing lanes, modify SR-55 connectors to SR-91, and add flyover connector from WB SR-91 to SB SR-55	CALTRANS	2025	2008 RTP; Riv/OC MIS; 09 Impl Plan	$ 200,000
	2M0736	Add 1 GP in each direction from SR-57 to SR-55.	OCTA	2022	2008 RTP; 09 Impl Plan	$ 425,000

Appendix B: Benefit-Cost Analysis Results

This appendix provides more detailed benefit-cost analysis (BCA) results than found in Section 6 of the SR-22 Corridor System Management Plan (CSMP) Final Report. The BCA results for this CSMP were estimated by using the *California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C) Version 4.0* developed for Caltrans by System Metrics Group (SMG).

Caltrans uses Cal-B/C to conduct investment analyses of projects proposed for the interregional portion of the State Transportation Improvement Program (STIP), the State Highway Operations and Protection Program (SHOPP), and other ad hoc analyses requiring BCA. Cal-B/C is a spreadsheet-based tool that can prepare analyses of highway, transit, and passenger rail projects. Users input data defining the type, scope, and cost of projects. The model calculates life-cycle costs, net present values, benefit-cost ratios, internal rates of return, payback periods, annual benefits, and life-cycle benefits. Cal-B/C can be used to evaluate capacity expansion projects, transportation management systems (TMS), and operational improvements.

Cal-B/C measures, in constant dollars, four categories of benefits:

- Travel time savings (reduced travel time and new trips)
- Vehicle operating cost savings (fuel and non-fuel operating cost reductions)
- Accident cost savings (safety benefits)
- Emission reductions (air quality and greenhouse gas benefits).

Each of these benefits was estimated for the peak period for the following categories:

- **Life-Cycle Costs** - present values of all net project costs, including initial and subsequent costs in real current dollars.
- **Life-Cycle Benefits** - sum of the present value benefits for the project.
- **Net Present Value** - life-cycle benefits minus the life-cycle costs. The value of benefits exceeds the value of costs for a project with a positive net present value.
- **Benefit/Cost Ratio** - benefits relative to the costs of a project. A project with a benefit-cost ratio greater than one has a positive economic value.
- **Rate of Return on Investment** - discount rate at which benefits and costs are equal. For a project with a rate of return greater than the discount rate, the benefits are greater than costs and the project has a positive economic value. The user can use rate of return to compare projects with different costs and different benefit flows over different time periods. This is particularly useful for project staging.

- **Payback Period** - number of years it takes for the net benefits (life-cycle benefits minus life-cycle costs) to equal the initial construction costs. For a project with a payback period longer than the life-cycle of the project, initial construction costs are not recovered. The payback period varies inversely with the benefit-cost ratio. A shorter payback period yields a higher benefit-cost ratio.

The model calculates these results over a standard 20-year project life-cycle, itemizes each user benefit, and displays the annualized and life-cycle user benefits. Below the itemized project benefits, Cal-B/C displays three additional benefit measures:

- **Person-Hours of Time Saved** - reduction in person-hours of travel time due to the project. A positive value indicates a net benefit.
- **Additional CO_2 Emissions (tons)** - additional CO_2 emissions that occur because of the project. The emissions are estimated using average speed categories using data from the California Air Resources Board (CARB) EMFAC model. This is a gross calculation because the emissions factors do not take into account changes in speed cycling or driver behavior. A negative value indicates a project benefit. Projects in areas with severe congestion will generally lower CO_2 emissions.
- **Additional CO_2 Emissions (in millions of dollars)** - valued CO_2 emissions using a recent economic valuing methodology.

A copy of Cal-B/C v4.0, the User's Guide, and detailed technical documentation can be found at the Caltrans' Division of Transportation Planning, Office of Transportation Economics website at http://www.dot.ca.gov/hq/tpp/offices/ote/benefit.html.

The exhibits in this appendix are listed as follows:

- Exhibit B-1: Scenarios 1 & 2 Benefit-Cost Analysis Results
- Exhibit B-2: Scenarios 3 & 4 Benefit-Cost Analysis Results
- Exhibit B-3: Scenarios 5 & 6 Benefit-Cost Analysis Results
- Exhibit B-4: Scenarios 7 & 8 Benefit-Cost Analysis Results
- Exhibit B-5: Scenarios 11 & 12 Benefit-Cost Analysis Results
- Exhibit B-6: Scenario 13 Benefit-Cost Analysis Results (Incremental)
- Exhibit B-7: Cumulative Benefit-Cost Analysis Results

Exhibit B-1: Scenarios 1 & 2 Benefit-Cost Analysis Results

3

INVESTMENT ANALYSIS
SUMMARY RESULTS

Life-Cycle Costs (mil. $)	$352.4
Life-Cycle Benefits (mil. $)	$3,671.6
Net Present Value (mil. $)	$3,319.2
Benefit / Cost Ratio:	10.4
Rate of Return on Investment:	n/a
Payback Period:	n/a

ITEMIZED BENEFITS (mil. $)	Average Annual	Total Over 20 Years
Travel Time Savings	$146.7	$2,933.9
Veh. Op. Cost Savings	$26.3	$526.6
Accident Cost Savings	$0.0	$0.0
Emission Cost Savings	$10.6	$211.1
TOTAL BENEFITS	$183.6	$3,671.6
Person-Hours of Time Saved	18,520,832	370,416,648
Additional CO_2 Emissions (tons)	-132,045	-2,640,908
Additional CO_2 Emissions (mil. $	-$3.9	-$77.1

Exhibit B-2: Scenarios 3 & 4 Benefit-Cost Analysis Results

3

INVESTMENT ANALYSIS
SUMMARY RESULTS

Life-Cycle Costs (mil. $)	$354.7
Life-Cycle Benefits (mil. $)	$3,664.7
Net Present Value (mil. $)	$3,310.0
Benefit / Cost Ratio:	10.3
Rate of Return on Investment:	47.7%
Payback Period:	3 years

ITEMIZED BENEFITS (mil. $)	Average Annual	Total Over 20 Years
Travel Time Savings	$148.5	$2,969.5
Veh. Op. Cost Savings	$24.7	$493.3
Accident Cost Savings	$0.0	$0.0
Emission Cost Savings	$10.1	$201.8
TOTAL BENEFITS	$183.2	$3,664.7
Person-Hours of Time Saved	18,673,911	373,478,215
Additional CO_2 Emissions (tons)	-124,014	-2,480,272
Additional CO_2 Emissions (mil. $	-$3.6	-$72.3

Incremental Costs (mil. $)	$2.4
Incremental Benefits (mil. $)	-$226.5
Incremental Benefit / Cost Ratio	-96.1

Exhibit B-3: Scenarios 5 & 6 Benefit-Cost Analysis Results

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INVESTMENT ANALYSIS
SUMMARY RESULTS

Life-Cycle Costs (mil. $)	$679.9
Life-Cycle Benefits (mil. $)	$5,024.4
Net Present Value (mil. $)	$4,344.4
Benefit / Cost Ratio:	7.4
Rate of Return on Investment:	34.0%
Payback Period:	4 years

ITEMIZED BENEFITS (mil. $)	Average Annual	Total Over 20 Years
Travel Time Savings	$205.1	$4,102.2
Veh. Op. Cost Savings	$33.0	$659.2
Accident Cost Savings	$0.0	$0.0
Emission Cost Savings	$13.1	$263.0
TOTAL BENEFITS	$251.2	$5,024.4
Person-Hours of Time Saved	26,335,005	526,700,106
Additional CO_2 Emissions (tons)	-168,551	-3,371,024
Additional CO_2 Emissions (mil. $	-$4.9	-$97.5

Incremental Costs (mil. $)	$325.2
Incremental Benefits (mil. $)	$1,359.7
Incremental Benefit / Cost Ratio	4.2

Exhibit B-4: Scenarios 7 & 8 Benefit-Cost Analysis Results

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INVESTMENT ANALYSIS
SUMMARY RESULTS

Life-Cycle Costs (mil. $)	$694.9
Life-Cycle Benefits (mil. $)	$5,097.6
Net Present Value (mil. $)	$4,402.7
Benefit / Cost Ratio:	7.3
Rate of Return on Investment:	33.6%
Payback Period:	4 years

ITEMIZED BENEFITS (mil. $)	Average Annual	Total Over 20 Years
Travel Time Savings	$209.1	$4,182.4
Veh. Op. Cost Savings	$32.7	$653.9
Accident Cost Savings	$0.0	$0.0
Emission Cost Savings	$13.1	$261.4
TOTAL BENEFITS	$254.9	$5,097.6
Person-Hours of Time Saved	26,838,601	536,772,030
Additional CO_2 Emissions (tons)	-167,810	-3,356,210
Additional CO_2 Emissions (mil. $	-$4.8	-$96.9

Incremental Costs (mil. $)	$15.0
Incremental Benefits (mil. $)	$73.2
Incremental Benefit / Cost Ratio	4.9

Exhibit B-5: Scenarios 11 & 12 Benefit-Cost Analysis Results

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INVESTMENT ANALYSIS
SUMMARY RESULTS

Life-Cycle Costs (mil. $)	$1,134.9
Life-Cycle Benefits (mil. $)	$5,116.7
Net Present Value (mil. $)	$3,981.7
Benefit / Cost Ratio:	4.5
Rate of Return on Investment:	23.0%
Payback Period:	6 years

ITEMIZED BENEFITS (mil. $)	Average Annual	Total Over 20 Years
Travel Time Savings	$209.6	$4,191.1
Veh. Op. Cost Savings	$33.0	$659.3
Accident Cost Savings	$0.0	$0.0
Emission Cost Savings	$13.3	$266.3
TOTAL BENEFITS	$255.8	$5,116.7
Person-Hours of Time Saved	26,859,670	537,193,409
Additional CO_2 Emissions (tons)	-169,101	-3,382,019
Additional CO_2 Emissions (mil. $)	-$4.9	-$97.6

Incremental Costs (mil. $)	$440.0
Incremental Benefits (mil. $)	$19.1
Incremental Benefit / Cost Ratio	0.0

Exhibit B-6: Scenario 13 Benefit-Cost Analysis Results (Incremental)

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INVESTMENT ANALYSIS
SUMMARY RESULTS

Life-Cycle Costs (mil. $)	$625.0
Life-Cycle Benefits (mil. $)	$47.9
Net Present Value (mil. $)	-$577.1
Benefit / Cost Ratio:	0.1
Rate of Return on Investment:	#DIV/0!
Payback Period:	20+ years

ITEMIZED BENEFITS (mil. $)	Average Annual	Total Over 20 Years
Travel Time Savings	$3.8	$76.4
Veh. Op. Cost Savings	-$0.9	-$18.1
Accident Cost Savings	$0.0	$0.0
Emission Cost Savings	-$0.5	-$10.4
TOTAL BENEFITS	$2.4	$47.9
Person-Hours of Time Saved	482,650	9,652,998
Additional CO_2 Emissions (tons)	3,886	77,719
Additional CO_2 Emissions (mil. $)	$0.1	$2.4

Exhibit B-7: Cumulative Benefit-Cost Analysis Results

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INVESTMENT ANALYSIS
SUMMARY RESULTS

Life-Cycle Costs (mil. $)	$1,759.9
Life-Cycle Benefits (mil. $)	$4,945.1
Net Present Value (mil. $)	$3,185.1
Benefit / Cost Ratio:	2.8
Rate of Return on Investment:	n/a
Payback Period:	n/a

ITEMIZED BENEFITS (mil. $)	Average Annual	Total Over 20 Years
Travel Time Savings	$202.6	$4,051.5
Veh. Op. Cost Savings	$32.1	$641.8
Accident Cost Savings	$0.0	$0.0
Emission Cost Savings	$12.6	$251.7
TOTAL BENEFITS	$247.3	$4,945.1
Person-Hours of Time Saved	25,988,073	519,761,460
Additional CO_2 Emissions (tons)	-164,859	-3,297,188
Additional CO_2 Emissions (mil. $	-$4.8	-$95.2

Note: Benefits on SR-57 removed (Scenarios 1A & 2A) and benefits of SR-91 projects on SR-57 added.

District 12 CSMP Team Organization Chart