State Route 91

Corridor System Management Plan

August 2010

CALTRANS DISTRICT 12

corridor system management plans

Corridor System Management Plan
State Route 91 (Orange County)

Executive Summary

Caltrans District 12

State Route 91

Corridor System Management Plan

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LIST OF EXHIBITS

1. Introduction

This document contains the Executive Summary for the Orange County State Route 91 (SR-91) Corridor System Management Plan (CSMP) Final Report developed on behalf of the California Department of Transportation (Caltrans) by System Metrics Group, Inc. (SMG). A more detailed technical CSMP is available upon request.

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). There are two CMIA funded projects on the SR-91 corridor:

- Add an eastbound auxiliary lane from SR-241 to SR-71 in Orange and Riverside Counties. This project is expected to be delivered in December 2010 at a total cost of $94 million, of which $82 million are CMIA funds.

- Add a one general purpose lane on eastbound SR-91 from the SR-55/SR-91 connector to east of the Weir Canyon Road interchange and on westbound SR-91 from just east of the Weir Canyon Road interchange to the Imperial Highway (SR-90) interchange. This project is anticipated to be delivered in February 2012 at a total cost of $96 million, of which $22 million are CMIA funds.

To receive CMIA funds, the California Transportation Commission (CTC) guidelines require that project nominations describe in a CSMP how mobility gains from funded corridor improvements would be maintained over time. A CSMP, therefore, aims to define how corridors will be managed, 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.

This Executive Summary and the full technical CSMP represent the results of the study, which included several key steps:

- Stakeholder Involvement
- Corridor Performance Assessment
- Bottleneck Identification and Causality Analysis
- Scenario Development and Analysis
- Conclusions and Recommendations

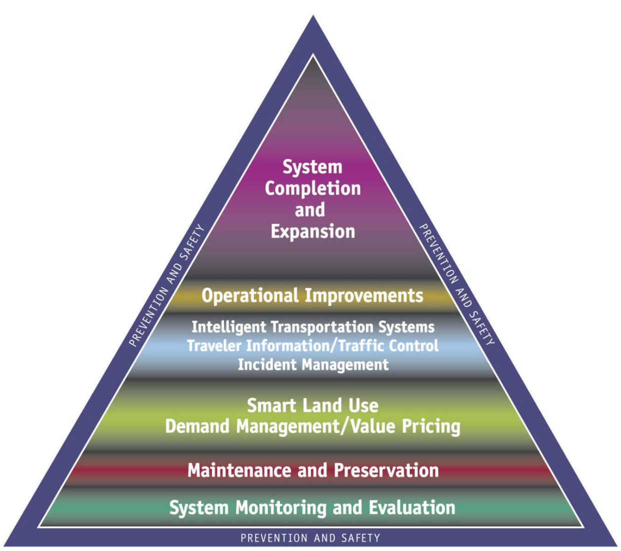
2. Background

Orange County's transportation system faces numerous challenges – the demand for transportation keeps rising, congestion is increasing, and infrastructure is aging. At the same time, traditional transportation finance mechanisms are not able to provide adequate funding to continue expanding the infrastructure and keep up with demand. Caltrans recognized that infrastructure expansion cannot keep pace with demand, and adopted a system management philosophy to address current and future transportation needs in a comprehensive manner.

Exhibit ES-1 illustrates the concept of system management as a pyramid. The exhibit shows that transportation decision makers and practitioners at all jurisdictions must expand their "tool box" to include many complementary strategies, including smart land use, demand management, and an increased focus on operational investments (shown in the middle part of the pyramid) to complement the traditional system expansion investments. All of these strategies build on a strong foundation of system monitoring and evaluation.

This CSMP aims to define how Caltrans and its stakeholders will manage the SR-91 corridor over time,

Exhibit ES-1: System Management Pyramid



focusing on operational strategies in addition to already funded expansion projects. The CSMP fully respects previous decisions (including land use, pricing, and demand management) and complements them with additional promising investment suggestions, where appropriate. The CSMP development effort relies on complex analytical tools, including micro-simulation models, to isolate deficiencies and quantify improvements for even relatively small operational investments.

The CSMP study team developed a calibrated 2007 Base Year model for the SR-91 corridor. This model was calibrated using California and Federal Highway Administration (FHWA) guidelines. Following approval of a 2007 Base Year model, the study team developed a 2020 Horizon Year model to test the impacts of short-term programmed projects as well as future operational improvements. 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.

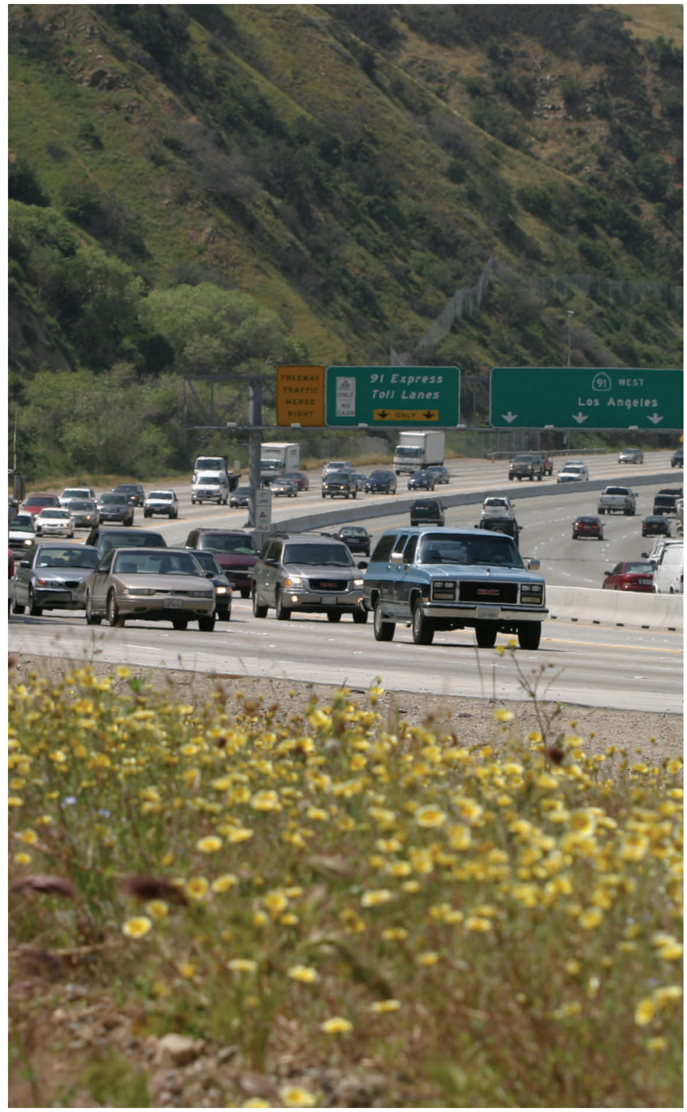
Caltrans develops integrated multimodal projects in balance with community goals, plans, and values. Caltrans seeks to address the safety and mobility needs of bicyclists, pedestrians, and transit users in all projects, regardless of funding. Bicycle, pedestrian, and transit travel is facilitated by 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 focuses 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.

3. 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, corridor 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:

- Orange County Transportation Authority (OCTA)
- Southern California Association of Governments (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.



4. Corridor Performance Assessment

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.

CORRIDOR DESCRIPTION

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. As shown in Exhibit ES-2, the Orange County SR-91 CSMP Corridor covers a smaller area. The CSMP corridor extends approximately 19 miles as an east-west route from I-5 in Buena Park at postmile R3.6 to the Orange/Riverside County Line at postmile R18.9.

As shown in Exhibit ES-2, the SR-91 CSMP Corridor passes through Anaheim, Fullerton, Placentia, and Yorba Linda and includes four major freeway-to-freeway interchanges: I-5, SR-57, SR-55, and the SR-241 Eastern Transportation Corridor Toll Road.

SR-91 is a six to eight-lane freeway with a concrete barrier median for most of the study corridor with auxiliary lanes along some sections. High Occupancy Vehicle (HOV) lanes are available in the western portion of the corridor between I-5 and SR-55, a distance of just under nine miles. The HOV lanes operate as a 2+ vehicle-occupancy facility, 24-hours 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 prepaid accounts. Reduced tolls are available to vehicles with three or more occupants as an incentive.

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.

Three major transit operators provide service on or near SR-91: OCTA, Riverside Transit Agency (RTA), and the Southern California Regional Rail Authority (SCRRA) – commonly known as Metrolink.

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 operate near SR-91, the following routes operate on or directly adjacent to SR-91: Routes 794, 721, 213/213A, 30, and 38.

RTA provides 38 fixed routes and paratransit services in western Riverside County. Along the SR-91 corridor, it offers both weekday and weekend service on Route 149 between the Cities of Riverside and Anaheim.

Exhibit ES-2: Orange County SR-91 CSMP Corridor Map

SCRRA 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. Along the SR-91 corridor, Metrolink provides service to the Anaheim Canyon Metrolink Station and the Fullerton Transportation Center.

Several major special event facilities generate trips along the SR-91 corridor including the Disneyland Resort and Theme Park; "Angels Stadium of Anaheim," home of the Los Angeles Angels' professional baseball team; and the "Honda Center" arena, home to the Anaheim Ducks professional hockey team. The SR-91 Corridor is also the main transportation corridor for beach access from the Inland Empire.

There are major universities and colleges near the SR-91 corridor and other post-secondary and trade schools nearby. There also exist several nearby medical facilities. Kaiser Permanente and the Anaheim Memorial Medical Center are located within one-mile of SR-91. Kaiser Permanente is moving from Lakeview to Tustin Avenue. In addition, there are several major shopping centers along freeways connecting to the SR-91 corridor, but no major shopping malls are located directly adjacent to the corridor.

CORRIDOR PERFORMANCE ASSESSMENT

The SR-91 CSMP focuses on four categories of performance measures:

- *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.

Mobility

Two primary measures quantify mobility in this report: delay and travel time. Each is estimated from field automatic detection data and forecasted using macro or micro-simulation models. The Performance Measurement System (PeMS)[1] provides access to the historical freeway detection data needed to estimate the two mobility measures. PeMS collects detector volume and vehicle occupancy data on the freeway, which are used to estimate speed, delay and travel time. The vehicle occupancy data are not the same as person occupancy.

Delay

Delay is defined as the observed travel time less the travel time during free-flow conditions (assumed 60 miles per hour). It is reported as vehicle-hours of delay.

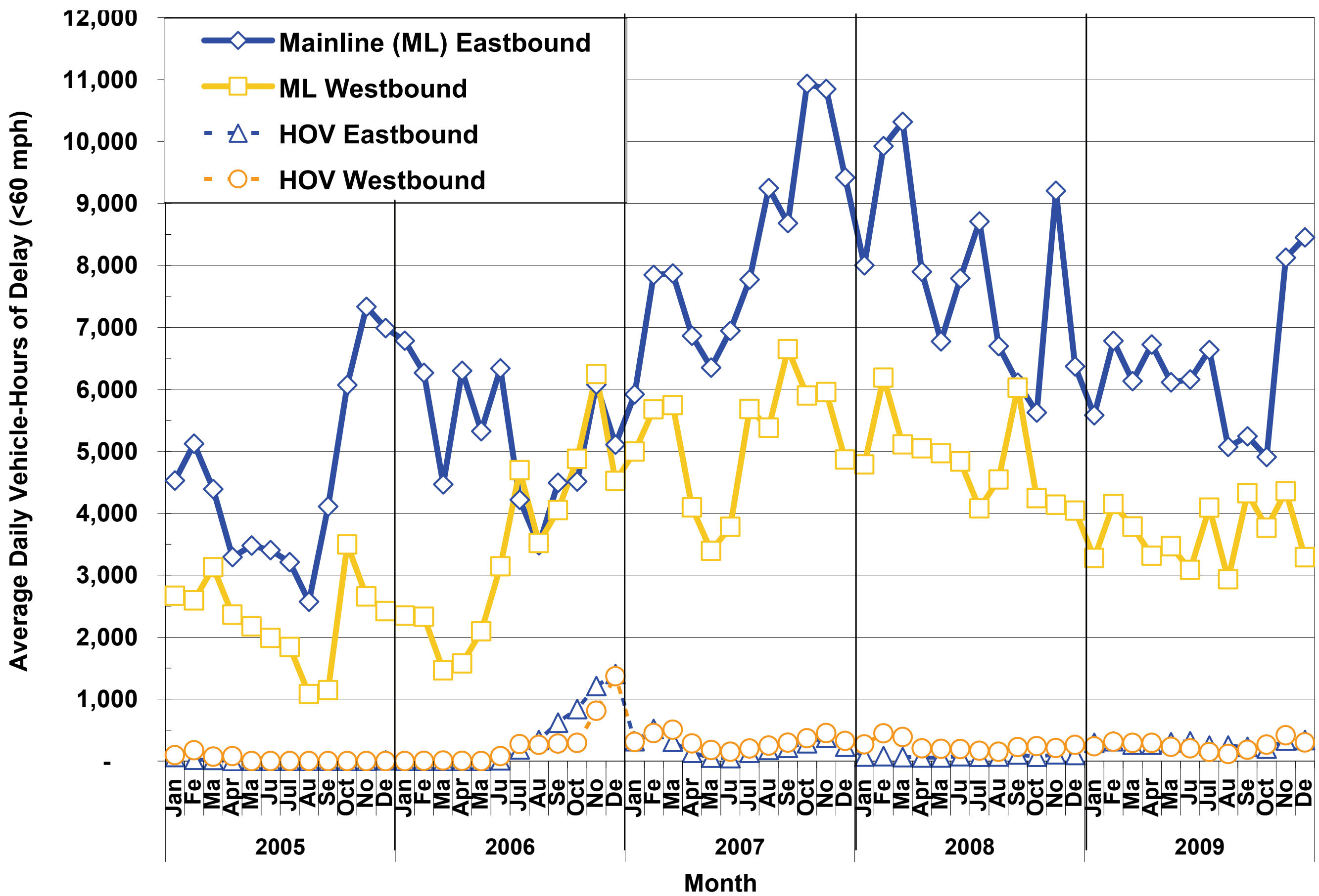
Exhibit ES-3 shows the average weekday daily vehicle-hours of delay for each month between 2005 and 2009 for both mainline and high occupancy vehicle (HOV) lanes. These trends exclude weekends and holidays. It is important to note that the mainline and HOV facilities are not the same distance in length. The mainline facility extends 19 miles, whereas the HOV facility extends about 9 miles from I-5 to SR-55.

Exhibit ES-3 reveals the following delay trends on the mainline and HOV facilities:

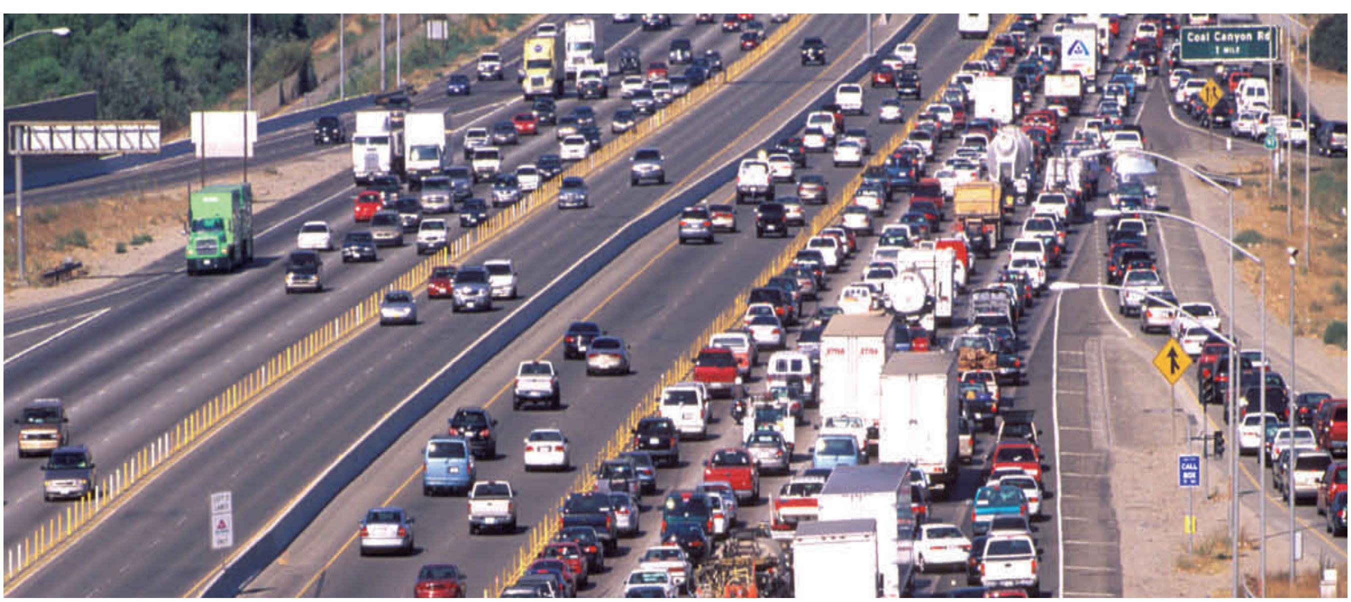
- As expected, the mainline, or general purpose lanes, experience significantly more congestion than the HOV facility, and the eastbound mainline lanes can experience more than twice the delay of the westbound lanes.
- Between 2005 and 2007, mainline delay (with the exception of typical summer season lows) grew from about 6,800 vehicle-hours of delay for both directions to nearly 17,000 vehicle-hours with the eastbound mainline lanes reaching nearly 11,000 vehicle-hours in October 2007.
- Since 2007, delay has declined to around 2006 levels.

[1]Developed and maintained by Caltrans and accessible at http://pems.dot.ca.gov.

Exhibit ES-3: Mainline and HOV Weekday Delay by Month (2005-2009)



Source: Caltrans automatic detector data



The CSMP separates delay into two components: severe delay and other delay. Severe delay occurs when speeds are below 35 mph and other delay occurs when speeds are between 35 and 60 mph. Severe delay represents breakdown conditions. "Other" delay represents conditions approaching or leaving breakdown congestion, or areas that experience temporary slowdowns. However, it can also be a leading indicator of future, severe delay.

Exhibits ES-4 (mainline lanes) and ES-5 (HOV lanes) show average severe and other daily vehicle-hours of delay by day of the week. A few notes related to Exhibits ES-4 and ES-5:

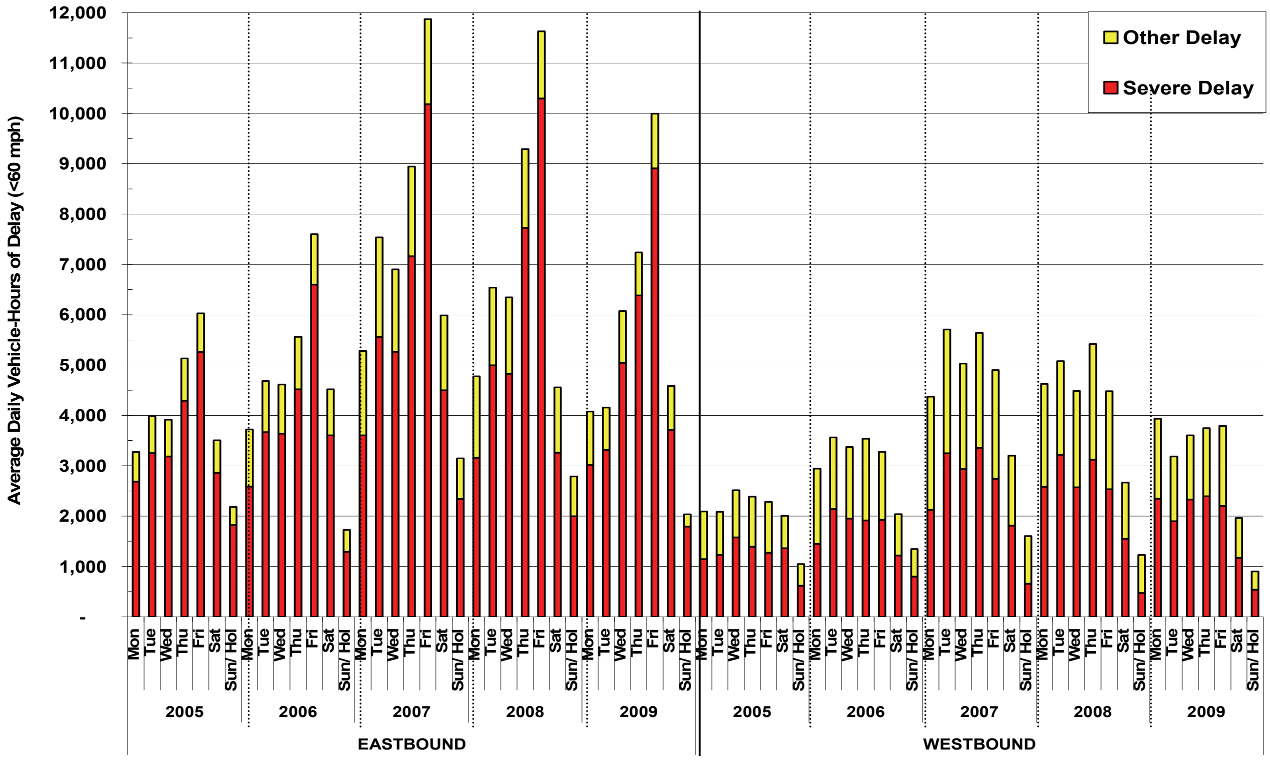
- On the mainline lanes, severe delay accounts for just under 80 percent of all weekday delay on the corridor in the eastbound direction, while making up less than 60 percent in the westbound direction (Exhibit ES-4). HOV delays tend to average just over 40 percent of total delay in either direction.
- In the eastbound direction, Fridays experience the highest delays, probably due to weekend travel. The second highest delays generally occurred on Thursdays.
- In the westbound direction, the day-of-week trends are more typical for urban commute corridors. The midweek days experience the highest delays. Mondays and Fridays show slightly less congestion, while the weekends show much lower delays than the weekdays.

Exhibits ES-6 and ES-7 summarize average annual weekday delay by hour of the day over the five-year period on the mainline eastbound and westbound, respectively. 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. Note that the HOV lanes are not shown in this summary report since they follow similar peaking trends as the mainline lanes. The main technical report contains the HOV delay by hour results.

A few notes on these two exhibits:

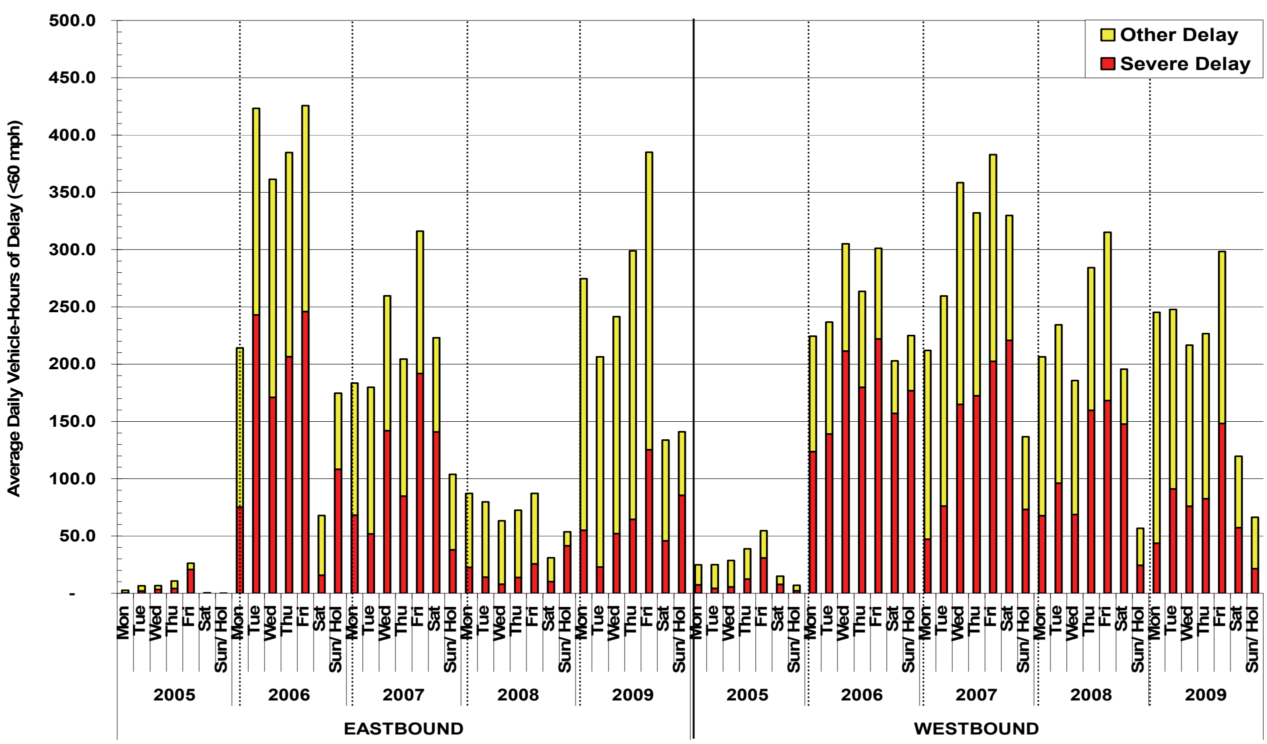
- Delay in the westbound direction peaks during the AM period, while delay peaks in the eastbound direction during the PM period.
- The peak period of delay lasts from 6:00 AM to 9:00 AM and from 3:00 PM to 6:00 PM. The AM peak hour is 7:00 AM, while the PM peak period has two peak hours depending on 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 ES-4: Mainline Lane Delay by Day of Week (2005-2009)



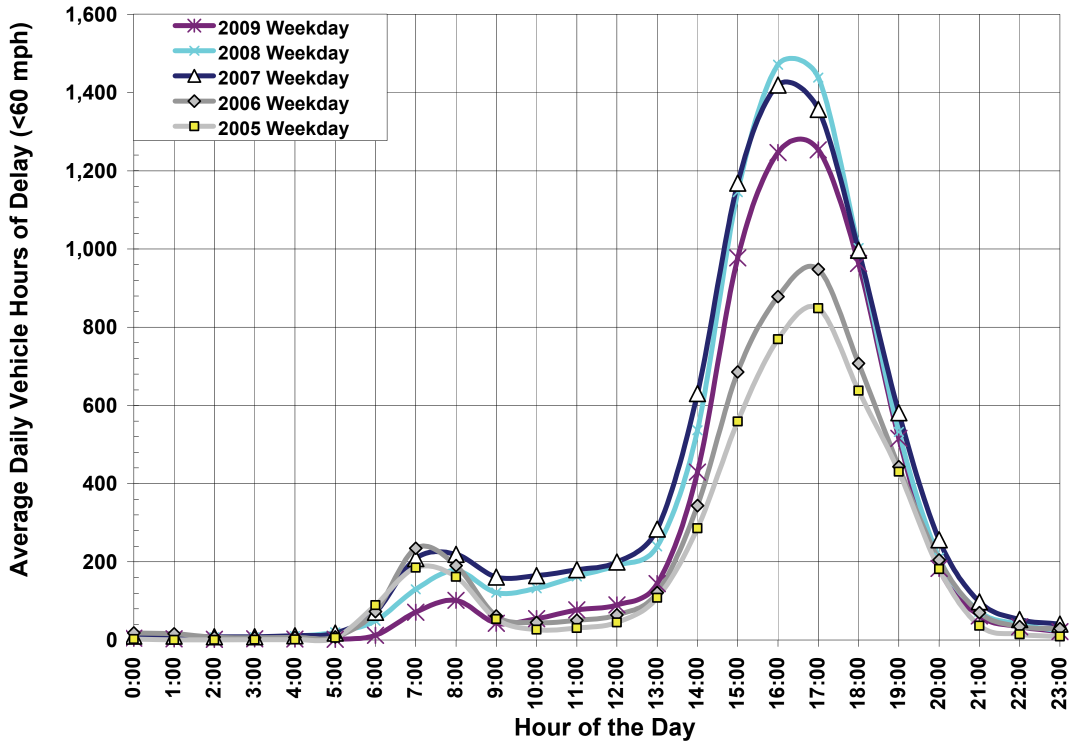
Source: Caltrans automatic detector data

Exhibit ES-5: HOV Lane Delay by Day of Week (2005-2009)



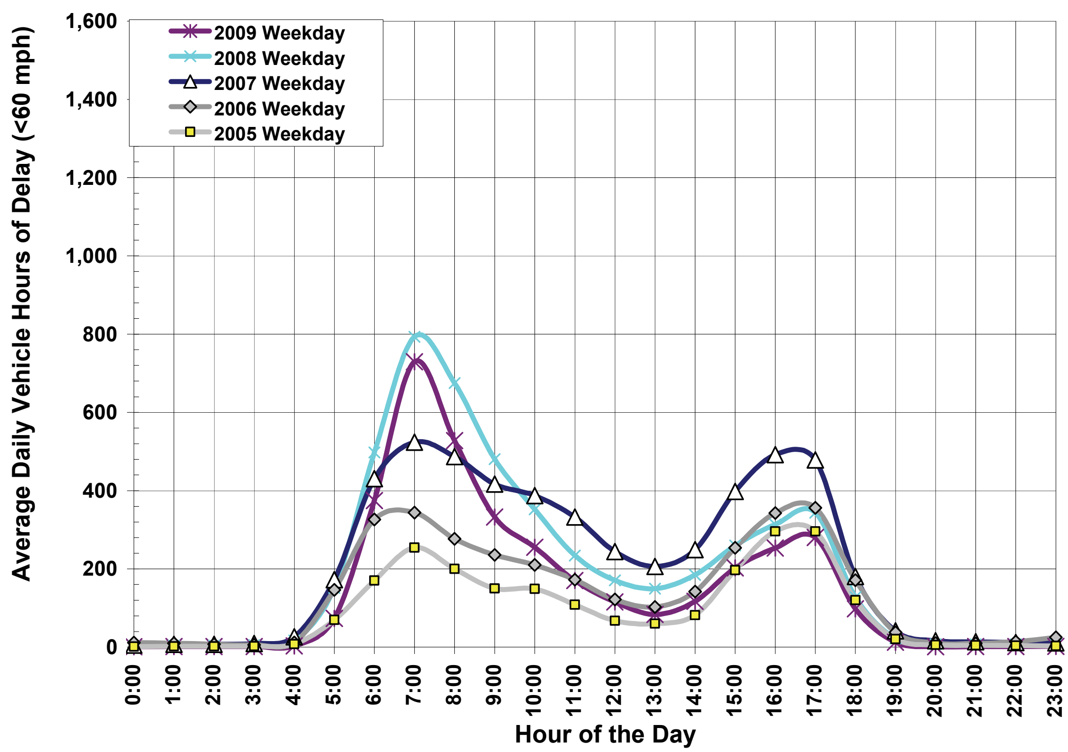
Source: Caltrans automatic detector data

Exhibit ES-6: Eastbound Mainline Lanes Hourly Delay (2005-2009)



Source: Caltrans automatic detection data

Exhibit ES-7: Westbound Mainline Lanes Hourly Delay (2005-2009)



Source: Caltrans automatic detection 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 corridor. Caltrans detection data were used to compute and analyze travel times.

Exhibits ES-8 and ES-9 present the travel time results for the mainline facility of the SR-91 corridor for 2005 through 2009. The eastbound direction had travel times of approximately 32 to 40 minutes during its PM peak hour. The westbound direction had travel times of approximately 20 to 25 minutes during its AM 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).

Travel times on the HOV facility remained steady in both directions during the four years analyzed at approximately 8.5 minutes along the nine-mile HOV facility (charts can be found in the detailed Final Report). 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.

Reliability

Reliability captures the degree of predictability in travel time. Reliability focuses on how travel time varies from day to day and reflects the impacts of accidents, incidents, weather, and special events. Improving reliability is an important goal for transportation agencies. Efforts to improve reliability include incident management, traveler information, and special event planning.

To measure reliability, the CSMP uses the "buffer index", which reflects the additional time required (over and beyond the average) to ensure an on-time arrival 95 percent of the time. In other words, if a person must be on time 95 days out of 100 (or 19 out of 20 workdays per month), then that person must add additional time to their average expected travel time to ensure an on-time arrival. That additional time is the buffer time. Severe events, such as collisions, could cause longer travel times, but the 95th percentile represents a balance between days with extreme events (e.g., major accidents) and other, more "typical" travel days.

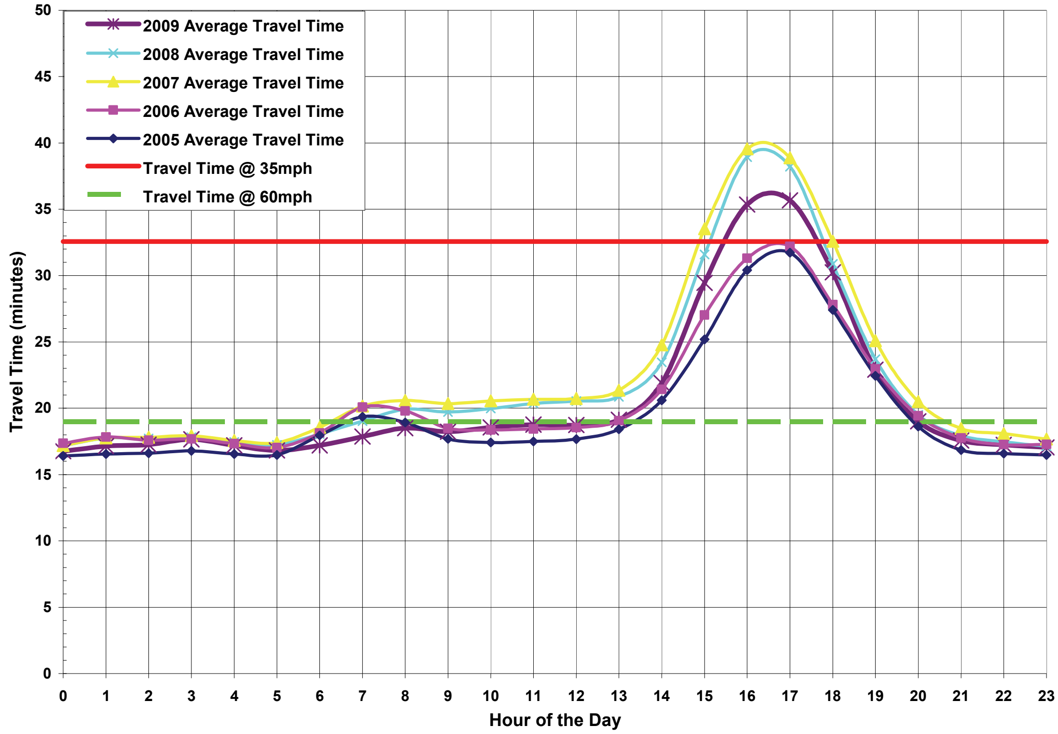
Exhibits ES-10 and ES-11 illustrate the variability of travel time along the mainline lanes for non-holiday weekdays in 2007. The detailed final report shows the buffer index for the years from 2005 to 2009 for both mainline and HOV lanes. This Executive Summary reports only mainline data for 2007 since that year was the base for modeling.

The following observations on the mainline facility are worth noting:

- In 2007 in the eastbound direction, 4:00 PM had the highest estimated average travel time at approximately 40 minutes and the highest estimated buffer time of 21 minutes (a buffer index of 52 percent). In other words, to arrive on time 95 percent of the time, a commuter would need to leave for work 61 minutes before the start time to travel the entire length of the SR-91 study corridor.
- The westbound direction had both AM and PM peaks (7:00 AM and 5:00 PM) for variability. The AM peak had an estimated average travel time of 23 minutes in 2007 with a buffer time of 7 minutes (buffer index of 30 percent), while the PM peak also had a buffer index of just under 30 percent with a 24-minute average time and a 7-minute buffer time.

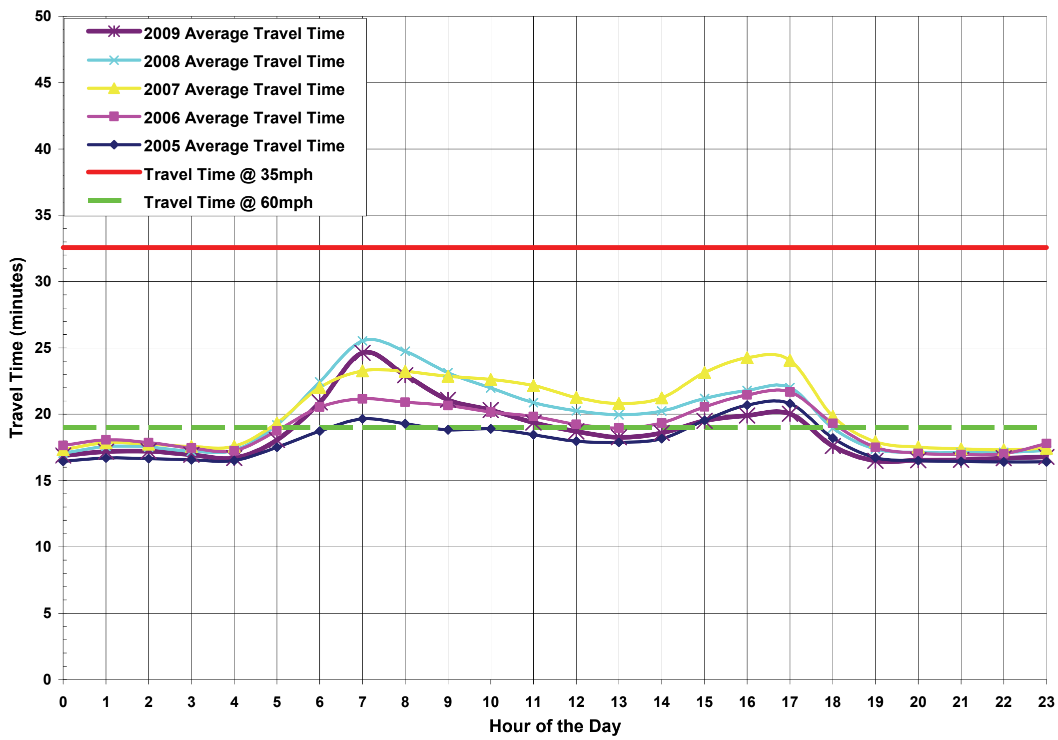
It is important to keep track of the reliability statistic, in part to evaluate incident management improvement strategies, and in part to gauge the effectiveness of safety projects delivered.

Exhibit ES-8: Eastbound Mainline Lanes Travel Time by Hour (2005-2009)



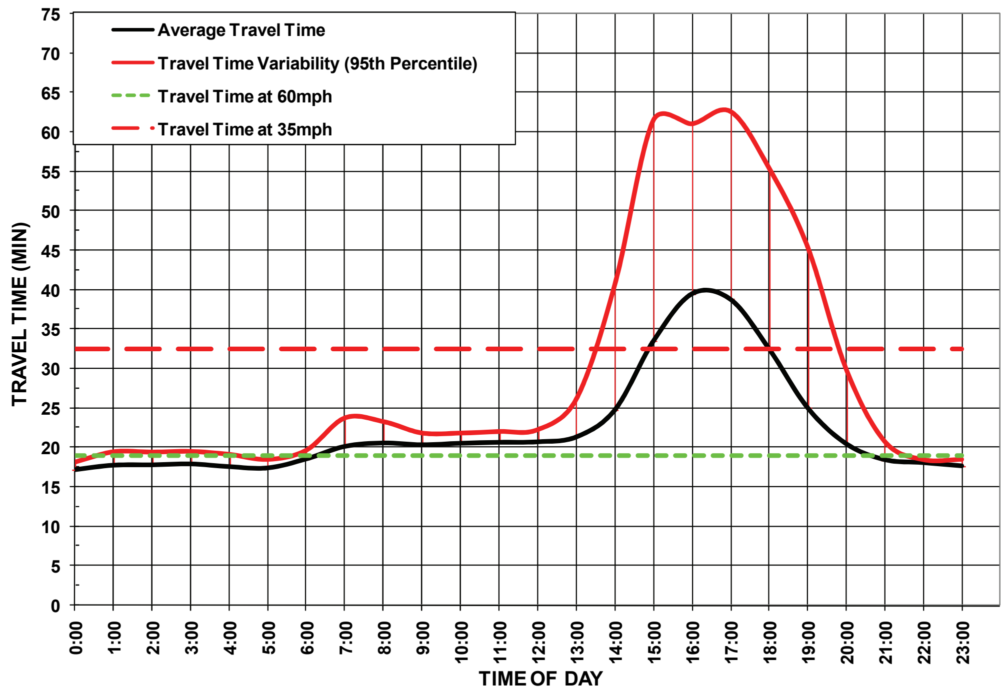
Source: Caltrans automatic detection data

Exhibit ES-9: Westbound Mainline Lanes Travel Time by Hour (2005-2009)



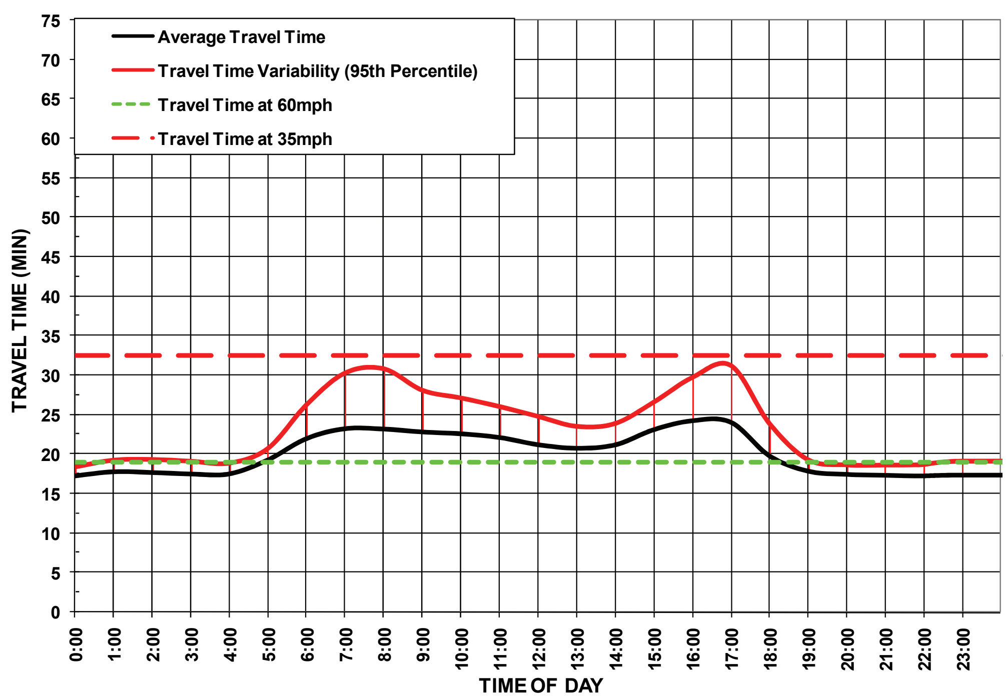
Source: Caltrans automatic detection data

Exhibit ES-10: Eastbound Mainline Lanes Travel Time Variability (2007)



Source: Caltrans automatic detection data

Exhibit ES-11: Westbound Mainline Lanes Travel Time Variability (2007)



Source: Caltrans automatic detection 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).

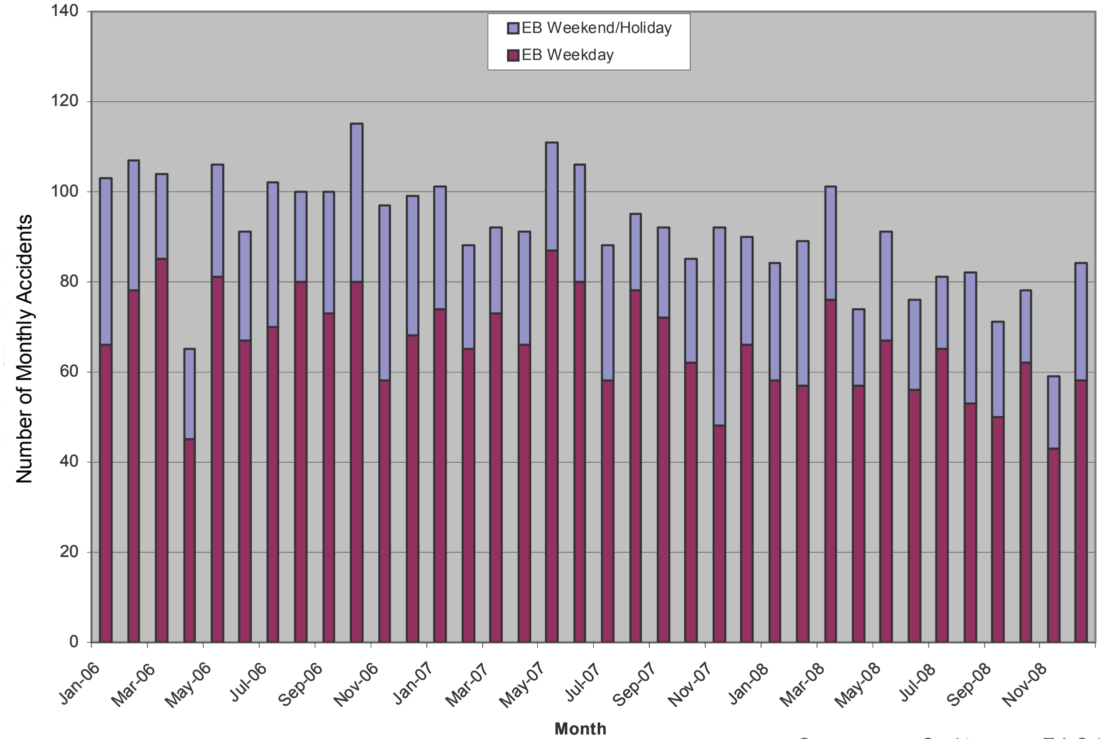
The safety assessment in this report intends to characterize the overall accident history and trends in the corridor. It also highlights notable accident concentration locations or readily apparent patterns. This report is not intended to replace more detailed safety investigations routinely performed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

Exhibits ES-12 and ES-13 show the total number of accidents by month on eastbound and westbound SR-91, respectively. The accidents reported for the study corridor are not separated by mainline and HOV facility. The exhibits summarize the latest available three-year data from January 1, 2006 through December 31, 2008.

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 (daily per day). There was a significant increase in total collisions in 2006, which indicates that there may have been more traffic in 2006 than in previous 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.

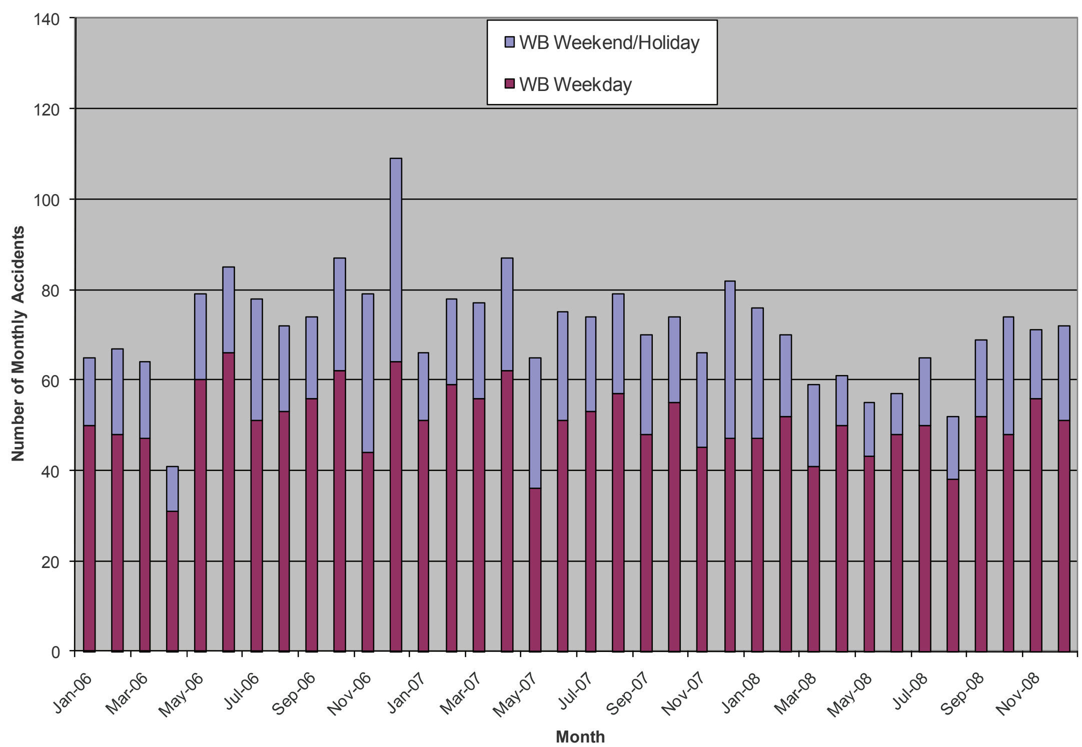
The SR-91 Corridor does not have many parallel routes that offer opportunities for motorists to bypass traffic incidents. To improve travel time reliability, increased incident response could focus on these areas.

Exhibit ES-12: Eastbound Monthly Accidents (2006-2008)



Source: Caltrans TASAS

Exhibit ES-13: Westbound Monthly Accidents (2006-2008)



Source: Caltrans TASAS

Productivity

Productivity is a system efficiency measure used to analyze the throughput of the corridor during congested conditions. Restoring lost productivity is a focus of CSMPs.

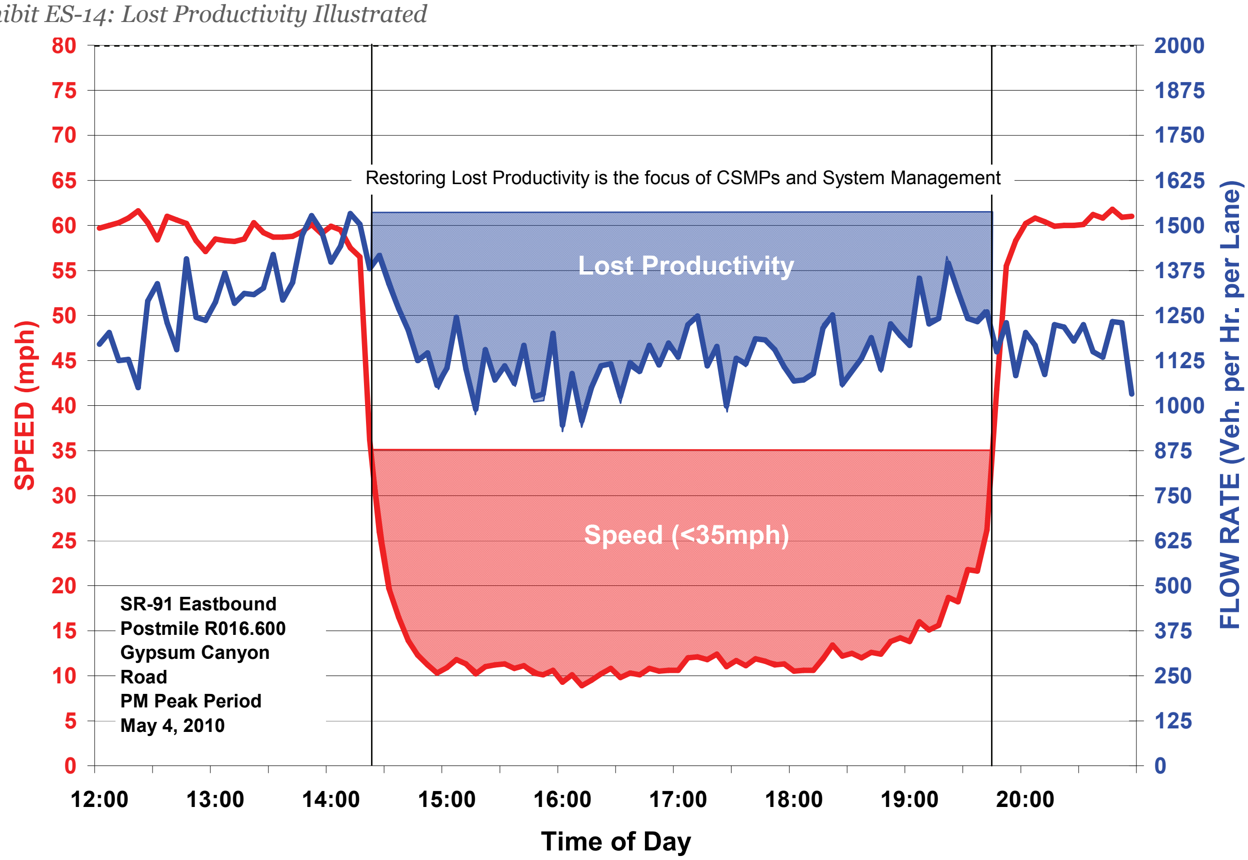
Exhibit ES-14 illustrates how congestion leads to lost productivity. The exhibit uses observed data from sensors for a typical spring PM peak period (Tuesday, May 4, 2010) on SR-91. It shows speeds (in red) and flow rates (in blue) on eastbound SR-91 at Gypsum Canyon Road, one of the most congested locations on the corridor.

Flow rates (measured as vehicles per hour per lane or "vphpl") at Gypsum Canyon Road between 1:30 PM and 2:30 PM averaged around 1,500 vphpl. This is slightly less than a typical peak period maximum flow rate. Generally, freeway flow rates over 2,000 vphpl cannot be sustained over a long period.

Once volumes approach this maximum rate, traffic becomes unstable. With any additional merging or weaving, traffic breaks down and speeds can rapidly plummet to below 35 mph. In essence, every incremental merge takes up two spots on the freeway for a short time. However, since the volume is close to capacity, these merges lead to queues. Rather than accommodating the same number of vehicles, flow rates also drop and vehicles back up, creating bottlenecks and associated congestion.

At the location shown in Exhibit ES-14, throughput drops by nearly 25 percent on average during the peak period (from over 1,500 to around 1,100 vphpl). This five-lane segment therefore operates as if it were a four-lane road just when demand is at its highest. Stated differently, just when the corridor needed the most capacity, it performed in the least productive manner and effectively lost lanes. This loss in throughput can be aggregated and presented as "Equivalent Lost-Lane-Miles."

Exhibit ES-14: Lost Productivity Illustrated



Average weekday (non-holiday) lost lane-miles by time period and year for SR-91 are shown in Exhibits ES-15 (mainline) and ES-16 (HOV). A few notes on these two exhibits:

- The largest productivity losses occurred in the eastbound direction during the PM peak hours, which are the direction and time period that experienced the most congestion.
- On the mainline facility, the westbound direction during the AM peak period experienced productivity losses nearly as high as the eastbound direction during the PM peak period.
- On the HOV lanes, a greater productivity loss is more evident in the eastbound peak period.
- 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.

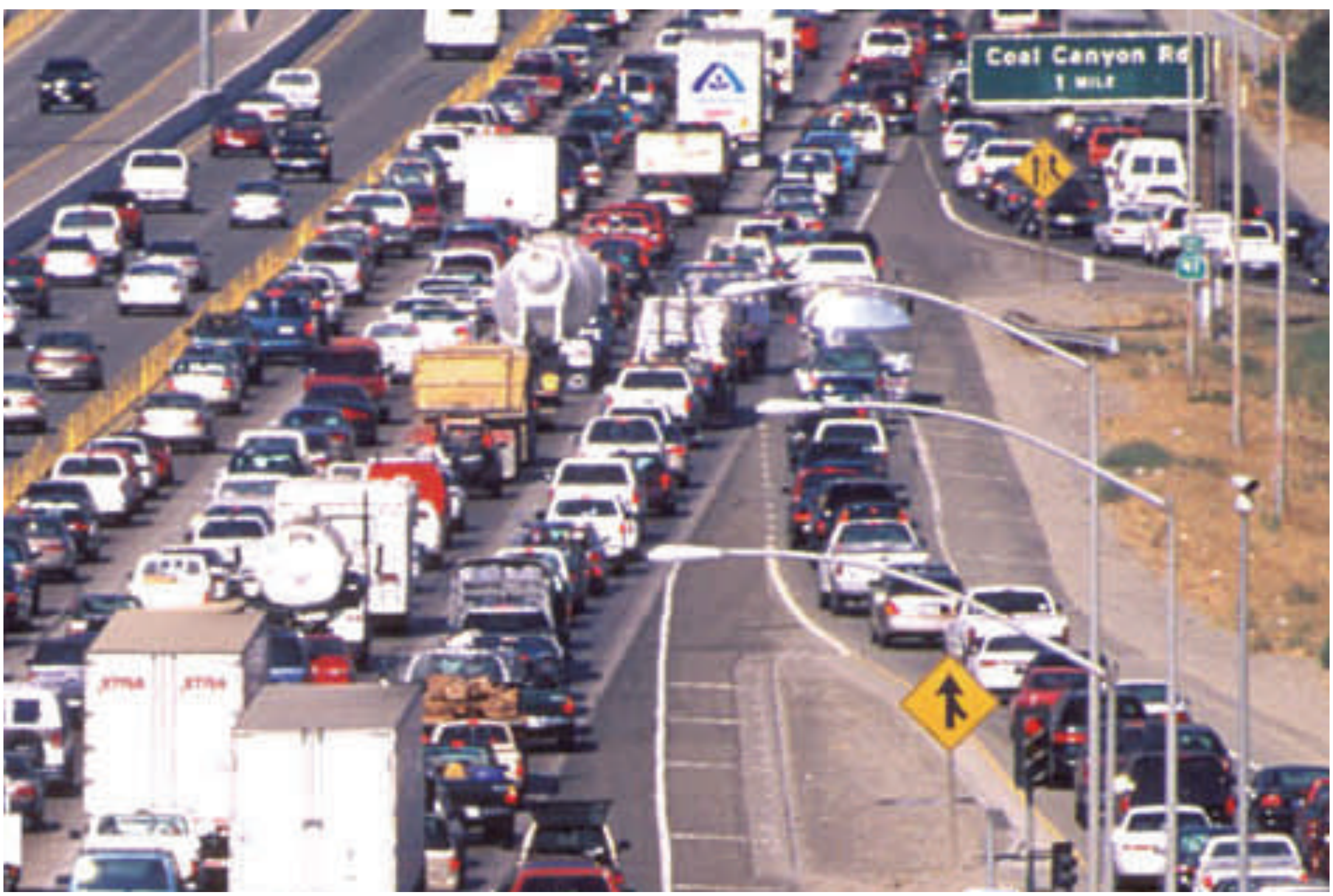


Exhibit ES-15: Mainline Daily Equivalent Lost Lane-Miles by Direction and Period (2005-2009)

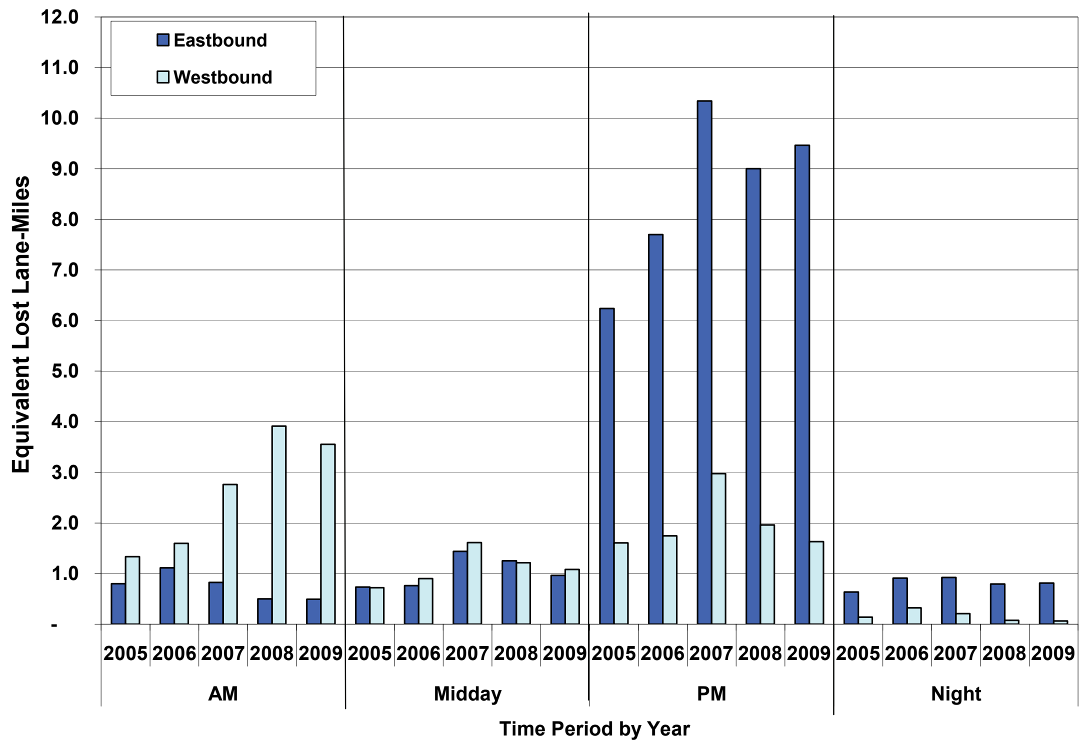
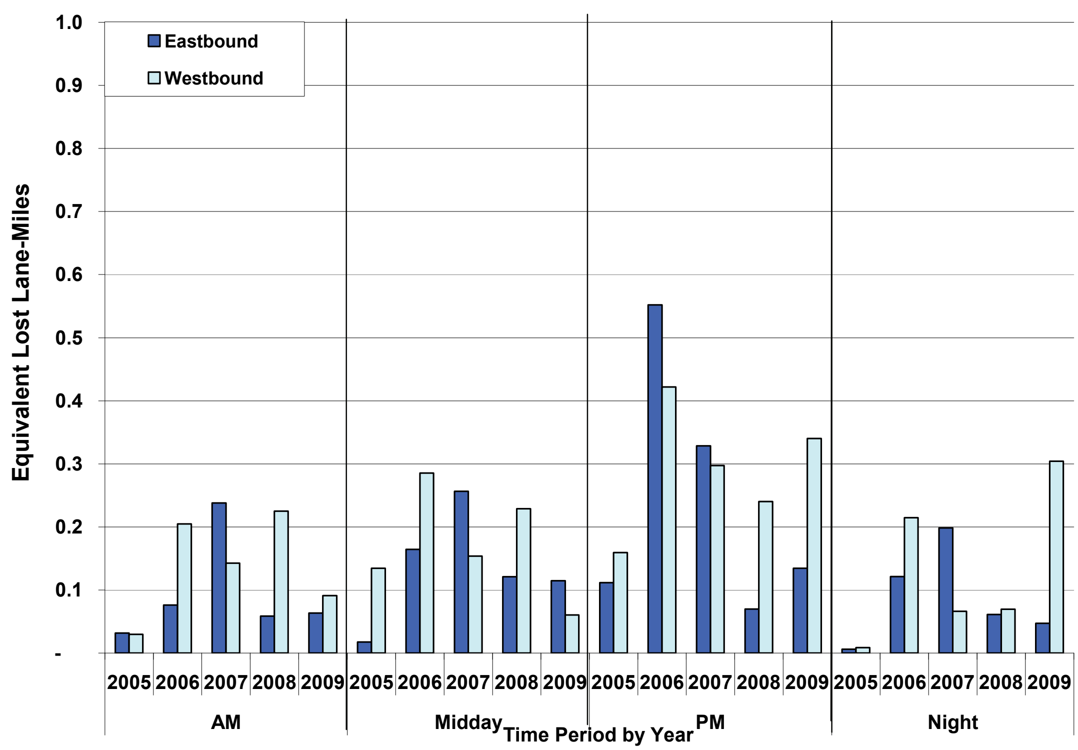


Exhibit ES-16: HOV Daily Equivalent Lost Lane-Miles by Direction and Period (2005-2009)



Source: SMG analysis of Caltrans TASAS data

5. Bottleneck Identification and Causality Analysis

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.

Exhibit ES-17 summarizes eastbound and westbound bottleneck locations on SR-91, the period these bottlenecks are active, and the causes of the bottlenecks. 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 ES-18 and ES-19 are maps showing verified bottleneck locations for the AM and PM peak periods, respectively.

The specific location and causality of each major SR-91 bottleneck were verified in multiple field observations on separate weekdays. Many bottleneck locations were videotaped to validate specific locations and causes and to assist in micro-simulation model calibration. The detailed final report fully explains the process and results of the bottleneck identification and causality analysis.

Exhibit ES-17: SR-91 Bottleneck Locations and Causality

Dir	Bottleneck Location	Causality	Active Period		Location Postmile
			AM	PM	
Eastbound	Euclid St	Not directly observable during 2008 field visits due to lower traffic volumes	✓	✓	2.4
Eastbound	State College Blvd	Not directly observable during 2008 field visits due to lower traffic volumes	✓	✓	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	Merging from consecutive on-ramps	✓	✓	R11.7
Eastbound	Gypsum Canyon Rd On/SR-241	Merging from consecutive on-ramps; heavy demand from SR-241	✓	✓	R16.4
Eastbound	Coal Canyon Rd	Lane drop		✓	R17.8
Westbound	Weir Canyon Rd Off	Heavy demand from northbound SR-241 on-ramp; loss of aux lane to Weir Canyon	✓	✓	R14.5
Westbound	Truck Weigh Station	Heavy demand from Weir Canyon on-ramps	✓		R13.3
Westbound	SR-55 Off	Queuing on SR-55 off-ramp; weaving	✓	✓	R8.9
Westbound	SR-57 Off	Indicated by Caltrans and did not appear until 2009			
Westbound	SR-57 On	Merging from consecutive on-ramps	✓	✓	6.1
Westbound	State College Blvd	Continuation of SR-57 On bottleneck. Crest of uphill grade.	✓	✓	5.1
Westbound	Harbor Blvd	Horizontal and vertical grade	✓	✓	3.1
Westbound	I-5 Off	Horizontal and vertical grade; weaving	✓	✓	R3.6

Exhibit ES-18: Map of Major SR-91 AM Existing Bottlenecks

Exhibit ES-19: Map of Existing SR-91 PM Bottlenecks

6. Scenario Development and Analysis

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 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.

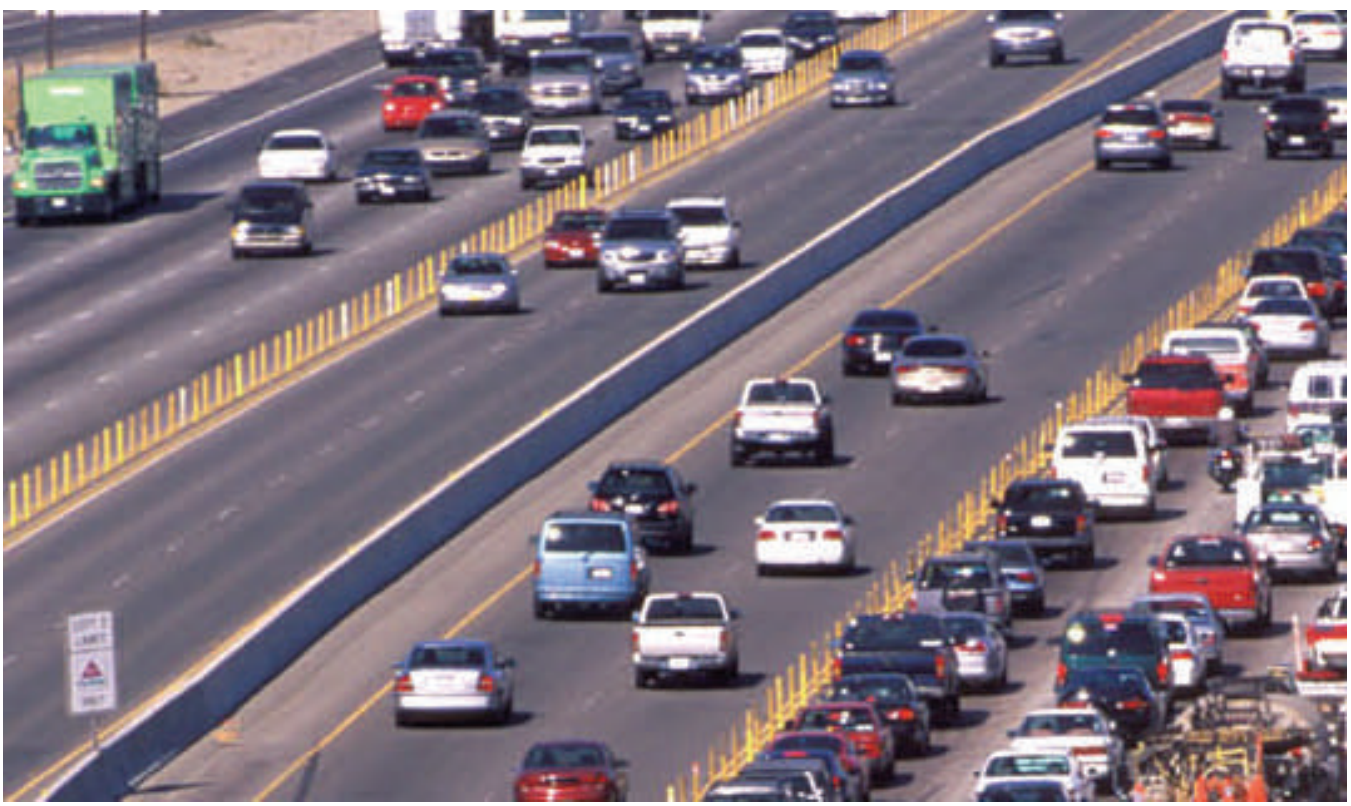


Exhibit ES-20: SR-91 Micro-Simulation Model Network

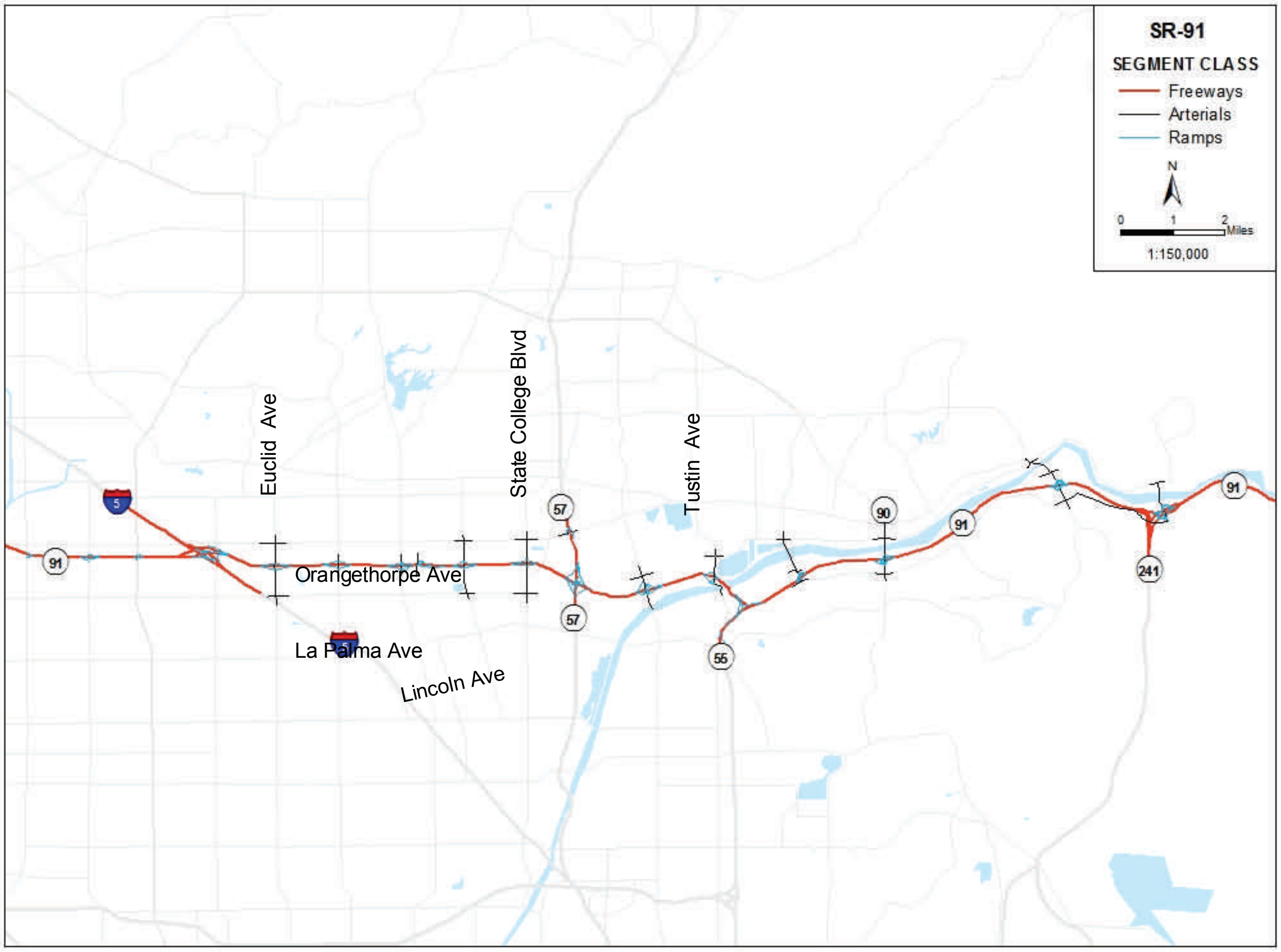


Exhibit ES-20 shows the corridor roadway network included in the model. All freeway interchanges were included as well as on and off-ramps along the SR-91 corridor. The study team calibrated the base year model against the actual 2007 conditions presented earlier. This effort required several submittal 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 OCTA travel demand model. Caltrans selected 2020 as the horizon year to test operational improvements and other system management strategies.

These 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.

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 corridor was consistent with the origin-destination matrices in the OCTA regional travel demand model.

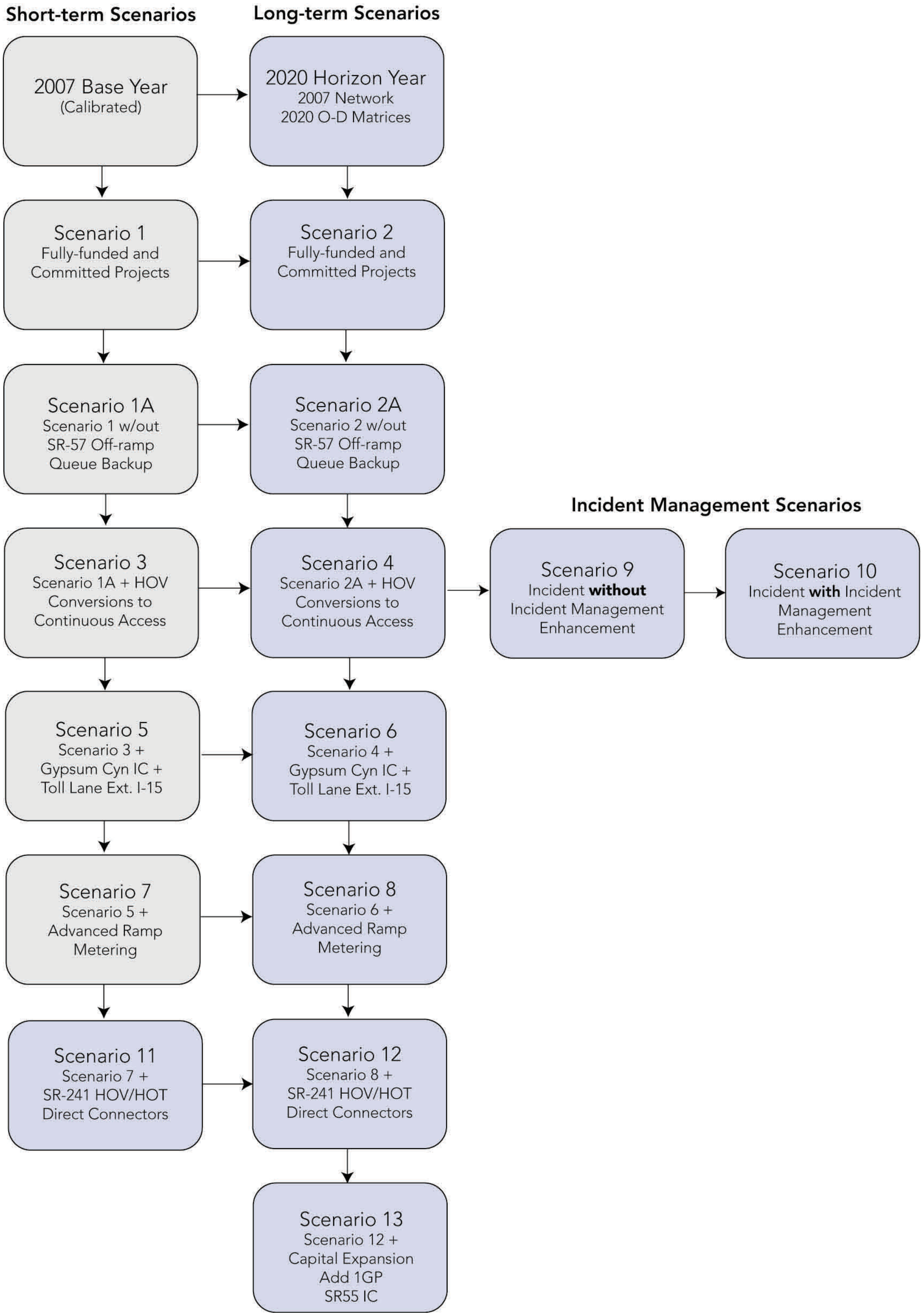
When OCTA updates its travel demand model and SCAG updates its Regional Transportation Plan (RTP), they may wish to update the micro-simulation model with revised demand projections.

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, and 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.

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 ES-21 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 ES-21: Paramics Micro-Simulation Modeling Approach



SCENARIO EVALUATION RESULTS

Exhibits ES-22 and ES-23 show the delay results for all the 2007 scenarios evaluated for the AM and PM peak periods, respectively. Exhibits ES-24 and ES-25 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 for each modeling analysis to ensure they were consistent with general traffic engineering principles.

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.

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 w/o 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 relieved these backups with the improvements on the SR-57 corridor. The difference between the benefits of these two sets of scenarios belongs to the SR-57 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 by a significant reduction in delay (reduction of over 75 percent or over 12,000 vehicle-hours delay) peak period. This reduction occurs almost entirely in the east-bound 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 3 lanes of storage)
- NB-57 to EB-91 (widen connector to 2 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 3 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 Los Angeles I-210 freeway corridor. For the SR-91 modeling purposes, the Asservissement Lineaire d'Entrée Autoroutiere (ALINEA) system was tested as a 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 a review of the actual 2010 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 that includes 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 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. These results reflect benefits realized during the peak direction period. Additional benefits would be realized during off-peak hours and in the off-peak direction.

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, restriping existing lanes, modifying 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 that remains to address 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.

Exhibit ES-22: AM Peak Micro-Simulation Delay Results by Scenario (2007)

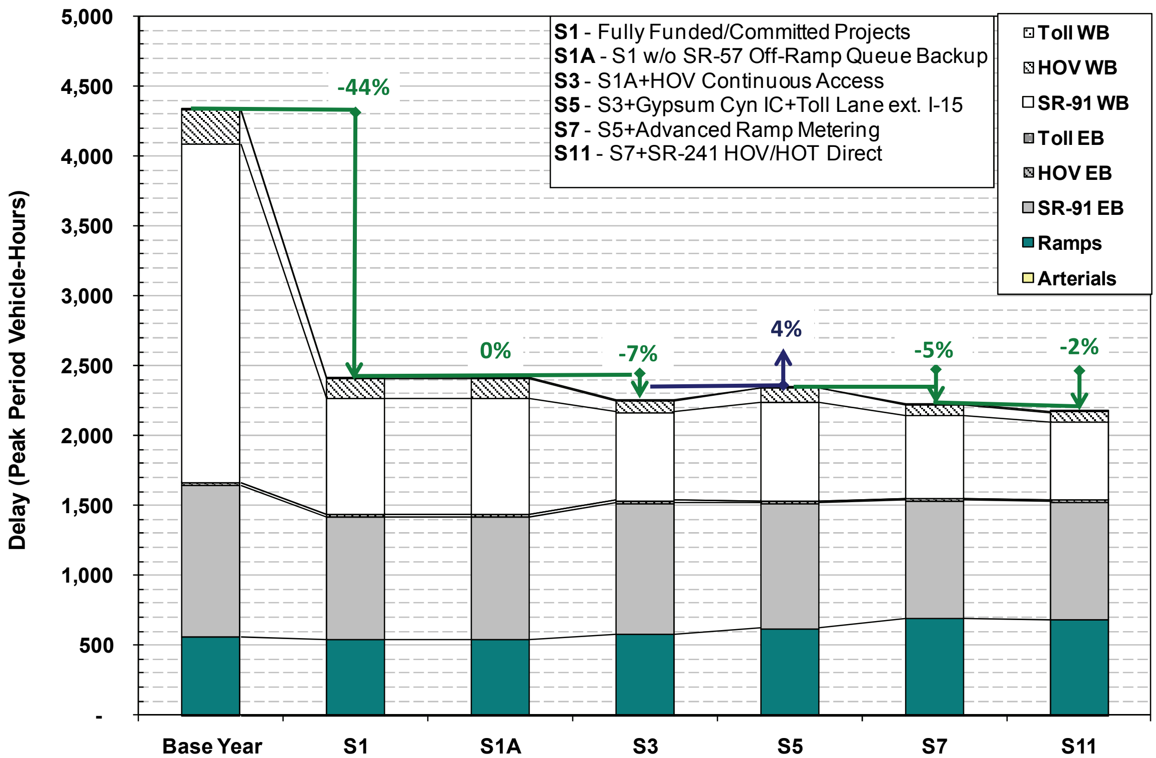


Exhibit ES-23: PM Peak Micro-Simulation Delay Results by Scenario (2007)

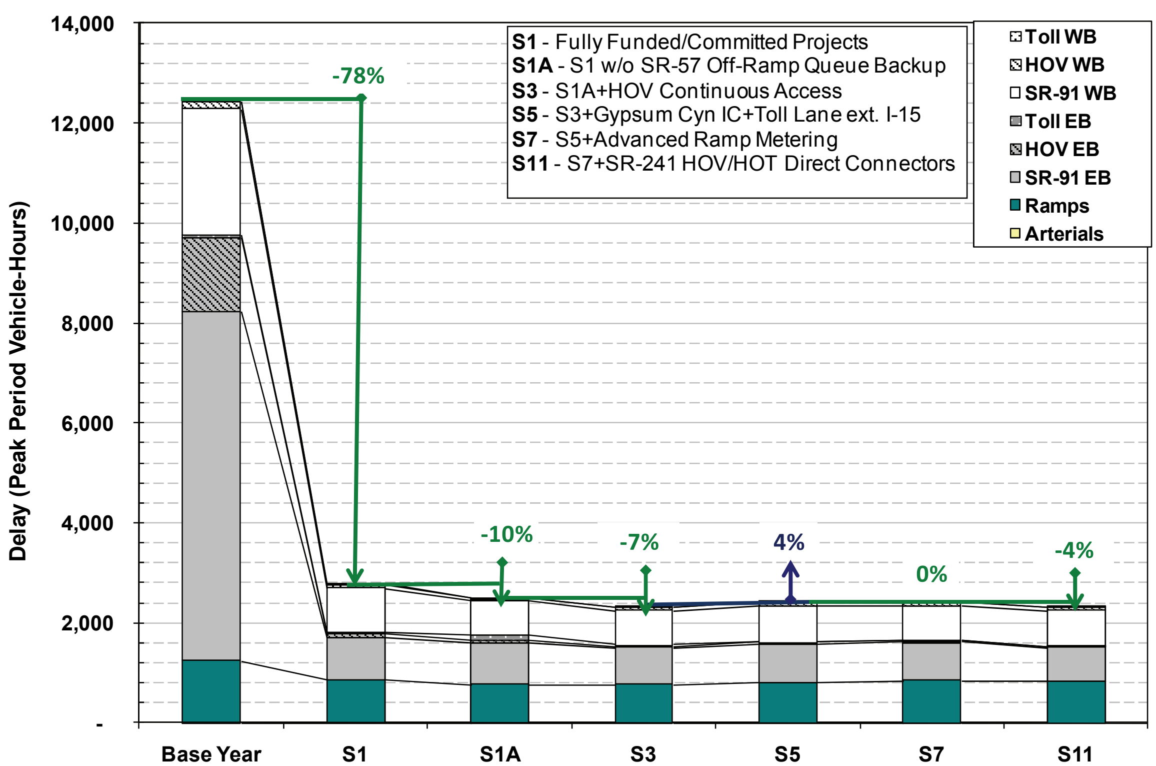


Exhibit ES-24: AM Peak Micro-Simulation Delay by Scenario (2020)

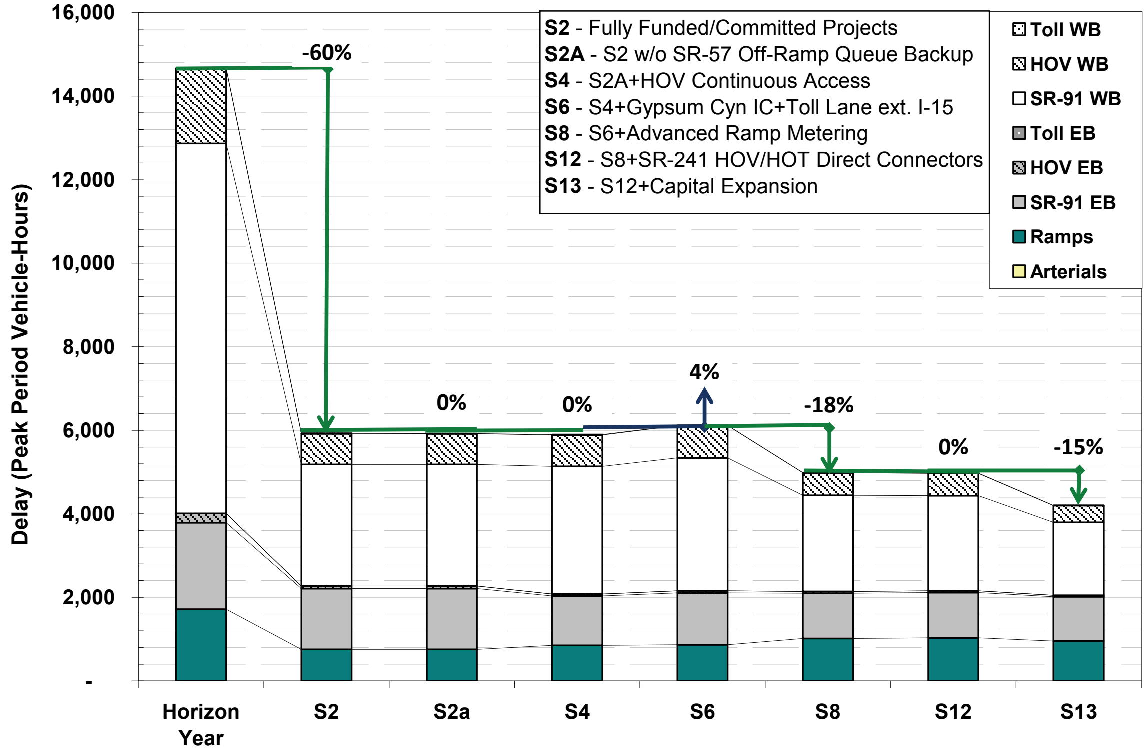
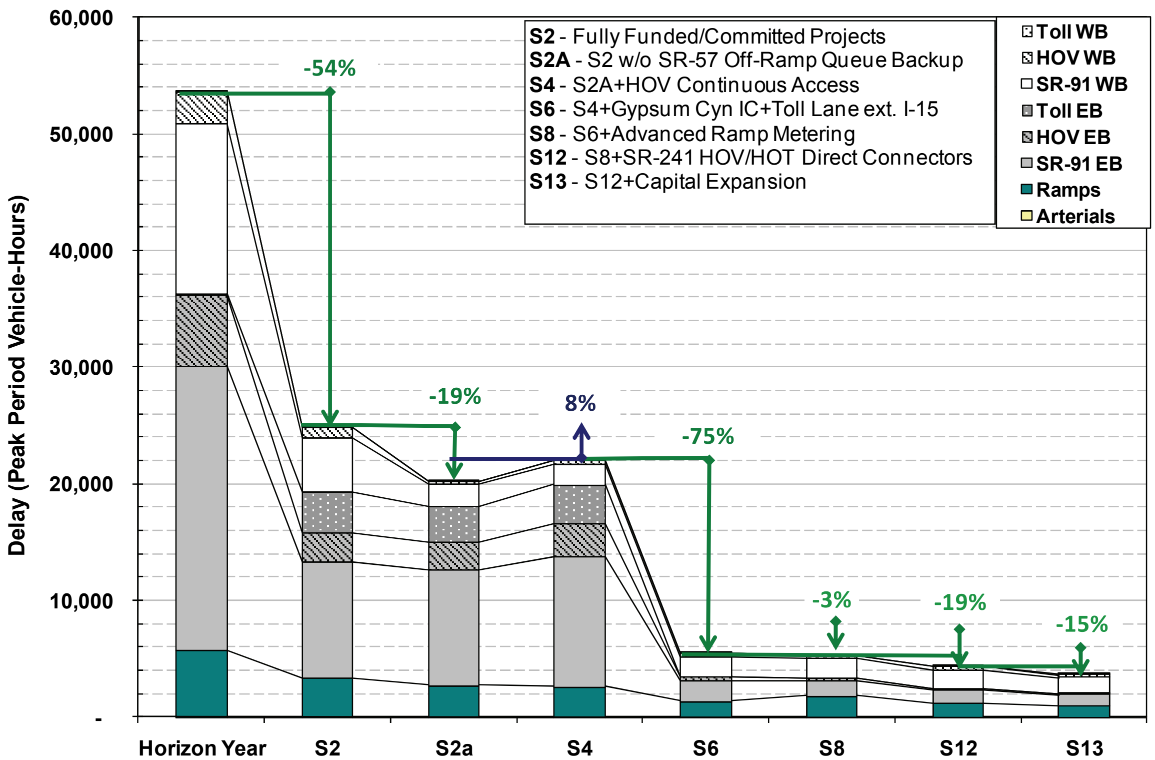


Exhibit ES-25: PM Peak Micro-Simulation Delay by Scenario (2020)



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 Benefit-Cost 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. The B/C results are shown in Exhibit ES-26.

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

- Scenarios 1 and 2 (completed or fully funded programmed projects) produce a high B/C 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 B/C 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 B/C of less than 1, mainly due to the high cost and limited benefits from nominal remaining congestion to reduce.
- 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.

Exhibit ES-26: Scenario Benefit/Cost (B/C) Results

Scenario	Scenario Description	Benefit/Cost Ranges				
		Low	Medium	Medium-High	High	Very High
		<1	≥1 and <2	≥2 and <5	≥5 and <10	>10
1/2	Fully-funded and committed projects w/o SR-57 off-ramp queue backup					★★★★★
3/4	HOV conversion to continuous access	★				
5/6	Gypsum Cyn IC + Toll Lane ext. I-15			★★★		
7/8	Advanced ramp metering			★★★		
11/12	HOV/HOT direct connectors	★				
13	Capital Expansion (Add 1 GP from SR57 to SR55+SR55 IC)	★				

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. There are engineering and professional judgment and experience, among other technical factors to take 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 these 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 other scenarios 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.

- There is very little noticeable congestion by year 2020 after all of the scenarios are implemented. 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.

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.

Exhibit ES-27: District 12 CSMP Team Organization Chart