System Metrics Group, Inc.

in association with

CLR Analytics, Inc.

Corridor System Management Plan (CSMP)

Orange County I-5 Corridor

Final Report

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Interstate 5

Corridor System Management Plan

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1. INTRODUCTION

This document represents the Comprehensive Performance Assessment Report of the Orange County Interstate 5 (I-5) Corridor System Management Plan (CSMP) developed by the California Department of Transportation (Caltrans). The I-5 corridor runs in a north-south direction from the San Diego County Line at Post Mile 0.0 to the Los Angeles County Line at Post Mile 44.38.

A CSMP aims to define how corridors will be managed in the short to medium term, 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 report presents performance measurement findings, identifies bottlenecks that lead to less than optimal performance, diagnoses the causes for these bottlenecks in detail, develops micro-simulation models that evaluate different project scenarios, and quantifies the associated congestion relief benefits of these scenarios.

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 among other changes. Such changes could influence the conclusions of the CSMP and the relative priorities in investments.

It is recommended that updates occur at least every two to three years or when other major studies have been completed to ensure that the existing CSMP report findings and recommendations are still applicable. To the extent possible, this document has been organized to facilitate such updates. The following discussion provides background to the system management approach in general and CSMPs in particular.

What is a Corridor System Management Plan (CSMP)?

This CSMP is the first attempt to integrate the overall concept of system management into Caltrans' planning and decision making processes for the I-5 corridor. Traditional planning approaches identify localized freeway problem areas and then develop solutions to fix those problems, often by building expensive capital improvement projects.

This I-5 CSMP focuses on the system management approach with a 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. The performance assessment involves analyses of existing conditions and

identification of corridor bottlenecks and causality. CSMPs also include development of micro-simulation models that test short-term and medium- to long-term project scenarios and detailed benefit-cost assessments to determine the return on investment for each scenario.

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.

What is System Management?

With the rising cost and complexity of construction and right of way acquisition, it is more challenging to construct large-scale freeway projects. 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 from HICOMP Reports. HICOMP reports are only available up to 2008. Subsequent to 2008, Caltrans produces the Mobility Performance Report (MPR) to document congestion. Due to different methodologies used to analyze congestion, it is not recommended to compare the results of these two sources.

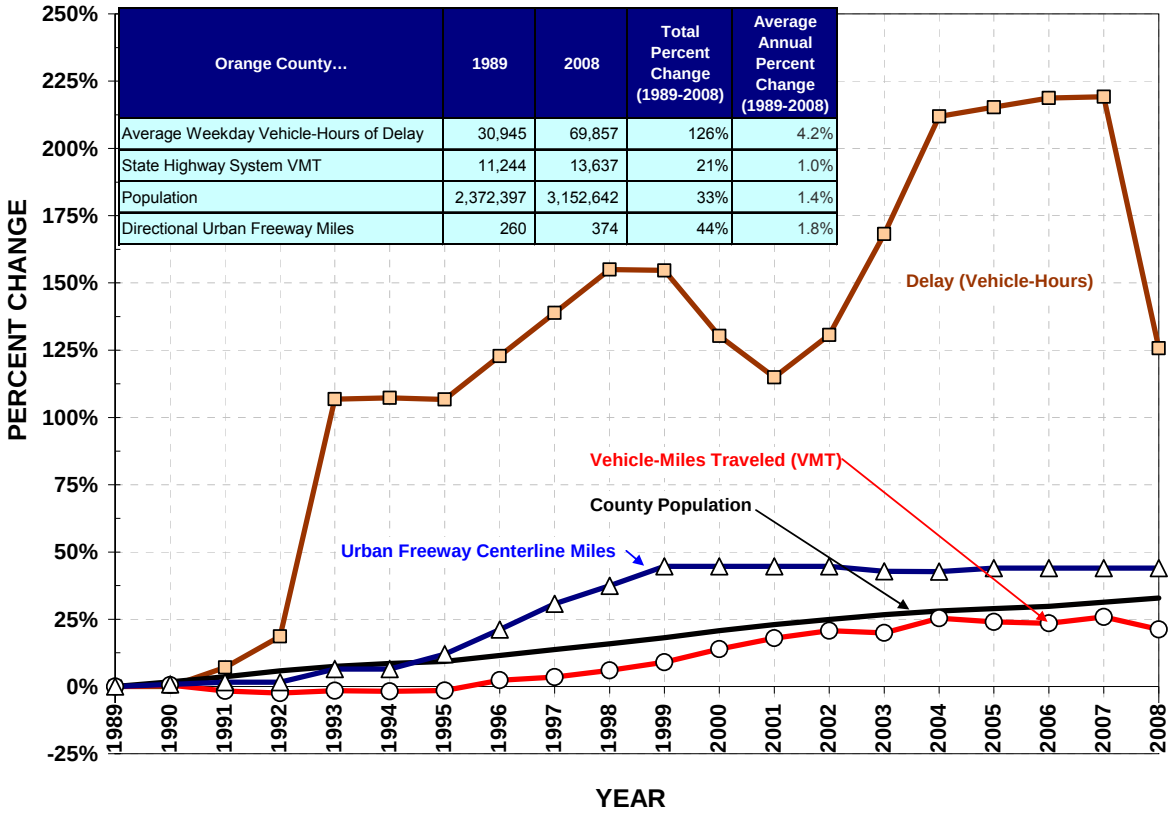
Over that 20-year period, the following should be noted:

- Congestion, as measured by vehicle hours of delay increased by more than 125 percent from 1989 levels (just over four percent per year).
- Excluding the sharp decline in 2008 due to the economic downturn, congestion had actually increased by more than 200 percent.
- While congestion rose by more than 125 percent, VMT and population rose by 21 percent and 33 percent, respectively.

- Urban freeway miles grew by less than 50 percent, but mostly between 1989 and 1999.

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

Exhibit 1-1: District 12 (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%

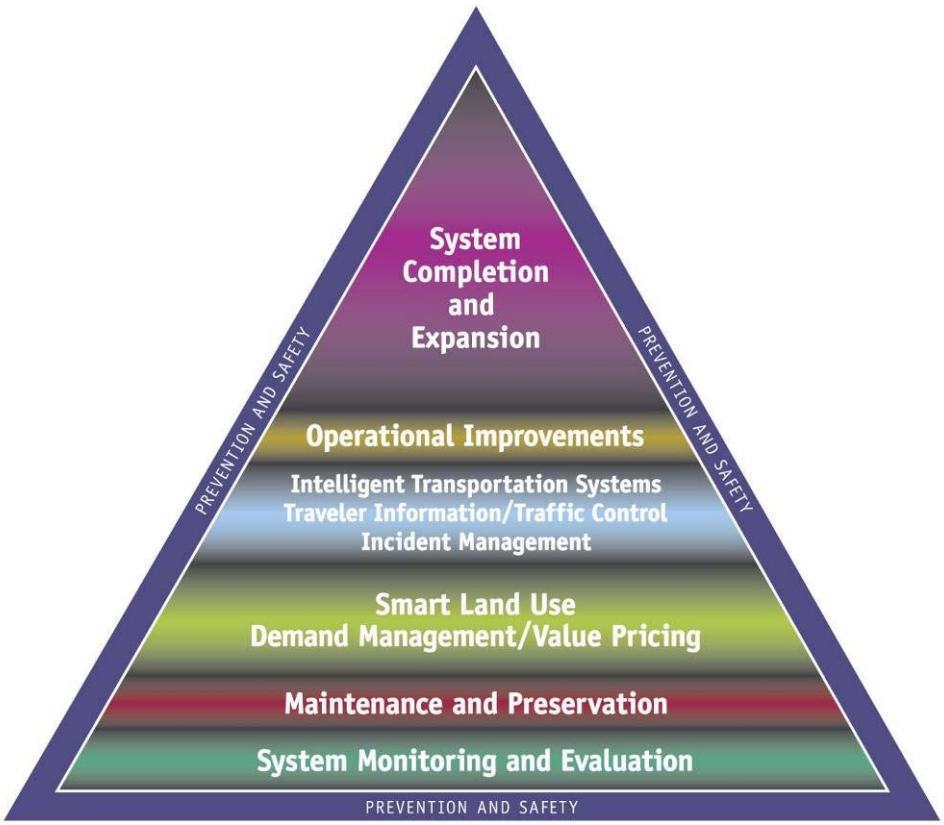
Source: 1989 - 2008 HICOMP Reports

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 approach illustrated in the System Management pyramid shown in Exhibit 1-2.

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 comprehensive regional system management plan to address all components of the pyramid for an entire region. However, because system management 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 assessments and evaluation. Understanding how a corridor performs and why it performs the way it does is critical to crafting appropriate strategies. Section 3 of this report is dedicated to performance assessment. It is 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 traffic breakdown occurs on the corridor.

Exhibit 1-2: System Management Pyramid

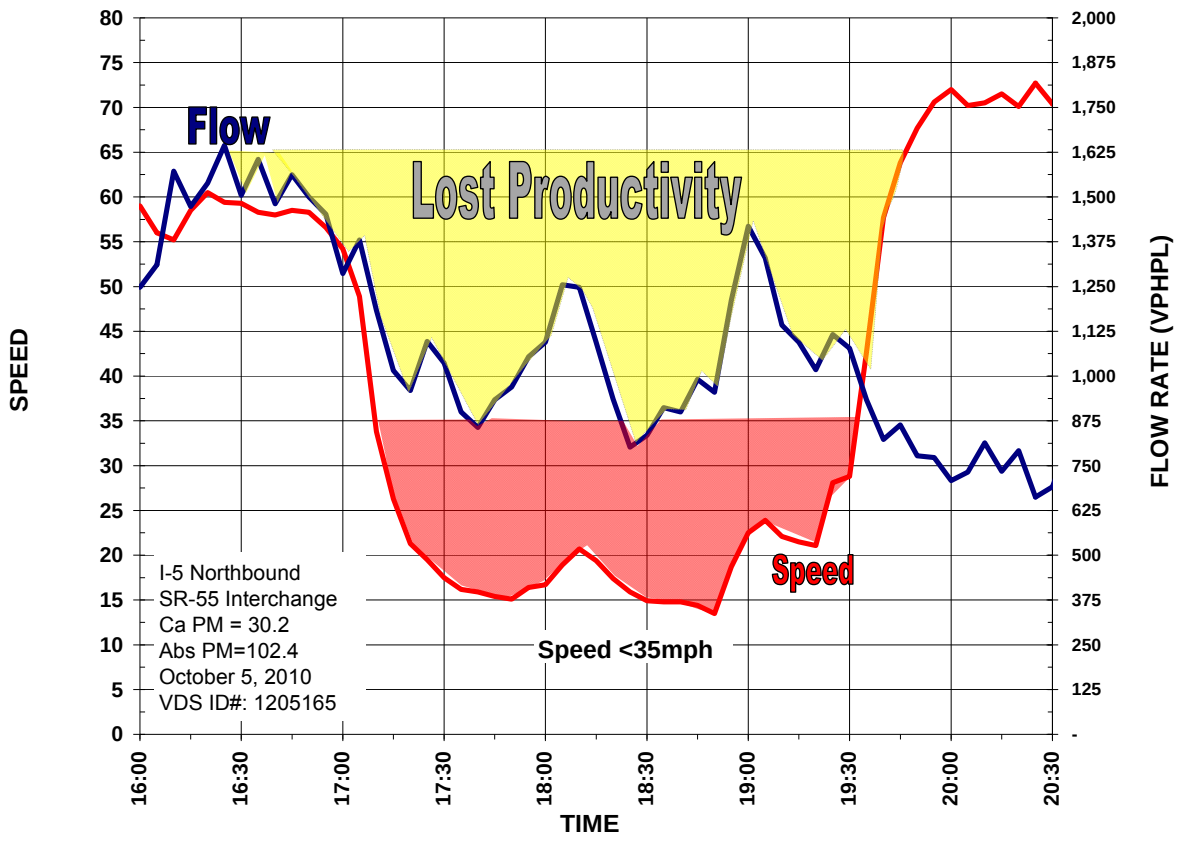


Source: Caltrans

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 that experience growing congestion, the opposite is true. When demand is the highest, the flow breaks down and productivity, also known as vehicle throughput, declines.

Exhibit 1-3 illustrates how congestion leads to lost productivity. The exhibit was created using observed I-5 data from automatic detectors for a typical afternoon peak period in the autumn of 2010. It shows speeds (in red) and flow rates (in blue) on northbound I-5 at the SR-55 Interchange, one of the most congested locations on this corridor.

Exhibit 1-3: Productivity Loss During Congestion



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Flow rates (measured as vehicles-per-hour-per-lane or "vphpl") at the SR-55 Interchange average slightly over 1,500 vphpl between 4:00 PM and 5:00 PM, which is slightly less than a typical peak period maximum flow rate.

Once volumes exceed this maximum rate, traffic breaks down and speeds plummet to below 35 miles per hour (mph). Rather than being able to accommodate the same number of vehicles, flow rates also drop and vehicles back up, creating congestion. At the location shown in Exhibit 1-3, vehicle throughput drops by 40 percent during the peak period (from over 1,500 to around 900 vphpl). This five-lane freeway now operates as if it has lost two lanes 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 lane capacities. This is a major cost of congestion that is rarely discussed and 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 northbound I-5 were over eight daily lane-miles during the PM peak period in 2010. Caltrans works hard to recover this lost productivity by investing in improvements that use public funds in the most effective manner. By largely implementing operational strategies, Caltrans can leverage past investments and restore productivity.

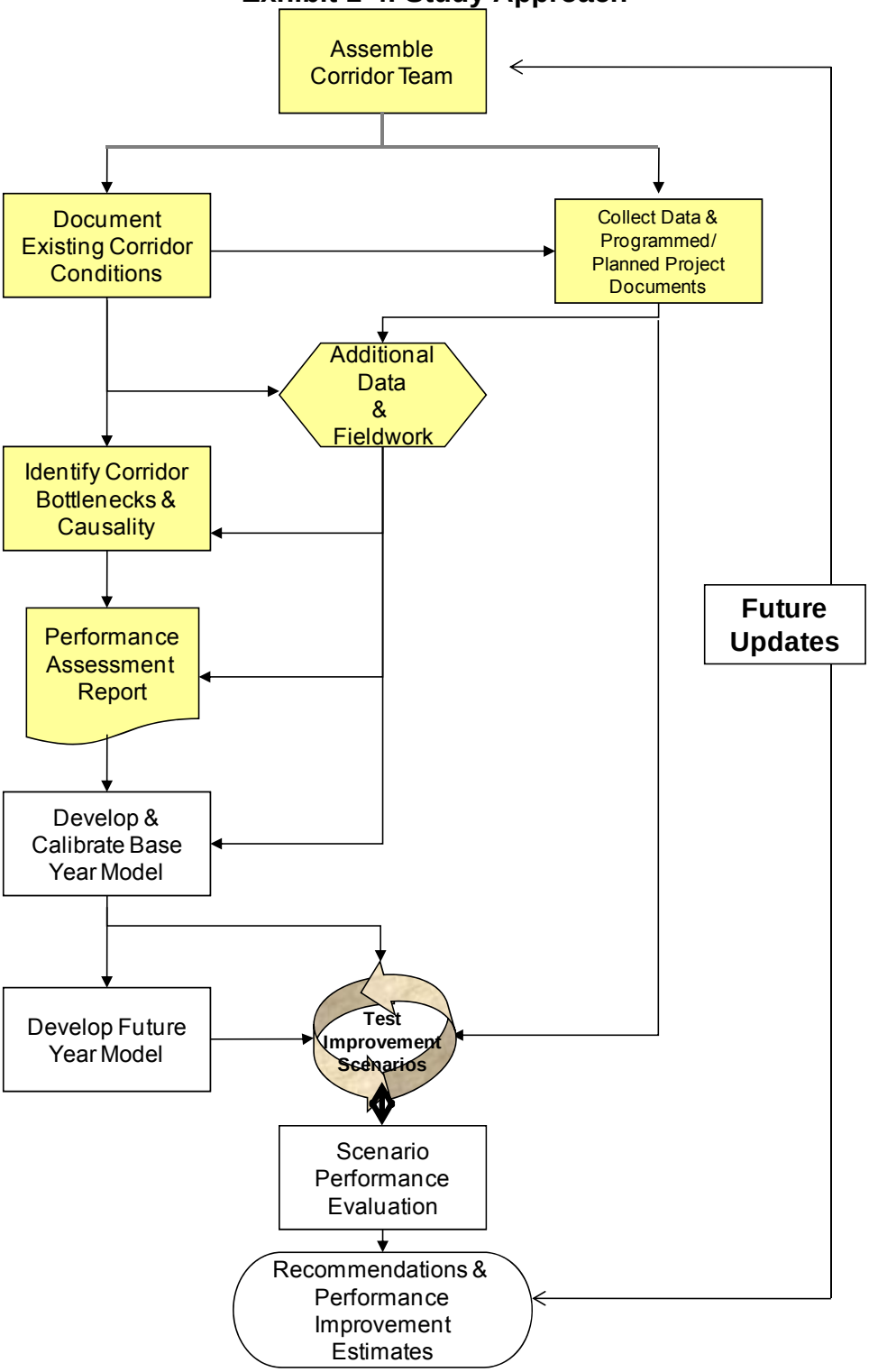
Although still an important strategy, infrastructure expansion (at the top of the pyramid in Exhibit 1-2) cannot be the only strategy to address mobility needs in Orange County. System management must be an important consideration as Caltrans and its partners evaluate the need for facility expansion. 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 approaches 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.

Study Approach

The I-5 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, with the yellow shading indicating the steps which have been completed to date. Each step of the approach is described following the chart.

Exhibit 1-4: Study Approach



Assemble Corridor Team

The first task in this effort was undertaken by Caltrans with the creation of an I-5 CSMP team. The team met periodically to review project progress and to provide input to the study.

Document Existing Conditions

As part of this step, the study team evaluated the performance of the corridor by focusing on the four key areas of mobility, reliability, safety, and productivity. Using various data sources, including automatic detector data, the existing conditions of the corridor were documented in order to better understand how it performs. The study team also compiled information relevant to traffic patterns along the corridor, such as traffic volumes, truck percentages, transit options, and major trip generators near I-5.

Collect Data and Programmed/Planned Project Information

The study team reviewed existing studies, plans, and other programming documents to assess additional data collection needs for modeling and future scenario development.

Additional Data Collection and Fieldwork

The study team determined locations where additional manual traffic counts would be needed to calibrate the 2010 Base Year model and coordinated the collection of this data. Traffic data counts collected included peak period turning movement counts, 24-hour average daily traffic (ADT) counts, peak period connector counts, and travel time/speed surveys. Additionally, signal timing data were obtained from Caltrans for use in the model calibration.

The study team conducted extensive field visits in June and July 2011 to observe conditions during peak periods. Some of the field observations were conducted collaboratively with Caltrans District 12 staff. This fieldwork will be discussed in Section 4: Bottleneck Identification and Causality Analysis.

Identify Corridor Bottlenecks and Causality

Building on the corridor performance evaluation and fieldwork, the study team identified major AM and PM peak period bottlenecks along the corridor. These bottlenecks will be discussed in detail in Section 4 of this report.

Performance Assessment Report

This document represents the Performance Assessment, which compiles all of the analysis conducted in the previous steps. It includes the corridor performance results for three years (2008, 2009, and 2010) and the identification of bottlenecks and their causes along the corridor. The report also includes performance results for each individual bottleneck area (i.e., segment between major bottleneck locations).

Develop and Calibrate Base Year Model

Using the bottleneck areas as the basis for calibration, the modeling team will develop a calibrated 2010 Base Year micro-simulation model for the corridor. This model will be calibrated against California and Federal Highway Administration (FHWA) guidelines for micro-simulation model calibration. In addition, the model will be evaluated to ensure that each bottleneck area was represented and that travel times and speeds are consistent with observed data.

Develop Future Year Model

Following the approval of the 2010 Base Year model, the modeling team will develop 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 enhanced incident management on the corridor. Projects that are expected to be delivered well beyond 2020 will not be tested in the model.

Test Improvement Scenarios

The study team will develop scenarios to be evaluated using the micro-simulation model. Short-term scenarios will include 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 will also be tested using the 2020 Horizon Year model to assess their long-term impacts. These scenarios will likely include programmed and planned projects that are not expected to be completed within five years of 2010 and that would likely only experience benefits in the long-term.

Scenario Performance Evaluations

Once scenarios are developed and fully tested, simulation results for each scenario will be subjected to a benefit-cost evaluation to determine how much return on investment each scenario will deliver. This detailed benefit-cost assessment will be performed using the California Benefit-Cost model (Cal-B/C).

Recommendations and Performance Improvement Estimates

The study team expects to develop final recommendations for future operational improvements that could be reasonably expected to maintain the mobility gains achieved by existing programmed and planned projects.

This report is organized into five sections, including the Introduction. The remainder of this report is organized into four subsequent sections:

1. *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, corridor socio-economic characteristics, and an I-5 origin-destination demand profile from the Orange County Transportation Authority Orange County Transportation Analysis Model (OCTAM).

3. *Corridor-wide Performance and Trends* presents multiple years (2008 to 2010) of performance data for the freeway portion of the I-5 corridor. Statistics are included for the mobility, reliability, safety, and productivity performance measures.

4. *Bottleneck Identification and Performance Assessment* describes how bottlenecks, or choke points, on the freeway facility were identified. These bottlenecks are generally the major cause for mobility and productivity performance degradation and are often related to safety issues as well. This section reports performance results for delay, productivity, and safety by major "bottleneck area". This performance assessment allows bottlenecks to be prioritized in terms of their contribution to corridor performance degradation.

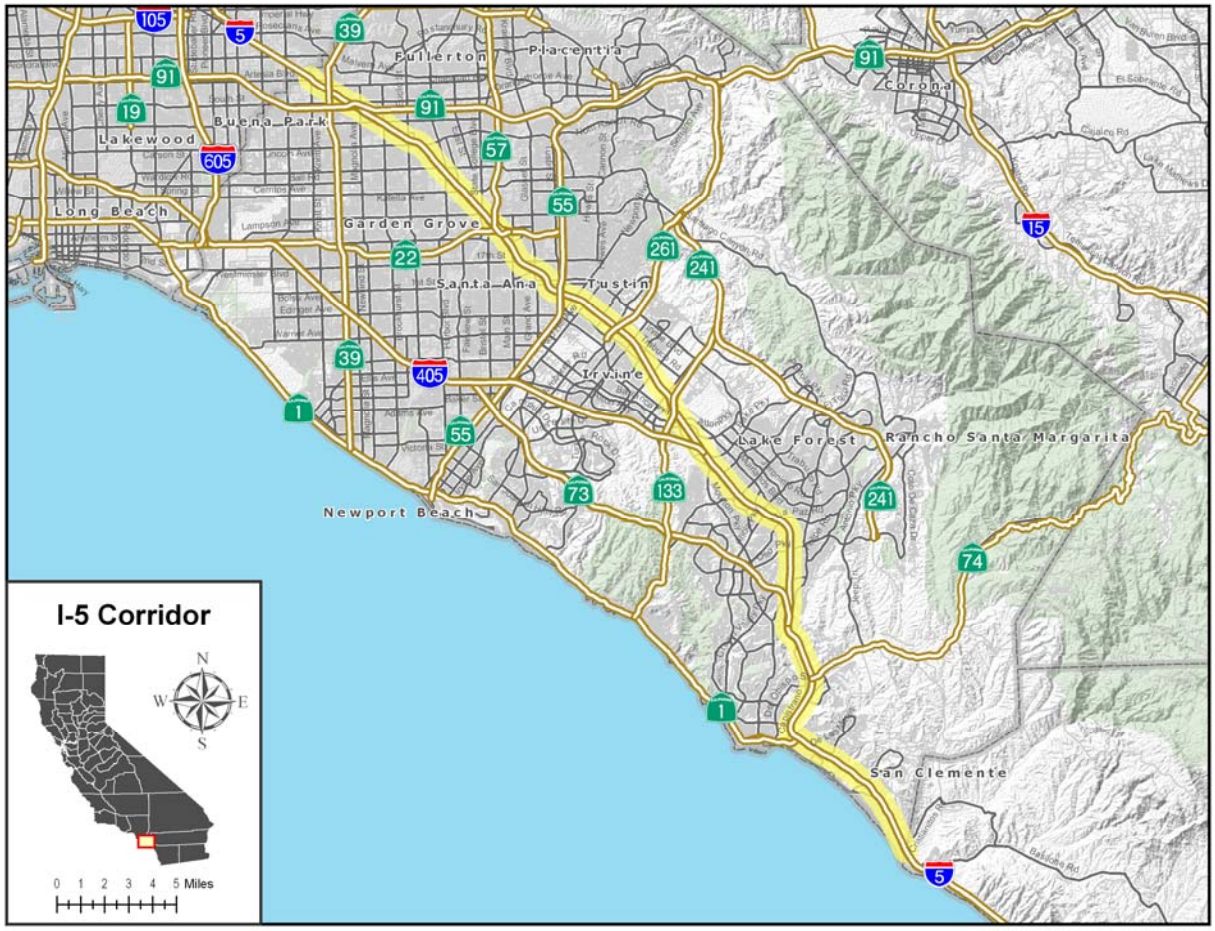
5. *Bottleneck Causality Analysis* diagnoses the bottlenecks identified in Section 4 and identifies the causes of each bottleneck through additional data analysis and significant field observations. Electronic videos were taken for many of the major bottlenecks (to the extent possible) to verify our conclusions. Sections 4 and 5

will provide valuable input in selecting projects to address critical bottlenecks. Moreover, they provide the baseline against which the micro-simulation models will be validated.

2. CORRIDOR DESCRIPTION

Interstate 5 is a major north-south route that traverses the entire length of the state. In Orange County, I-5 is known as the Santa Ana Freeway. As shown in Exhibit 2-1, the Orange County I-5 CSMP Corridor covers the length of the county limits from the San Diego County line (PM 0.0) to the Los Angeles County Line (PM 44.38).

Exhibit 2-1: Orange County I-5 CSMP Corridor Map



Source: System Metrics Group, Inc.

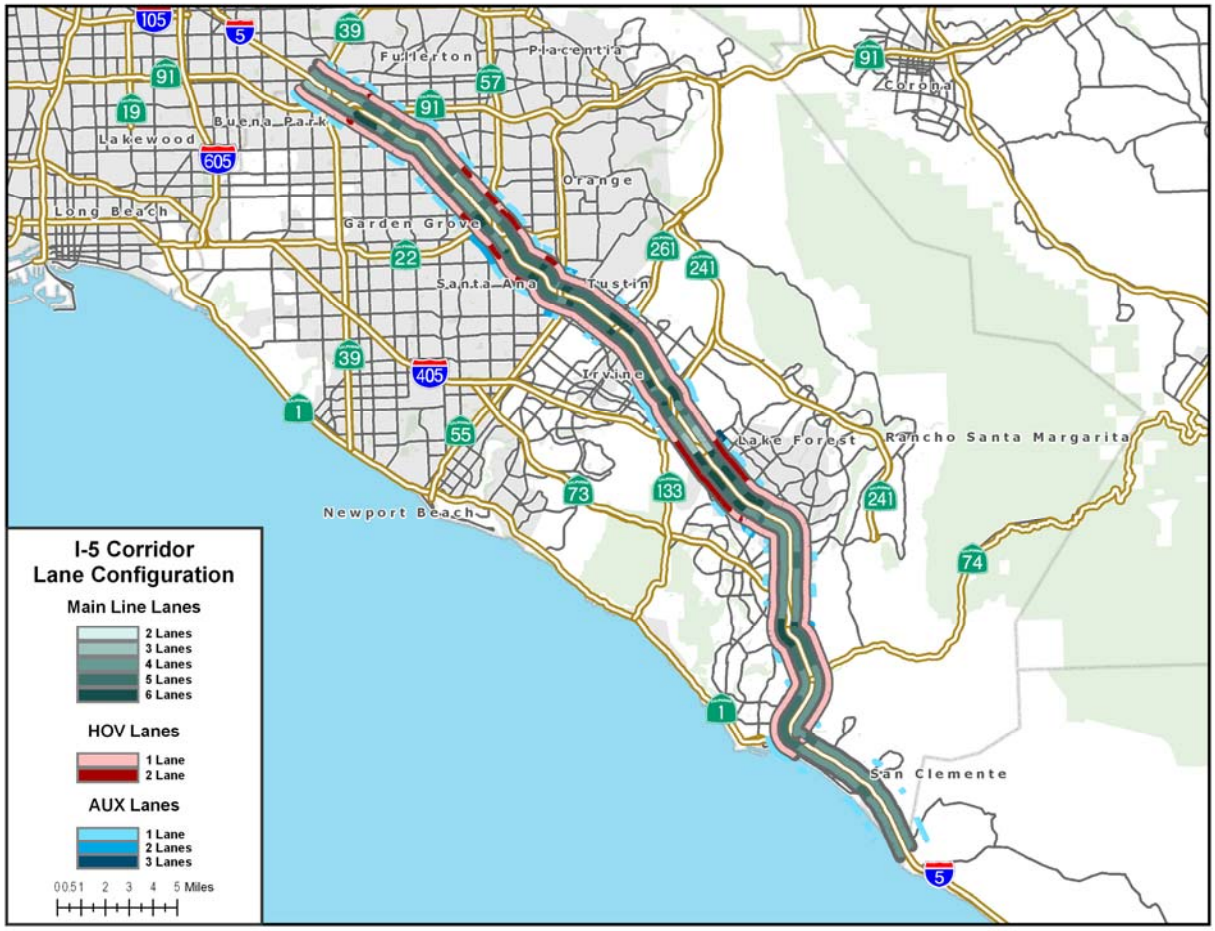
Corridor Roadway Facility

The study corridor passes through the cities of San Clemente, Dana Point, San Juan Capistrano, Mission Viejo, Laguna Hills, Irvine, Tustin, Santa Ana, Orange, Anaheim, Fullerton, and Buena Park. There are nine freeway-to-freeway interchanges along the corridor:

- SR-22 is one of two main east-west routes in the county and is 13 miles long, stretching from the City of Seal Beach in the west to the City of Orange in the east.
- SR-57 is a north-south route that runs from the I-5/SR-22 Interchange (the "Orange Crush") in the south to the Los Angeles County line in the north.
- SR-91 is the other east-west corridor in the county and links Riverside and San Bernardino Counties to Orange and Los Angeles Counties.
- SR-55 provides access to Newport Beach in the south and to the SR-22 and SR-91 corridors in the north.
- SR-133 provides access to the Eastern Transportation Corridor.
- I-405 begins at the I-5 interchange (the El Toro Y) in Irvine and runs in a northwest direction, parallel to the ocean until it terminates and connects back to I-5 in the San Fernando Valley.
- SR-73 connects the I-5 corridor in San Juan Capistrano to the I-405 corridor in Costa Mesa. It runs through Crystal Cove State Park and the University of California at Irvine.
- SR-74 (the Ortega Highway) is part of the Pines to Palms Scenic Byway, which runs northeast from San Juan Capistrano to Palm Desert in Riverside County.
- SR-1 terminates at the junction with I-5 in San Juan Capistrano. It provides coastal access near Dana Point in Orange County along the coast to Mendocino County.

As depicted in Exhibit 2-2, the study corridor is an eight- to sixteen-lane freeway with a concrete median barrier that separates northbound and southbound traffic. There is one HOV lane in both directions of the corridor from SR-1/Camino Las Ramblas at the south end to the Los Angeles County Line at the north end. Most of the HOV facility is buffer-separated with limited points of ingress/egress with the exception of the northbound segment from Tustin Ranch to Redhill Avenue, which has continuous HOV access. There are HOV direct connectors linking the I-5 HOV facility with the SR-55, SR-57, and SR-91 HOV facilities.

Exhibit 2-2: I-5 Corridor Lane Configuration



Source: System Metrics Group, Inc.

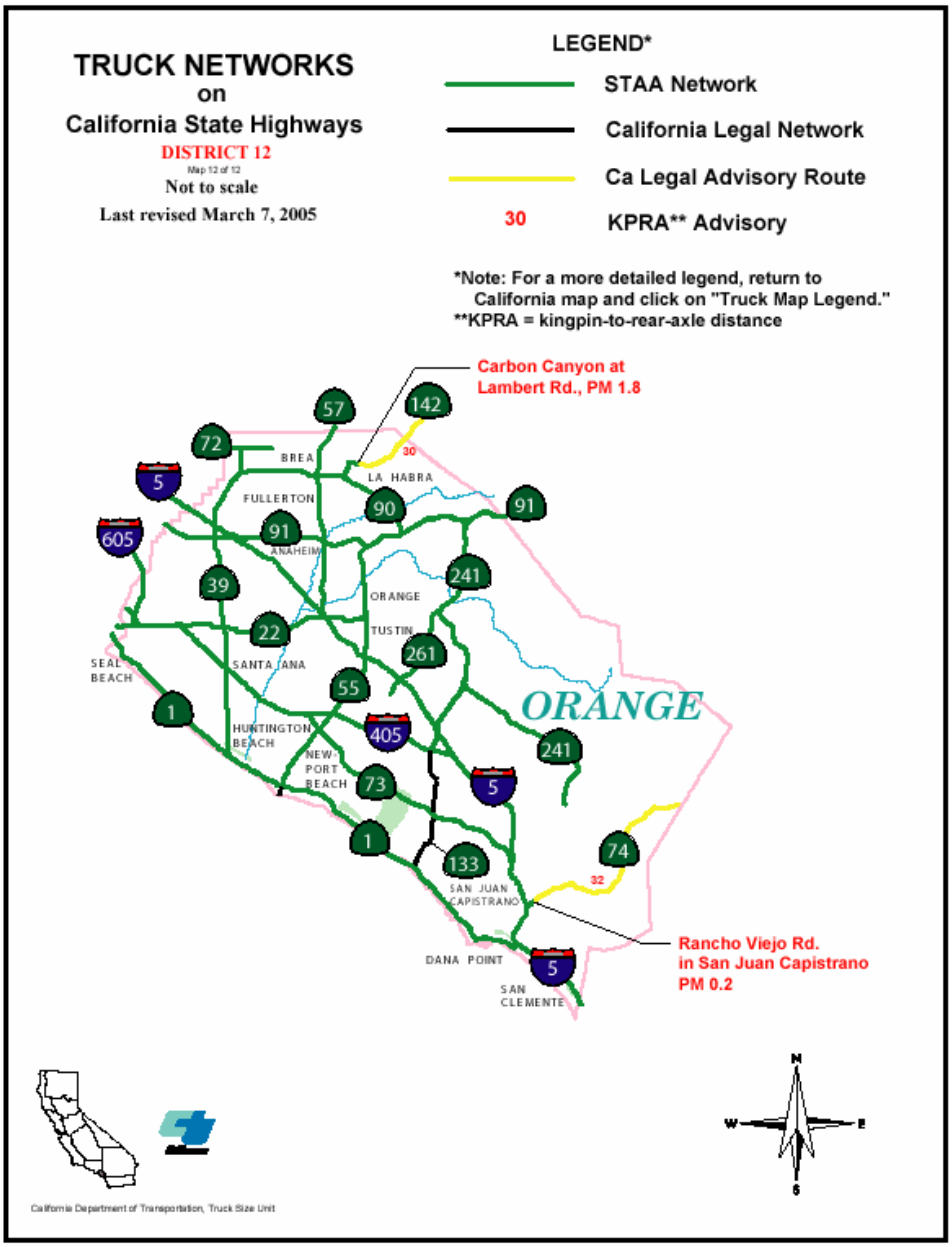
According to the Caltrans Traffic and Vehicle Data Systems Annual Traffic Volumes Report for 2010, Orange County I-5 carries between 85,000 and 357,000 annual average daily traffic (AADT) as shown in Exhibit 2-3. The highest average daily traffic volume on the corridor occurs near 17th Street in Santa Ana, just south of the SR-22 interchange.

As a key route that links Mexico with the largest cities on the west coast, I-5 carries a relatively high volume of trucks. It is designated a Surface Transportation Assistance Act (STAA) route shown in Exhibit 2-4, which means that trucks are allowed to operate on the corridor. According to the latest truck volumes from the 2010 Caltrans Annual Average Daily Truck Traffic data, trucks comprise between three and ten percent of total daily traffic along the corridor. Truck volumes are higher at the north end of the corridor, approaching the Los Angeles County Line.

Exhibit 2-3: 2010 Annual Average Daily Traffic Volumes and Truck Percentage on I-5

Source: Caltrans Traffic and Vehicle Data Systems

Exhibit 2-4: Orange County Truck Network on California State Highways



Source: Caltrans STAA Network

Corridor Transit Services

Three major public transportation operators provide service near the study corridor:

- Southern California Regional Rail Authority (SCRRA) – Metrolink.
- Amtrak Pacific Surfliner and Southwest Chief train service.
- Orange County Transportation Authority (OCTA).

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 roundtrips on three lines:

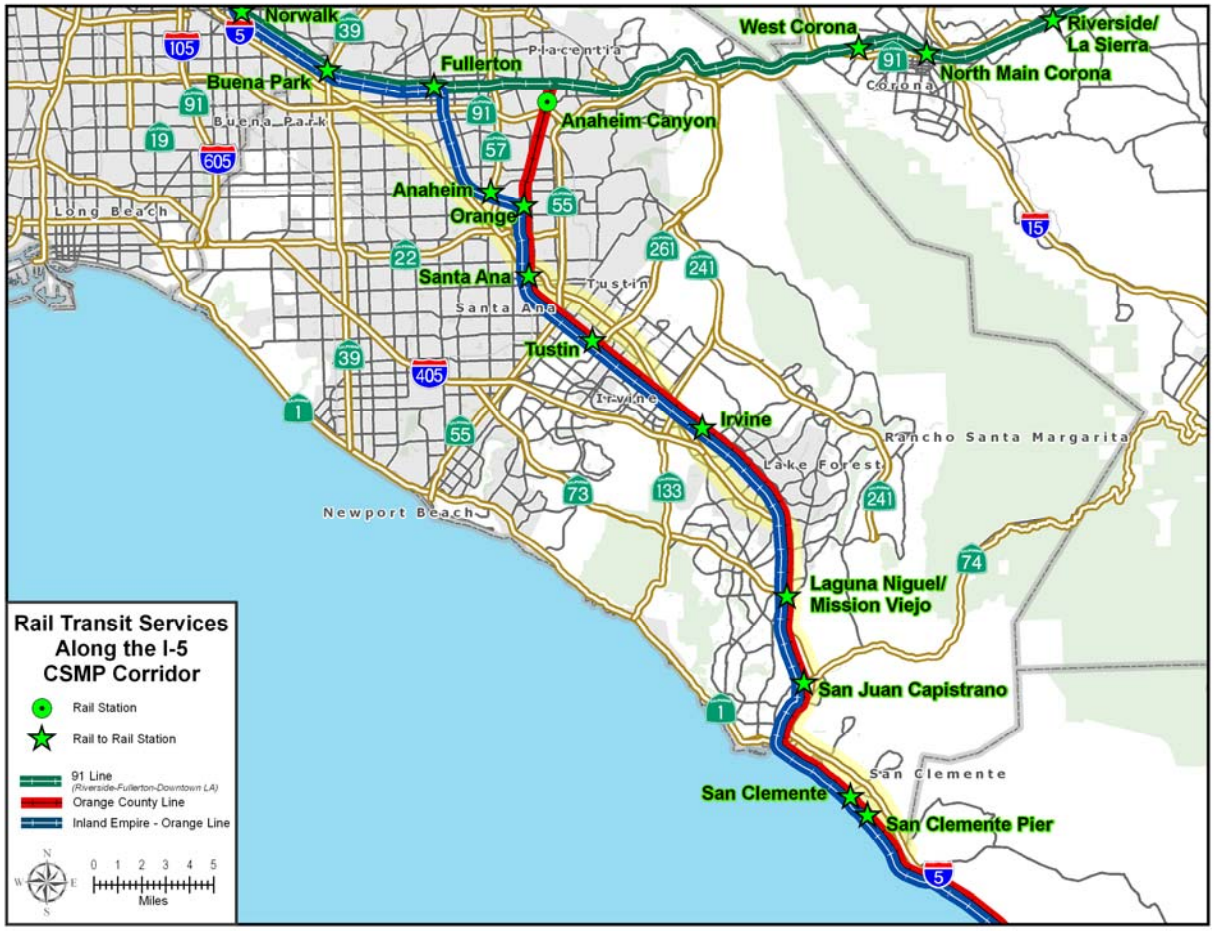
- The Orange County Line provides service from Los Angeles Union Station to Oceanside.
- The Inland Empire-Orange County Line provides service from San Bernardino to Oceanside.
- The 91 Line provides service from Riverside to Los Angeles Union Station via Fullerton and Buena Park.

<u>Amtrak Pacific Surfliner</u>

While Metrolink provides intra-regional service throughout Southern California, Amtrak provides interregional service. Two Amtrak trains use the same route as Metrolink's trains. Amtrak's Pacific Surfliner, which offers service from San Diego to San Luis Obispo, travels along the same route as Metrolink's Orange County Line; and Amtrak's Southwest Chief, which offers service from Los Angeles to Chicago, travels along the same route as Metrolink's Inland Empire-Orange County Line.

Exhibit 2-5 shows the primary rail services offered by SCRRA and Amtrak near the study corridor.

Exhibit 2-5: Rail Transit Services near I-5



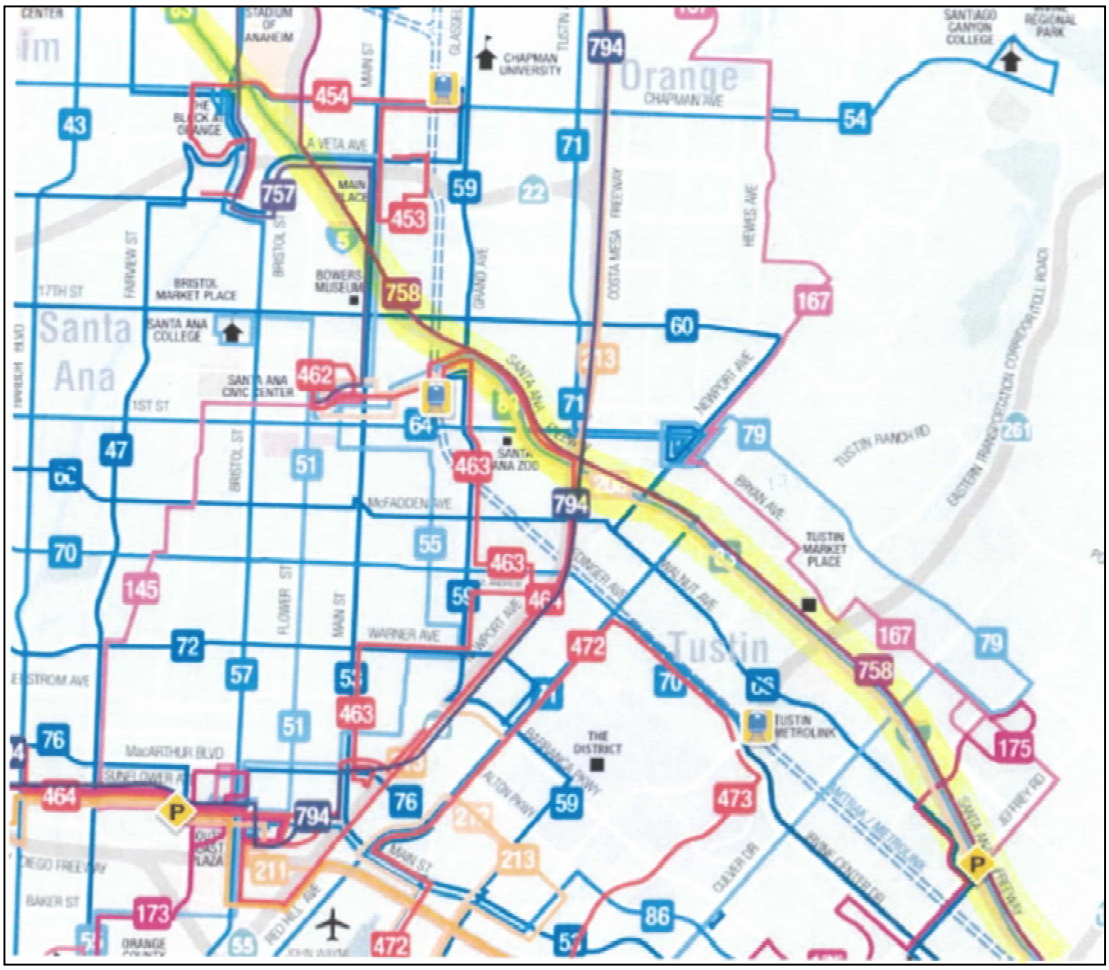
Source: SCRRA and Amtrak

Orange County Transportation Authority (OCTA)

As the primary bus transit provider in Orange County, OCTA provides fixed-route bus and paratransit services throughout the county. In addition to several local and express routes that run in the vicinity of I-5 as shown in Exhibit 2-6, the following routes operate on the study corridor:

- Route 206 provides weekday express service from Santa Ana to Lake Forest via I-5.
- Route 464 provides weekday service from The Depot at Santa Ana to Costa Mesa via I-5, SR-55, and Sunflower Avenue.
- Route 758 provides weekday express service between Irvine and Chino (in San Bernardino County), with stops in Diamond Bar and Brea. The route operates on I-5 between Irvine Center Drive and the SR-57 corridor.

Exhibit 2-6: OCTA Bus Service along I-5



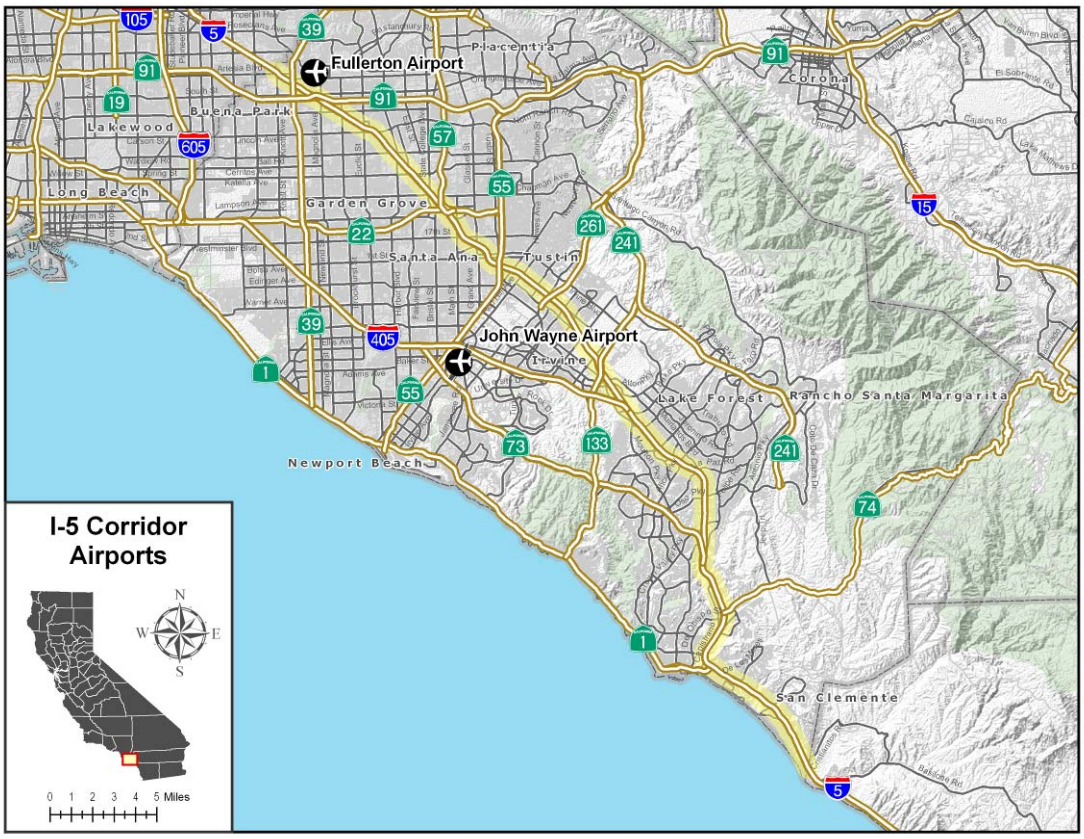
Source: OCTA

Intermodal Facilities

There are various intermodal facilities throughout the I-5 study area, including two airports and various park and ride facilities.

The two airports near the I-5 study corridor are shown in Exhibit 2-7. The first is the Fullerton Municipal Airport, a small general aviation airport located north of the I-5/SR-91 interchange on Commonwealth Avenue. The Airport encompasses 86 acres and has room to accommodate 600 planes.

Exhibit 2-7: Airport Facilities



Source: System Metrics Group, Inc./GIS/Internet

The second airport near the I-5 study corridor is John Wayne Airport (SNA). This airport is located immediately adjacent to the SR-55 corridor between the I-405 and SR-73 interchanges. It is approximately four miles southwest of the I-5 corridor.

Exhibit 2-8 shows the John Wayne Airport annual passenger boarding statistics from 2003 to 2010. Ten commercial, two commuter and two all-cargo airlines operate at the airport. In addition to serving passengers, John Wayne Airport also handles more than 15,000 tons of cargo each year. It hosts air carrier, general aviation, air taxi, military, and air cargo services.

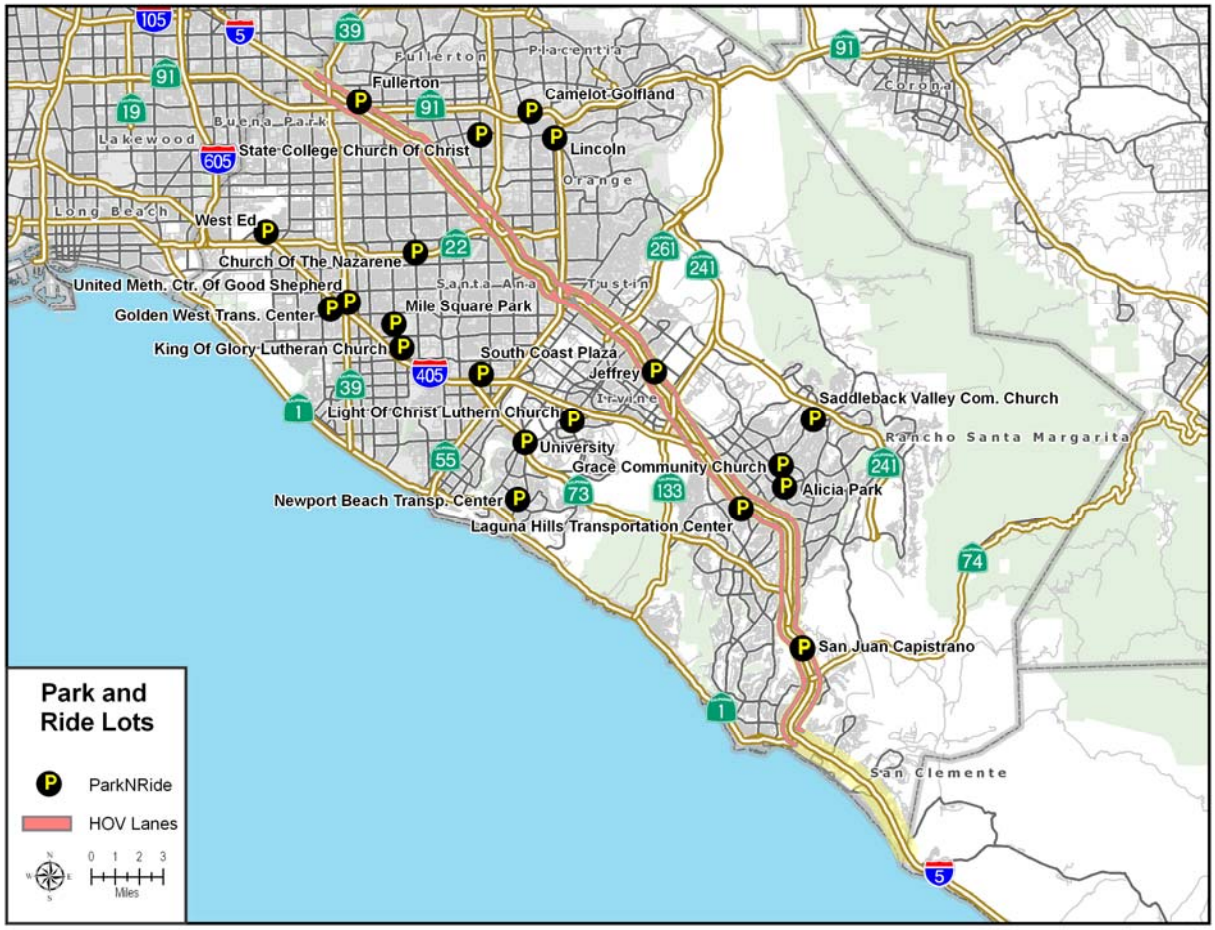
Exhibit 2-8: John Wayne Airport Passenger Boarding Statistics

	2003	2004	2005	2006	2007	2008	2009	2010
Passenger Boardings	4,266,083	4,621,107	4,791,786	4,777,896	4,948,846	4,464,380	4,311,329	4,278,623
Difference		355,024	170,679	-13,890	170,950	-484,466	-153,051	-32,706
Percent Difference		8.3%	3.7%	-0.3%	3.6%	-9.8%	-3.4%	-0.8%

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

Several park and ride facilities are situated near the I-5 study corridor, as shown in Exhibit 2-9. There are four facilities directly next to the corridor in the cities of Fullerton, Irvine, Mission Viejo, and San Juan Capistrano.

Exhibit 2-9: Park and Ride Facilities



Source: Caltrans

According to the Caltrans 2008 HOV Annual Report, the I-5 Corridor has high HOV lane use with more than 1,740 vphpl during the southbound PM peak hours at the Los Alisos Boulevard interchange area. While carpools comprise up to 95 percent of HOV lane users, motorcycles, low-emission vehicles, vans, and buses also use the facility. HOV lane violators can exceed 10 percent during the AM peak hour at the southbound HOV connector to southbound SR-55. Average vehicle occupancy (AVO) rates range from two persons per vehicle to 3.36 persons per vehicle at the Disney Way HOV drop ramps. Adjacent mainline lanes are mostly used by cars (up to 96.5 percent) with smaller numbers of carpools, trucks, buses, motorcycles, and vans.

Special Event Facilities/Trip Generators

There are various facilities and institutions located along I-5 that have the potential to generate significant trips on the corridor. Exhibit 2-10 shows the location of significant traffic generators.

John Wayne Airport is a major trip generator for the Orange County area. It is the second largest airport by passenger volume in the area, including Los Angeles Airport, Ontario Airport, and Long Beach Airport. The airport can be accessed from the I-5 corridor via SR-55 or Red Hill Avenue.

I-5 also serves as a major commute route for Orange County residents as well as residents from areas of Riverside and San Bernardino Counties due to the major employment centers located within central and southern Orange County.

The special event facilities located within several miles of the I-5 corridor include:

- The Disneyland Resort and Theme Park is located about four miles north of the I-5/SR-22/SR-57 interchange between Ball Road and Katella Avenue. It is 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.
- Angel Stadium is home to the professional baseball team, the Los Angeles Angels of Anaheim. The stadium seats over 45,000 fans and is located about one mile east of I-5.
- The Honda Center is home to the professional hockey team, the Anaheim Ducks. Other events such as concerts, rodeos, basketball tournaments, and major performances take place at this venue. It is located less than two miles east of I-5 on Katella Avenue.
- Orange County Great Park is the official name of a plan for the public, non-aviation reuse of the decommissioned Marine Corps Air Station El Toro in Irvine, California. Current attractions at the park are The Great Balloon, Great Park Carousel, Palm Court Arts Complex, Farmers Market, Kids Rock, and special events (such as concerts, workshops, outdoors movies, etc.).

Universities and colleges can also generate significant trips. The following institutions are located near the study corridor:

- Cal State University Fullerton is situated near SR-57 about eight miles north of the I-5/SR-57 Interchange. It is four-year public university offering Bachelor and Masters Degree programs to over 35,000 students (Fall 2010).

- Santa Ana College is a public community located two miles west of I-5 on 17th Street and Bristol Street. It has over 18,000 students enrolled as of Fall 2010.
- Irvine Valley College is situated about a mile west of I-5 on Jeffrey Road and Irvine Center Drive. It has an enrollment of over 15,000 students (Fall 2010) and offers associate degrees and occupational certificates.
- The University of California at Irvine (UCI) is located about six miles southwest of I-5, between the SR-73 and I-405 corridors. This four-year public university enrolls almost 27,700 students (Fall 2010) and offers Bachelors, Masters, and Doctorates degree programs.
- Saddleback College is located east of I-5 in the city of Mission Viejo. It offers over 300 associate degrees, certificates, and occupational skills awards in 190 program areas. Established in 1968, the college has over 20,000 students enrolled.

There are several medical facilities close to I-5 which can generate significant trips:

- The UC Irvine Medical Center is the only university hospital in the county. It is located north of SR-22 and immediately west of I-5 in the City of Orange. The facility has more than 400 specialty and primary care physicians and offers a full range of acute and general care services.
- St. Joseph Hospital, located north of SR-22 and east of I-5 on Main Street, is one of the highest volume hospitals in the county with a 1,000-member medical staff.
- The Children's Hospital of Orange County (CHOC) is adjacent to St. Joseph Hospital and has an emergency room for children.
- Saddleback Memorial Medical Center Laguna Hills is located southwest of I-5 on Paseo de Valencia. It is a 325-bed hospital that offers complete critical care, a Women's Hospital and an array of inpatient and outpatient surgical services.
- Mission Hospital Regional Medical Center is located east of I-5 off Crown Valley Parkway in the City of Mission Viejo. It is the largest hospital in the county and is one of only three designated trauma centers in the county.
- Saddleback Memorial Medical Center San Clemente is situated northeast of I-5 on Camino De Los Mares. The center offers state-of-the-art imaging, infusion, surgical, outpatient rehabilitation, digital mammography, orthopedics, home care, ancillary services and more.
- Kaiser Irvine Medical Center is located southwest of I-5 at the El Toro Y interchange. The center offers emergency services, 24-Hour pharmacy, and a Neonatal Intensive Care Unit (NICU).
- Hoag Memorial Hospital Presbyterian is a not-for-profit regional healthcare facility in Orange County that treats nearly 30,000 inpatients and 350,000 outpatients

annually. Hoag Irvine has 84 beds (12 in the Intensive Care Unit (ICU) and 72 in medical-surgical). It also has an emergency department with 14 beds.

The I-5 Corridor serves many shopping facilities in the Orange County Area:

- Westfield MainPlace, at the southeast corner of the I-5/SR-22 interchange, is located in the City of Santa Ana and features over 200 specialty shops.
- The Block at Orange, an outdoor shopping mall, is located at the northwest corner of the I-5/SR-22 interchange.
- Tustin Marketplace is located east of I-5 off of Jamboree Road. It is an outdoor retail center with more than 120 stores, services, restaurants, cafes, and theaters.
- The District at Tustin Legacy is located between the I-5 and I-405 freeways at Dyer and Jamboree. The District is an open outdoor retail center with an AMC theater, a 30 lane bowling facility, and a Costco. It also has 25 restaurants and bars and over 30 retail shops.
- The Irvine Spectrum Center is located at the I-5/I-405 interchange. It is an outdoor mall with a large cinema complex, two major department stores, and over 130 specialty stores.
- The Laguna Hills Mall is situated immediately west of I-5 off of El Toro Road. It is anchored by four department stores and features nearly 100 specialty stores.
- The Shops at Mission Viejo is located east of I-5 and can be accessed by Marguerite Parkway from the south and Crown Valley Parkway from the north. This is an upscale shopping mall with over 130 specialty shops and restaurants as well as Edwards Kaleidoscope.

Recent Roadway Improvements

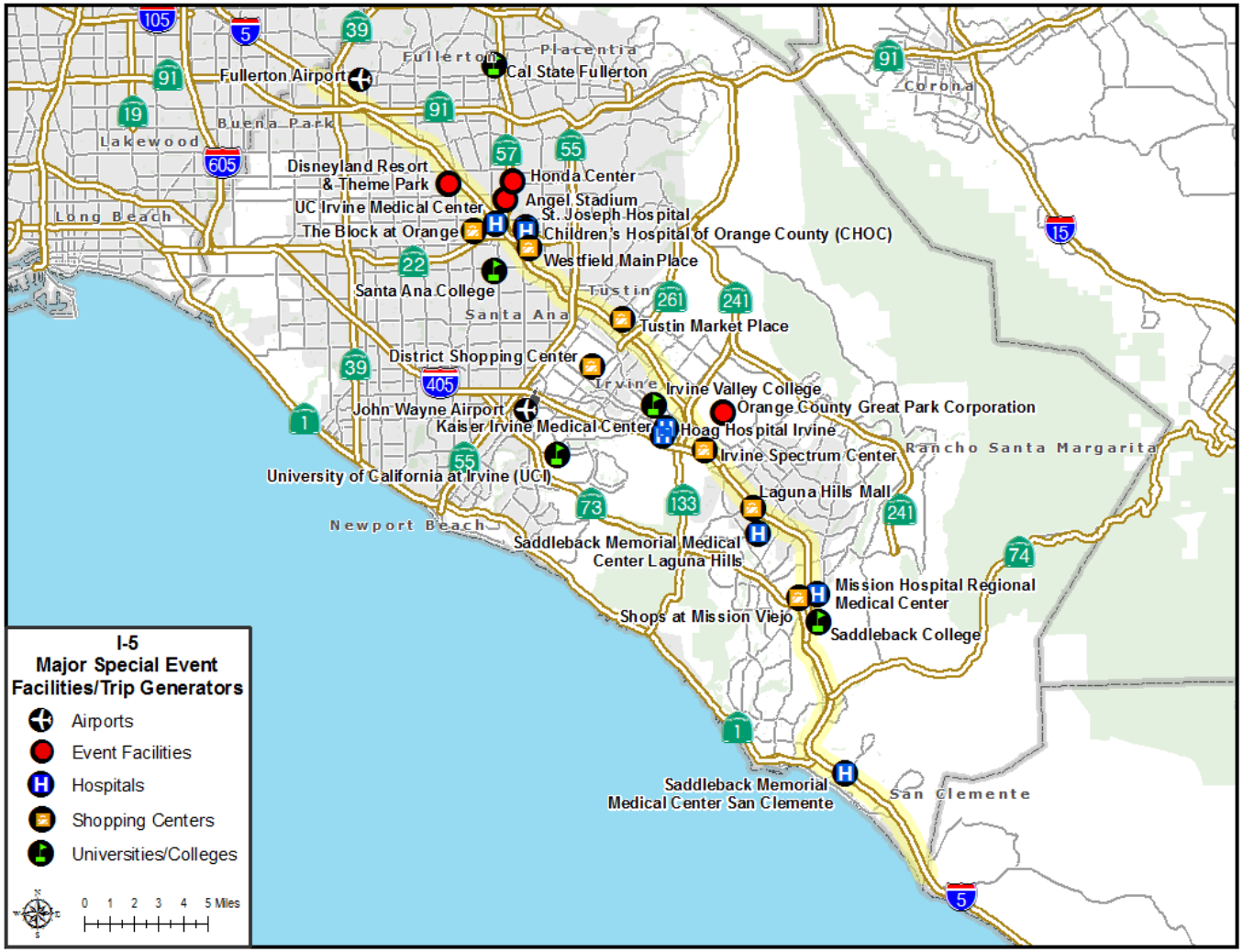
The following roadway improvements were recently completed along the I-5 corridor:

- In early 2011, Caltrans converted a short stretch of limited access HOV lane to a continuous access HOV lane from Tustin Ranch Road to Red Hill Avenue.

- In late 2010, the I-5 Gateway project was finished to widen the remaining two miles of I-5 in Orange County from SR-91 to the Los Angeles County line. Improvements included adding a new travel lane in each direction, adding a new HOV lane in each direction, adding extended merging lanes where possible, rebuilding overpasses at Stanton Avenue, Beach Boulevard and Western Avenue, and rebuilding Artesia Boulevard underpass and realigning the northbound ramps.

- Other recently completed projects in 2008 and 2009 included ramp widening projects at Avenida Pico, Oso Parkway, Culver Drive, and Crown Valley Parkway.

Exhibit 2-10: Trip Generators on I-5



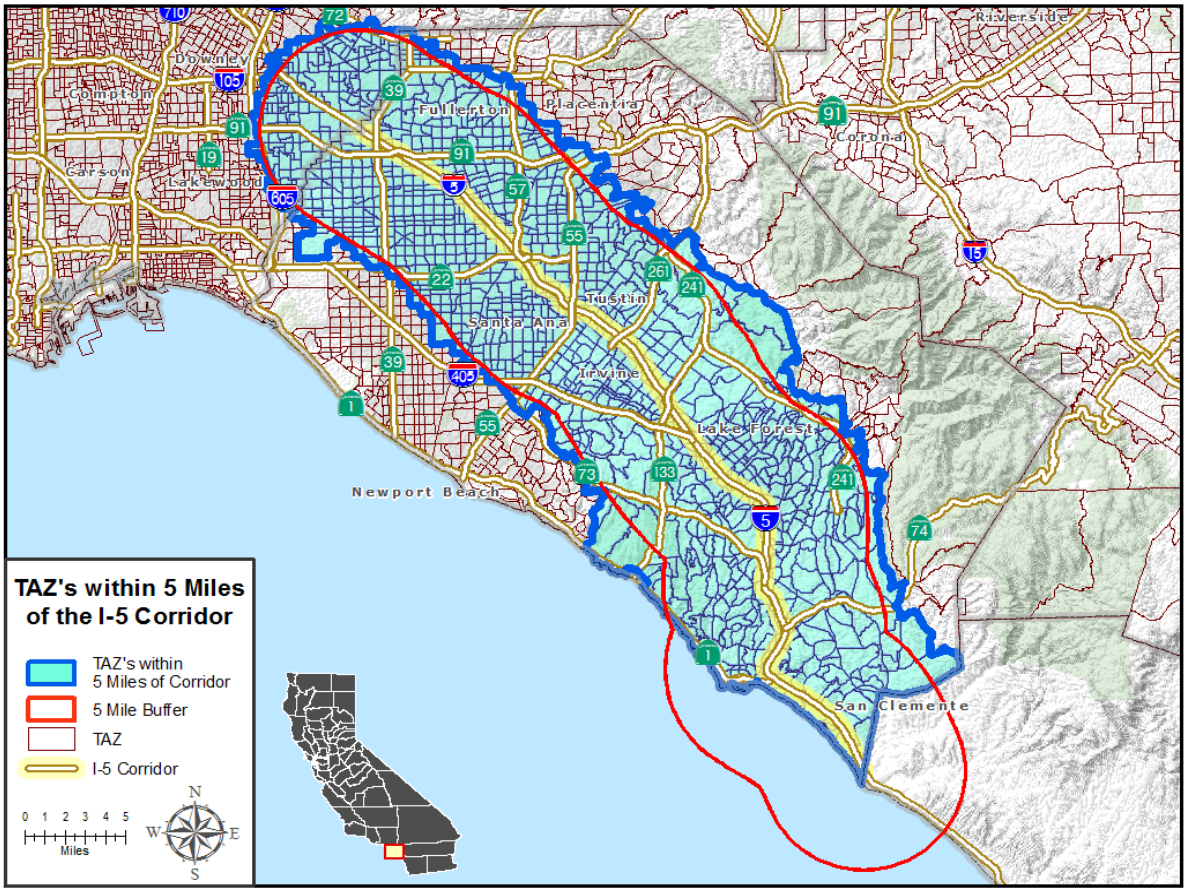
Source: System Metrics Group, Inc./GIS/Internet

Corridor Socio-Economic Characteristics

This section is new for Orange County CSMPs. It has been added in part to address the increased emphasis on employment housing balance goals of Senate Bill 375 to reduce green-house gas emissions and limit VMT growth. It also looks at socio-economic factors, namely age and income levels. This type of analysis has generally been conducted at the regional or sub-regional level. However, for this CSMP, it was decided to include corridor-specific analyses as a means to more comprehensively describe the corridor and understand the transportation demand factors.

The analysis is based on the Southern California Association of Governments (SCAG) Traffic Analysis Zone (TAZ) data. The first step of the analysis was to identify all TAZs within five miles of the I-5 corridor. This is shown in Exhibit 2-11. The red line represents the five mile "buffer" and the blue line delineates the TAZs that fall within that distance.

Exhibit 2-11: TAZ's within 5 Miles of the I-5 Corridor



Source: SCAG TAZ data

Exhibit 2-12 presents the summary statistics aggregated for all the TAZs within the five miles. The statistics are shown for 2008, 2020, and 2035. A few observations to note:

- The population age groups overlap. For instance, the age group from 18 to 24 is part of the age group from 16 to 64. The groupings were defined by SCAG and could not be modified.

- The number of people by age group change very little except for the over 65 age group which almost doubles from 2008 to 2035. This reflects the aging of the baby boom generation and lower employment growth (discussed later). The overall population around the corridor is projected to increase by a total 15 percent between 2008 and 2035.

- Household income is projected to decline by 1.3 percent in constant dollars (i.e., net of inflation) between 2008 and 2035. This is partly due to the aforementioned increase in population in the retirement age group and partly because the households with income levels below $25,000 are projected to grow slightly faster than other categories - 16 percent versus 15 percent.

- Overall employment grows by less than 12 percent, which is slower than the 15 percent growth projections for both population and households. Manufacturing employment is projected to decrease by almost 15 percent. Sectors projected to increase the most in employment are construction and professional services.

- The Employment to Population Ratio declines from 2008 to 2020 and then grows from 2020 to 2035.

- The Employment to Household Ratio also declines from 2008 to 2020 and then grows from 2020 to 2035.

Exhibit 2-12: Summary Table

	2008	2020	2035	Percent Change from 2008 to 2035
Population				
Age 5 to 17	472,505	483,356	502,860	6%
Age 18 to 24	262,888	270,604	280,975	7%
Age 16 to 64	1,670,849	1,770,011	1,765,452	6%
Age 65 and over	253,594	351,927	480,162	89%
Total Population	**2,498,250**	**2,722,890**	**2,872,776**	15%
HouseHolds				
Median Household Income ($1999)	$ 61,973.13	$ 60,862.25	$ 61,178.91	-1%
Number of household with Less than $25,000	176,146	189,380	204,251	16%
Number of household with $25,000 to $49,999	210,420	224,119	241,225	15%
Number of household with $50,000 to $99,999	251,123	266,392	286,693	14%
Number of household with more than $100,000	140,229	149,688	162,177	16%
Total Households (Occupied Housing Units)	**777,918**	**829,579**	**894,346**	15%
Average Population per Household	**3.21**	**3.28**	**3.21**	0%
Employment				
Agriculture & Mining jobs	3,614	4,008	4,263	18%
Construction jobs	81,070	89,259	110,483	36%
Manufacture jobs	143,558	124,727	122,446	-15%
Wholesale Trade jobs	77,589	74,953	82,301	6%
Retail Trade jobs	129,431	124,662	142,403	10%
Transportation and Warehousing and Utility jobs	42,616	40,623	47,018	10%
Information jobs	28,282	27,524	28,666	1%
Financial Activity(FIRE) jobs	97,218	97,629	101,996	5%
Professional and Business Services jobs	257,411	282,147	317,713	23%
Education and Health Services jobs	241,451	254,381	270,197	12%
Leisure and Hospitality (art/entertainment) jobs	150,532	146,438	172,475	15%
Other services jobs	48,355	49,060	51,224	6%
Public/administration jobs	26,633	25,959	30,678	15%
Total Employment	**1,327,760**	**1,341,370**	**1,481,863**	12%
Employment Population Ratio				
Ratio (Total Employment/Total Population)	**0.53**	**0.49**	**0.52**	-3%
Employment to Household Ratio				
Ratio (Total Employment/Total Households)	**1.71**	**1.62**	**1.66**	-3%

Source: SCAG TAZ data

The rest of this section presents maps that show some of the statistics by TAZ instead to complement the aggregate statistics just discussed. Three maps for 2008 are presented for the selected TAZs:

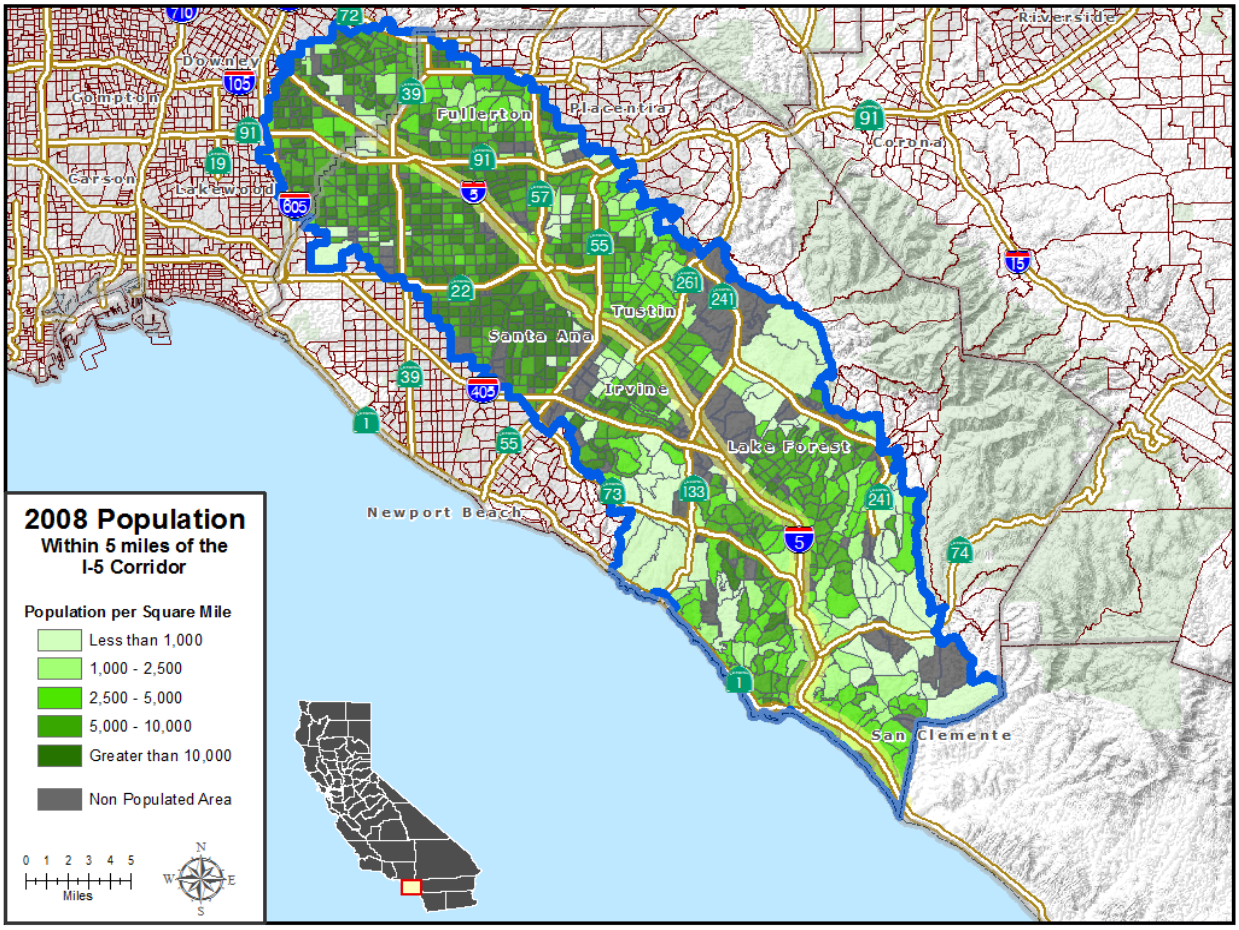
- Population Density – defined as population per square mile.
- Employment Density – defined as employment per square mile.
- Employment/Population Ratio – defined as the TAZ employment divided by TAZ population.

The Population Density, presented in Exhibit 2-13, shows that the density around the I-5 in the Orange/Santa Ana area is greatest, generally higher than 10,000 per square miles. Further south along the I-5 corridor at the SR-133 and south of SR-74 (Ortega Highway), the density is much less.

The Employment Density, presented in Exhibit 2-14, also shows that the Orange/Santa Ana has some of the highest employment concentrations in a triangle formed by SR-55, SR-91, and I-5. High employment concentrations can also be seen south of I-5 along SR-55 corridor and at the north end of the I-5 study corridor.

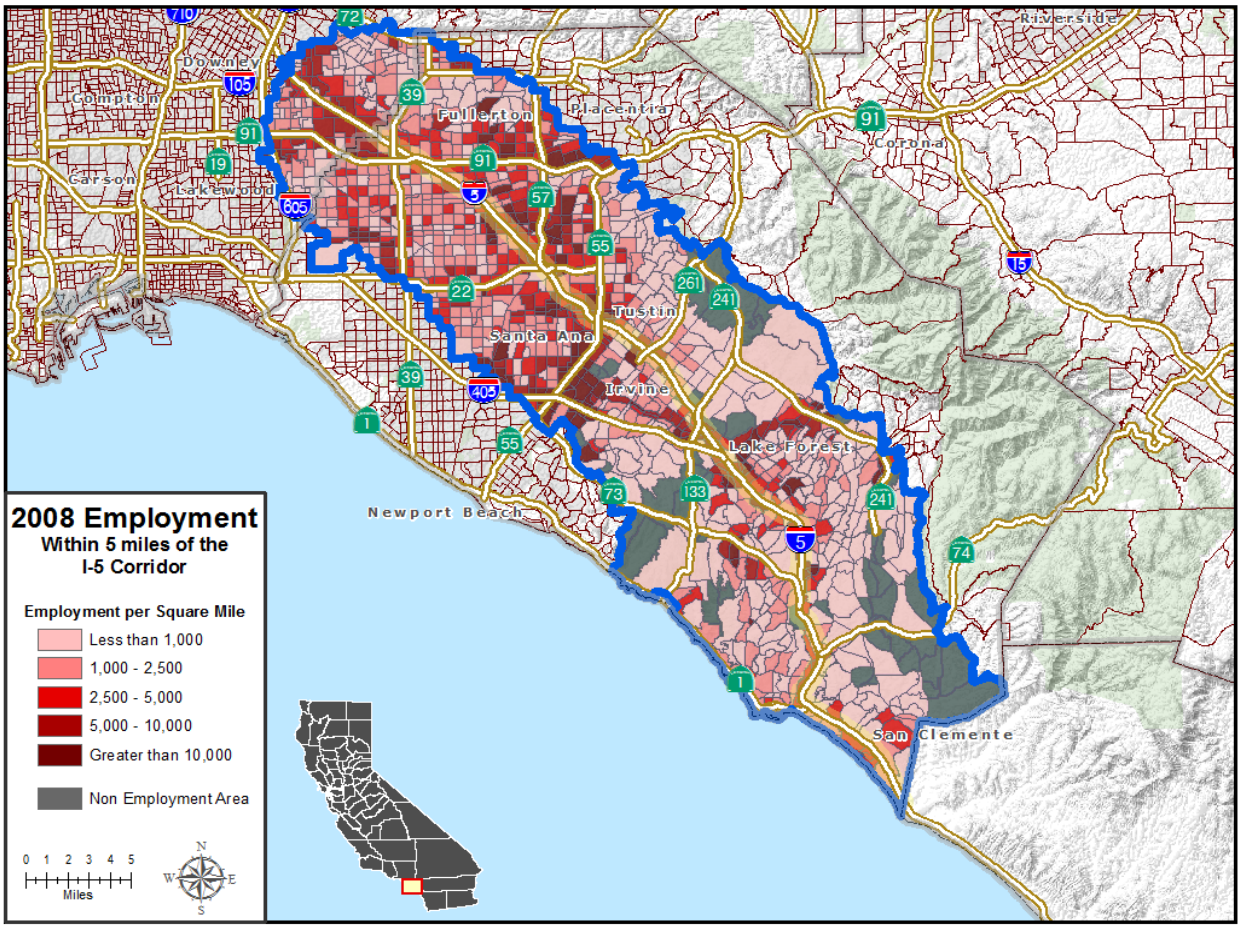
In Exhibit 2-15, the Employment Ratio is mapped out by dividing the TAZ employment total by the TAZ population total.

Exhibit 2-13: 2008 Population within 5 miles of the I-5 Corridor



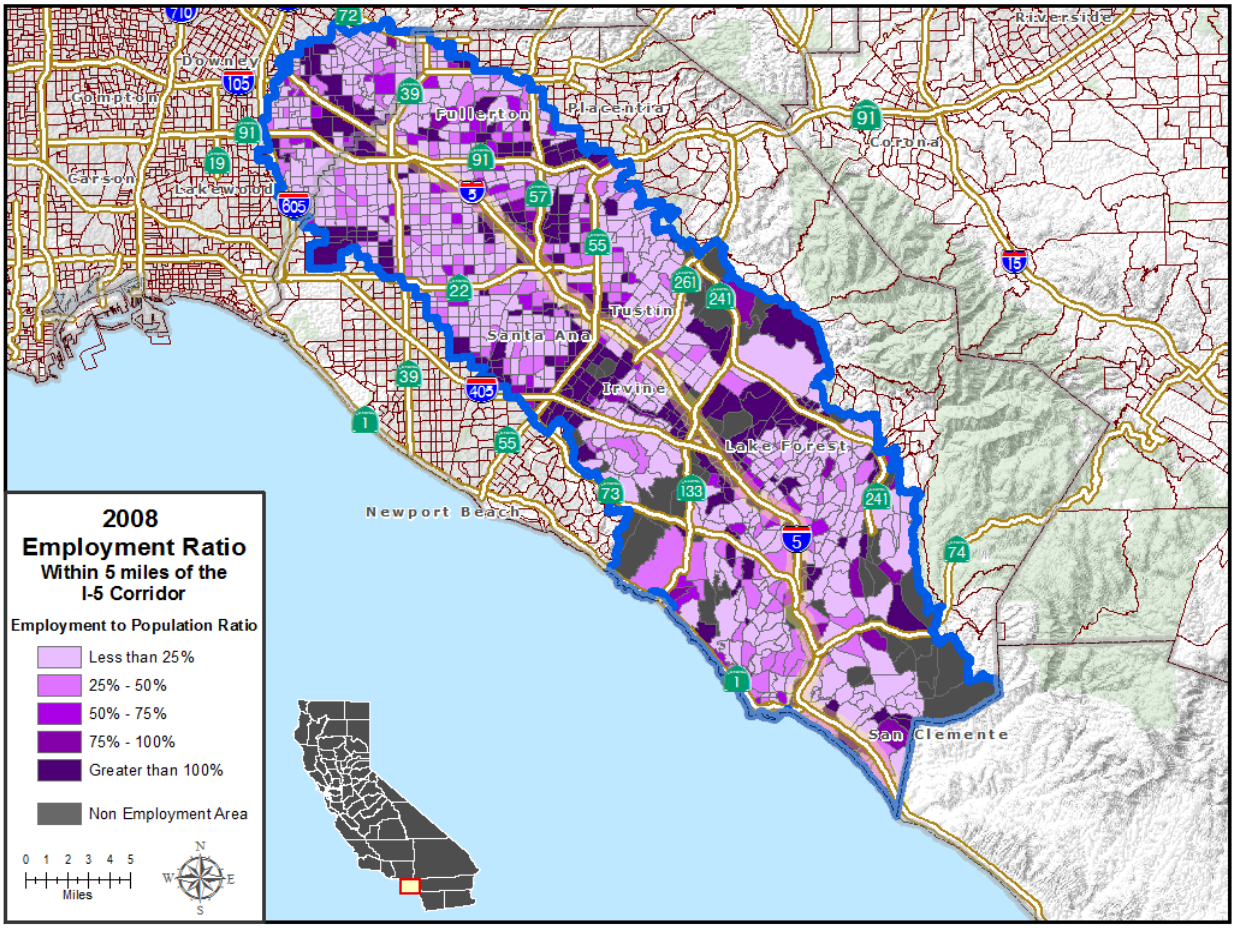
Source: SCAG TAZ data

Exhibit 2-14: 2008 Employment within 5 miles of the I-5 Corridor



Source: SCAG TAZ data

Exhibit 2-15: 2008 Employment Ratio within 5 miles of the I-5 Corridor



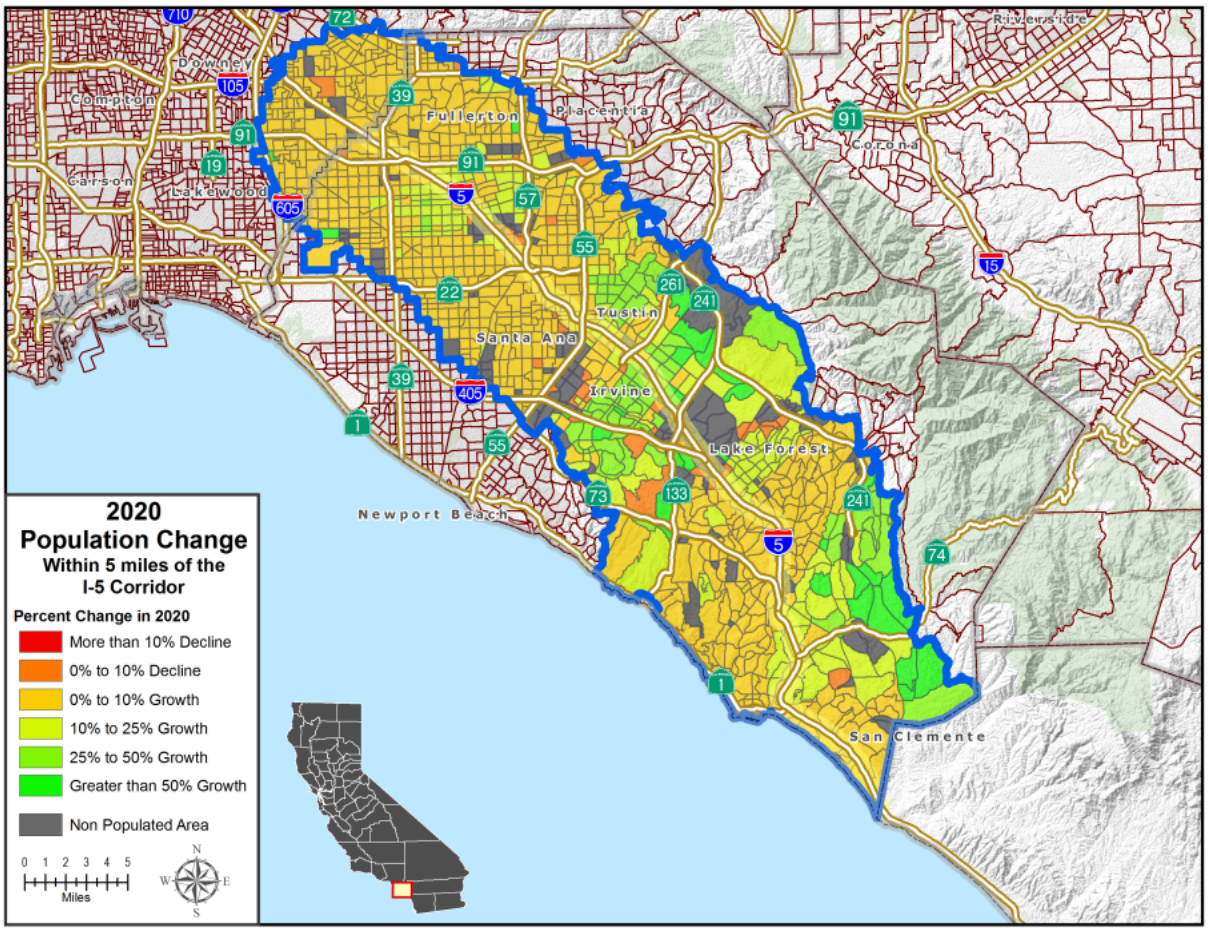
Source: SCAG TAZ data

Exhibit 2-16 shows the Population Change from 2008 to 2020. The map shows most of the TAZs within the 5 miles radius of the I-5 is projected to grow by less than 10 percent (the 0-10% category on the map). A few TAZs are projected to actually experience modest declines in population. The area of Irvine is projected to grow by more than 25% and the area a little north of San Clemente between the end of SR-241 and the SR-73 is also projected to grow by more than 25%.

Exhibit 2-17 presents the projected Employment Change from 2008 to 2020. Several areas are projected to experience 25% or greater employment growth, including: Laguna Hills, Tustin, and San Juan Capistrano. Notably, the Santa Ana area is projected to see a net decline in jobs.

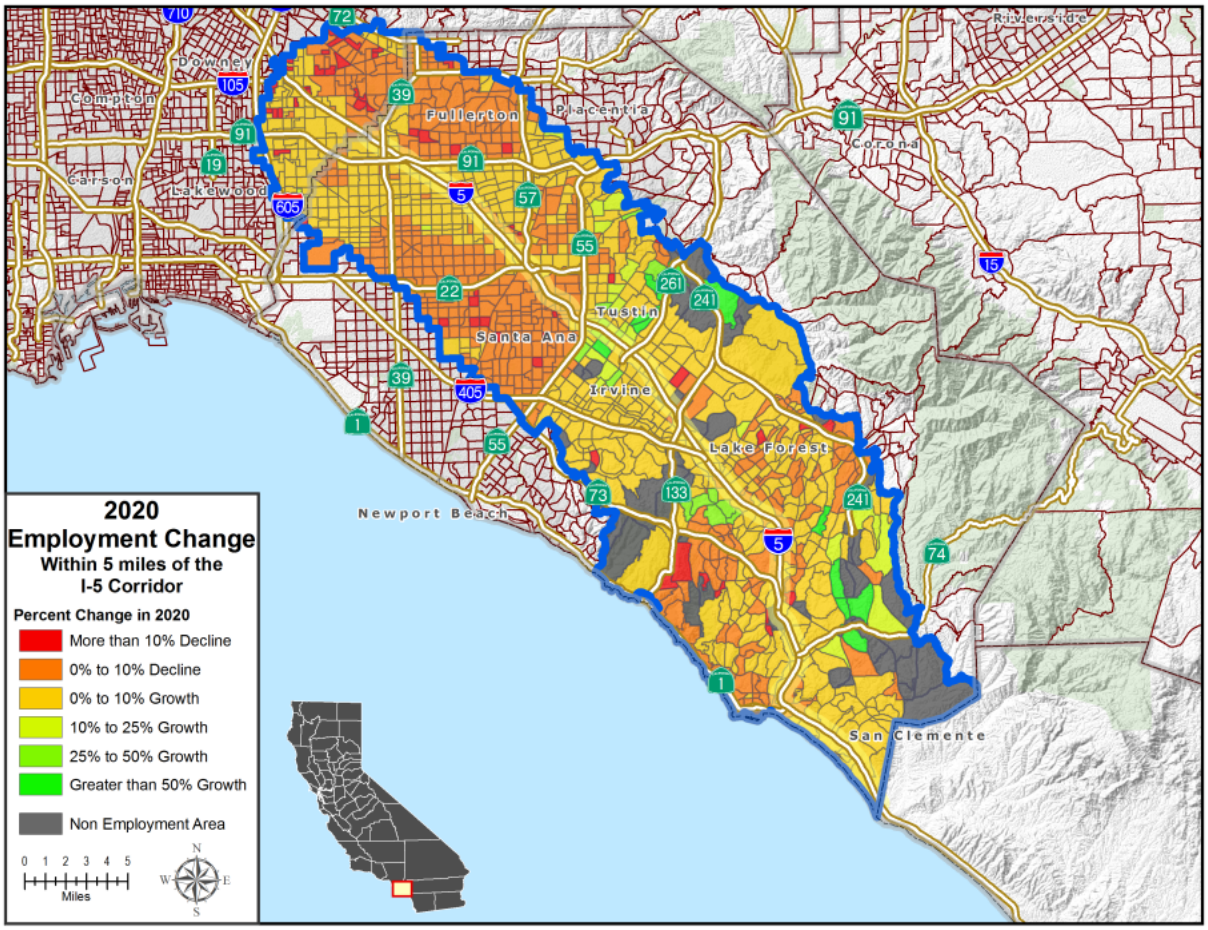
Exhibit 2-18 presents the Employment Ratio for the year 2020. The areas with the highest projected ratios are parts of Irvine, Orange, San Clemente, Lake Forest, Stanton, Anaheim, Placentia, and Buena Park.

Exhibit 2-16: 2020 Population Change within 5 miles of the I-5 Corridor



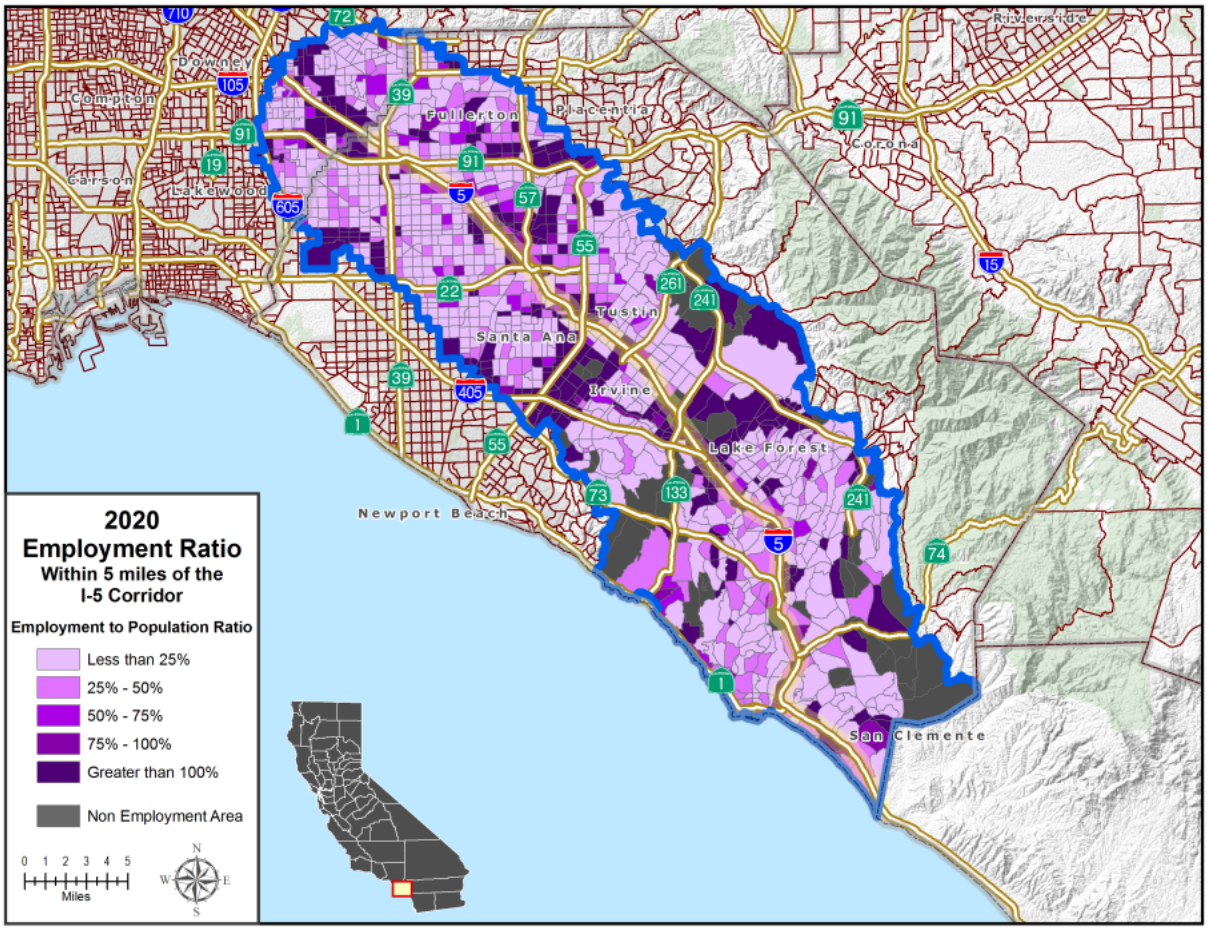
Source: SCAG TAZ data

Exhibit 2-17: 2020 Employment Change within 5 miles of the I-5 Corridor



Source: SCAG TAZ data

Exhibit 2-18: 2020 Employment Ratio within 5 miles of the I-5 Corridor

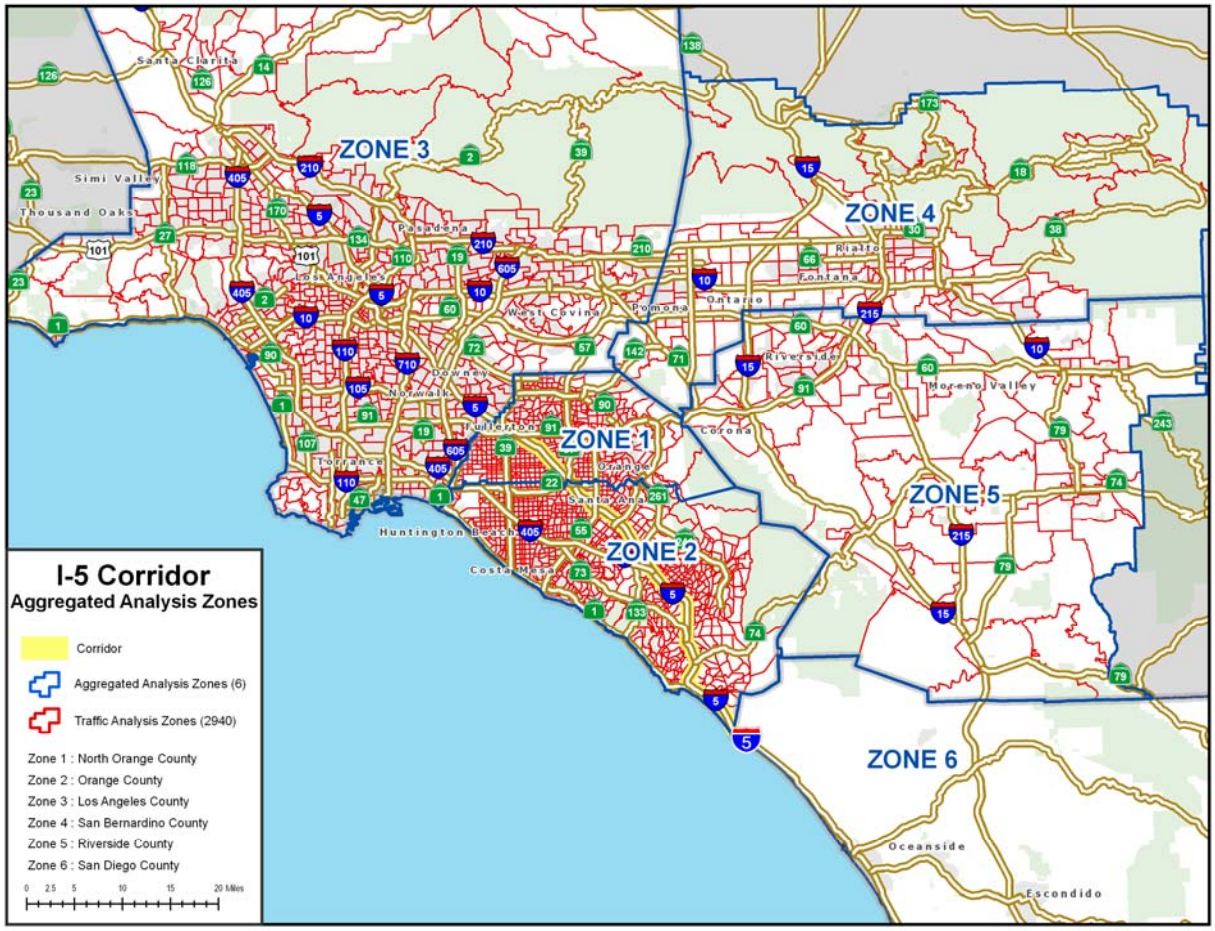


Source: SCAG TAZ data

Demand Profiles

An analysis of origins and destinations was conducted to determine the travel pattern of trips made on I-5. Based on the Orange County Transportation Analysis Model (OCTAM), this "select link analysis" isolated the I-5 CSMP Corridor and identified the origins and destinations of trips made on the corridor. The origins and destinations were identified by Traffic Analysis Zone (TAZ), which were grouped into six aggregate analysis zones as shown in Exhibit 2-19. These zones were determined by county line and proximity to the corridor.

Exhibit 2-19: Aggregate Analysis Zones for Demand Profile Analysis



Source: OCTA OCTAM Model

Based on this aggregation, demand on the corridor was summarized by aggregated origin-destination zone as shown on Exhibits 2-20 and 2-21 for the AM and PM peak periods. This analysis shows that almost half of all trips using the I-5 corridor are intra-county trips.

Exhibit 2-20: AM Peak Origin Destination by Aggregated Analysis Zone

		TO ZONE						
	AM Trips	**North Orange County**	**Orange County**	**Los Angeles County**	**San Bernardino County**	**Riverside County**	**San Diego County**	**Outside Zones**
FROM ZONE	**North Orange County**	3.5%	10.0%	6.5%	0.0%	0.0%	0.5%	0.0%
	Orange County	9.9%	32.9%	9.1%	0.6%	0.3%	2.0%	0.0%
	Los Angeles County	6.4%	8.1%	0.0%	0.0%	0.2%	1.1%	0.0%
	San Bernardino County	0.1%	1.2%	0.1%	0.0%	0.0%	0.1%	0.0%
	Riverside County	0.1%	1.8%	0.6%	0.0%	0.0%	0.2%	0.0%
	San Diego Coutny	0.6%	2.1%	1.2%	0.1%	0.2%	0.0%	0.2%
	Outside Zones	0.1%	0.1%	0.0%	0.0%	0.0%	0.1%	0.0%

Trips starting and ending in Orange County ~ 56%
Trips starting in Orange County and ending outside of Orange County ~ 19%
Trips starting outside of Orange County and ending in Orange County ~ 21%
Trips starting and ending outside of Orange County ~ 4%

Source: OCTA OCTAM Model

Exhibit 2-21: PM Peak Origin Destination by Aggregated Analysis Zone

		TO ZONE						
	PM Trips	**North Orange County**	**Orange County**	**Los Angeles County**	**San Bernardino County**	**Riverside County**	**San Diego County**	**Outside Zones**
FROM ZONE	**North Orange County**	4.2%	9.1%	6.9%	0.0%	0.0%	0.6%	0.1%
	Orange County	10.1%	32.4%	7.9%	1.0%	1.2%	2.3%	0.2%
	Los Angeles County	5.7%	8.6%	0.1%	0.0%	0.3%	1.5%	0.0%
	San Bernardino County	0.0%	0.6%	0.1%	0.0%	0.0%	0.2%	0.0%
	Riverside County	0.0%	0.4%	0.5%	0.0%	0.0%	0.2%	0.0%
	San Diego County	0.6%	2.1%	1.4%	0.2%	0.2%	0.0%	0.4%
	Outside Zones	0.1%	0.2%	0.0%	0.0%	0.0%	0.3%	0.0%

Trips starting and ending in Orange County ~ 56%
Trips starting in Orange County and ending outside of Orange County ~ 20%
Trips starting outside of Orange County and ending in Orange County ~ 18%
Trips starting and ending outside of Orange County ~ 6%

Source: OCTA OCTAM Model

During the AM peak period from 6:00 AM to 9:00 AM, about 56 percent of all trips originate and terminate in Orange County (Zones 1 and 2). The remaining trips

originate in Orange County and terminate in another county (19 percent); originate outside of Orange County and terminate in Orange County (21 percent); or originate and terminate outside of Orange County (four percent).

During the PM peak period from 3:00 to 7:00 PM (which experiences more than twice the delay than the AM peak period), the picture is similar. Roughly 56 percent of trips originate and terminate in Orange County. The remaining trips originate in Orange County and terminate in another county (20 percent); originate outside of Orange County and terminate in Orange County (18 percent); or originate and terminate outside of Orange County (six percent).

This corridor serves inter-regional travel since more than 50 percent of the demand either starts or ends outside of Orange County. It is a critical link to other counties, especially Los Angeles.

3. CORRIDOR-WIDE PERFORMANCE AND TRENDS

This section summarizes the performance measures used to evaluate the existing conditions of the I-5 corridor. The measures provide a technical basis to describe traffic performance on I-5 and were used to calibrate the micro-simulation model. Data from the mainline 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 detector data used for the analysis was sufficiently reliable.

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

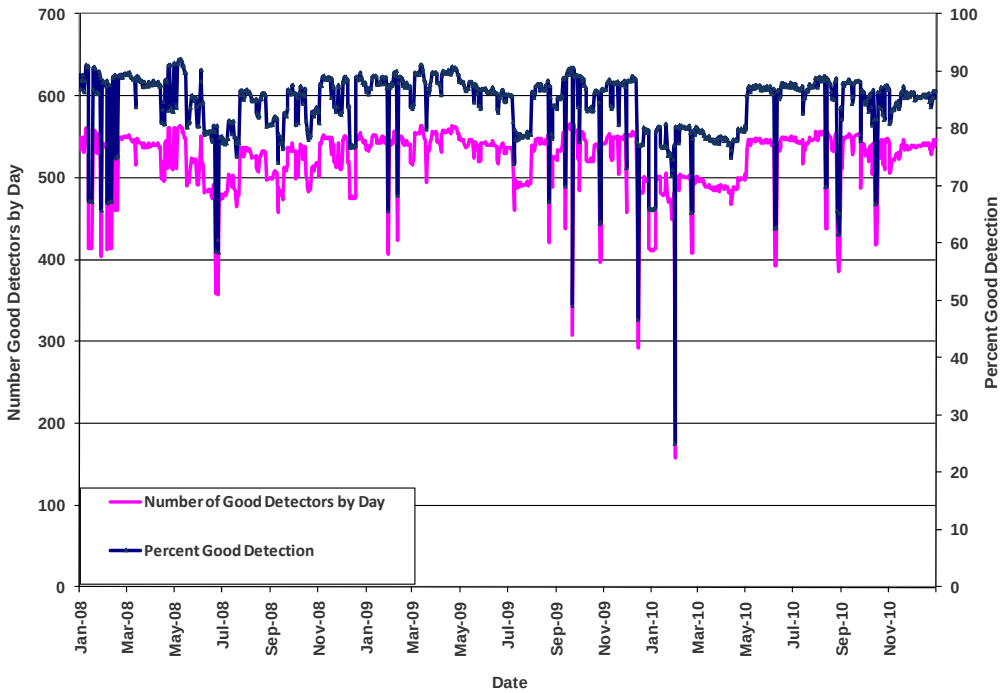
- *Mobility* describes how quickly people and freight move along the corridor.
- *Reliability* captures the relative predictability of travel time along the corridor.
- *Safety* provides an overview of collisions along the corridor.
- *Productivity* quantifies the degree to which traffic inefficiencies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

Detection

Given the need for comprehensive and continuous monitoring and evaluation, detection coverage and quality are discussed in greater detail.

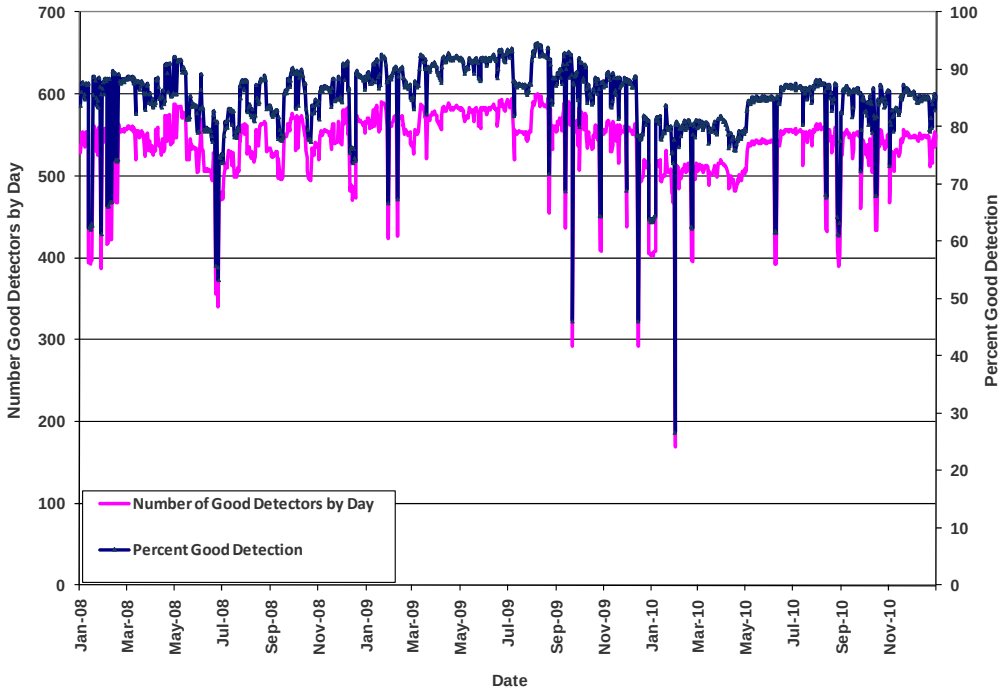
Exhibits 3-1 and 3-2 report the number and percentage of “good” detectors by day for the mainline facility of I-5 from 2008 to 2010. The left y-axis shows the scale used for the number of detectors, while the right y-axis shows the scale used for the percent good detectors. These exhibits suggest that detection in both directions of the mainline was about the same, hovering between 80 and 90 percent good detection on average. Overall, the number and percentage of good detectors has stayed fairly consistent with the exception of the first few months in 2010, when the number of good detectors dipped near or below 500.

Exhibit 3-1: Amount of Good Detection on Northbound I-5 Mainline



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

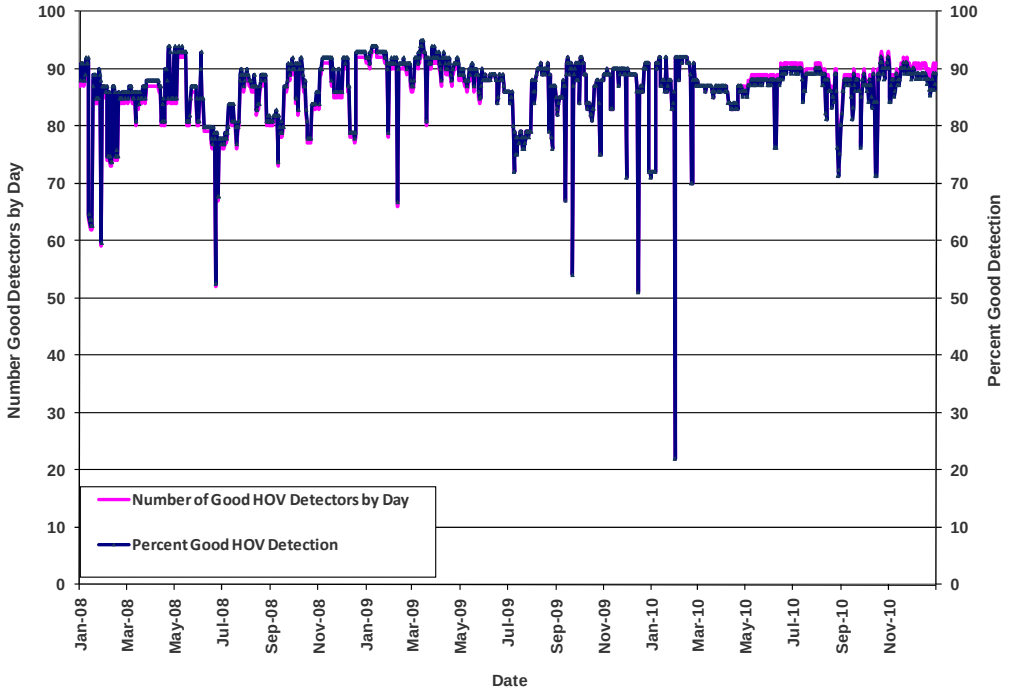
Exhibit 3-2: Amount of Good Detection on Southbound I-5 Mainline



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

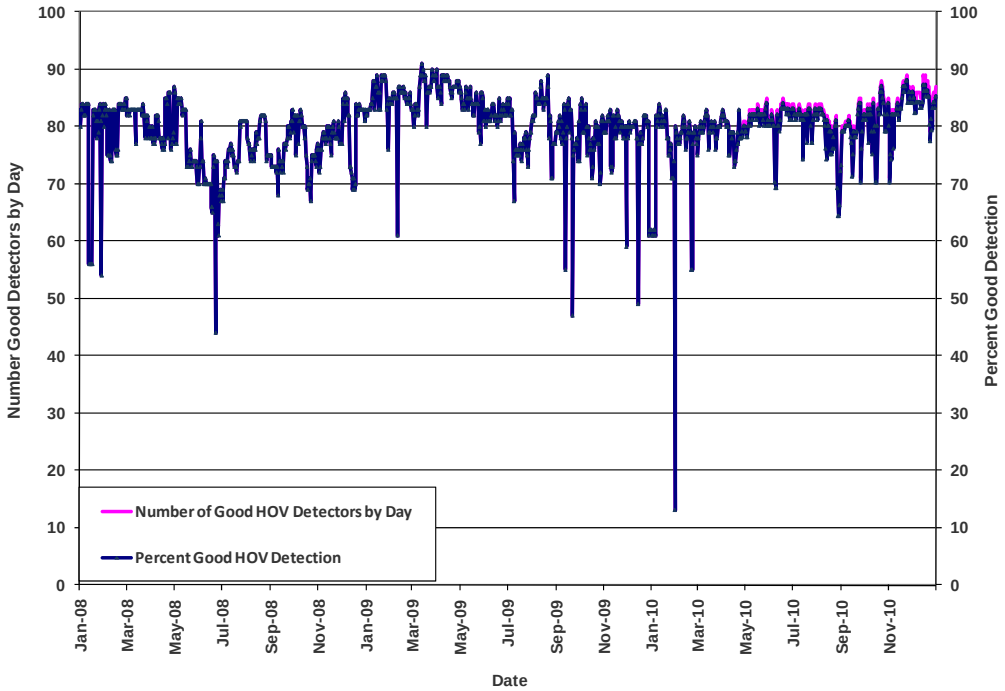
Exhibits 3-3 and 3-4 reports the number and percentage of good detectors on the HOV facility. Both directions of the HOV lane exhibited between 80 and 90 percent good detection, which corresponds to about 80 to 90 good detectors. The northbound HOV lane reported slightly more good detectors than the southbound lane. Similar to the mainline facility, detection on the HOV lane remained steady with a few hiccups in early 2010.

Exhibit 3-3: Amount of Good Detection on Northbound I-5 HOV Lane



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-4: Amount of Good Detection on Southbound I-5 HOV Lane



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

An analysis of gaps without detection is shown in Exhibit 3-5 for the mainline facility and in Exhibit 3-6 for the HOV facility. The locations with the "1" or "2" suffix represent the first set or second set of detectors that are installed at that interchange, usually within 1,000 feet of each other. There are several segments extending over 0.75 miles without detection in each direction. These should be considered for deployment of additional detection when funding becomes available.

Exhibit 3-5: I-5 Mainline Gaps In Detection (June 2, 2011)

From		To		Length
Location	Abs PM	Location	Abs PM	(Miles)
Northbound Mainline				
S of Vaquero	76.758	N of Vaquero	77.658	0.90
Junipero Serra	83.308	Wildwood	84.168	0.86
S of 73	84.518	Avery Park	85.308	0.79
At 405	93.508	Alton 2	94.358	0.85
Yale	98.058	Culver 1	98.818	0.76
Tustin Ranch	100.350	Red Hill	101.491	1.14
Gene Autry	107.851	Orangewood 2	108.651	0.80
South 2	110.351	Lincoln	111.151	0.80
Magnolia 2	114.151	Beach 1	115.531	1.38
Southbound Mainline				
Beach 1	115.488	Magnolia 2	114.088	1.40
Red Hill	101.208	Tustin Ranch	100.288	0.92
Jamboree 1	99.618	Culver 2	98.86	0.76
Yale	97.995	Jeffrey 1	97.035	0.96
Alton 2	94.335	At 405	93.445	0.89
Alicia 1	89.455	La Paz 2	88.695	0.76
Faircourt	86.655	Crown Va1	85.795	0.86
Crown Va1	85.795	Avery 1	84.995	0.80
Sacramento	78.665	Estrella	77.785	0.88
N of Vaquero	77.595	S of Vaquero	76.695	0.90

Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-6: I-5 HOV Gaps In Detection (June 2, 2011)

From		To		Length
Location	Abs PM	Location	Abs PM	(Miles)
Northbound HOV				
Trabuco	83.628	S of 73	84.518	0.89
S of 73	84.518	Avery Park	85.308	0.79
At 405	93.508	Alton 2	94.358	0.85
Yale	98.058	Culver 1	98.818	0.76
Solar	100.451	Redhill	101.491	1.04
Gene Autry	107.851	Orangewood 2	108.651	0.80
South 2	110.351	Lincoln	111.151	0.80
Magnolia 2	114.151	Beach 1	115.551	1.40
Southbound HOV				
Beach 1	115.488	Magnolia 2	114.088	1.40
Newport	101.978	Redhill	101.208	0.77
Jamboree 1	99.618	Culver 2	98.855	0.76
Yale	97.995	Jeffrey 1	97.035	0.96
Alicia 1	89.455	La Paz 2	88.695	0.76
Faircourt	86.655	Crown Va1	85.795	0.86
Crown Va1	85.795	Avery 1	84.995	0.80

Source: SMG analysis of Caltrans Performance Measurement System (PeMS) 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 and are readily 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 severe congested conditions using the following formula:

$$(Vehicles\ Affected\ per\ Hour) \times (Distance) \times (Duration) \times \left[\frac{1}{(Congested\ Speed)} - \frac{1}{35mph} \right]$$

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 experienced 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).

Caltrans MPR

The Mobility Performance Report 2009 (MPR 2009) is a new report prepared by Caltrans that provides transportation system performance information at a statewide level for each Caltrans district. It replaces the HICOMP Report previously prepared by Caltrans up to 2008. The MPR 2009 presents annual vehicle hours of delay (AVHD), lost productivity, and bottleneck locations. It uses a new, standardized statewide methodology for measuring freeway traffic congestion from detector data collected from Caltrans PeMS. Delay is determined by calculating the difference between the observed travel time and the travel time at two benchmark speeds, 35 mph and 60 mph. The hours of delay are then multiplied by the vehicular flow on the facility to produce

VHD. Within District 12 in 2009, the AVHD at 35 mph is 9,736,000 comprising over 12 percent of statewide delay, the AVHD at 60 mph is 21,792,000 comprising over 11 percent of statewide delay.

The MPR 2009 lists the District's top twenty freeway bottleneck locations in 2009 and the suspected causes of the bottlenecks. Four of the bottlenecks are on I-5. Northbound and southbound I-5 at 17th Street are listed as the No. 6 and No. 19 bottlenecks respectively, with the suspected cause of the bottlenecks due to the ramp configuration that results in weaving between on-ramp and off-ramp traffic. Southbound I-5 at El Toro is listed as the No. 7 bottleneck with the suspected cause of two lane drops at Alicia Parkway and one lane drop at El Toro. The suspected cause of the northbound bottleneck No. 10 at Red Hill is due to a lane drop.

Caltrans Detector Data

The performance assessment includes three years of automatic detector data: 2008, 2009, and 2010. Delay presented in this section represent the difference in travel time between actual conditions and free-flow conditions at 60 miles per hour, applied to the actual output flow volume collected from a vehicle detector station.

According to Caltrans detector data, I-5 reported the highest total delay of all monitored corridors in Orange County. In 2008, the corridor accounted for 27 percent of the county's delay, which is equivalent to about 5.8 million vehicle-hours of delay. The following discussion analyzes delay on the corridor in many different ways, including by time period, by month, by severity, and by hour for both mainline and HOV facilities.

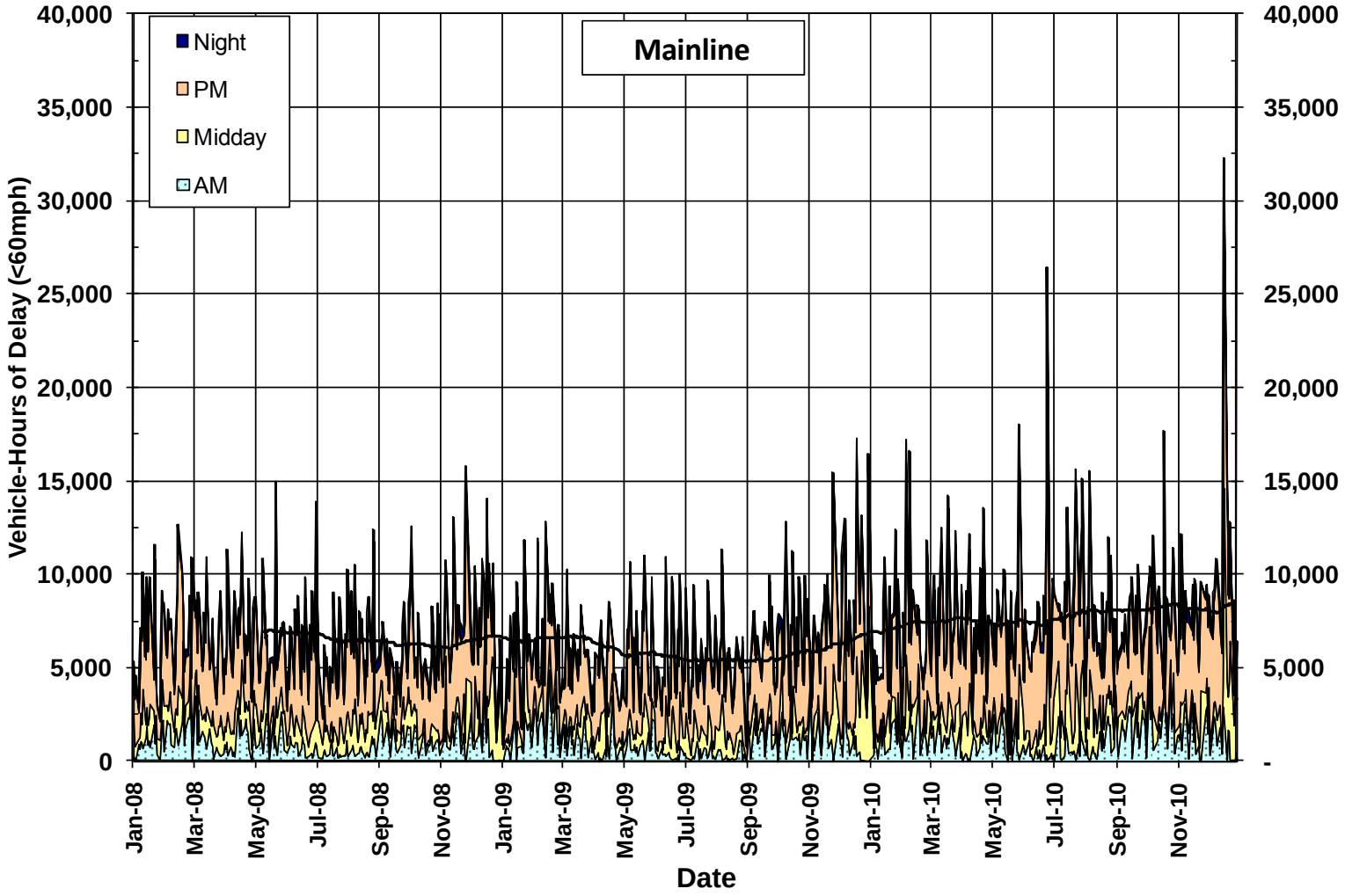
Exhibits 3-7 through 3-10 illustrate the delay experienced on weekdays (i.e., excluding weekends and holidays) for the study corridor. Exhibits 3-7 and 3-8 report delay on the mainline facility while Exhibits 3-9 and 3-10 report delay on the HOV facility. The exhibits also show a 90-day moving average (represented by the horizontal curved line) that reduces the day-to-day variations and more easily illustrates the seasonal and annual changes in congestion over time. Total delay along the study 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).

As indicated in Exhibits 3-7 and 3-8, daily delay on the mainline facility was greater in the northbound direction than the southbound. Northbound delay exceeded southbound delay by about 35 percent during each of the three years analyzed. The exhibits also show that daily delay in both directions of the mainline was concentrated in the PM peak period, as noted by the tan shading. In 2010, delay in the PM peak accounted for about 60 percent of total delay in the northbound direction and about 52 percent in the southbound direction. In both directions, daily delay declined from 2008 to 2009, but increased from 2009 to 2010.

Combining both directions, daily delay on I-5 was higher than that of the SR-91 and I-405 corridors. This makes sense given that the I-5 corridor is almost twice as long in distance as the SR-91 and I-405 corridors.

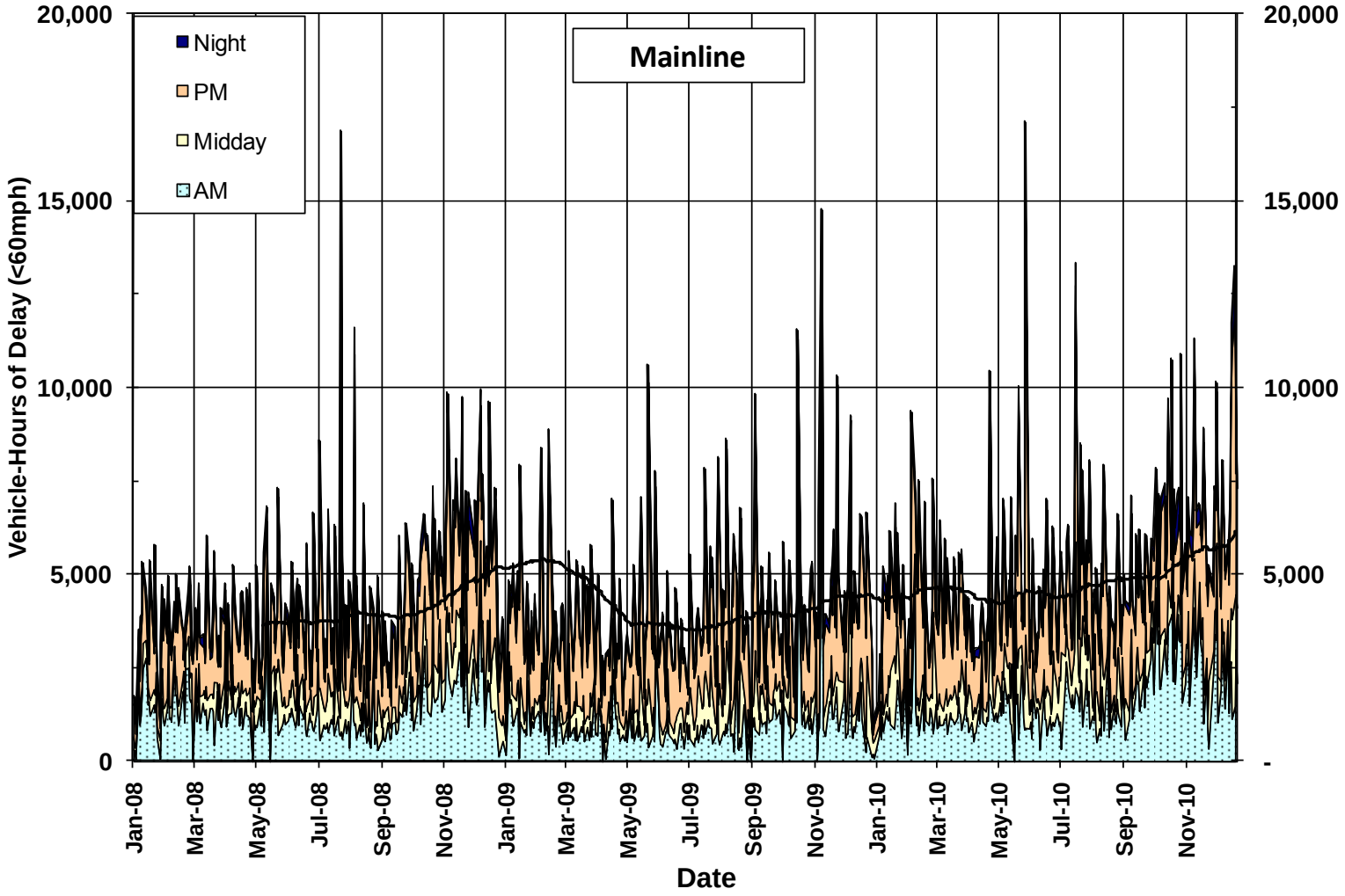
Exhibits 3-9 and 3-10 show the daily delay on the HOV facility for the same three year period. Similar to the mainline facility, delay on the HOV facility declined from 2008 to 2009, but increased from 2009 to 2010 to levels slightly greater than in 2008. Additionally, delay on both directions of the HOV lane was greatest in the PM peak. Overall, delay in the northbound direction of the HOV lane exceeded delay in the southbound direction.

Exhibit 3-7: Northbound I-5 ML Average Daily Delay by Time Period (2008-2010)



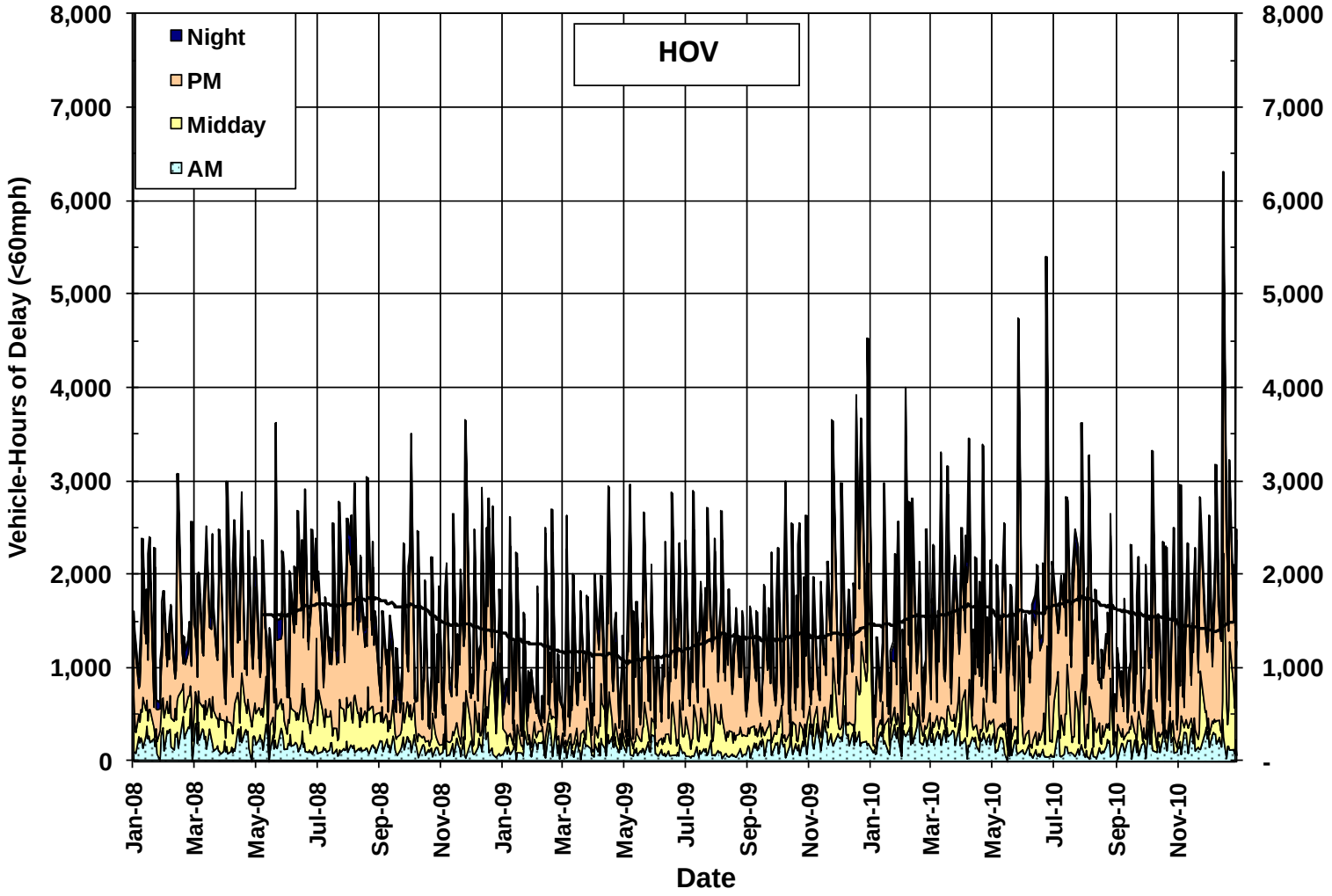
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-8: Southbound I-5 ML Average Daily Delay by Time Period (2008-2010)



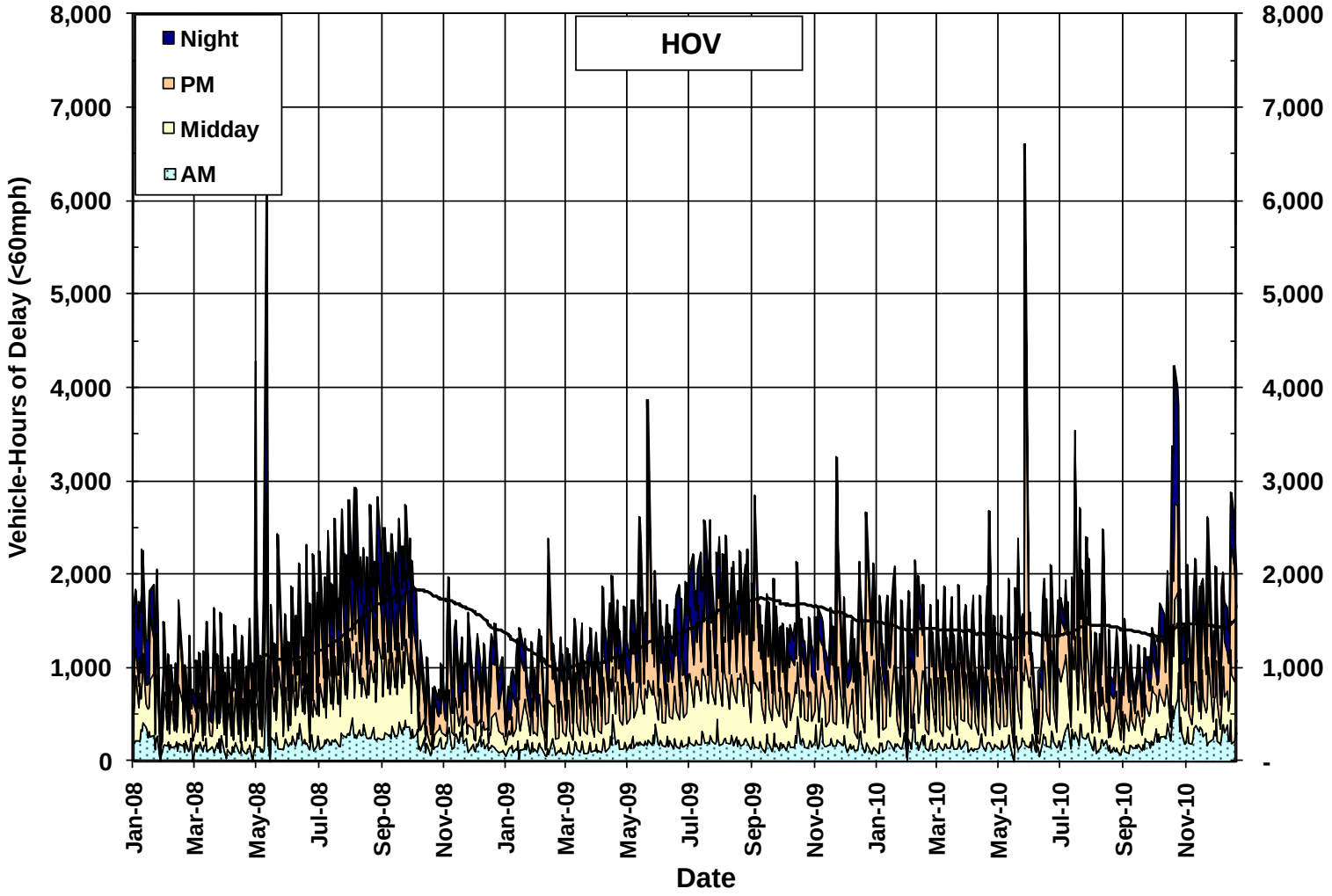
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-9: Northbound I-5 HOV Average Daily Delay by Time Period (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-10: Southbound I-5 HOV Average Daily Delay by Time Period (2008-2010)

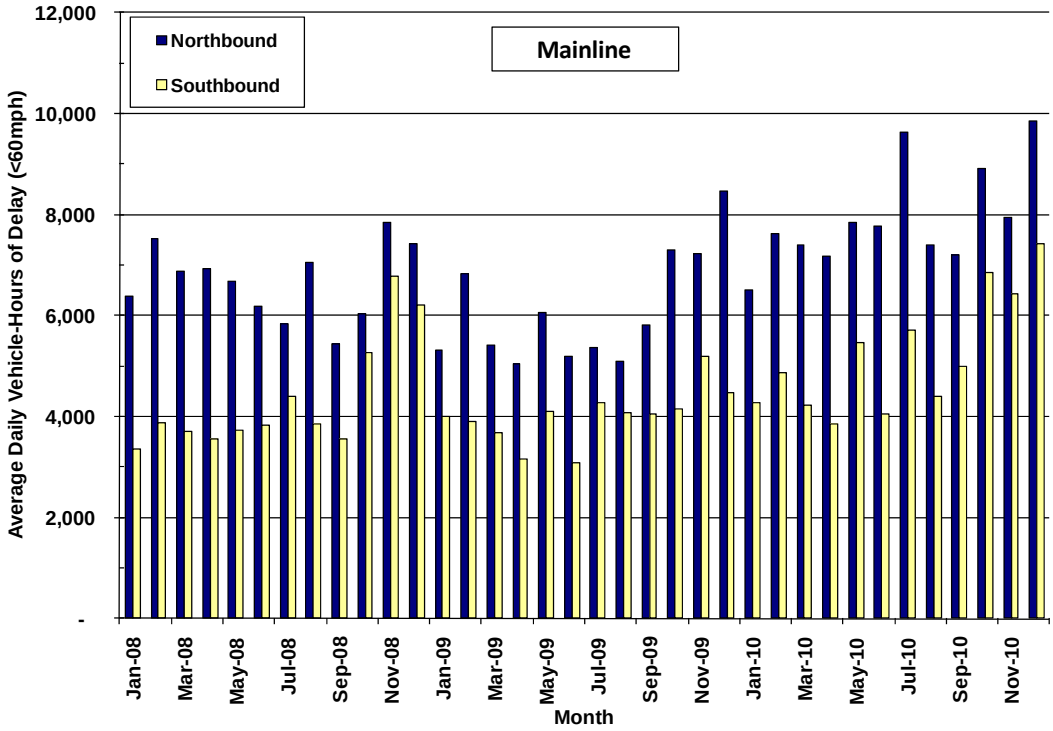


Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-11 shows the average weekday daily vehicle-hours of delay for each month between 2008 and 2010 for the mainline facility. These figures exclude weekends and holidays. This exhibit reveals the following delay trends on the mainline:

- Congestion on the mainline slightly decreased from 2008 to 2009, but rebounded in 2010 to levels higher than 2008.
- Northbound delay exceeded southbound delay for every month during the three-year period.

Exhibit 3-11: I-5 ML Average Weekday Delay by Month (2008-2010)

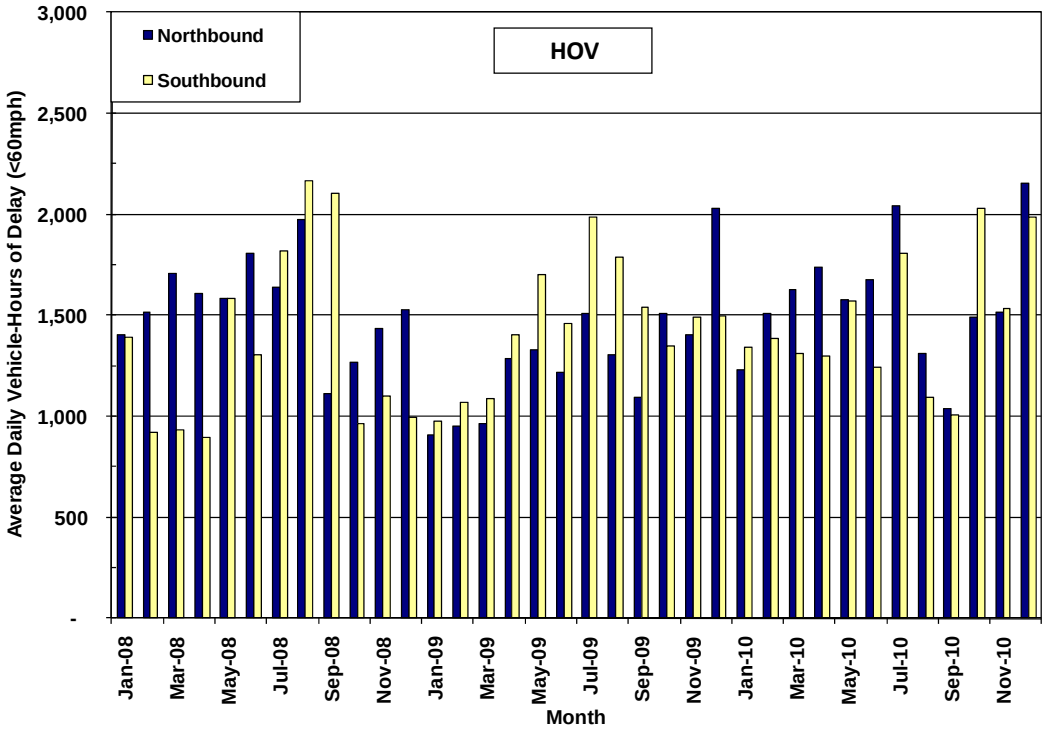


Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-12 reveals the following delay trends for the HOV facility:

- Congestion on the HOV facility decreased from 2008 to 2009, but rebounded in 2010.
- Northbound delay exceeded southbound delay in 2008 and 2010 while southbound delay was higher in 2009.

Exhibit 3-12: I-5 HOV Average Weekday Delay by Month (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

The exhibits presented above reflect congestion delay from speeds falling below 60 miles per hour (free-flow) threshold speed. This delay can be segmented into two components as shown in the following two exhibits:

- Severe delay – delay occurring when speeds are below 35 miles per hour.
- Other delay – delay occurring when speeds are between 35 and 60 miles per hour.

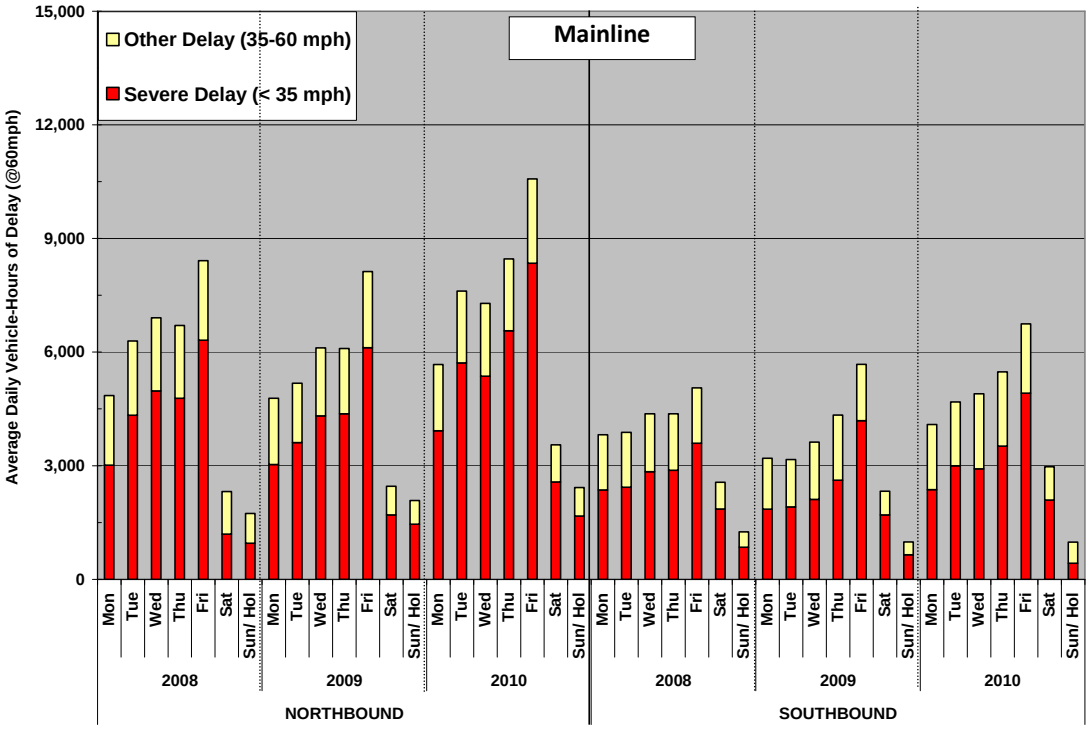
Severe delay represents breakdown conditions and is the focus of most congestion mitigation strategies. "Other" delay represents conditions approaching the breakdown congestion, leaving the breakdown conditions, or areas that cause temporary slowdowns rather than widespread breakdowns.

Exhibit 3-13 shows average severe and other daily vehicle-hours of delay by day of the week for the mainline facility. As depicted in the exhibit:

- Severe delay makes up over 60 percent of all weekday delay on the corridor in either the northbound or the southbound directions except for Mondays in 2009 and 2010 where it fell to under 60 percent.

- Fridays experienced the highest delays in both the northbound and southbound directions.
- Delay was highest in 2010 compared to previous years, and greater in the northbound direction than the southbound.

Exhibit 3-13: I-5 ML Average Delay by Day of Week by Severity (2008-2010)

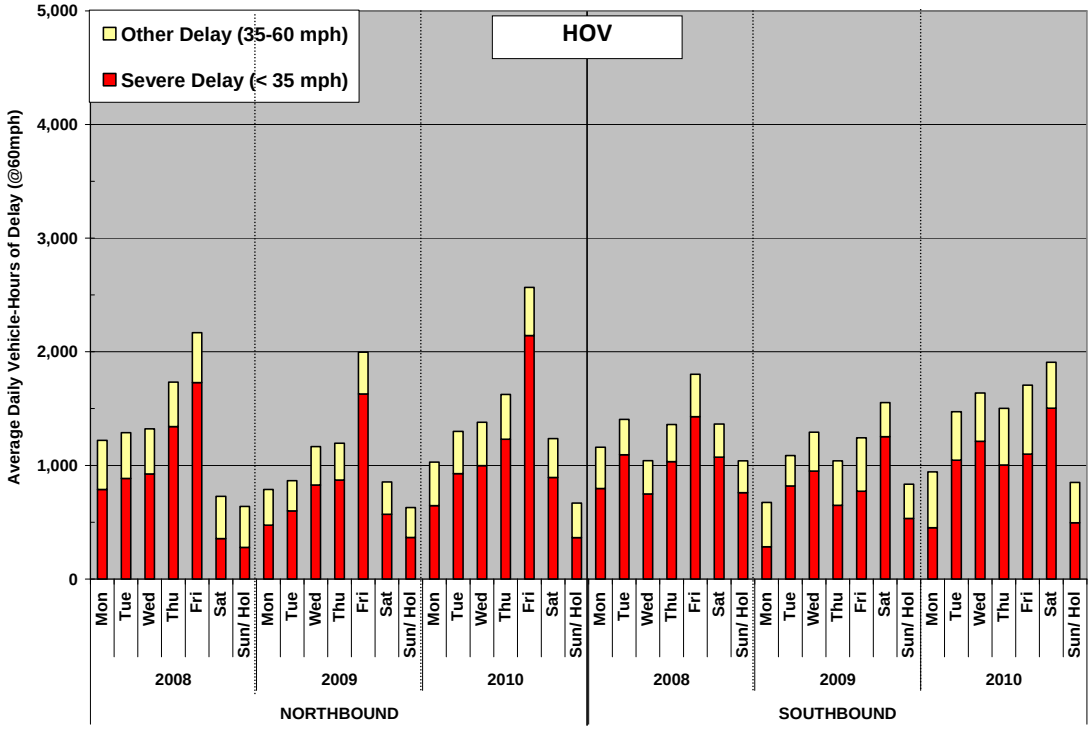


Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-14 summarizes the delay trend for the HOV facility:

- Severe delay makes up at least 60 percent of all weekday delay on the corridor in both the northbound and southbound directions except for Mondays in the southbound direction in 2009 and 2010, where it comprised less than 50 percent.
- Fridays experience the highest delays in the northbound direction, which may be due to weekend travel.
- In the southbound direction of the HOV facility, Fridays experienced the highest delays in 2008. This changed in 2009 and 2010 to Saturday exhibiting the highest delay.
- Delay was highest in 2010 than in previous years, and greater in the northbound direction than the southbound.

Exhibit 3-14: I-5 HOV Average Delay by Day of Week by Severity (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

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.

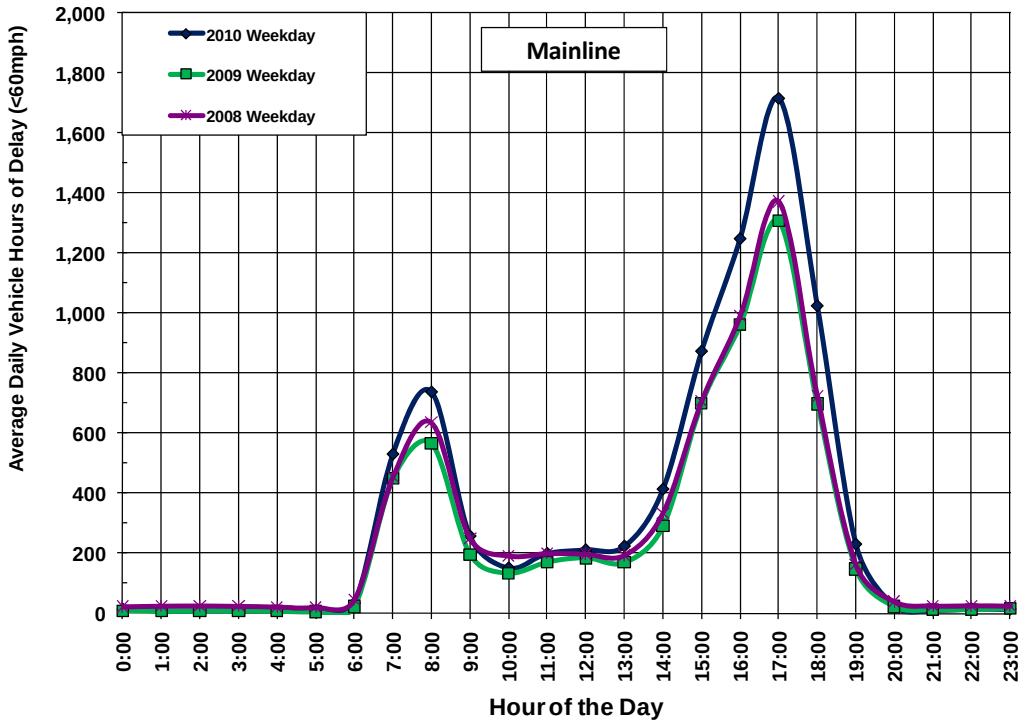
Another way to understand the characteristics of congestion and related delays is to examine average weekday delays by hour. The following exhibits summarize average weekday hourly delay for each year over a three-year period from 2008 to 2010. Exhibits 3-15 and 3-16 depict the mainline facility, while Exhibits 3-17 and 3-18 show the HOV facility. Each point represents the total delay for the hour. For example, the 7:00 AM point is the sum of delay from 7:00 AM to 8:00 AM. The exhibits show the peaking characteristics of congestion and how the peak period changes over time.

In both the northbound and southbound directions of the mainline, delay in the PM peak exceeded delay in the AM peak. Exhibit 3-15 shows that in the northbound direction, the AM peak occurred between 6:00 AM and 9:00 AM, and the PM peak occurred between 2:00 PM and 7:00 PM.

During the 5:00 PM peak hour in the northbound direction of the mainline facility, Exhibit 3-15 reveals delay decreased slightly from almost 1,375 vehicle-hours in 2008 to

around 1,300 vehicle-hours in 2009, and then increased to about 1,720 vehicle-hours in 2010.

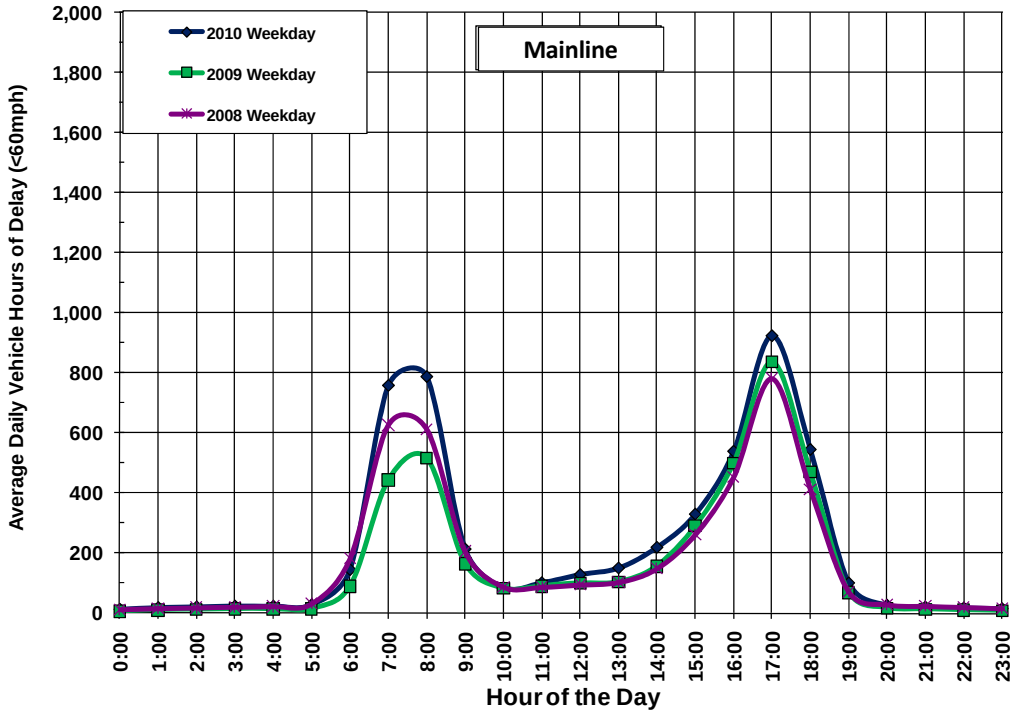
Exhibit 3-15: Northbound I-5 ML Average Weekday Hourly Delay (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-16 shows the hourly delay profile for the southbound direction of the mainline facility, which is similar to the northbound direction. Again, the biggest delays occurred during the PM peak hours centered at 5:00 PM. The AM peak hours also show sizeable delays from 6:00 AM to 9:00 AM. At the 5:00 PM peak hour, 2010 experienced the highest delay with almost 925 vehicle-hours, followed by 2009 with 840 vehicle-hours, and 2008 with 780 vehicle-hours. The 7:30 AM peak hour experienced the highest delay in 2010 with 800 vehicle-hours.

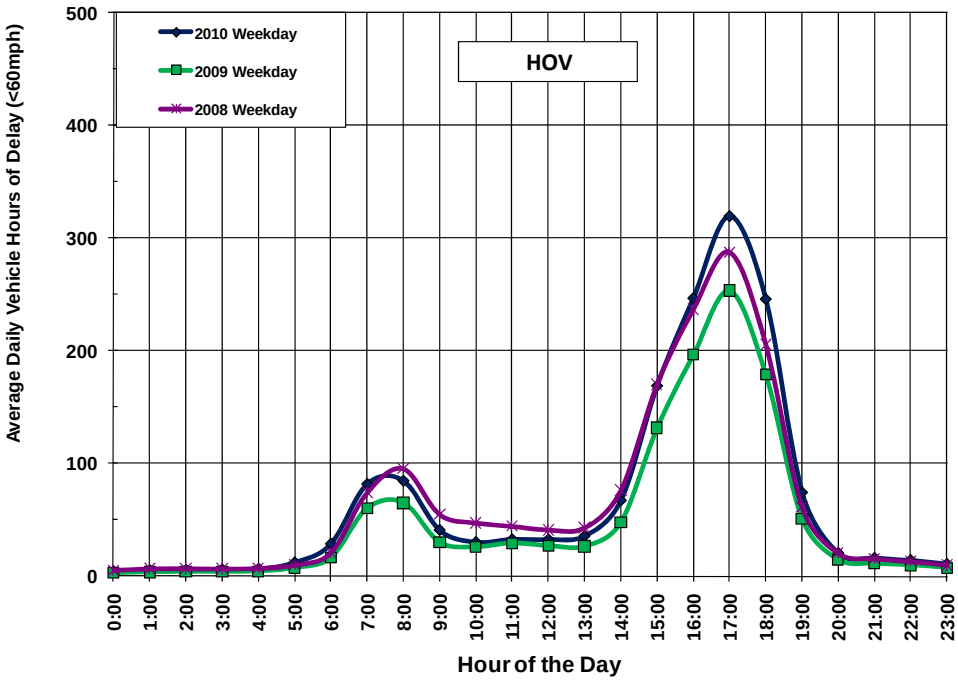
Exhibit 3-16: Southbound I-5 ML Average Weekday Hourly Delay (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

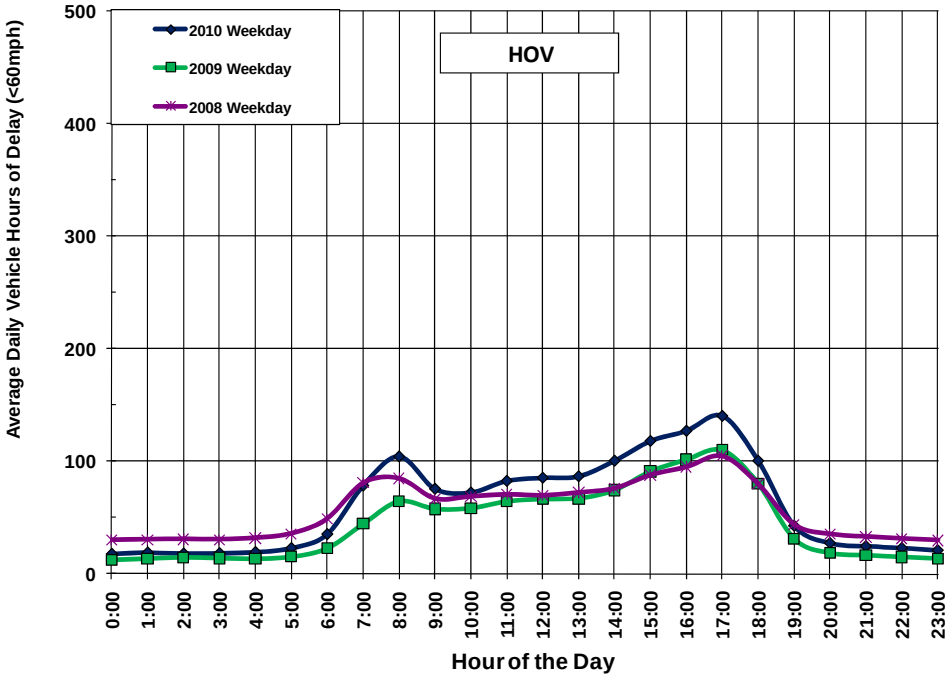
The HOV facility exhibited the same trends as the mainline facility. Both the northbound and southbound HOV lanes experienced the most congestion during the PM peak. During the 5:00 PM peak hour in 2010, the northbound HOV lane experienced 320 vehicle-hours of delay while the southbound HOV lane experienced 140 vehicle-hours.

Exhibit 3-17: Northbound I-5 HOV Average Weekday Hourly Delay (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-18: Southbound I-5 HOV Average Weekday Hourly Delay (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

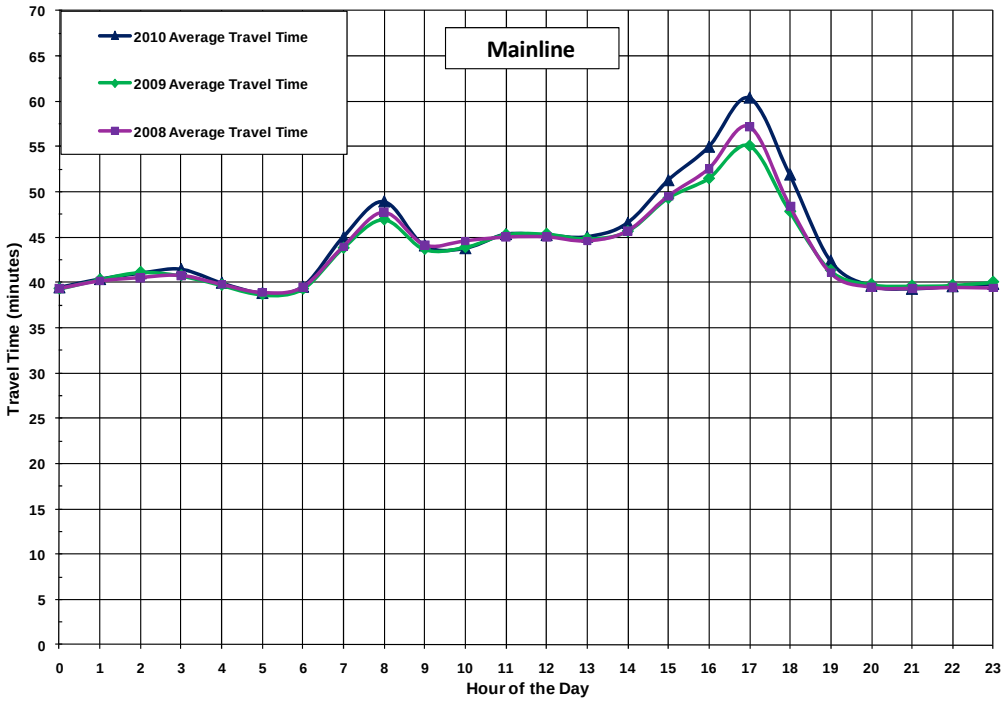
Travel Time

Travel time is reported as the amount of time it takes a vehicle to travel between two points on a corridor, as estimated using automatic detector data in this analysis. To travel the entire 44 miles of the mainline facility, it takes approximately 44 minutes traveling at 60 mph. Travel time on parallel arterials is not included in the analysis.

Exhibits 3-19 and 3-20 summarize average annual travel times estimated for the mainline facility by hour of day for weekdays for the years 2008 through 2010. Similar to delay trends, travel times were highest in 2010 compared to the prior two years.

As shown in Exhibit 3-19, the northbound direction of the mainline had travel times ranging from 55 to 60 minutes during the PM peak hour. During the 5:00 PM peak hour, travel times in the northbound direction decreased slightly from 57 minutes in 2008 to 55 minutes in 2009, and then increased to 60 minutes in 2010.

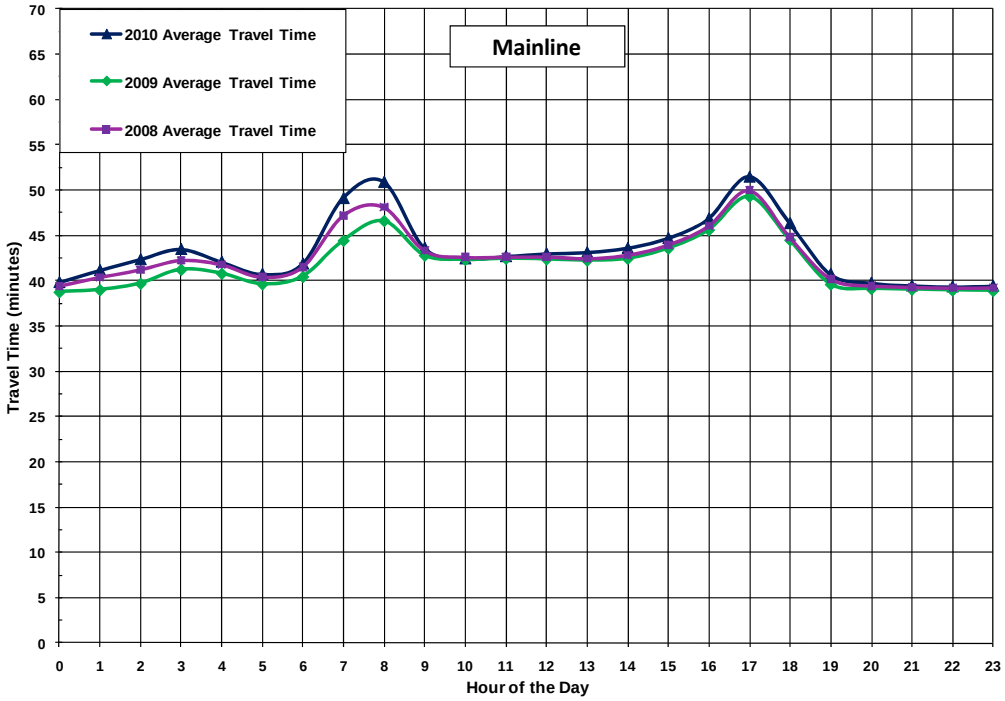
Exhibit 3-19: Northbound I-5 ML Travel Time by Hour (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

As shown in Exhibit 3-20, the southbound direction had travel times of approximately 47 to 51 minutes during the 8:00 AM peak hour. The PM peak hour at 5:00 PM also had similar travel times ranging from 49 to 51 minutes. Again, travel times decreased from 2008 to 2009, and increased from 2009 to 2010. Travel times were greatest in 2010 compared to the prior two years.

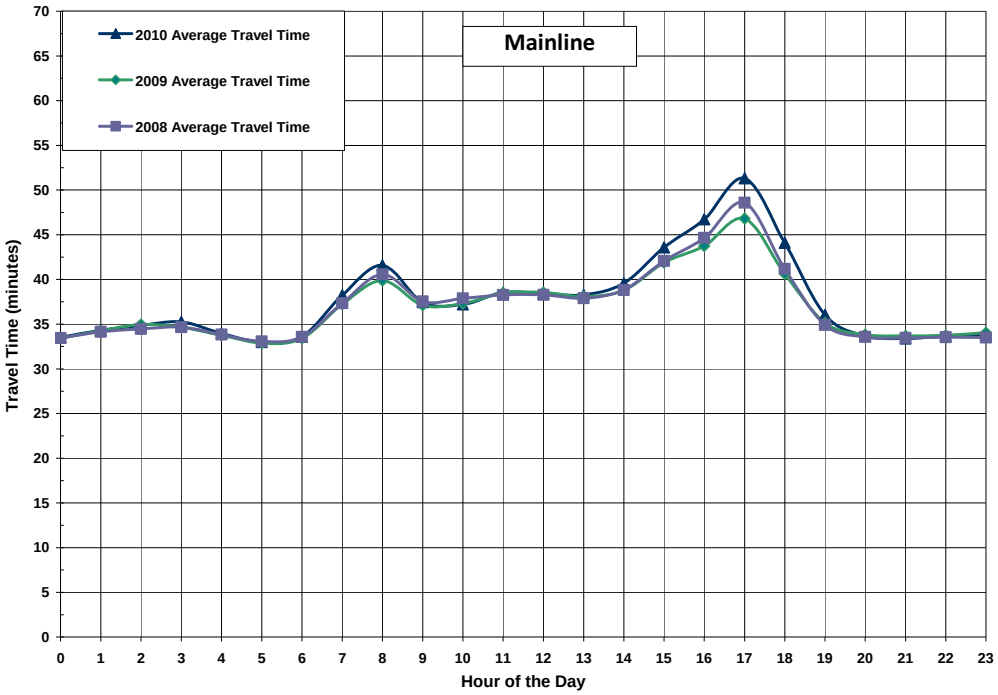
Exhibit 3-20: Southbound I-5 ML Travel Time by Hour (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

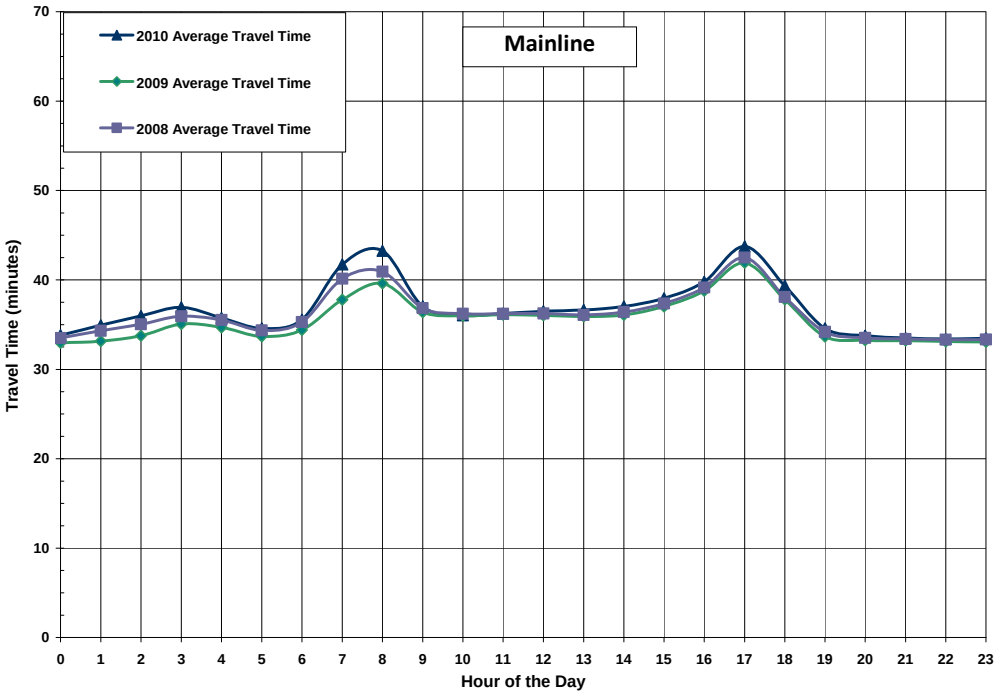
Exhibits 3-21 and 3-22 show the mainline travel times within the same limits as the HOV facility. Exhibits 3-23 and 3-24 illustrate travel times for the HOV facility. To travel the entire 38 miles of the HOV facility, it takes approximately 38 minutes traveling at 60 mph. As shown in Exhibit 3-21, the northbound direction had typical travel times of approximately 47 to 51 minutes during the PM peak period for the mainline facility within the HOV limits. This is slightly lower than the average travel times of 49 to 53 minutes for the HOV facility, as shown in Exhibit 3-23. For both facilities, travel times during the 5:00 PM hour slightly decreased from 2008 to 2009 and increased from 2009 to 2010. The same trend can be seen in the southbound direction of the mainline and HOV facilities as indicated in Exhibits 3-22 and 3-24. Overall, 2010 experienced the highest travel times from 2008 through 2010 in both the northbound and southbound directions.

Exhibit 3-21: Northbound I-5 ML (HOV Limits) Travel Time by Hour (2008-2010)



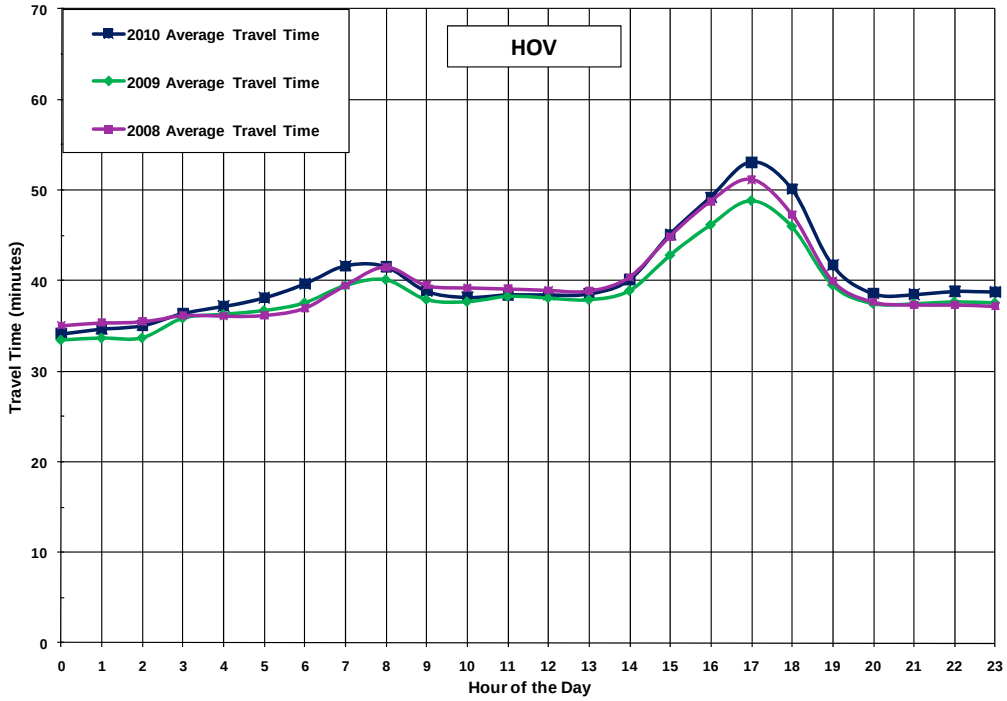
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-22: Southbound I-5 ML (HOV Limits) Travel Time by Hour (2008-2010)



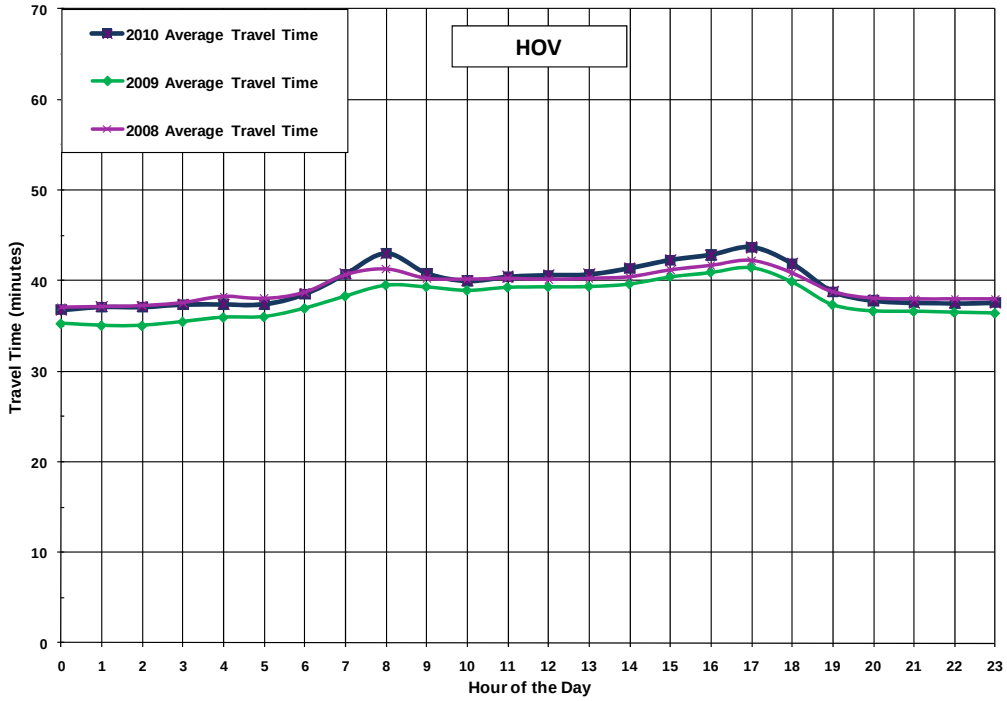
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-23: Northbound I-5 HOV Travel Time by Hour (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-24: Southbound I-5 HOV Travel Time by Hour (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

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 and efforts to accomplish this include incident management, traveler information, and special event planning.

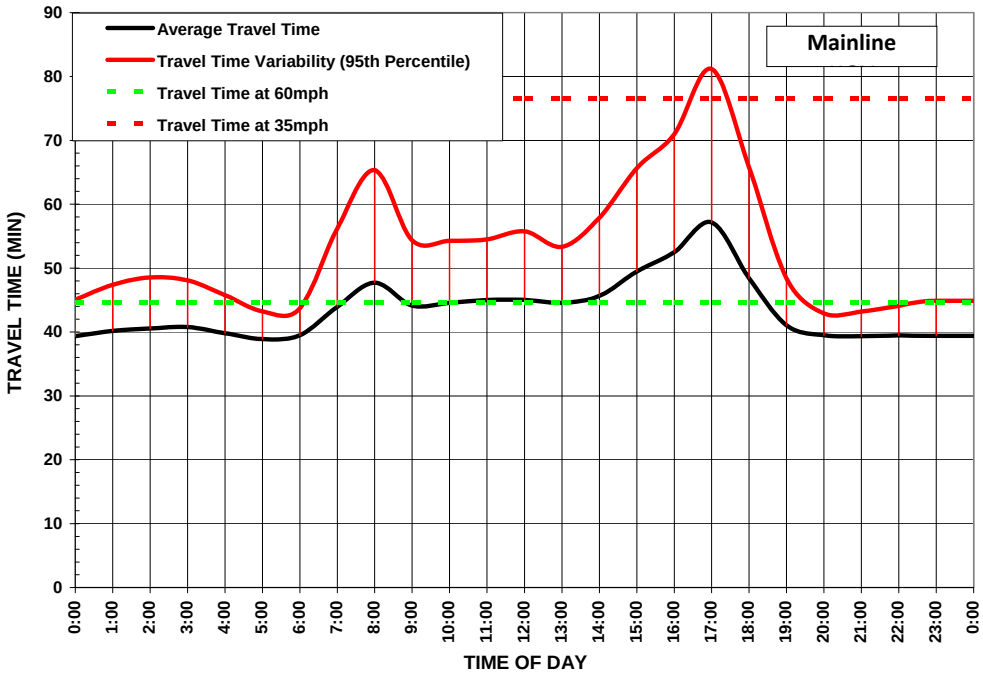
To measure reliability, the study team used automatic detector data to estimate the "buffer index." The buffer index reflects the additional time required (over and beyond the average) to ensure an on-time arrival 95 percent of the time. In other words, if a person must be on time 95 days out of 100 (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 3-25 through 3-42 on the following pages illustrate the variability of travel time along the I-5 Corridor on weekdays for the years 2008 through 2010.

Exhibits 3-25 through 3-30 present travel time variability for the mainline facility. In the northbound direction, the 5:00 PM peak hour was the most unreliable in addition to being the slowest hour. In 2008 (shown in Exhibit 3-25), motorists driving the entire length of the 44-mile corridor had to add 24 minutes to an average travel time of 57 minutes (for a total travel time of 81 minutes) to ensure that they arrived on time 95 percent of the time. This is 37 minutes longer than the 45-minute travel time at 60 mph. The time needed to arrive on time 95 percent of the time decreased from 81 minutes in 2008 to 69 minutes in 2009 (shown in Exhibit 3-26) and 79 minutes in 2010 (shown in Exhibit 3-27).

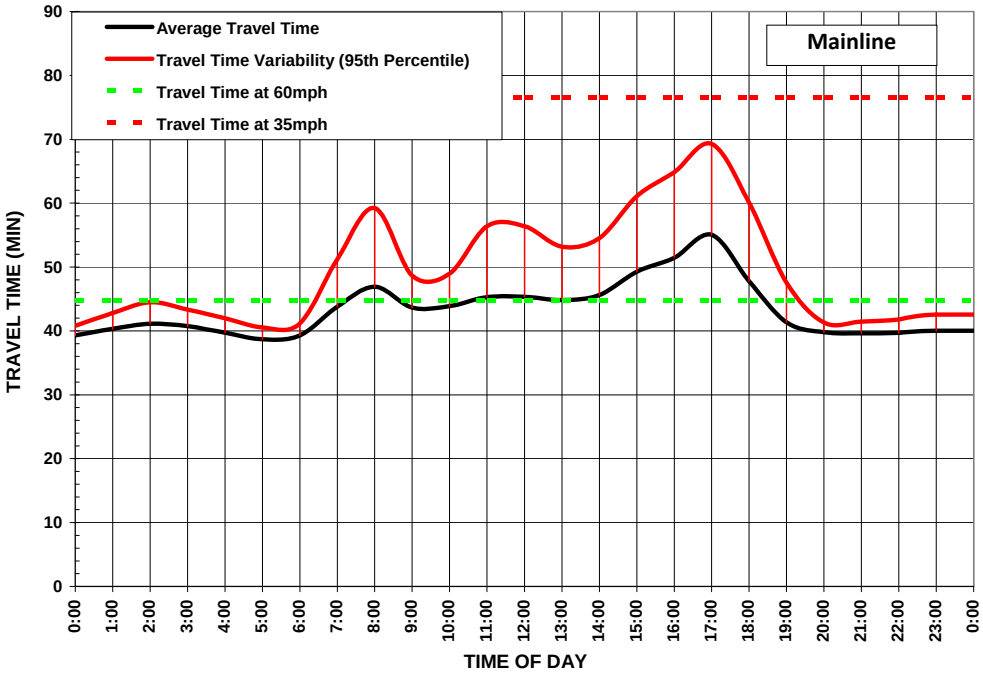
In the southbound direction of the mainline facility, the most unreliable hours were 7:30 AM and 5:00 PM. Unlike the northbound direction which experienced the highest travel time variability during the PM peak period, the southbound direction experienced evenly high travel time variability during both AM and PM peak periods. In 2008 (Exhibit 3-28), the time needed to arrive on time 95 percent of the time were 66 minutes at both 7:30 AM and 5:00 PM. Variability in travel times decreased in 2009 (Exhibit 3-29) to 59 minutes at 7:30 AM but increased to 69 minutes at 5:00 PM. In 2010 (Exhibit 3-30) travel time variability increased to 68 minutes at 7:30 AM but decreased to 65 minutes at the 5:00 PM peak hour.

Exhibit 3-25: Northbound I-5 ML Travel Time Variation (2008)



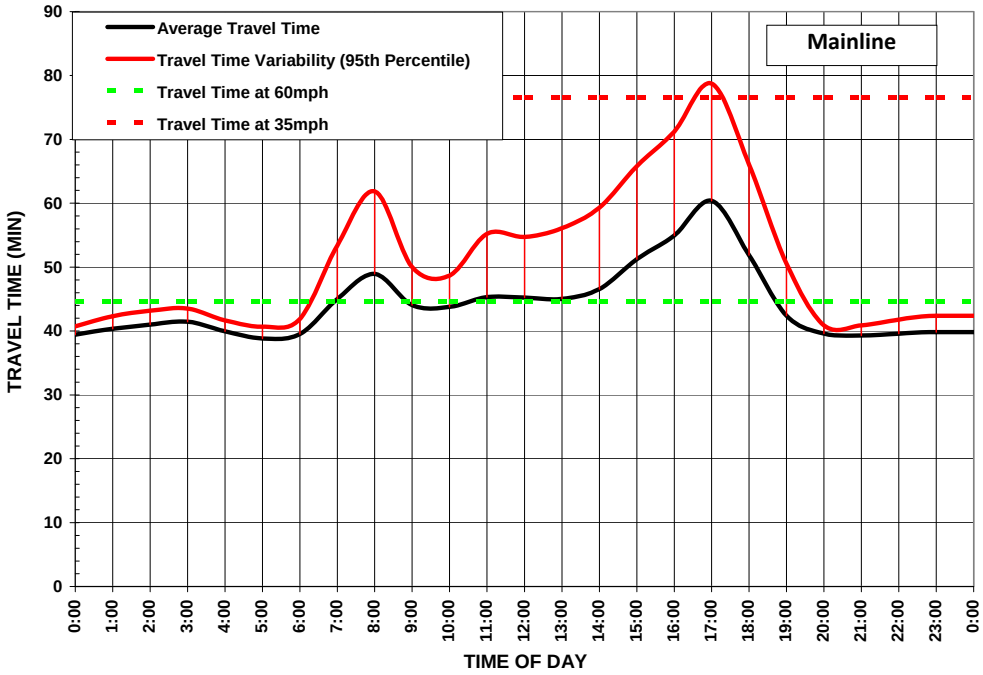
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-26: Northbound I-5 ML Travel Time Variation (2009)



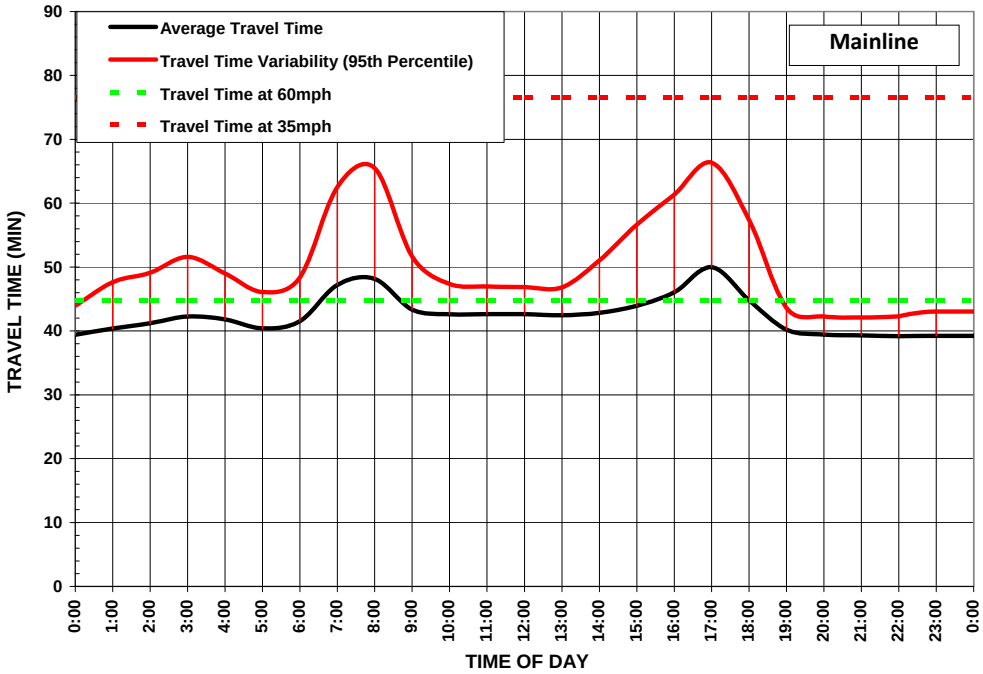
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-27: Northbound I-5 ML Travel Time Variation (2010)



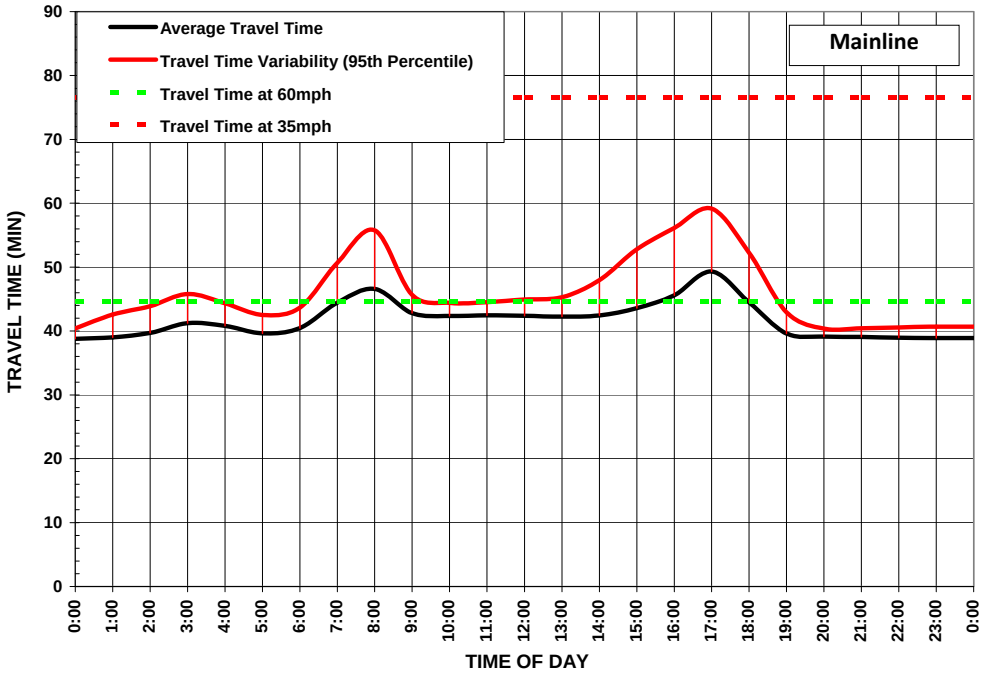
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-28: Southbound I-5 ML Travel Time Variation (2008)



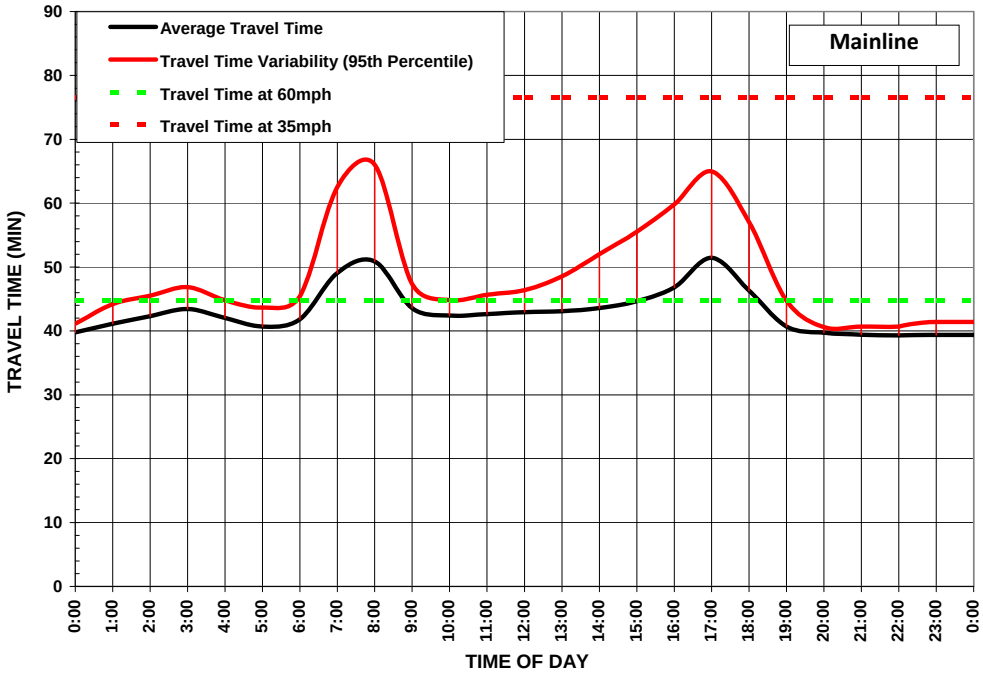
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-29: Southbound I-5 ML Travel Time Variation (2009)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-30: Southbound I-5 ML Travel Time Variation (2010)

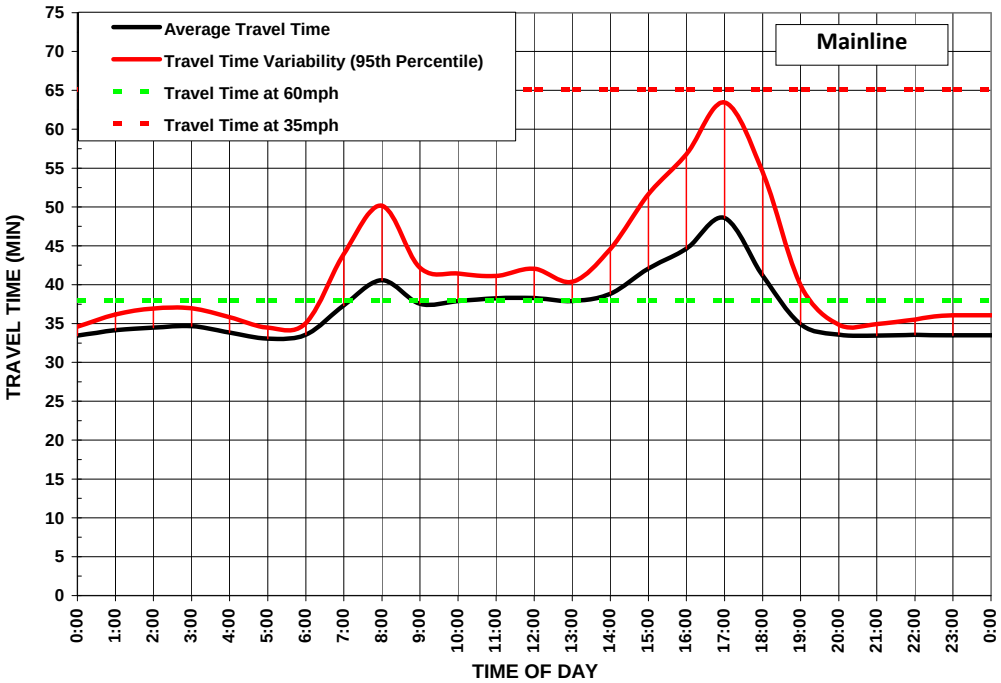


Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibits 3-31 through 3-36 present travel time variability for the mainline facility within the HOV facility limits while Exhibits 3-37 to 3-42 present travel time variability for the HOV facility. In the northbound direction of the HOV lane, the average travel time it takes to travel the 38-mile HOV facility varies from 51 minutes in 2008, to 49 minutes in 2009, and 53 minutes in 2010 during the 5:00 PM peak hour, which is the most unreliable and slowest hour. Similarly for the mainline facility within the same limits, while average travel times range from 33 to 51 minutes, the 5:00 PM peak hours is also the most unreliable and slowest hour. The time needed to arrive on time 95 percent of the time during this peak hour of travel was 68 minutes in 2008, 65 minutes in 2009, and 73 minutes in 2010. HOV travel time variability was higher than the mainline facility for all three years.

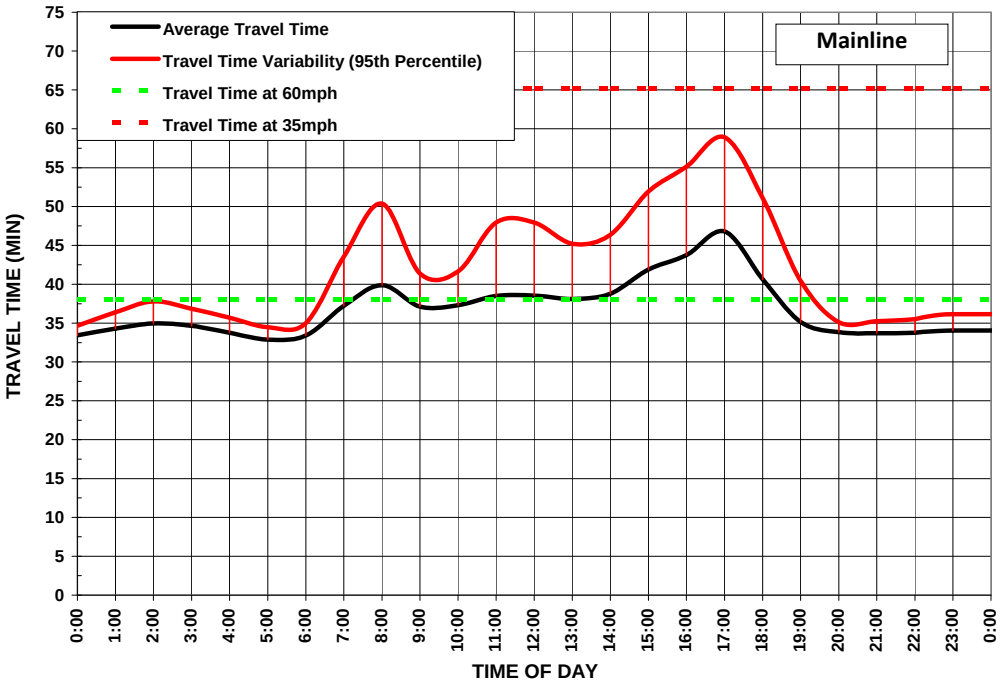
In the southbound direction of the HOV facility, the most unreliable hour shifted in 2008 from 4:00 PM to 5:00 PM in 2009 and 2010. During the 4:00 PM peak hour in 2008, motorists had to add 7 minutes to an average travel time of 42 minutes (for a total travel time of 49 minutes) to ensure they arrived on time 95 percent of the time. This is 11 minutes longer than the 38-minute travel time at 60 mph. In 2009, the time needed to arrive on time 95 percent of the time remained the same during the 5:00 peak hour at around 49 minutes, but increased to 53 minutes in 2010. For the mainline facility, while average travel times range from 33 to 44 minutes, to ensure on time arrival, motorists must add nine to 11 minutes (for a total travel time of up to 55 minutes).

Exhibit 3-31: Northbound I-5 ML (HOV Limits) Travel Time Variation (2008)



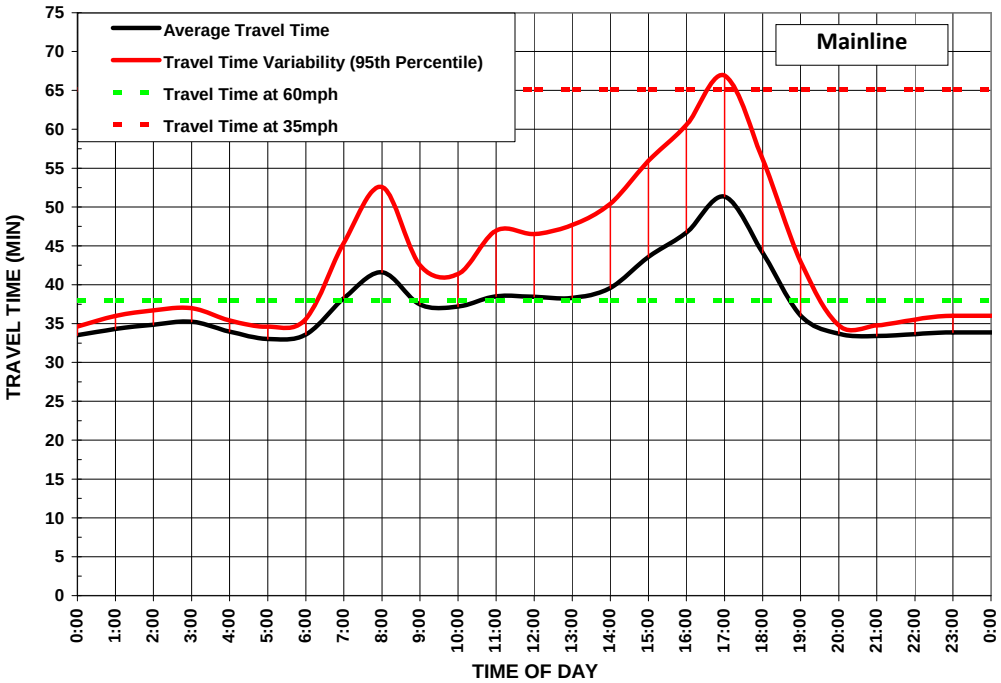
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-32: Northbound I-5 ML (HOV Limits) Travel Time Variation (2009)



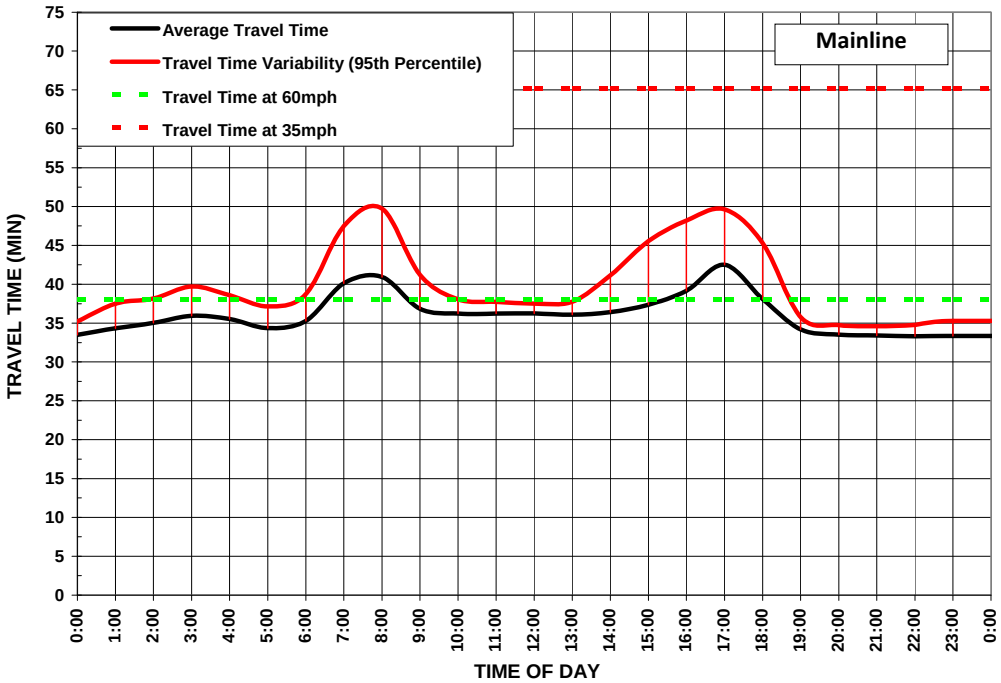
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-33: Northbound I-5 ML (HOV Limits) Travel Time Variation (2010)



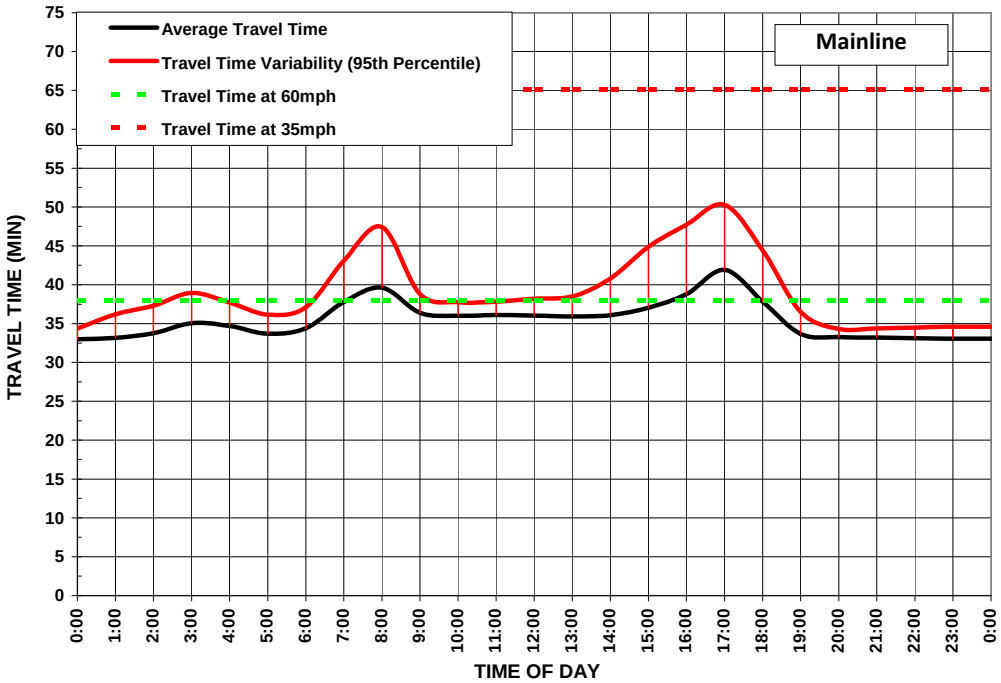
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-34: Southbound I-5 ML (HOV Limits) Travel Time Variation (2008)



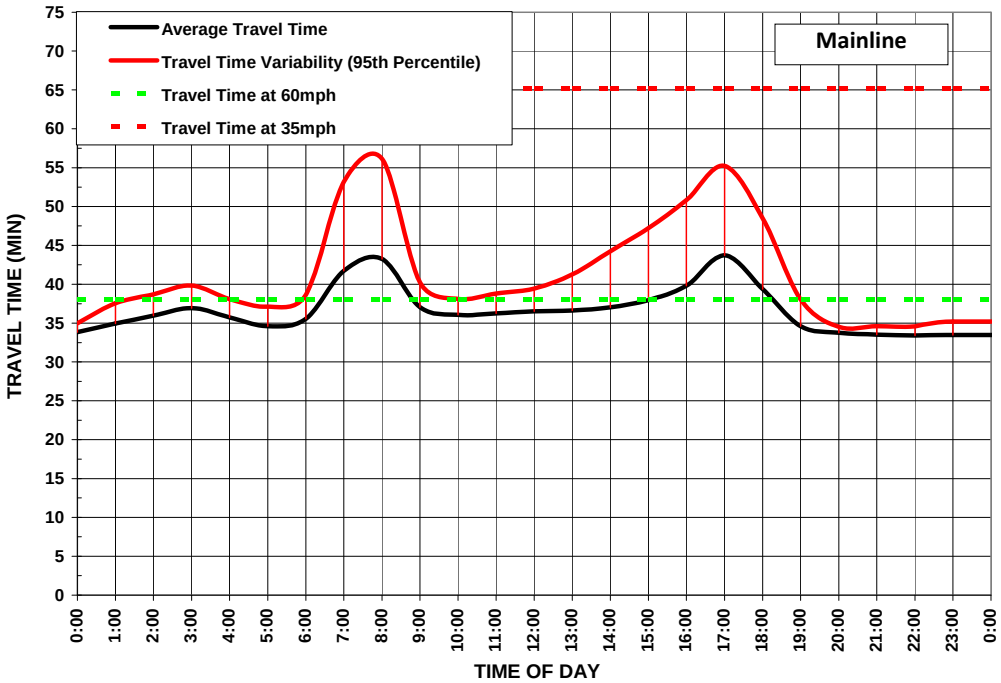
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-35: Southbound I-5 ML (HOV Limits) Travel Time Variation (2009)



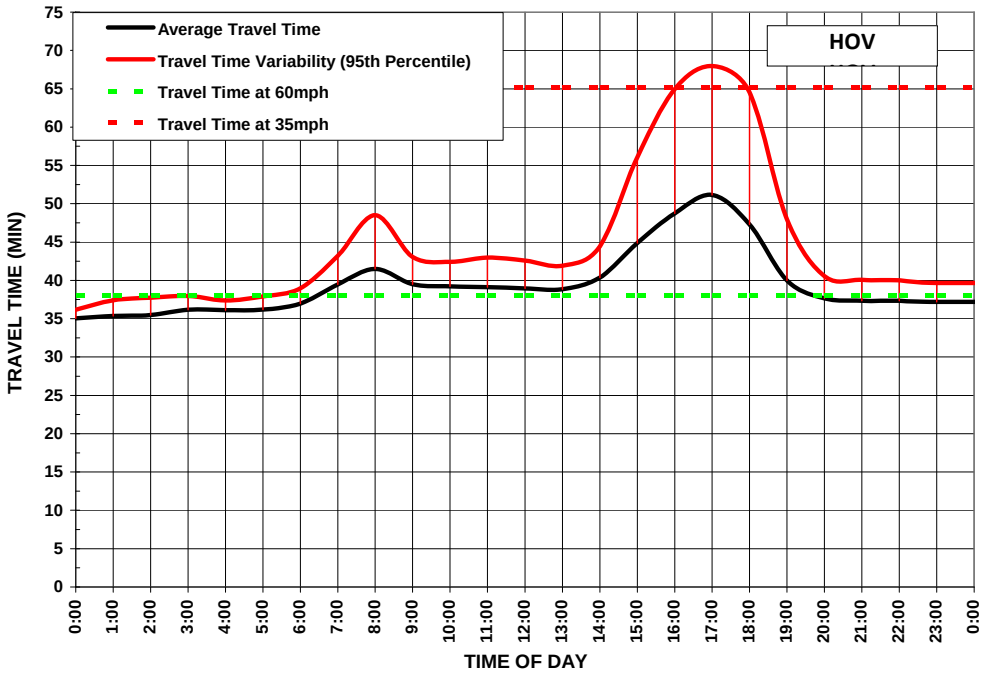
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-36: Southbound I-5 ML (HOV Limits) Travel Time Variation (2010)



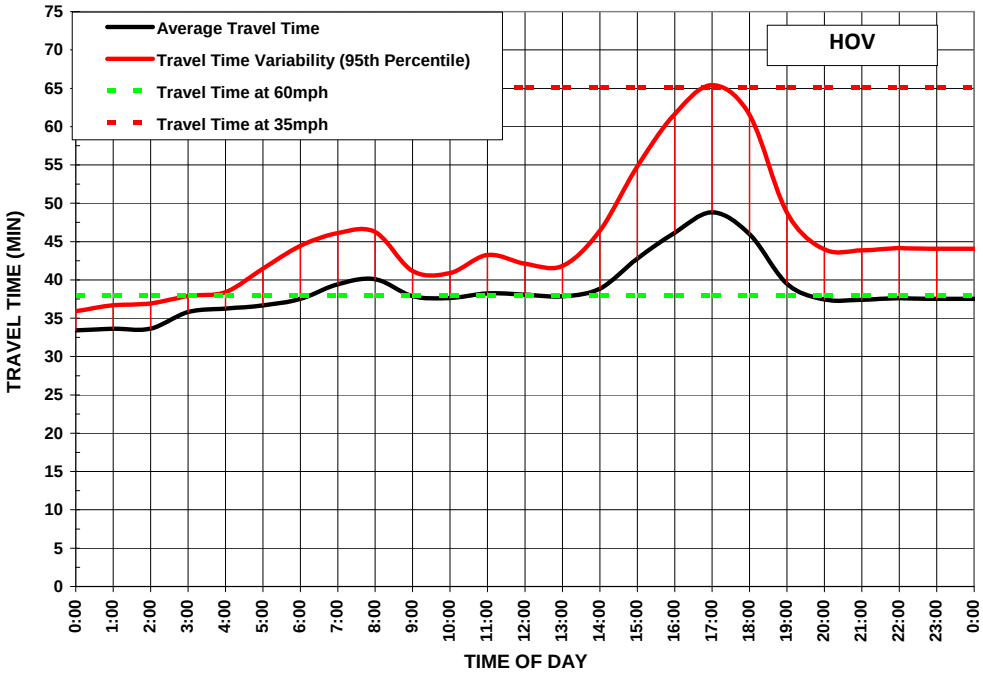
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-37: Northbound I-5 HOV Travel Time Variation (2008)



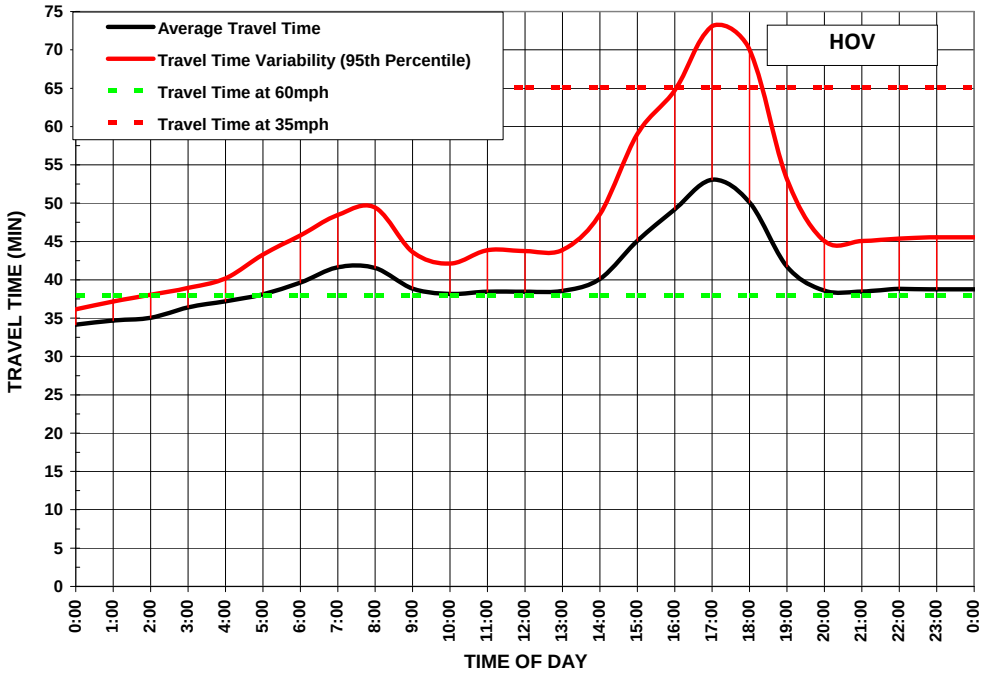
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-38: Northbound I-5 HOV Travel Time Variation (2009)



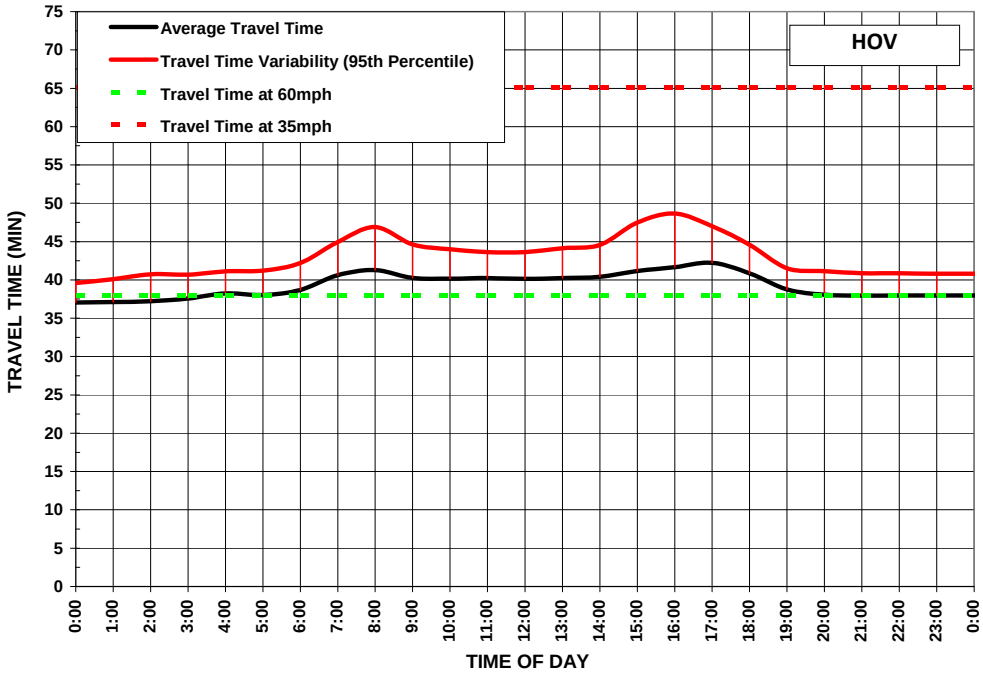
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-39: Northbound I-5 HOV Travel Time Variation (2010)



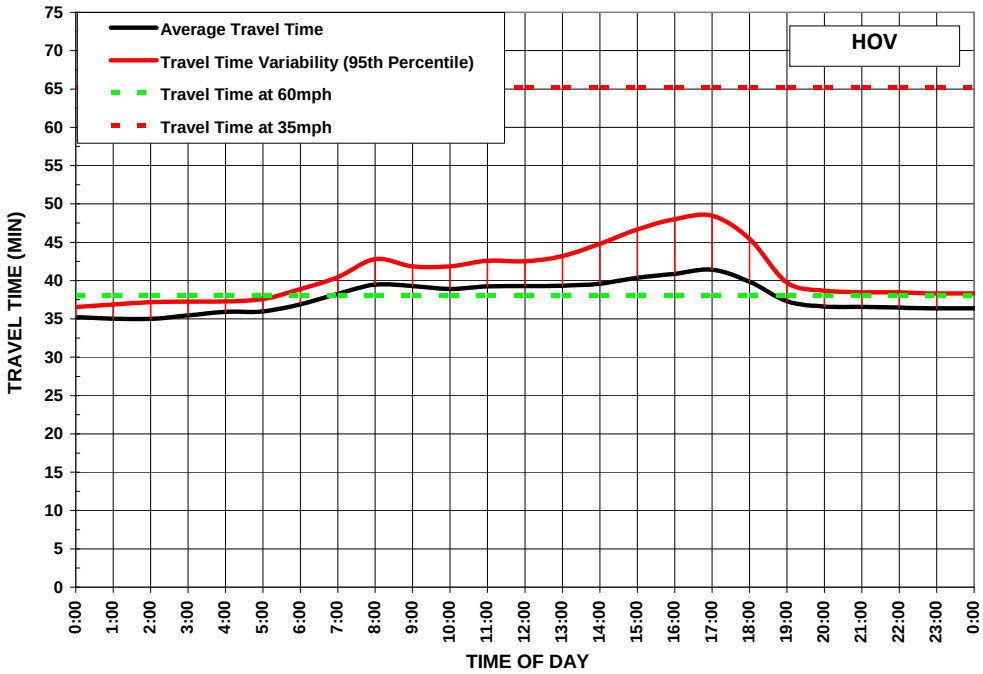
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-40: Southbound I-5 HOV Travel Time Variation (2008)



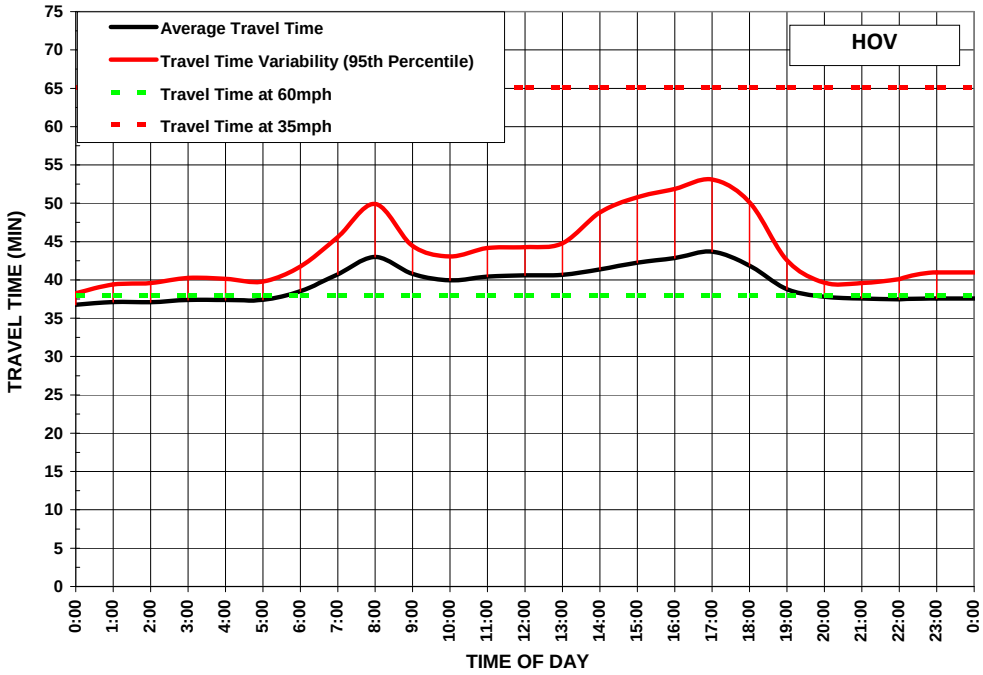
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-41: Southbound I-5 HOV Travel Time Variation (2009)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-42: Southbound I-5 HOV Travel Time Variation (2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Safety

Collision data in terms of the number of accidents and accident rates from the Caltrans Traffic Accident Surveillance and Analysis System (TASAS) were used for the safety measure. 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 is intended to characterize the overall accident history and trends in the corridor, and to highlight notable accident concentration locations or patterns that are readily apparent. This report is not intended to supplant more detailed safety investigations routinely performed by Caltrans staff.

Exhibit 3-43 shows TASAS Table B accident rates for the I-5 mainline facility from 2007 to 2009, divided into three segments by direction. It also shows the average accident rates experienced on facilities with similar operating characteristics. As indicated in this exhibit, the total average accident rates range from 1.03 to 1.04 for the segment south of El Toro (PM 0.0 to PM 18.685), while the segment from SR-22 to the Orange/Los Angeles County Line (PM 34.017 to PM 44.382) has a higher total average accident rate of 1.47 to 1.49. Actual I-5 accident rates were all below the average accident rates experienced by similar facilities. For the segment between El Toro to SR-22 (PM 18.685 to PM 34.017) in 2008, the total accident rate was slightly higher than the total average accident rate due to high numbers of property damage only accidents.

Exhibit 3-43: Table B Accident Rates (2007-2009)

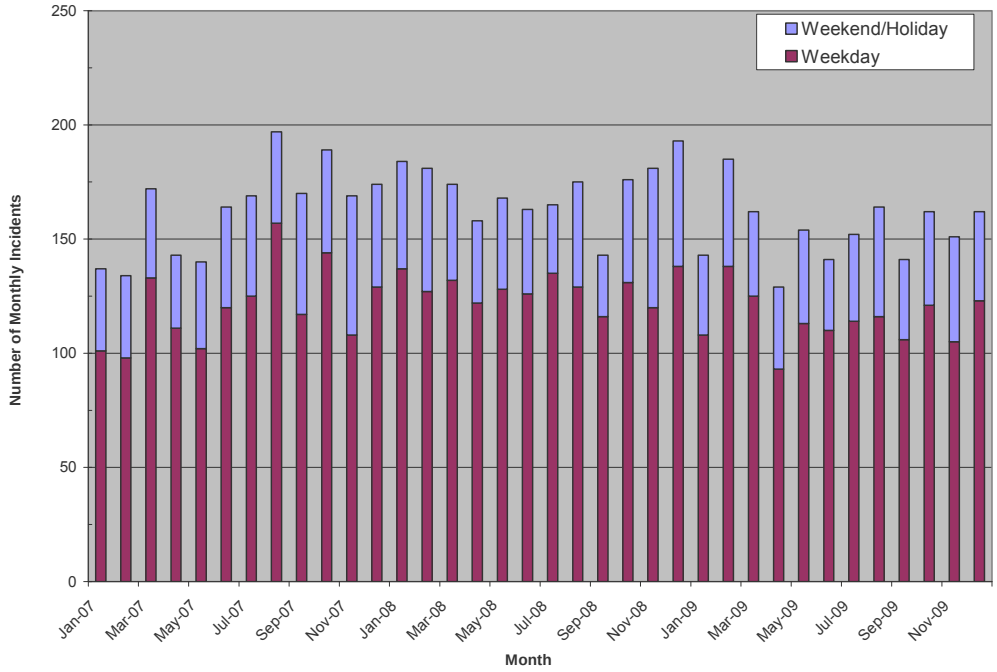
Year	Dir	Segment		Accident Rates					
				Actual Rates on I-5			Average Rates on Similar Facilities		
		From PM	To PM	Fat	F+I	Tot	Fat	F+I	Tot
2007	NB	0	18.685	0.001	0.16	0.62	0.010	0.31	1.03
		18.685	34.017	0.001	0.28	1.06	0.011	0.32	1.10
		34.017	44.382	0.000	0.18	0.69	0.015	0.46	1.49
	SB	44.382	34.017	0.002	0.18	0.74	0.015	0.46	1.49
		34.017	18.685	0.003	0.19	0.80	0.011	0.32	1.10
		18.685	0	0.002	0.20	0.62	0.010	0.31	1.03
2008	NB	0	18.685	0.004	0.16	0.62	0.010	0.31	1.03
		18.685	34.017	0.001	0.31	**1.15**	0.011	0.32	1.09
		34.017	44.382	0.002	0.22	0.81	0.015	0.45	1.47
	SB	44.382	34.017	0.002	0.17	0.70	0.015	0.45	1.47
		34.017	18.685	0.001	0.20	0.76	0.011	0.32	1.09
		18.685	0	0.001	0.17	0.63	0.010	0.31	1.03
2009	NB	0	18.685	0.001	0.18	0.58	0.010	0.31	1.04
		18.685	34.017	0.000	0.25	0.95	0.011	0.32	1.10
		34.017	44.382	0.002	0.20	0.74	0.015	0.45	1.47
	SB	44.382	34.017	0.000	0.17	0.63	0.015	0.45	1.47
		34.017	18.685	0.004	0.21	0.74	0.011	0.32	1.10
		18.685	0	0.001	0.17	0.56	0.010	0.31	1.04

Source: Caltrans Table B for I-5 mainline facility.

Another way to analyze safety data is to look at when accidents occur. The latest available three-year data from January 1, 2007 through December 31, 2009 were analyzed and summarized. Note that these TASAS data do not rely on automatic detection systems.

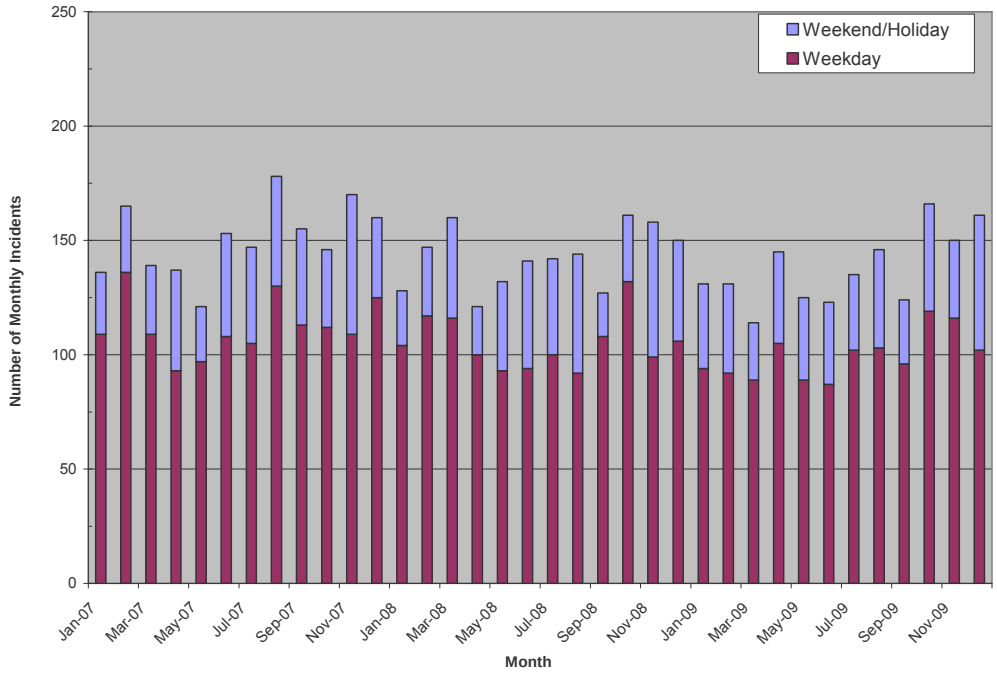
Exhibits 3-44 and 3-45 summarize the total number of weekday and weekend/holiday accidents by month in each direction. As shown in Exhibit 3-44, the number of northbound accidents increased from approximately 1,960 in 2007 to 2,070 in 2008 but decreased in to 1,850 in 2009. In the southbound direction, accidents decreased annually during the three-year period (from 1,800 in 2007, to 1,700 in 2008, and 1,650 in 2009). The northbound direction outnumbered the southbound direction in the number of accidents during all three years. Rear end accidents comprise over 50 percent of all accidents for each of the three years, followed by 20 percent sideswipes, and 20 percent hit objects. Primary collision factors were speeding, other violations, and improper turns. The high percentage of rear end accidents are generally associated with congested conditions. Similar to delay, when congestion increases, accidents increase.

Exhibit 3-44: Northbound Monthly Accidents (2007-2009)



Source: Caltrans TASAS

Exhibit 3-45: Southbound Monthly Accidents (2007-2009)



Source: Caltrans TASAS

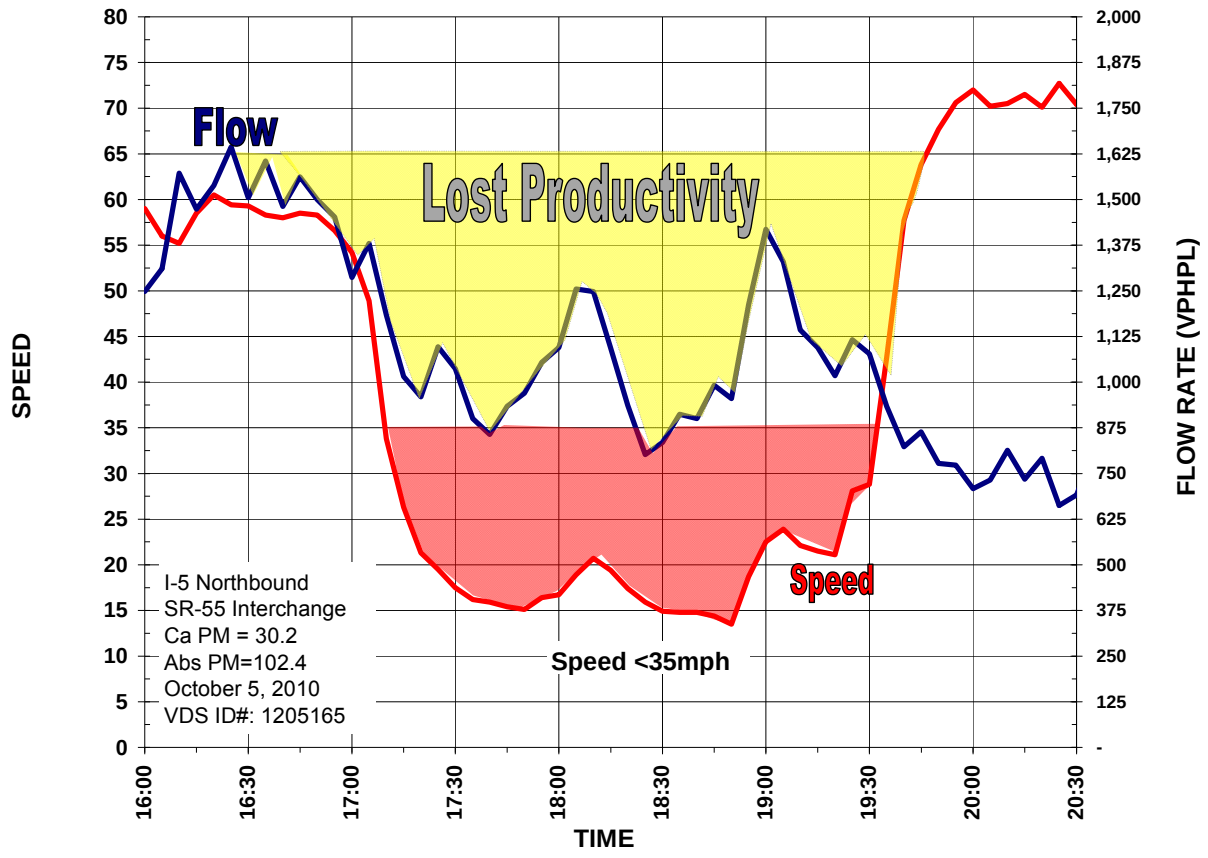
Productivity

Productivity is a system efficiency measure used to analyze the capacity of the corridor, and is defined as the ratio of output (or service) per unit of input. In the case of transportation, productivity is the percent utilization of a facility or mode under peak congested conditions.

For highways, it is the number of vehicles compared to the capacity of the roadways 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 3-46, which is same lost productivity chart presented in Section 1 of this report. 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 3-46: Lost Productivity Illustrated on I-5 Corridor



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

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." Equivalent lost lane-miles is computed as follows (for congested locations only):

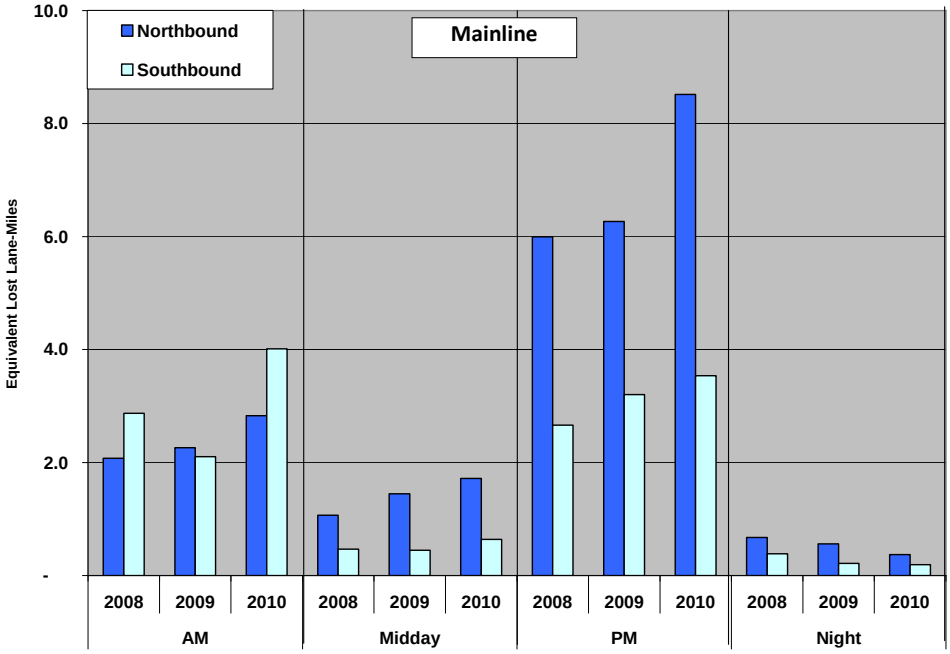
$$LostLaneMiles = \left(1 - \frac{ObservedLaneThroughput}{2000vphpl}\right) \times Lanes \times CongestedDistance$$

Strategies to combat such productivity losses are primarily related to operations. These strategies include: building new or extending auxiliary lanes, developing more aggressive ramp metering strategies without negatively influencing the arterial network, and improving incident clearance times.

Exhibit 3-47 summarizes the productivity losses on the mainline from 2008 to 2010. The largest productivity losses occurred during the PM peak hours in the northbound direction (as noted by the taller blue shaded bars), which is the time period and direction that experienced the most congestion or delay. During the PM peak in 2010, the northbound direction lost over eight equivalent lane-miles, which is an increase from the prior years. The southbound direction of the mainline (aqua shaded bars) also experienced significant productivity losses during the PM peak, but experienced the highest loss in productivity during the AM peak in 2010.

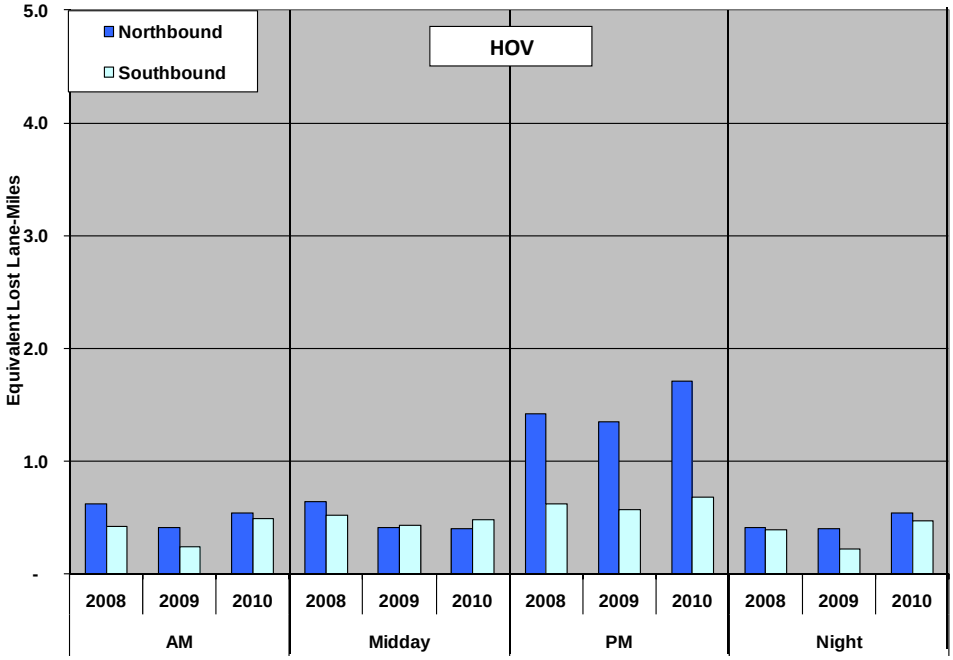
Exhibit 3-48 summarizes the productivity losses on the HOV facility during the same period. Again, the northbound direction shows the greatest productivity losses during the PM peak period. This is the same for the southbound direction as well.

Exhibit 3-47: I-5 ML Daily Equivalent Lost Lane-Mile by Direction and Period (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 3-48: I-5 HOV Daily Equivalent Lost Lane-Mile by Direction and Period (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Weekend Performance Measures Summary

Weekend performance assessment was also conducted for the three-year period (2008-2010) as the I-5 corridor is a heavily traveled corridor on weekends, providing access to San Diego, Los Angeles, and other destinations to the north. Weekend delay on the mainline facility was greater in the northbound direction than in the southbound direction during the three-year period. The greatest delays for both directions were concentrated during the midday period. Delays in the northbound direction increased every year from 2008 to 2010 while delays in the southbound direction decreased from 2008 to 2009 but increased from 2009 to 2010. On the HOV facility for the same three-year period, total delay was highest in the southbound direction. Delay in the northbound direction was highest during the PM peak period while delay in the southbound direction was highest during the midday peak period.

For detailed analysis of the weekend performance measures, reference is directed to Appendix B of this report.

Pavement Condition

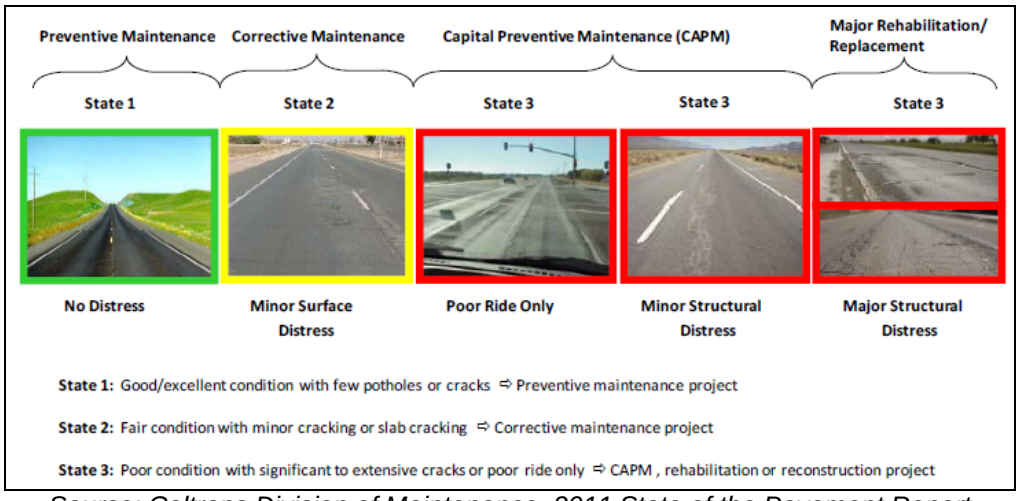
The condition of the roadway pavement (or ride quality) on the corridor can influence its traffic performance. Rough or poor pavement conditions can decrease the mobility, reliability, safety, and productivity of the corridor, whereas smooth pavement can have the opposite effect. Pavement preservation 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.

Pavement Performance Measures

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

Distressed lane-miles help to distinguish between pavement segments that require only preventive or corrective maintenance at relatively low costs and segments that require major rehabilitation/replacement at significantly higher costs. All segments that require major rehabilitation/replacement are considered to be distressed. Segments with poor ride quality are also considered to be distressed. Exhibit 3-49 provides an illustration of this distinction. The first two pavement conditions include roadways that provide adequate ride quality and are structurally adequate. The remaining three conditions are included in the calculation of distressed lane-miles.

Exhibit 3-49: Pavement Condition States Illustrated



Source: Caltrans Division of Maintenance, 2011 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 at 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 June 2011, identified 12,333 distressed lane-miles statewide. The 2011 PCS began in July 2009 and was completed in June 2011. In the past, the Caltrans conducted the PCS once a year to measure changes in pavement condition. In 2008, data collection was changed to provide pavement performance for the future Pavement Management System (PMS). Similarly, the 2007 PCS included a transitional methodology that covered a 23-month period from January 2006 to November 2007.

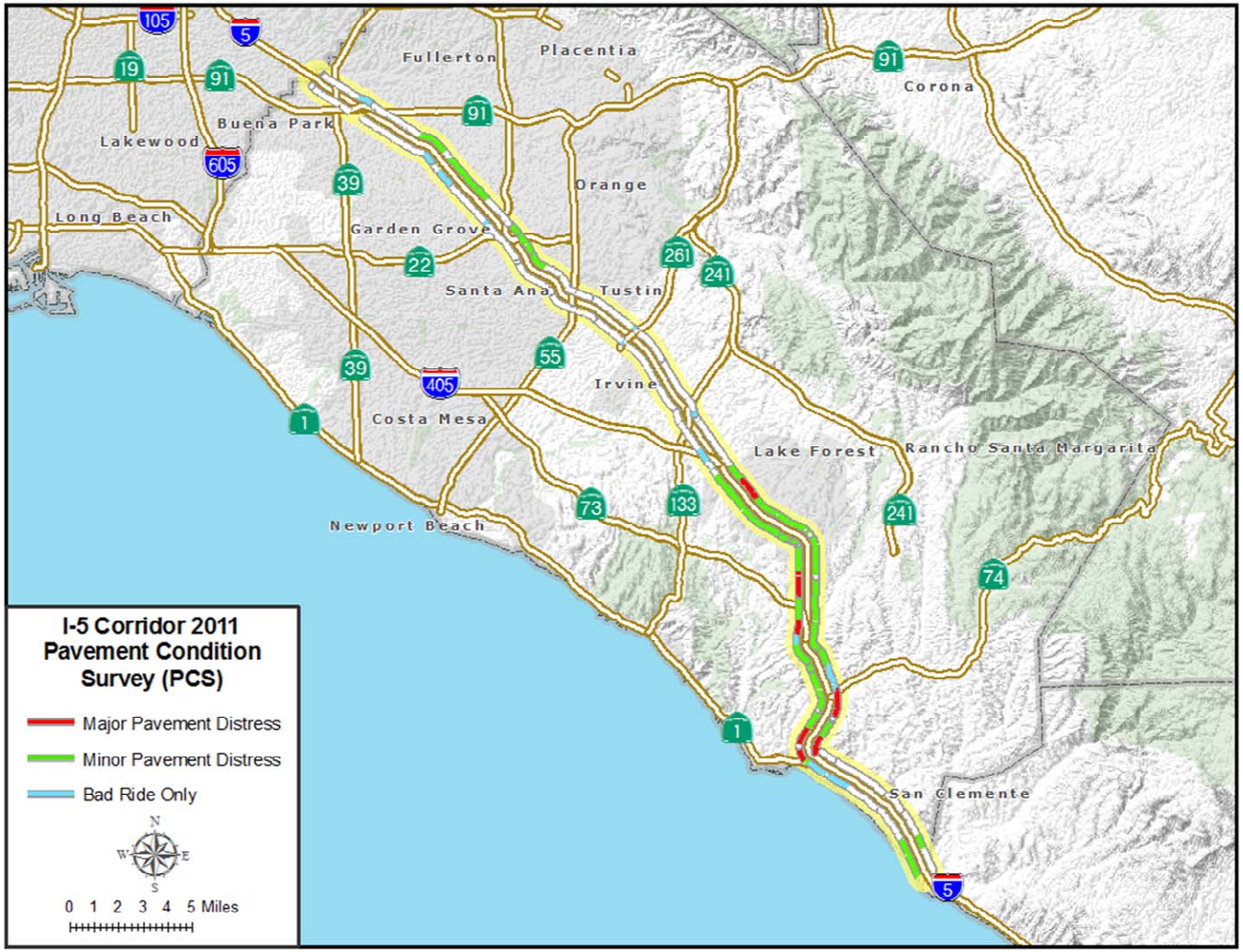
The field work consists of two parts. In the first part, pavement raters visually inspect the pavement surface to assess structural adequacy. In the second part, field staff uses vans with automated profilers to measure ride quality. The 2011 PCS revealed that the largest portion of distressed pavement (4,858 out of 12,333 distressed lane-miles) is on freeways and expressways (Class 1 roads), but the proportion has dropped. While approximately 52 percent of the State Highway System is Class 1, only 39 percent of the distressed lane-miles occur on these roads. As a percentage of total lane-miles by class, collectors and local roads (Class 3 roads) had the highest amount of distress.

Exhibit 3-50 shows pavement distress along the I-5 Corridor according to the 2011 PCS data. The three categories shown in this exhibit represent the three distressed conditions that require major rehabilitation or replacement (shown in Exhibit 3-49).

The I-5 Corridor has pavement distress comparable to a typical freeway in District 12 with only a few lanes exhibiting major pavement distress. The few, short sections with major pavement distress are located near the I-405 junction in Lake Forest, near SR-73, and at the southern end of the corridor near SR-74. The southern third of the corridor exhibits minor pavement distress as well as a section in the northbound direction near Garden Grove and Santa Ana. The rest of the corridor shows no pavement issues.

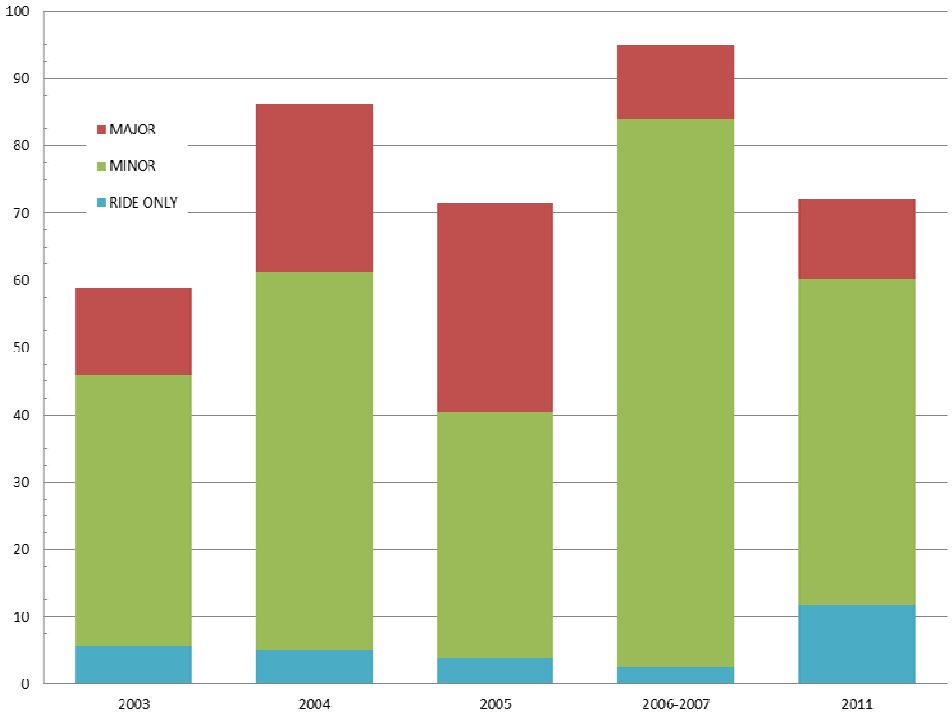
Exhibit 3-51 shows results from prior pavement condition surveys along the study corridor. The number of distressed lane-miles has increased slightly since 2003, but decreased since the last survey in 2006-07. Minor pavement distress has been reduced with a slight increase in ride quality issues. The change in mix of distressed lane-miles is shown more clearly in Exhibit 3-52. Ride quality accounts for a greater proportion of pavement issues in 2011 than in 2006-07. However, minor distress still accounts for most pavement issues along I-5.

Exhibit 3-50: Distressed Lane-Miles on I-5 Corridor (2011)



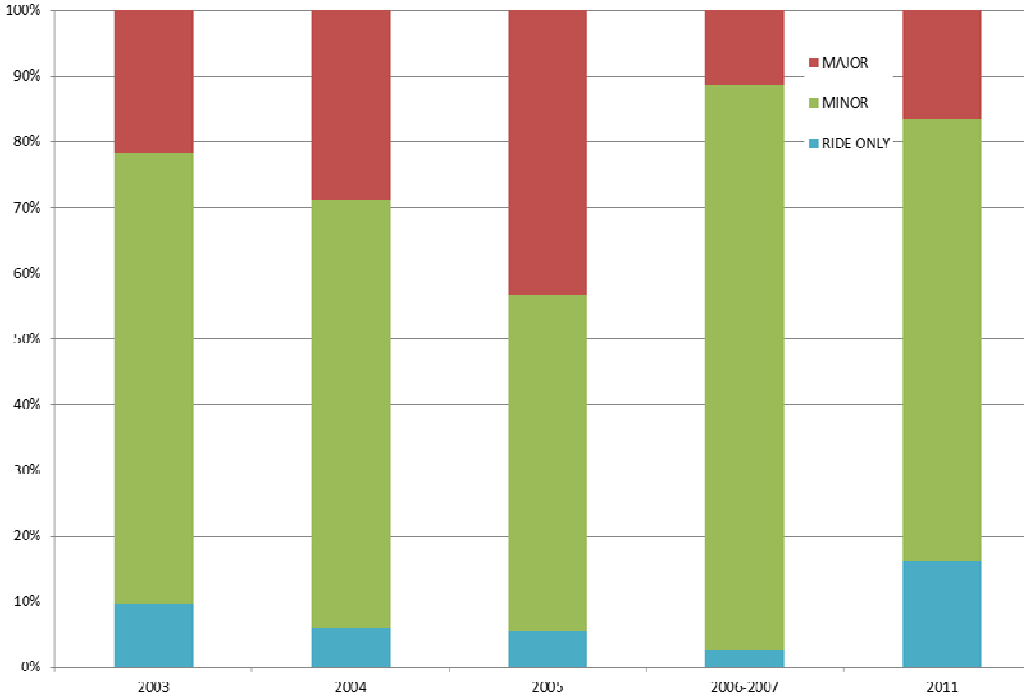
Source: Pavement Condition Survey data

Exhibit 3-51: I-5 Distressed Lane-Miles Trends (2003-2011)



Source: Pavement Condition Survey data

Exhibit 3-52: I-5 Distressed Lane-Miles by Type (2003-2011)



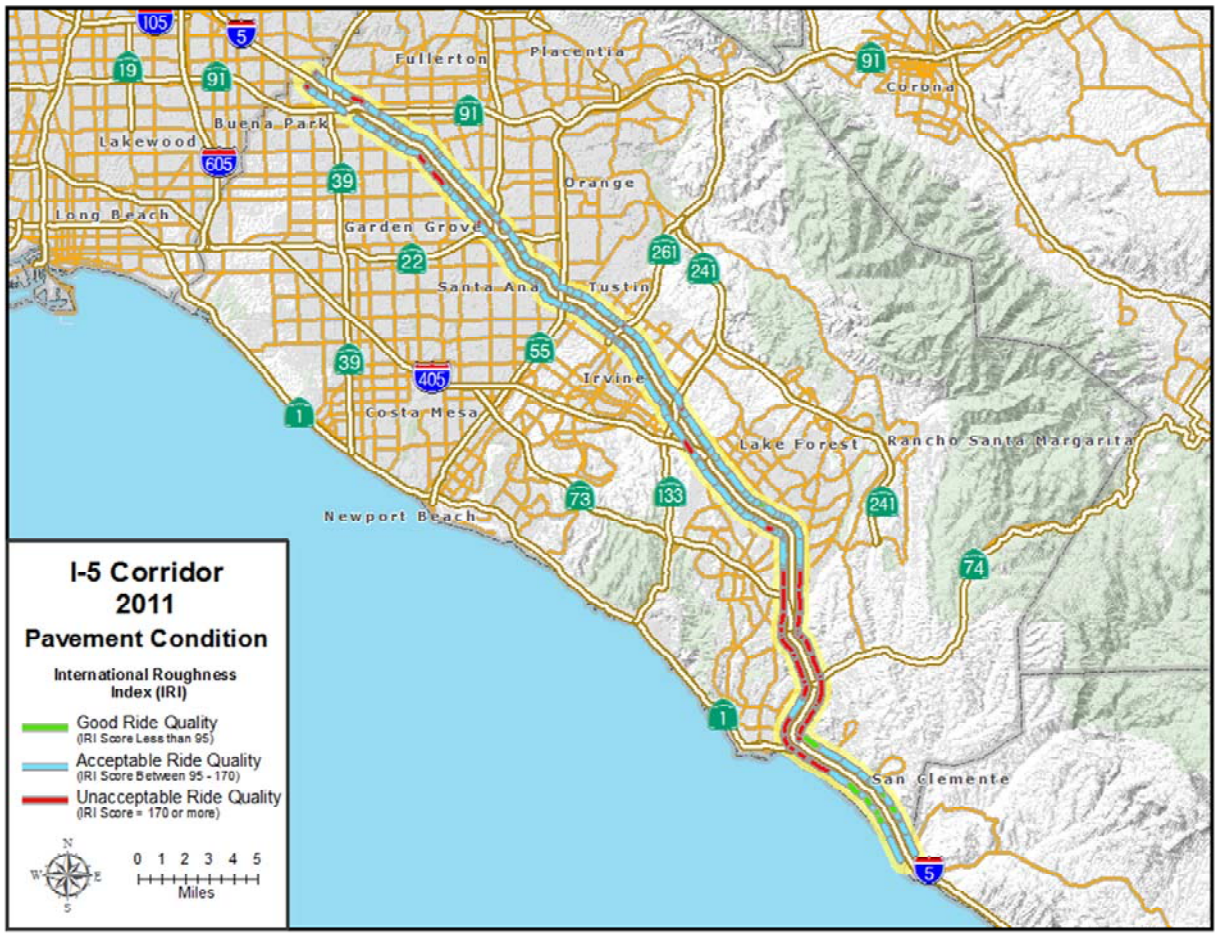
Source: Pavement Condition Survey data

Exhibit 3-53 shows IRI along the study corridor for the lane with the poorest pavement condition in each freeway segment. The poorest pavement conditions are shown in the exhibit because pavement investment decisions are made on this basis. As the exhibit shows, the majority of the corridor has good or acceptable ride quality (IRI less than 170), while the rest of the corridor has ride quality issues (IRI greater than 170).

When the conditions on all lanes are considered, the study corridor comprises roughly 487 lane-miles, of which:

- 131 lane-miles, or 27 percent, are considered to have good ride quality (IRI ≤ 95)
- 306 lane-miles, or 63 percent, are considered to have acceptable ride quality (95 < IRI ≤ 170)
- 50 lane-miles, or 10 percent, are considered to have unacceptable ride quality (IRI > 170)

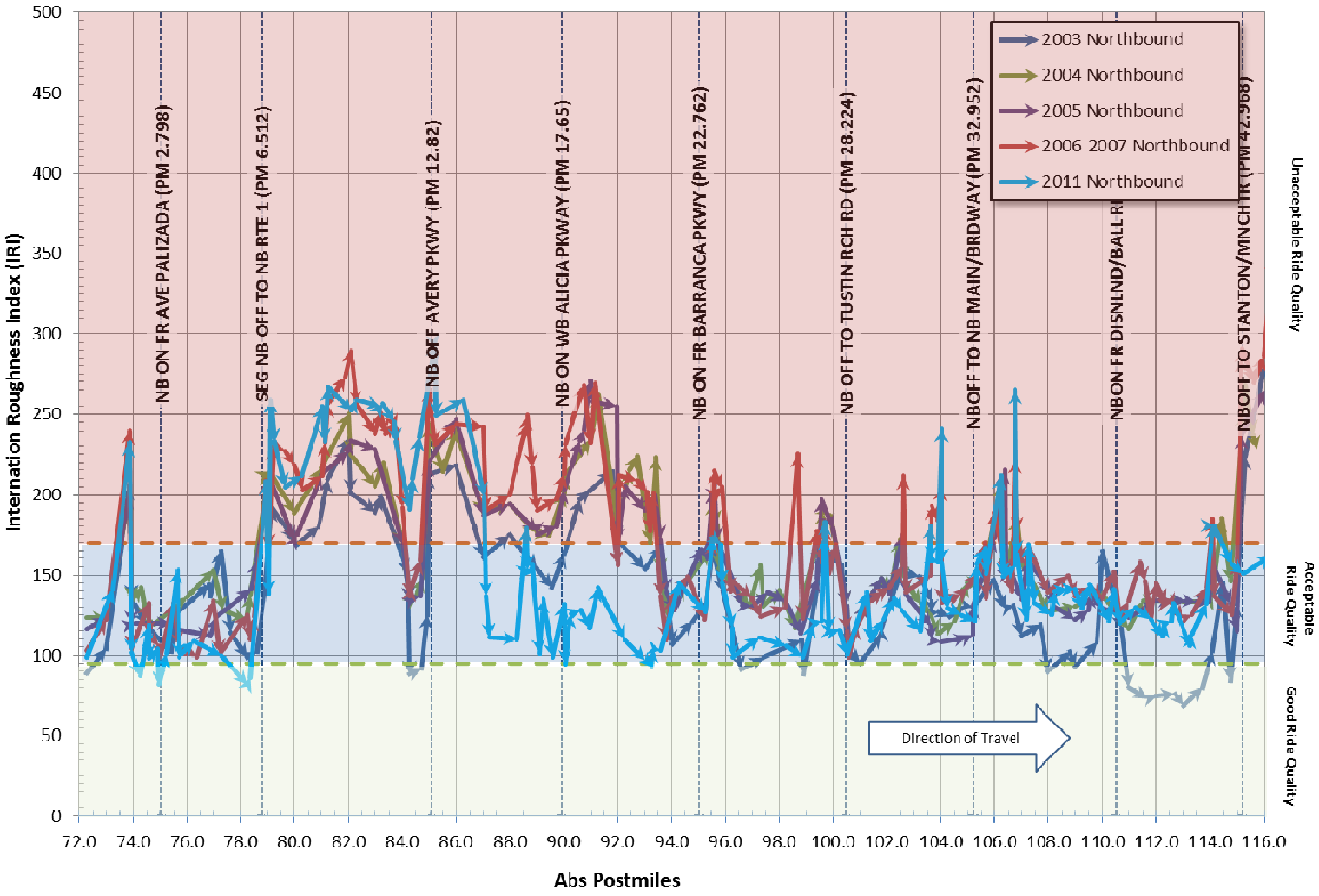
Exhibit 3-53: I-5 Road Roughness (2011)



Source: Pavement Condition Survey data

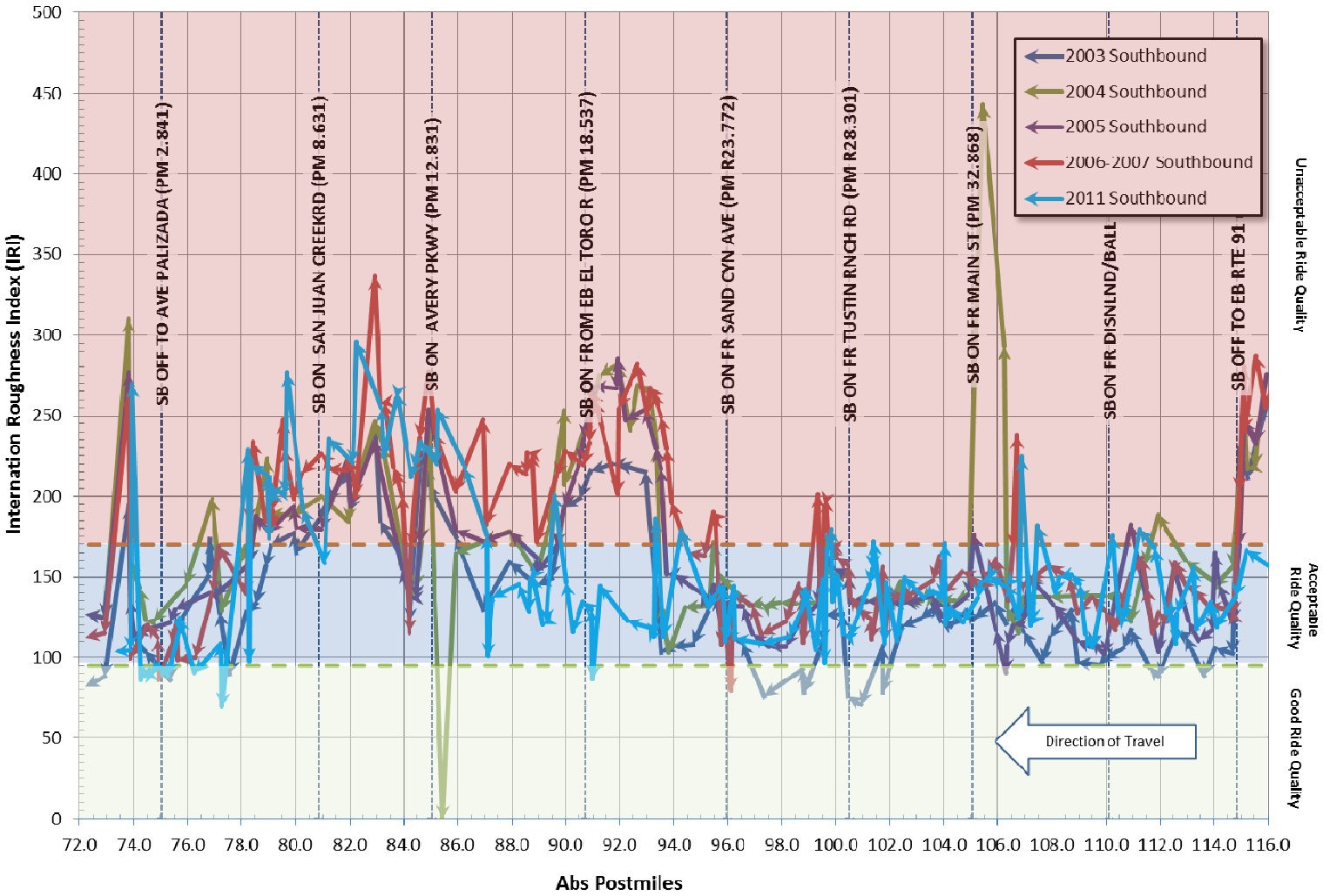
Exhibits 3-54 and 3-55 present ride conditions for the I-5 Corridor using IRI from the last five pavement surveys. The information is presented by Post Mile and direction. The exhibits include color-coded bands to indicate the three ride quality categories defined by Caltrans: good ride quality (green), acceptable ride quality (blue), and unacceptable ride quality (red). The surveys show consistent patterns of good, acceptable, and unacceptable ride quality. Ride quality worsened slightly over several of the surveys, which is expected with the aging of the freeway. However, ride quality has improved in a seven-mile section near Lake Forest since 2006-07.

Exhibit 3-54: Northbound I-5 Road Roughness (2003-2011)



Source: Pavement Condition Survey data

Exhibit 3-55: Southbound I-5 Road Roughness (2003-2011)



Source: Pavement Condition Survey data

4. BOTTLENECK IDENTIFICATION AND PERFORMANCE

Major bottlenecks are the primary cause of congestion and lost productivity. A bottleneck is a location where traffic demand exceeds the effective carrying capacity of the roadway. In most cases, a bottleneck is caused by a sudden reduction in capacity, such as a physical loss when a lane drop occurs or when heavy merging and weaving take place at on and off-ramps. On the demand side, surges in demand, often from on-ramps added to the mainline freeway already at or near the threshold level, can be greater than a roadway can accommodate. In many cases, it is a combination of increased demand and capacity reductions.

Bottlenecks along the Orange County I-5 Corridor were identified and verified based on a variety of data sources, including Caltrans detector data, Caltrans probe vehicle run data, and extensive consultant team field observations and video-taping. Some of the field observations were conducted collaboratively with Caltrans District 12 staff to verify bottlenecks and their causes. 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. Both major and hidden bottlenecks were identified. Hidden bottlenecks are bottlenecks that are hidden by queuing from a downstream bottleneck or by reduced traffic flow from an upstream bottleneck. Although they are hidden bottlenecks, some of them can be major in terms of congestion and delay impacts. The listed specific bottleneck locations were identified and verified. It should be noted that typical of most corridors, the freeway to freeway interchanges either result in or impact many of the bottleneck locations. Exhibits 4-2 and 4-3 are maps showing these bottleneck locations for the AM and PM peak periods, respectively.

Exhibit 4-1: I-5 Bottleneck Locations

Northbound

No.	Major Bottleneck Location	Hidden Bottleneck Location	Active Period		Post Mile	
			AM	PM	Abs	CA
NB1A		Avenida Pico	✓		75.8	3.6
NB1	Ave Vista Hermosa		✓	☑	76.5	4.2
NB2	Camino Las Ramblas		✓		79.2	6.9
NB3A		Crown Valley On	✓	☑	86.2	13.9
NB3	Oso Pkwy On		✓	☑	87.6	15.4
NB4B		La Paz On	✓		89.0	16.7
NB4A		Alicia Pkwy On	✓		89.9	17.7
NB4	El Toro On		✓	☑	91.1	18.8
NB5E		Sand Canyon On		✓	96.4	24.1
NB5D		Jeffrey On		✓	97.5	25.2
NB5C		Jamboree On		✓	100.0	27.7
NB5B		Tustin Ranch On		✓	100.7	28.4
NB5A		Red Hill/Newport On		✓	101.5	29.2
NB5	NB-55 Off		☑	✓	102.3	30.0
NB6C		NB-55 On		✓	102.9	30.6
NB6B		4th On		✓	103.5	31.2
NB6A		Grand Off		✓	103.9	31.6
NB6	17th Street On			✓	104.9	32.6
NB7A		SR-22 Off (Main St)		✓	105.5	33.2
NB7	Anaheim On			✓	108.9	36.6
NB8A		Ball Road		✓	110.0	37.7
NB8	Los Angeles County		✓	✓	116.6	44.4

Southbound

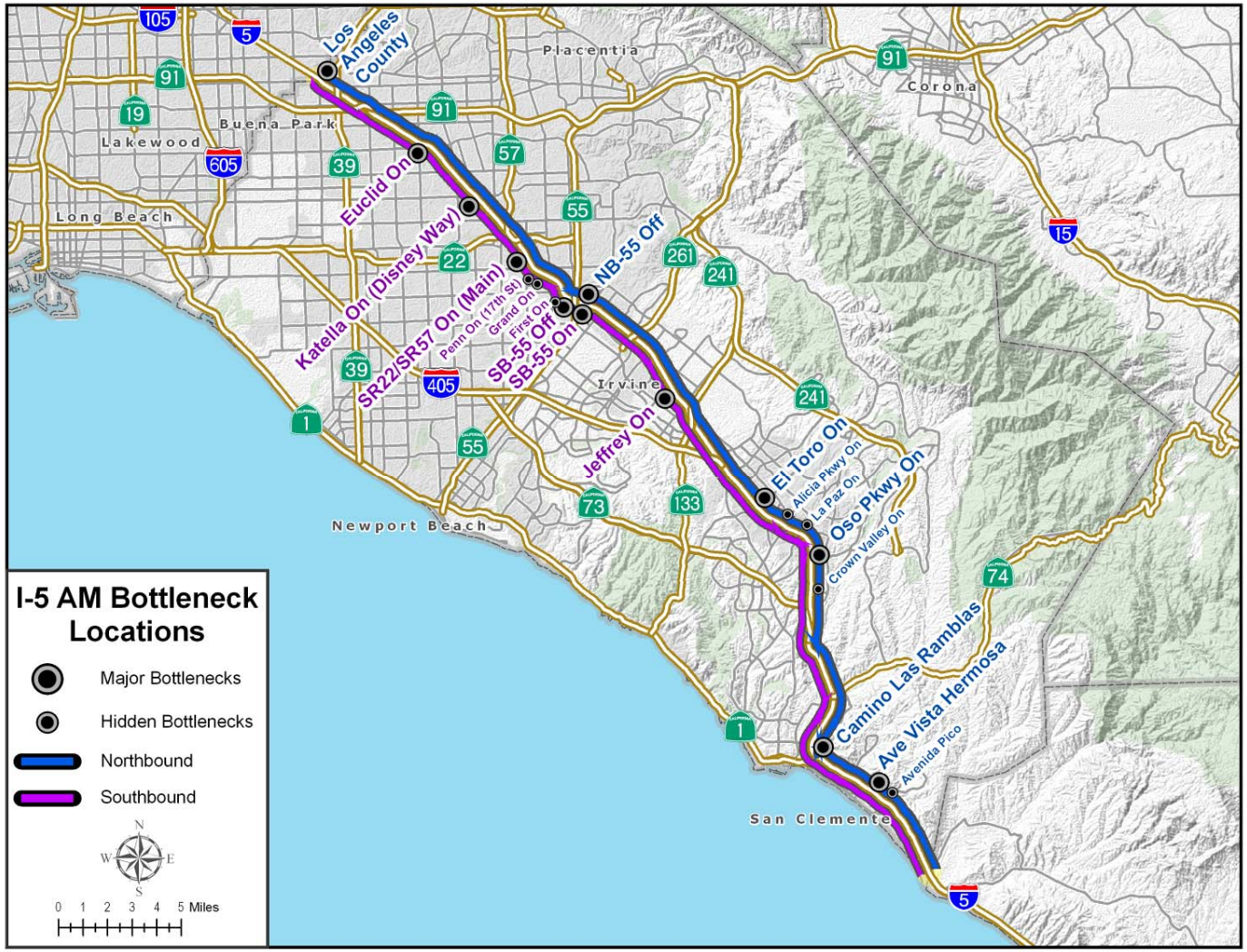
No.	Major Bottleneck Location	Hidden Bottleneck Location	Active Period		Post Mile	
			AM	PM	Abs	CA
SB1	Euclid On		✓		111.4	39.2
SB2	Katella On (Disney Way)		✓		108.5	36.3
SB3	SR22/SR57 On (Main)		✓	☑	105.4	33.2
SB4C		Penn On (17th St)	✓	☑	104.5	32.3
SB4B		Grand On	✓		104.1	31.9
SB4A		First On	✓		103.0	30.8
SB4	SB-55 Off		✓	☑	102.6	30.4
SB5	SB-55 On		✓	☑	101.8	29.6
SB6	Jeffrey On		✓		96.9	24.7
SB7A		SR-133		✓	95.1	22.9
SB7	SB-405 On			✓	92.9	20.7
SB8B		Truck Bypass On		✓	92.4	20.2
SB8A		Lake Forest On		✓	91.9	19.7
SB8	El Toro On			✓	90.7	18.5
SB9	Alicia Parkway Off			✓	89.8	17.6
SB10	Oso Parkway On			✓	87.2	15.0

Notes:

✓ Primarily active during this peak period

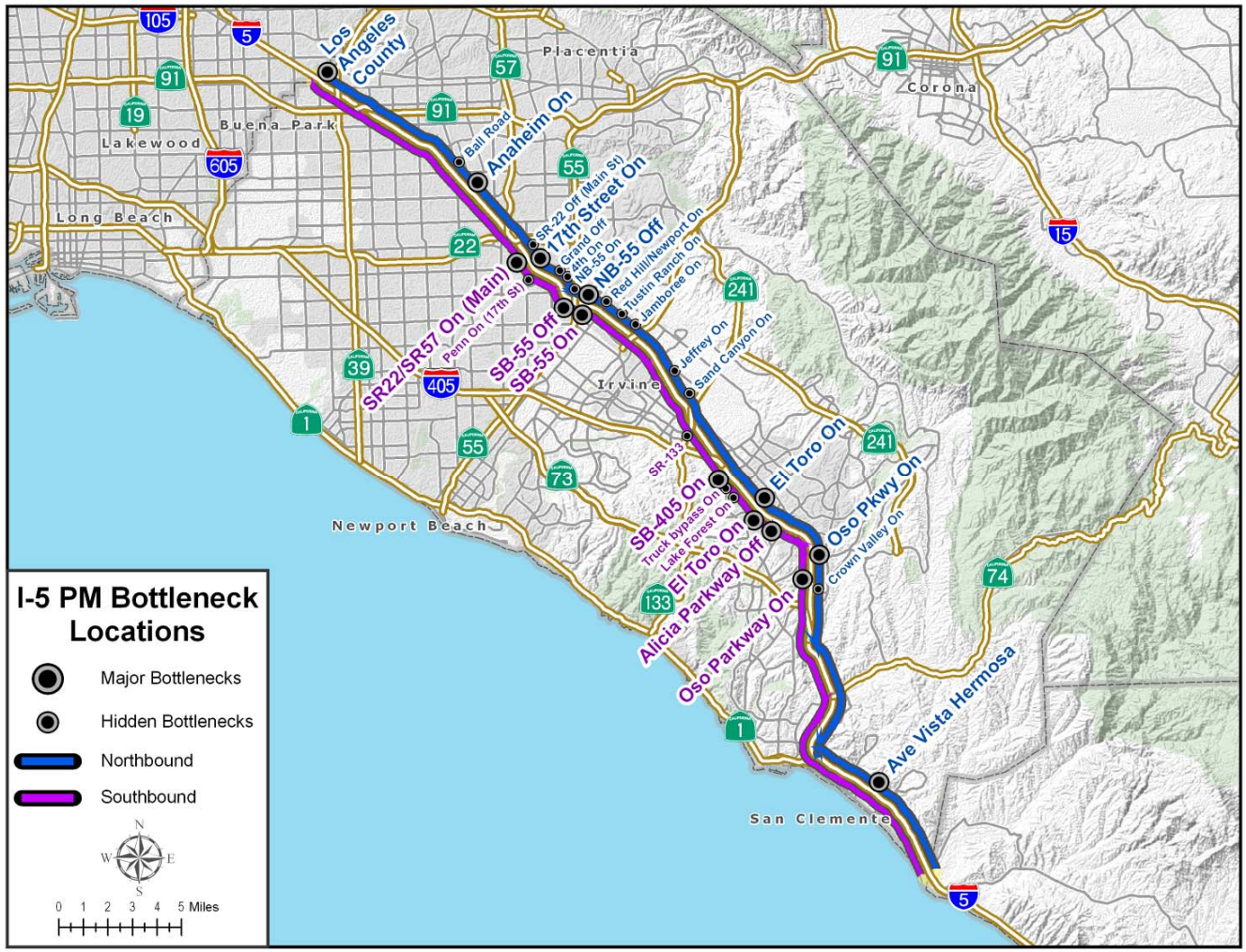
☑ To a lesser extent, bottleneck also occurs during this peak period

Exhibit 4-2: Map of AM Bottlenecks



Source: System Metrics Group, Inc. analysis

Exhibit 4-3: Map of PM Bottlenecks



Source: System Metrics Group, Inc. analysis

Bottleneck Identification

Caltrans detector data and probe vehicle runs using GPS technology are two major sources used to identify potential bottlenecks prior to field visits. The study team downloaded detector data from the Caltrans Performance Measurement System (PeMS) 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 graphs. Unlike the probe vehicle runs, 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 also 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, the two sets of graphs identify similar problem areas. These speed plots are then compiled at five minute intervals and presented in speed contour plots.

<u>Northbound I-5 Mainline Facility</u>

Speed contour and profile plots were analyzed for different mid-weekdays in November 2010 and in June 2011. Aggregate average speed contours of weekdays in November 2010 and June 2011 were also examined.

Exhibit 4-4 illustrates the speed contour plots for a sample midweek day in November 2011 and an aggregate average of November 2010 weekdays used to analyze the northbound direction of the corridor (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 San Diego County Line to the Los Angeles County Line.

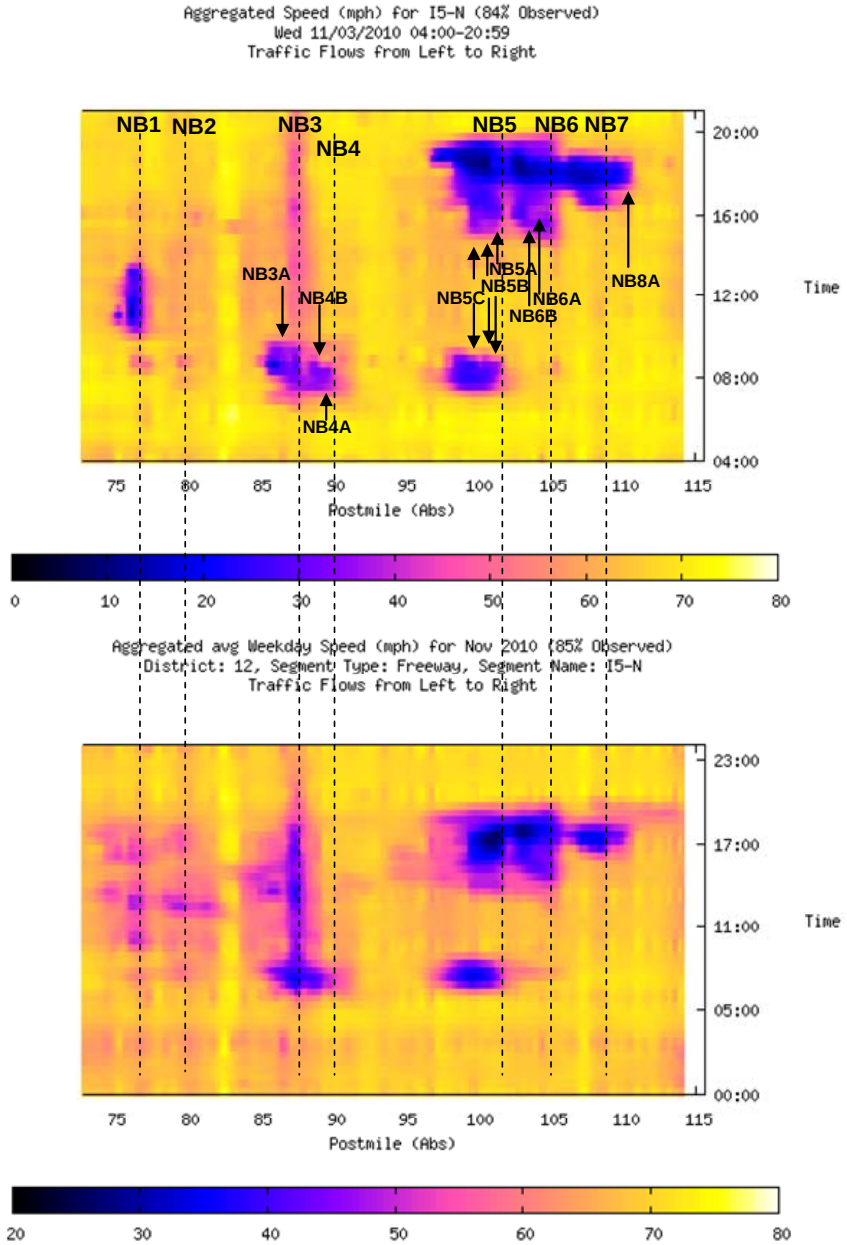
The dark blue spots indicate slow speeds and congestion. The vertical dotted lines identify the actual bottleneck location, which is currently labeled with a bottleneck number as listed in Exhibit 4-1. There are seven major bottleneck locations (labeled NB1 to NB7) and a number of minor or hidden bottlenecks (hidden from major downstream bottleneck congestion and queuing).

The last major bottleneck (NB8) occurs downstream of the Los Angeles County Line due to lane drops approaching the Carmenita Road Interchange, in Los Angeles County, which often queues back to Orange County. The most significant major bottleneck occurs at the SR-55 Interchange. This bottleneck and congestion occurs during both the AM and PM peak periods. The congestion queues extend as far back

as Sand Canyon Interchange, a distance of nearly six miles, during most of the PM peak period and lasts over five hours, from 3:00 PM to 8:00 PM.

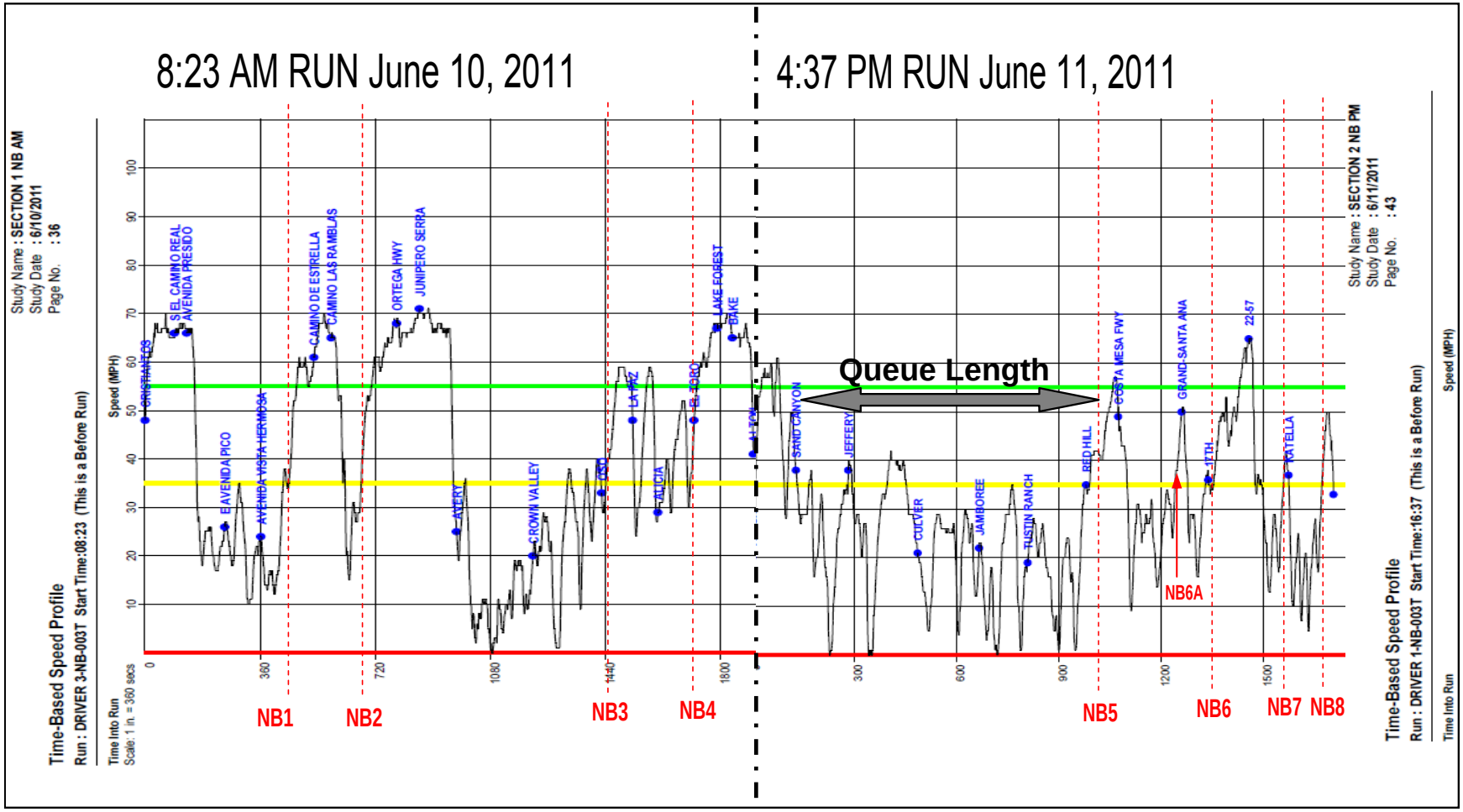
Exhibit 4-5 illustrates the speed profile plots, from probe vehicle runs conducted in June 2011 using GPS technology. As shown, the first half is from the probe vehicle run conducted on June 10, 2011 in the AM peak period, starting at 8:23 AM. The second half is from the probe vehicle run conducted on June 11, 2011 in the PM peak period, starting at 4:37 PM. The same major bottleneck locations identified in the previous exhibit have also been confirmed with this source. Not all of the minor or hidden bottleneck locations are identified here as these runs were only one sample run in the AM peak period and one sample run in the PM peak period.

Exhibit 4-4: Northbound I-5 Speed Contour Plots (November 2010)



Source: Caltrans Performance Measurement System (PeMS) data

Exhibit 4-5: Northbound I-5 Speed Profile Plots (June 2011)



Source: SMG probe vehicle run data

Southbound I-5 Mainline Facility

Speed contour and profile plots were also analyzed for different mid-weekdays in November 2010 and in June 2011 for the southbound direction. Aggregate average speed contours for weekdays in November 2010 and June 2011 were also examined.

Exhibit 4-6 illustrates the speed contour plots for a sample midweek day in November 2011 and an aggregate average of November 2010 weekdays used to analyze the southbound direction of the corridor (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 Los Angeles County Line to the San Diego County Line.

Again, the dark blue blotches indicate slow speeds and congestion. The vertical dotted lines identify the actual bottleneck location, which is currently labeled with a bottleneck number as listed in Exhibit 4-1. Exhibit 4-6 identifies ten major bottleneck locations (labeled SB1 to SB10) and a number of minor or hidden bottlenecks (hidden from major downstream bottleneck congestion and queuing).

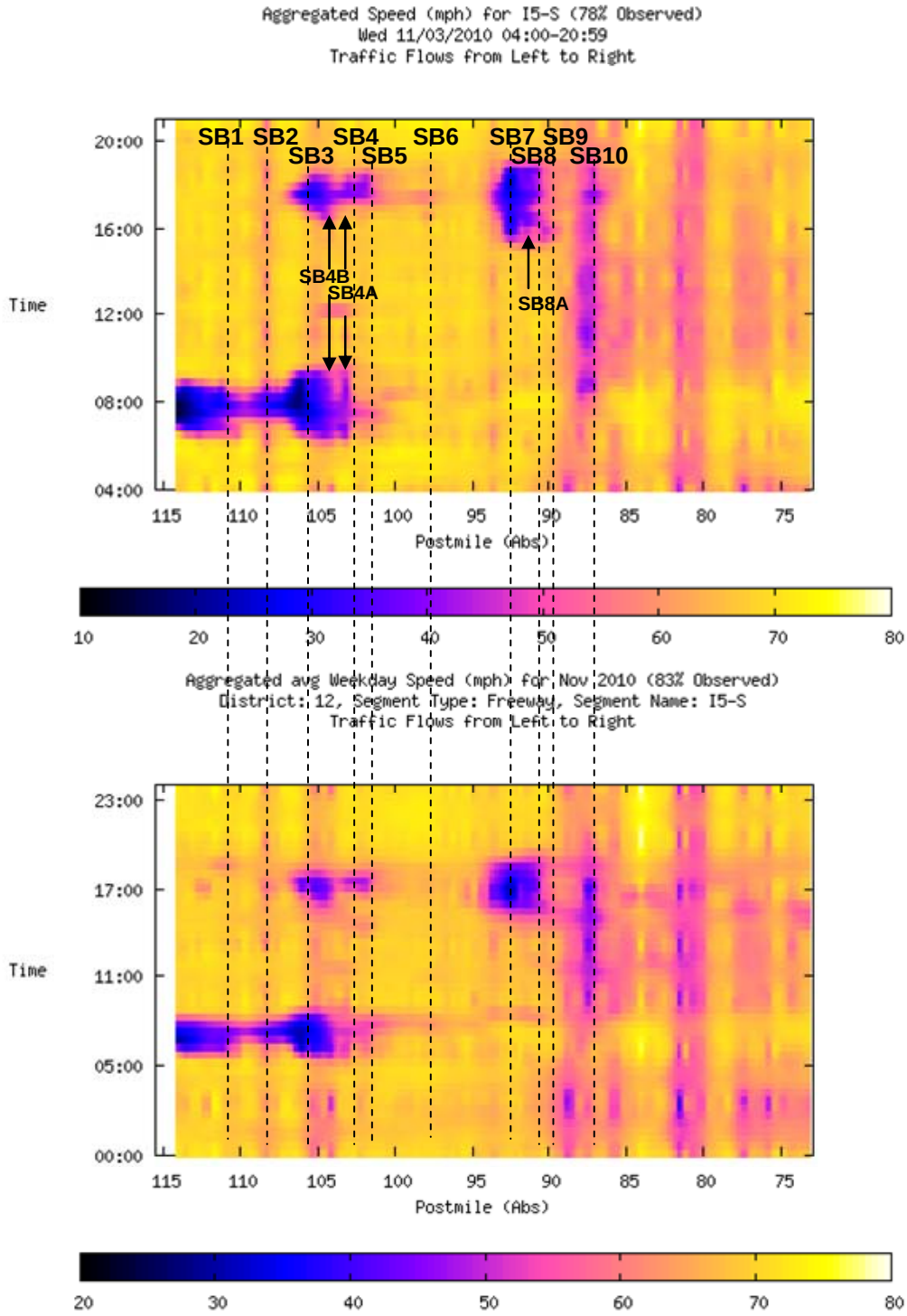
Like the northbound direction, the most significant major bottleneck occurs at the SR-55 Interchange. This bottleneck occurs during both the AM and PM peak periods. The congestion queues extend as far back as Los Angeles County Line, a distance of over 14 miles, during most of the AM peak period and lasts over 4 hours, from 6:00 AM to 10:00 AM.

Exhibit 4-7 illustrates the speed profile plots from probe vehicle runs conducted in June 2011 using GPS technology. As shown, the first half is from the probe vehicle run conducted on June 11, 2011 in the AM peak period, starting at 6:45 AM. The second half is from the probe vehicle run conducted on June 10, 2011 in the PM peak period, starting at 4:26 PM. The same major bottleneck locations (SB3, SB4, SB7, SB8, and SB9), identified previously (Exhibit 4-6) were also confirmed with this source. Not all of the bottleneck locations are identified here as these runs were only one sample run in the AM peak period and one sample run in the PM peak period. Many of the bottlenecks begin and end at different times of the day. For example, the bottleneck at Katella (SB2) is not likely to appear until after 7:00 AM.

Extensive detector data analysis of other days indicated the same bottlenecks for both northbound and southbound directions. The study team conducted numerous field visits in June and July 2011 to observe corridor conditions. Potential bottleneck locations identified from the data analysis were verified by both driving through the corridor during congested times of the day and by observing the traffic from vantage points such as overcrossings. Most of the bottlenecks that were videotaped were reviewed in the office to confirm the bottleneck locations and to identify their causes. Additional field visits were also conducted with Caltrans District 12 staff, which has

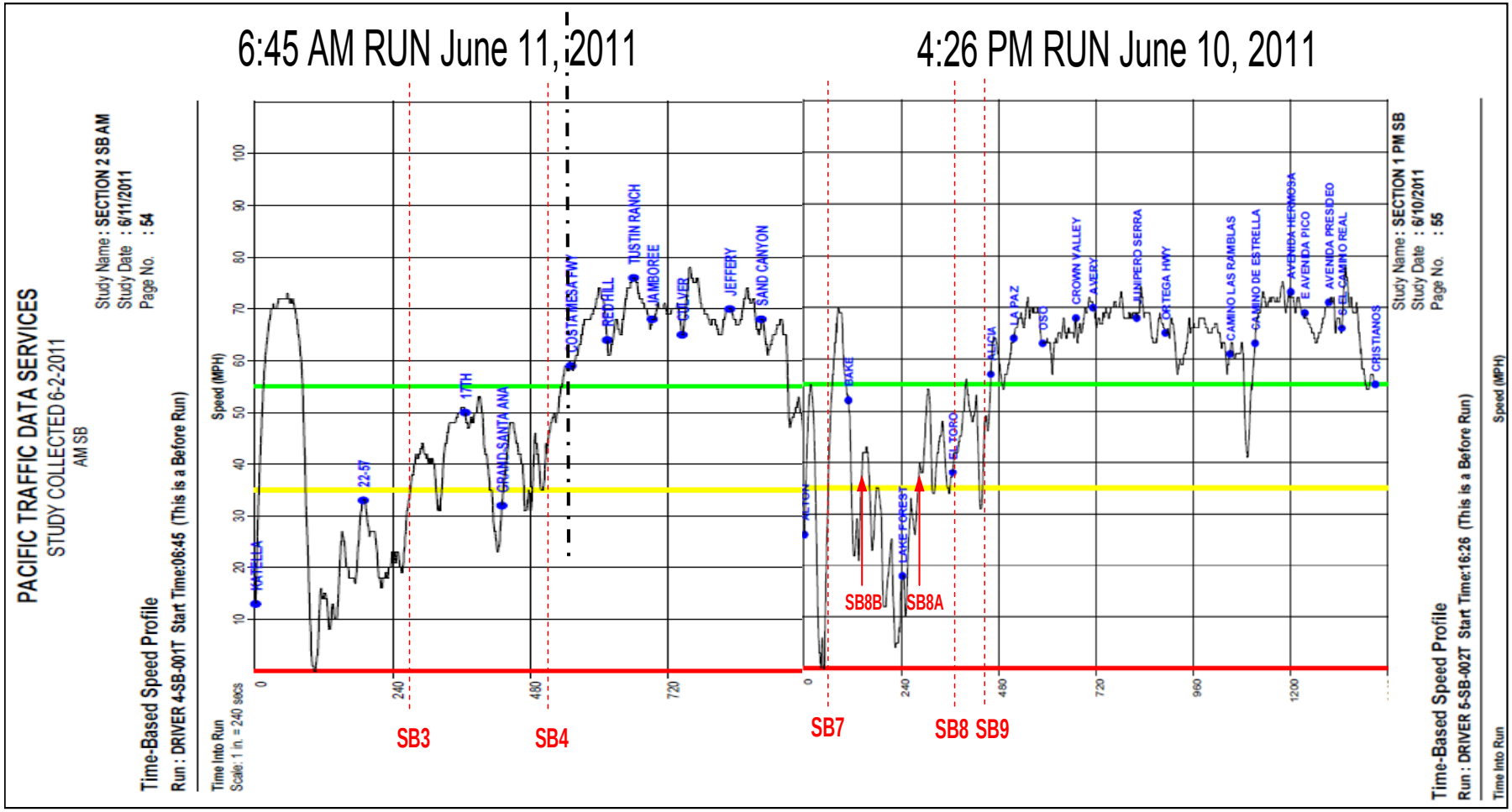
extensive corridor knowledge and experience to review and scrutinize the bottleneck locations identified.

Exhibit 4-6: Southbound I-5 Speed Contour Plots (November 2010)



Source: Caltrans Performance Measurement System (PeMS) data

Exhibit 4-7: Southbound I-5 Speed Profile Plots (June 2011)



Source: System Metrics Group, Inc. probe vehicle run data

I-5 High Occupancy Vehicle (HOV) Facility

Bottlenecks were also identified and verified for both directions of the HOV lane, using primarily Caltrans detector data, field observations, and video-taping. Caltrans PeMS speed contour plots show speeds for every detector location along the corridor for every five-minute period throughout the day. The resulting plot shows the location, extent, and duration of congestion. PeMS speed profile plots provide speeds across the corridor at a particular time of day. Where congested speeds fall below 35 miles per hour and then increase up over 45 miles per hour typically indicate a bottleneck location. Exhibit 4-8 summarizes the bottleneck locations identified on the HOV facility.

Exhibit 4-8: Orange County I-5 HOV Lanes Bottleneck Locations

Northbound

No.	Bottleneck Location	Active Period		To (At)	
		AM	PM	Abs	CA
HOVNB1	Crown Valley Pkwy	✓		86.2	13.9
HOVNB2	Oso Pkwy	✓		87.6	15.4
HOVNB3	Sand Canyon Avenue		✓	96.4	24.1
HOVNB4	Jeffrey Road		✓	97.5	25.2
HOVNB5	Jamboree Road		✓	100.0	27.7
HOVNB6	Red Hill/Newport Ave		✓	101.5	29.2
HOVNB7	NB-55 Off		✓	102.3	30.0
HOVNB8	NB-55 On		✓	102.9	30.6
HOVNB9	4th Street		✓	103.5	31.2
HOVNB10	Grand Avenue		✓	103.9	31.6
HOVNB11	17th Street		✓	104.6	32.4
HOVNB12	Broadway		✓	105.6	33.4

Southbound

No.	Bottleneck Location	Active Period		To (At)	
		AM	PM	Abs	CA
HOVSB1	SR57 On	✓	☑	106.3	34.1
HOVSB2	Jeffrey Road		✓	96.9	24.7
HOVSB3	I-405 On		✓	92.9	20.7
HOVSB4	El Toro Road		✓	90.7	18.5
HOVSB5	Crown Valley		✓	85.8	13.6

NOTES:

Causality was verified with multiple field observations and video taping during July 2011.

✓ Primarily active during this peak period

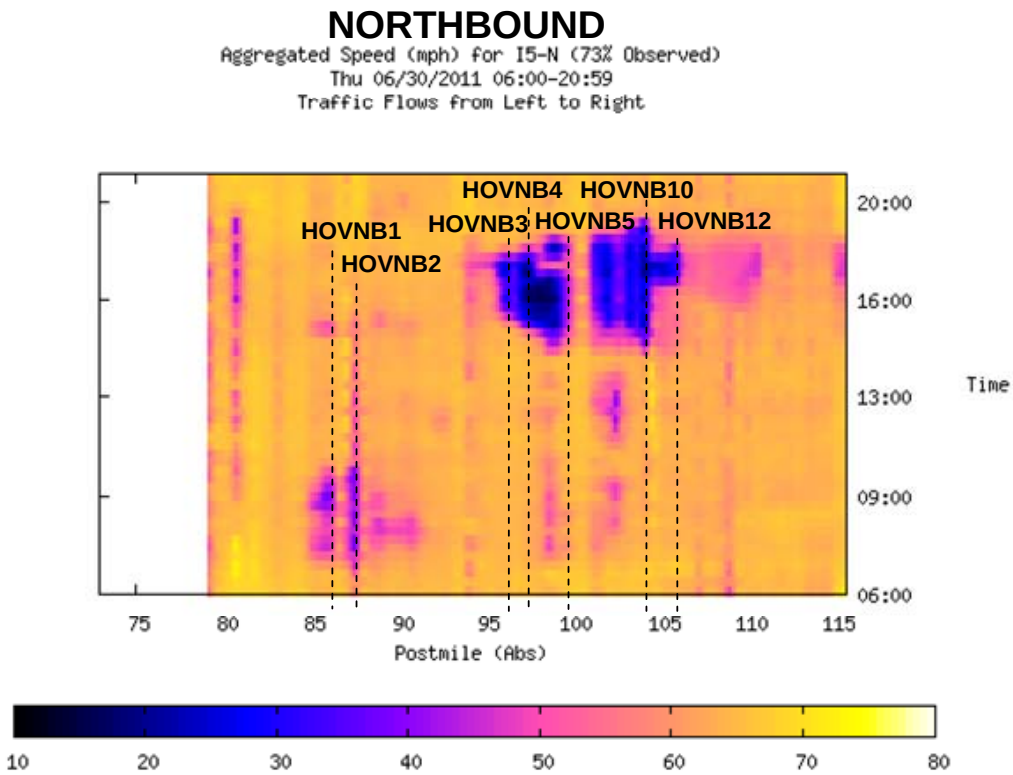
☑ Less active but also occurs during this peak period

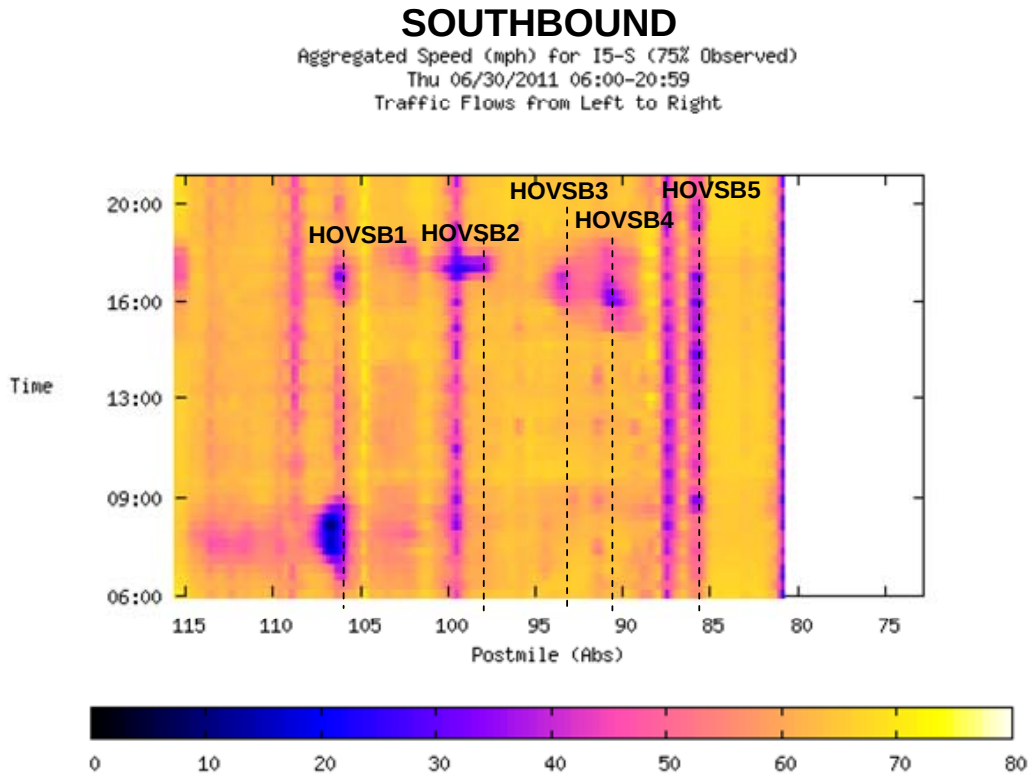
Speed contour and profile plots were analyzed for different mid-weekdays in November 2010 and in June 2011. Aggregate average speed contour of weekdays of November 2010 and June 2011 were also examined.

Exhibit 4-9 illustrates the speed contour plots for a sample midweek day in November 2011 and an aggregate average of November 2010 weekdays used to analyze both northbound and southbound directions of the HOV lane (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.

As shown in Exhibit 4-9, the dark blue blotches indicate slow speeds and congestion. The vertical dotted lines identify the actual bottleneck location, which is currently labeled with a bottleneck number as listed in Exhibit 4-8. As presented, there are 12 major bottleneck locations (labeled HOVNB1 to HOVNB12) in the northbound direction and five major bottleneck locations (labeled HOVSB1 to HOVSB5) in the southbound direction. The most significant major bottleneck in the northbound direction occurs at the Grand Avenue Interchange, where the two HOV lanes merge into one. This bottleneck and congestion occurs primarily during the PM peak period. The congestion queues can extend as far back as the Sand Canyon Interchange, a distance of over eight miles that lasts over five hours, from 3:00 PM to 8:00 PM. The most significant major bottleneck in the southbound direction occurs at the SR-57 Interchange, where the HOV lane from SR-57 merges into the I-5 HOV lane. This bottleneck and congestion occurs during both the AM and PM peak period, but is most prevalent during the AM peak period, where queues can extend as far back as three miles and lasts about three hours from 6:00 AM to 9:00 AM.

Exhibit 4-9: Northbound & Southbound I-5 HOV Lanes Speed Contour Plots





Source: Caltrans Performance Measurement System (PeMS) data

Weekend Bottleneck Identification Analysis Summary

Similar to the analysis of the weekend performance measures, bottleneck identification analysis was also conducted for weekend days. The study team downloaded Caltrans detector data from PeMS to conduct the weekend bottleneck analysis and produced various speed contour plots. 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 contour plots were analyzed for different weekend days in November 2010 for the northbound and southbound mainline facility. Aggregate average speed contours of weekends in November 2010 were also examined.

Exhibits B-31 and B-32 in Appendix B illustrate the speed contour plots for a sample weekend day in November 2011 and an aggregate average of November 2010 weekends used to analyze the corridor.

The analysis results indicate that essentially the same bottlenecks appear on the weekend days as the weekdays, only fewer and with less congestion, for either direction. There was no noticeable new bottleneck, either in the data analysis or in the field observations, in the weekend days that did not appear in the weekdays.

Bottleneck Area Analysis

Once the bottlenecks were identified, the corridor is divided into “bottleneck areas.” A bottleneck area is a segment of the corridor between two major bottleneck locations, not to be confused with queue lengths. Queue lengths are often shorter and within a bottleneck area, but can often extend to or past the next bottleneck area.

By segmenting the corridors into bottleneck areas, some performance statistics that were presented earlier for the entire corridor can be segmented by bottleneck area. This way, the relative contribution of each bottleneck area to the degradation of corridor performance can be gauged. The performance statistics that lend themselves to such segmentation include: delay, safety, and productivity.

The analysis of bottleneck areas is based on 2010 data and is limited to the mainline facility since the mainline has greater detection coverage than the HOV facility. Exhibit 4-10 illustrates the general concept of bottleneck areas. The red lines in the exhibit represent the bottleneck locations and the arrows represent the bottleneck areas. The shaded area represents the congestion and an illustrative queue behind each bottleneck.

Dividing the corridor into bottleneck areas makes it easier to compare the various segments of the freeway with each other. Based on the above, the major bottlenecks previously identified in Exhibit 4-1 are shown again in Exhibits 4-11 and 4-12 with the associated bottleneck areas.

Exhibit 4-10: Dividing a Corridor into Bottleneck Areas

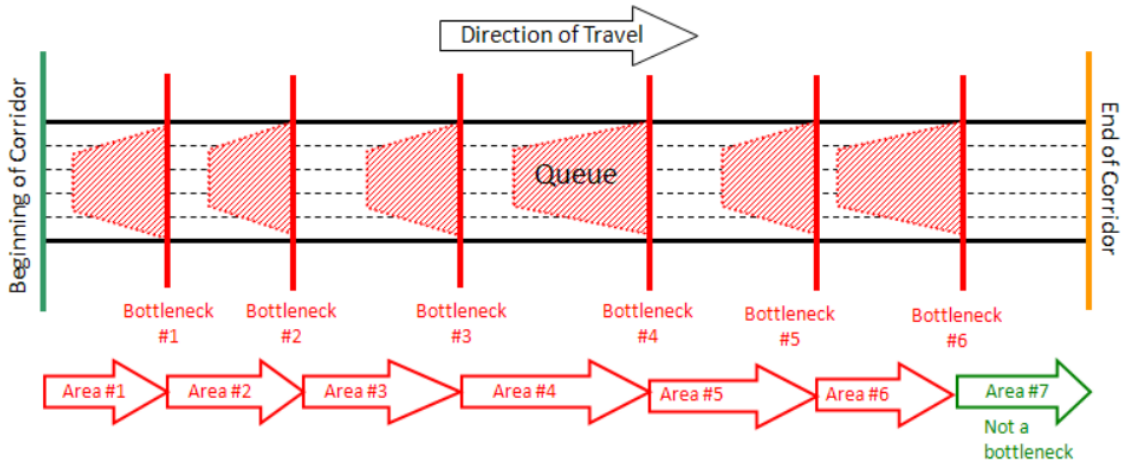


Exhibit 4-11: Orange County I-5 Bottleneck Areas

Northbound

Major Bottleneck Location	Bottleneck Area (Segment between Major Bottlenecks)	Active Period		From		To (At)		Distance (miles)
		AM	PM	Abs	CA	Abs	CA	
Ave Vista Hermosa	San Diego County Line to Ave Vista Hermosa	✓	☑	72.3	0.0	76.5	4.2	4.2
Camino Las Ramblas	Ave Vista Hermosa to Camino Las Ramblas On	✓		76.5	4.2	79.2	6.9	2.7
Oso Pkwy On	Camino Las Ramblas On to Oso Parkway On	✓	☑	79.2	6.9	87.6	15.4	8.5
El Toro On	Oso Parkway On to El Toro On	✓	☑	87.6	15.4	91.1	18.8	3.4
SR-55 Off	El Toro On to SR-55 Off	☑	✓	91.1	18.8	102.3	30.0	11.2
17th Street On	SR-55 Off to 17th Street On		✓	102.3	30.0	104.9	32.6	2.6
Anaheim On	17th Street On to Anaheim On		✓	104.9	32.6	108.9	36.6	4.0
Los Angeles County	Anaheim On to Los Angeles County	✓	✓	108.9	36.6	116.6	44.4	7.8

Southbound

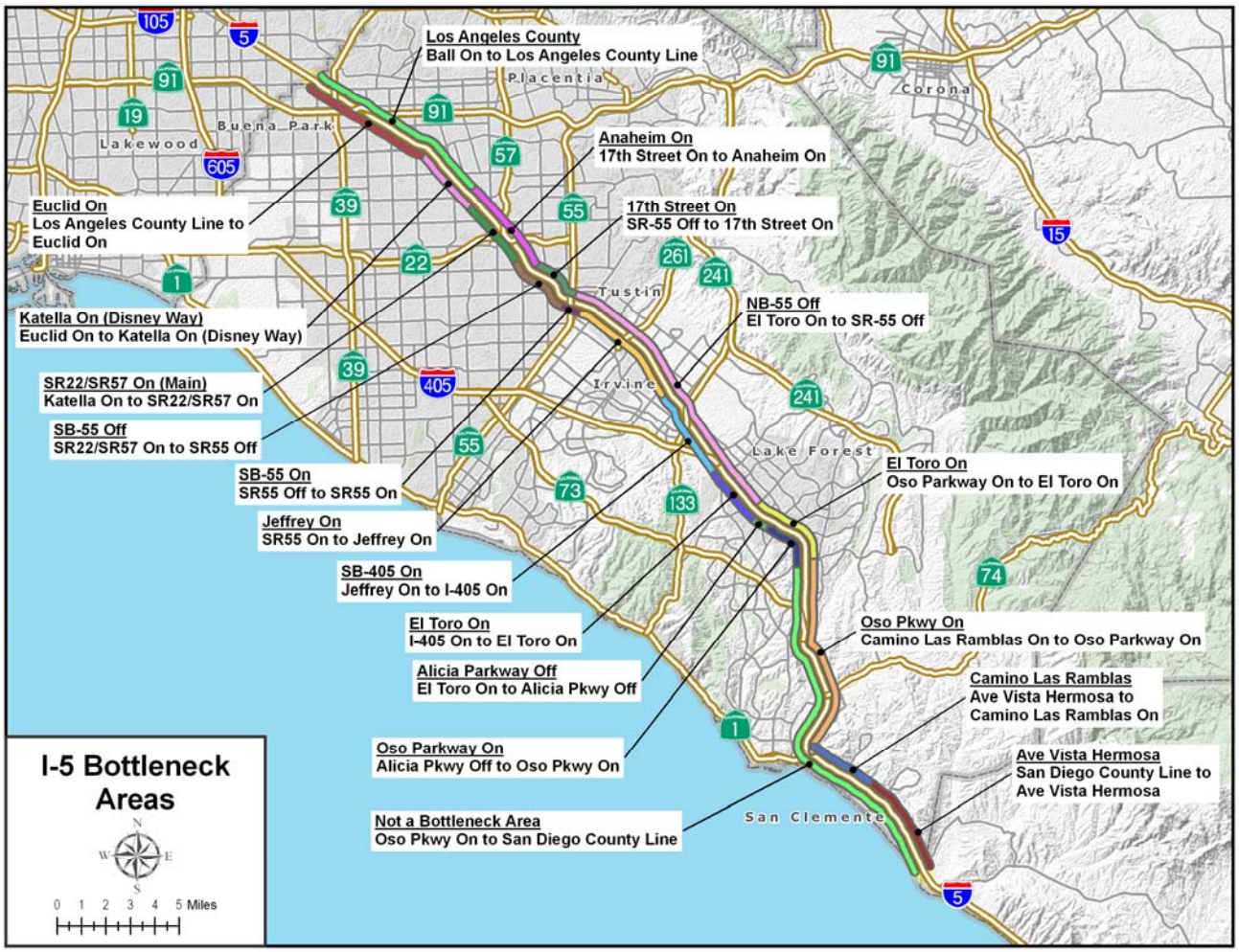
Major Bottleneck Location	Bottleneck Area (Segment between Major Bottlenecks)	Active Period		From		To (At)		Distance (miles)
		AM	PM	Abs	CA	Abs	CA	
Euclid On	Los Angeles County Line to Euclid On	✓		116.6	44.4	111.4	39.2	5.2
Katella On (Disney Way)	Euclid On to Katella On	✓		111.4	39.2	108.5	36.3	2.9
SR22/SR57 On (Main)	Katella On to SR22/SR57 On	✓	☑	108.5	36.3	105.4	33.2	3.1
SB-55 Off	SR22/SR57 On to SB-55 Off	✓	☑	105.4	33.2	102.6	30.4	2.8
SB-55 On	SB-55 Off to SB-55 On	✓	☑	102.6	30.4	101.8	29.6	0.8
Jeffrey On	SB-55 On to Jeffrey On	✓		101.8	29.6	96.9	24.7	4.9
SB-405 On	Jeffrey On to SB-405 On		✓	96.9	24.7	92.9	20.7	4.0
El Toro On	SB-405 On to El Toro On		✓	92.9	20.7	90.7	18.5	2.2
Alicia Parkway Off	El Toro On to Alicia Pkwy Off		✓	90.7	18.5	89.8	17.6	0.9
Oso Parkway On	Alicia Pkwy Off to Oso Pkwy On		✓	89.8	17.6	87.2	15.0	2.6
None	Oso Pkwy On to San Diego County Line			87.2	15.0	72.3	0.0	15.0

Notes:

✓ Primarily active during this peak period

☑ To a lesser extent, bottleneck also occurs during this peak period

Exhibit 4-12: Map of Orange County I-5 Bottleneck Areas



Source: System Metrics Group, Inc.

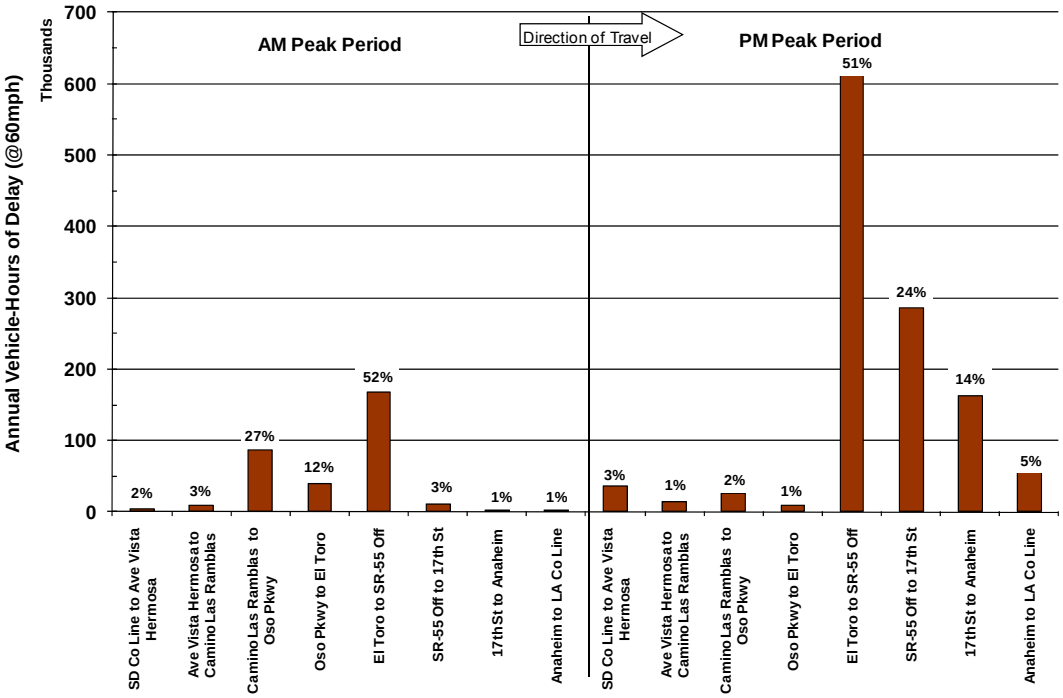
MOBILITY BY BOTTLENECK AREA

Mobility describes how efficiently the corridor moves vehicles. To evaluate how well (or poorly) each bottleneck area moves vehicles, vehicle-hours of delay were calculated for each segment. The results reveal the areas of the corridor that experience the worst mobility.

Exhibits 4-13 and 4-15 illustrate the vehicle-hours of delay experienced by each bottleneck area. As depicted in Exhibit 4-13, delay in the northbound direction is concentrated in the PM peak with almost three times more total delay than the AM peak. The segment between El Toro and SR-55 experienced the greatest delay during both AM and PM peaks with a little over half of the corridor's delay. This is expected

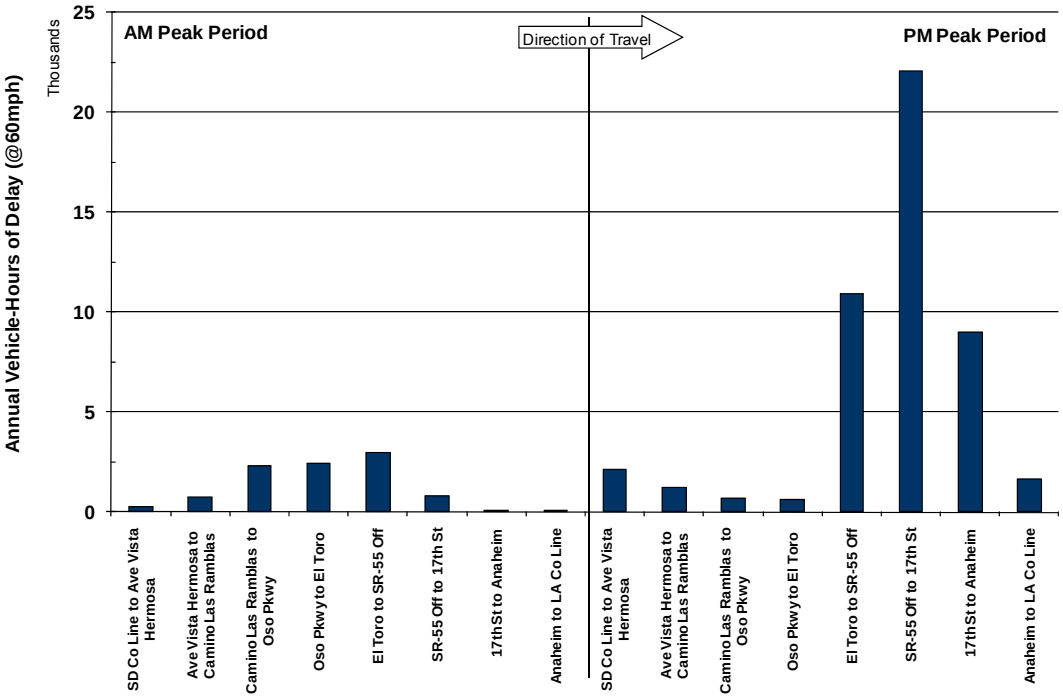
given that this segment is the longest in distance with sub-segment areas that experience demand and capacity imbalances. During the PM peak, the segments from SR-55 to 17th Street also experienced high levels of delay at just under 300,000 annual vehicle-hours of delay each, or 24 percent of the delay on the corridor. Unlike the northbound direction, delay in the southbound direction is spread more evenly between peak periods. Exhibit 4-15 shows that the segment from the Los Angeles County Line to Euclid Avenue experienced the greatest delay during the AM peak with slightly under 140,000 annual vehicle-hours of delay. During the PM peak, the segment from I-405 to El Toro Road experienced the greatest delay with 42 percent of the corridor's delay, or over 245,000 vehicle-hours of delay.

Exhibit 4-13: Northbound I-5 Annual Vehicle-Hours of Delay (2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

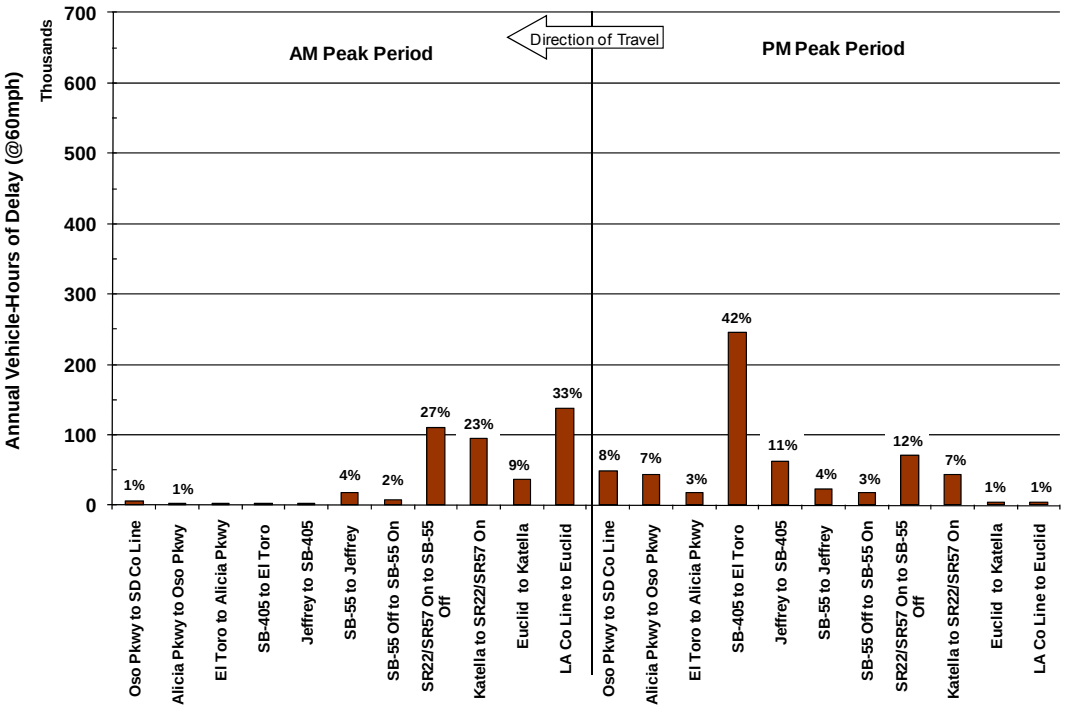
Exhibit 4-14: Northbound I-5 Delay per Lane-Mile (2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

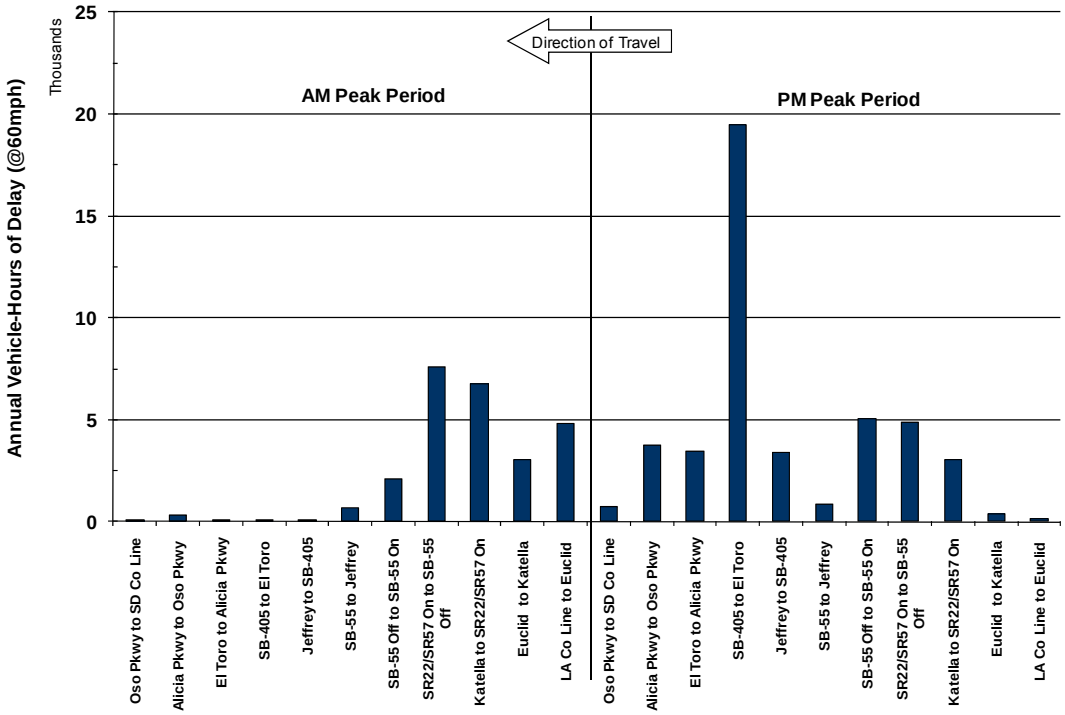
Exhibits 4-14 and 4-16 have been normalized to reflect delay per lane-mile. The delay calculated for each bottleneck area was divided by the total lane-miles for each bottleneck area to obtain delay per lane-mile. The results of these exhibits differ slightly from Exhibits 4-13 and 4-15. In the northbound direction, the segment from SR-55 to 17th Street experienced the highest delay per lane-mile during the PM peak. In the southbound direction, the segment from SR-22/SR-57 to SR-55 experienced the highest delay per lane-mile during the AM peak.

Exhibit 4-15: Southbound I-5 Annual Vehicle-Hours of Delay (2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit 4-16: Southbound I-5 Delay per Lane-Mile (2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

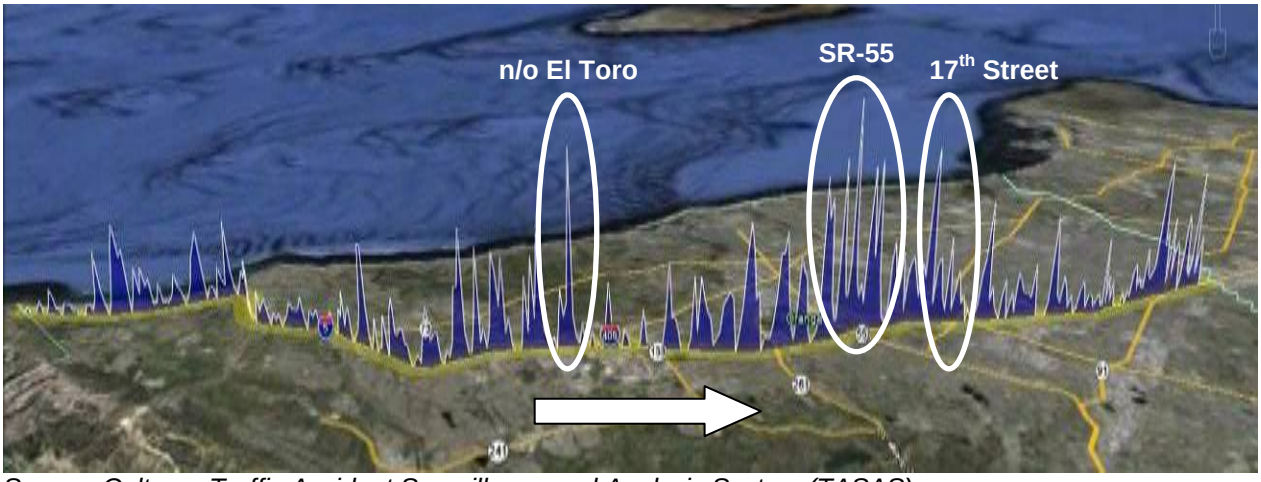
SAFETY BY BOTTLENECK AREA

As previously indicated in Section 3, the safety assessment in this report is intended to characterize the overall accident history and trends in the corridor, and to highlight notable accident concentration locations or patterns that are readily apparent. The following discussion examines the pattern of collisions by bottleneck areas for 2008 conditions. Due to the State's current budget constraints, safety by bottleneck area analysis updates for 2009 or later years cannot be performed at this time. Should future funding become available, this analysis will be updated.

Exhibit 4-17 shows the location of all collisions plotted along the I-5 Corridor in the northbound direction. The spikes show the total number of collisions (fatality, injury, and property damage only) occurring within 0.1 mile segments in 2008. The highest spike corresponds to roughly 34 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 4-17 shows, the largest group of collisions occurred near the SR-55 Interchange. Other groupings occurred north of El Toro Road, near 17th Street, and around Magnolia Avenue. In many cases, a spike in the number of collisions occurred in the same location as a bottleneck. For example, a spike occurred at the SR-55 Interchange, which is also a bottleneck location.

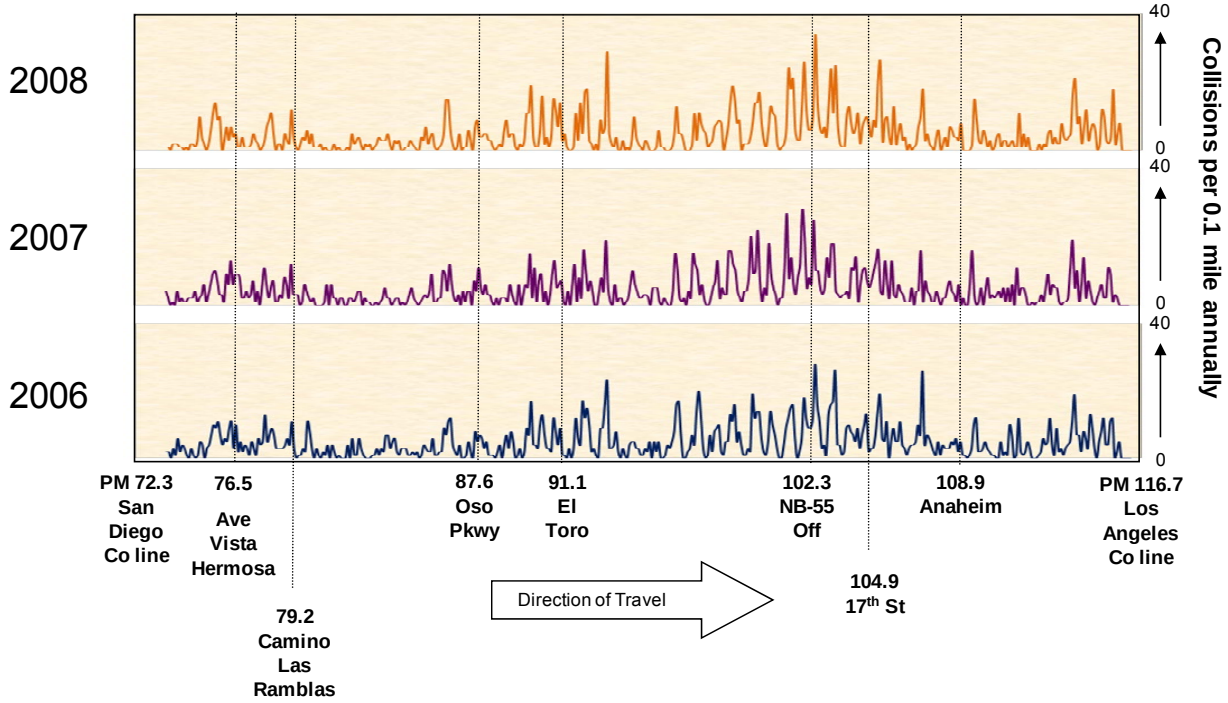
Exhibit 4-17: Northbound I-5 Collision Locations (2008)



Source: Caltrans Traffic Accident Surveillance and Analysis System (TASAS)

Exhibit 4-18 illustrates the same data for the three-year period from 2006 to 2008. The vertical lines in the exhibit refer to major bottleneck locations. The segments between the vertical lines correspond to bottleneck areas. This exhibit shows that the cluster of accidents near the SR-55 Interchange occurred in the previous two years. It also shows that the pattern of collisions has stayed fairly consistent from one year to the next.

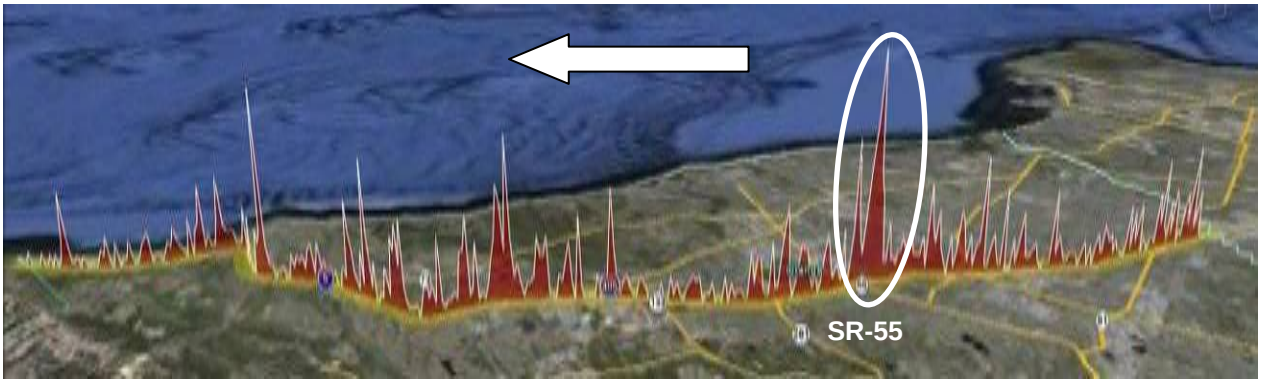
Exhibit 4-18: Northbound I-5 Collision Locations (2006-2008)



Source: Caltrans Traffic Accident Surveillance and Analysis System (TASAS)

Exhibit 4-19 shows the same 2008 collision data for the I-5 in the southbound direction. The largest spike in this exhibit corresponds roughly to 35 collisions per 0.1 miles. The pattern in the southbound direction is similar to that in the northbound direction but with less intensity. Again, the most notable cluster of accidents occurs near the SR-55 Interchange.

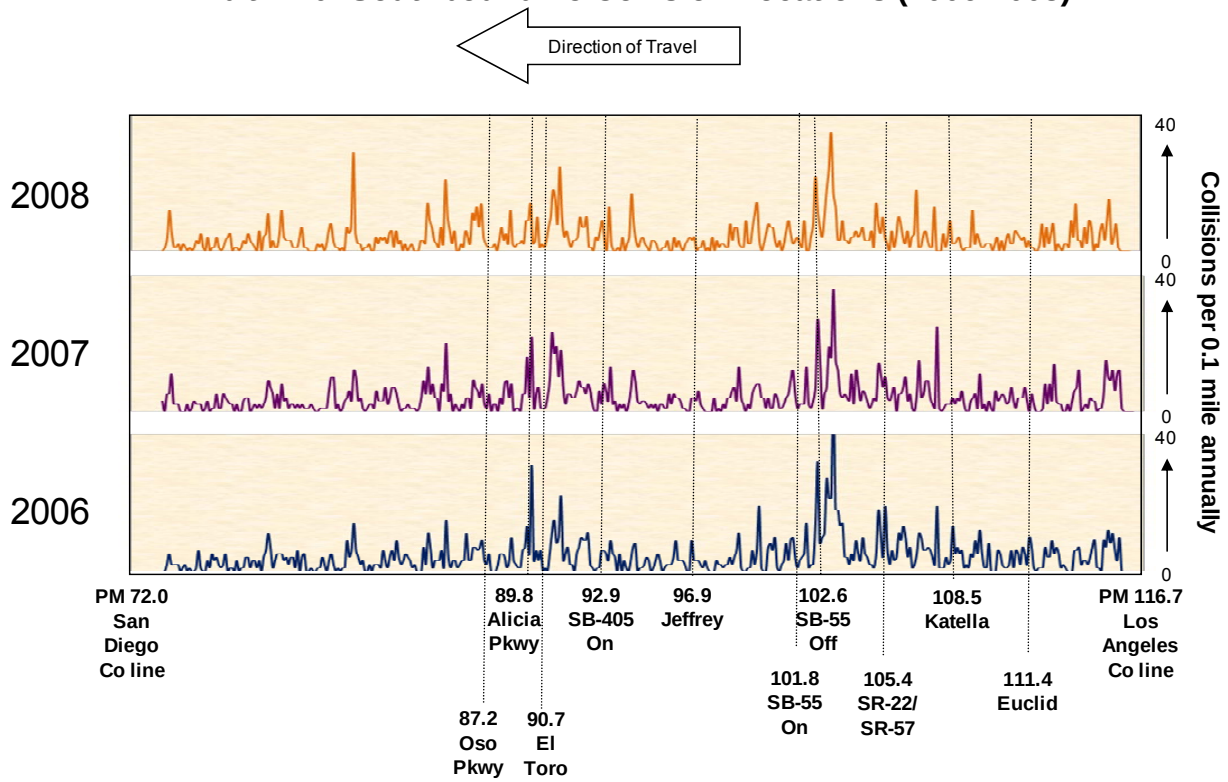
Exhibit 4-19: Southbound I-5 Collision Locations (2008)



Source: Caltrans Traffic Accident Surveillance and Analysis System (TASAS)

Exhibit 4-20 shows the trend of annual collisions for the southbound direction from 2006 to 2008. As the exhibit shows, the pattern of collisions has been fairly steady from one year to the next, with a slight decrease in collisions near Alicia Parkway. It also shows the high concentration near the SR-55 Interchange.

Exhibit 4-20: Southbound I-5 Collision Locations (2006-2008)

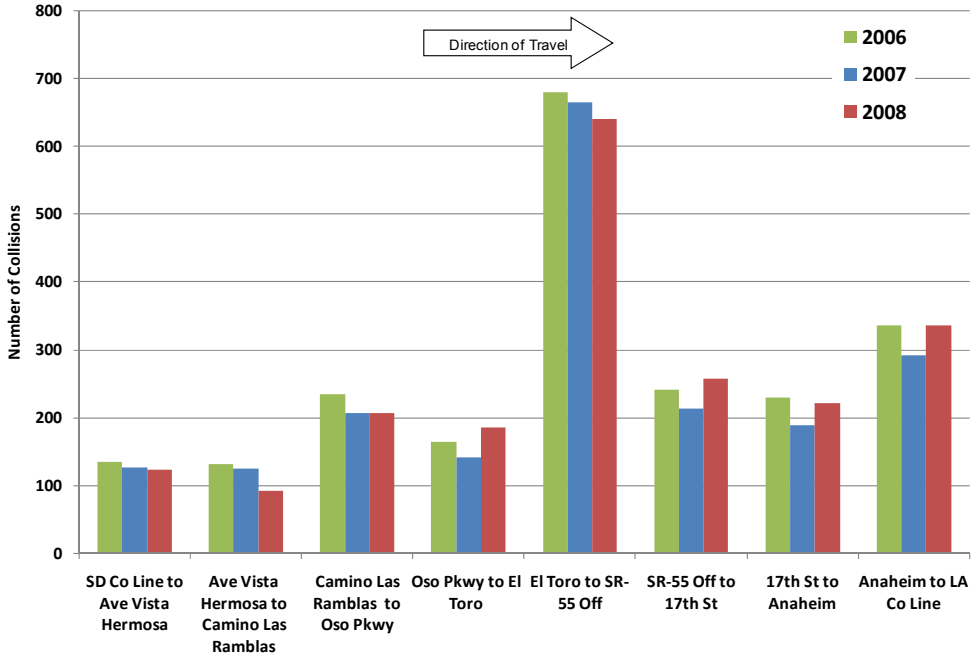


Source: Caltrans Traffic Accident Surveillance and Analysis System (TASAS)

Exhibits 4-21 and 4-22 summarize the total number of accidents reported in TASAS by bottleneck area. The bars show the total number of annual accidents which occurred in 2006, 2007, and 2008 (the latest three years available in TASAS). In the northbound direction, the segment from El Toro Road to SR-55 experienced the most accidents with roughly 650 each year. In the southbound direction, the segment from Oso Parkway to the San Diego County Line experienced the most accidents with about 400 each year. It is expected that these segments experience the highest number of accidents given that they are the longest in distance.

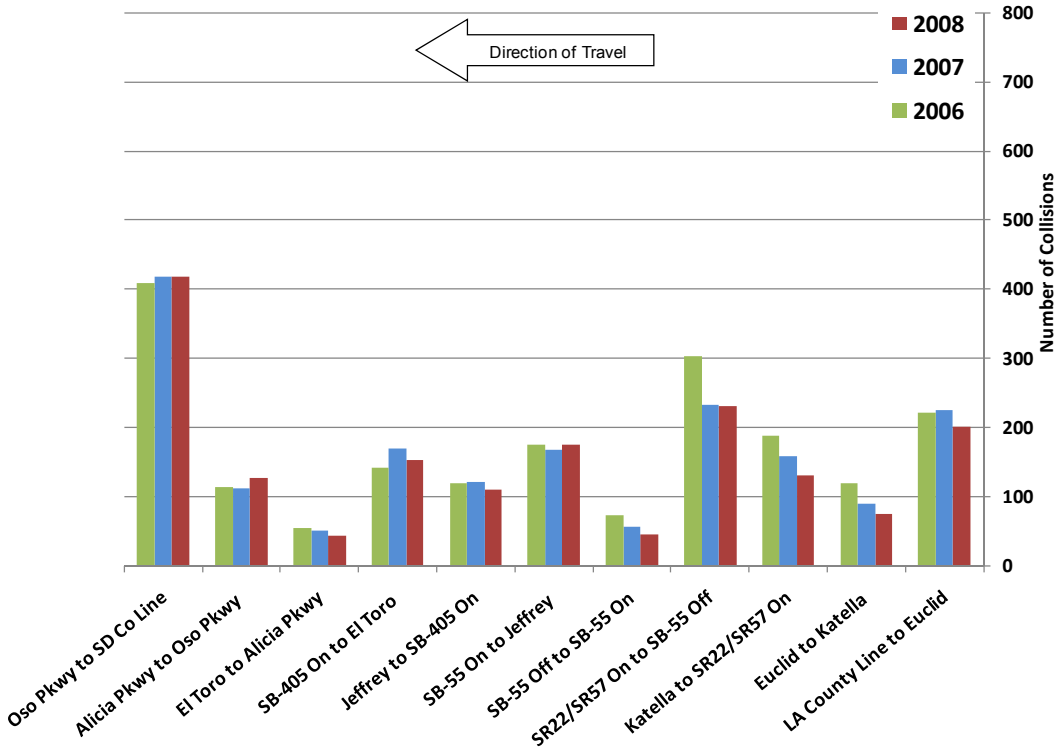
Exhibits 4-23 and 4-24 show the 2008 accident rates for the total number of accidents per million vehicle miles (MVM) by bottleneck areas. As indicated in the exhibits, although the northbound segment from El Toro Road to SR-55 and the southbound segment from Oso Parkway to the San Diego County Line have high total number of accidents due to the long length of the bottleneck areas, their respective accident rates are not the highest. The highest accident rate occurs from SR-55 to 17th Street in the northbound direction and from SR-22/SR-57 to SR-55 in the southbound direction.

Exhibit 4-21: Northbound I-5 Total Accidents (2006-2008)



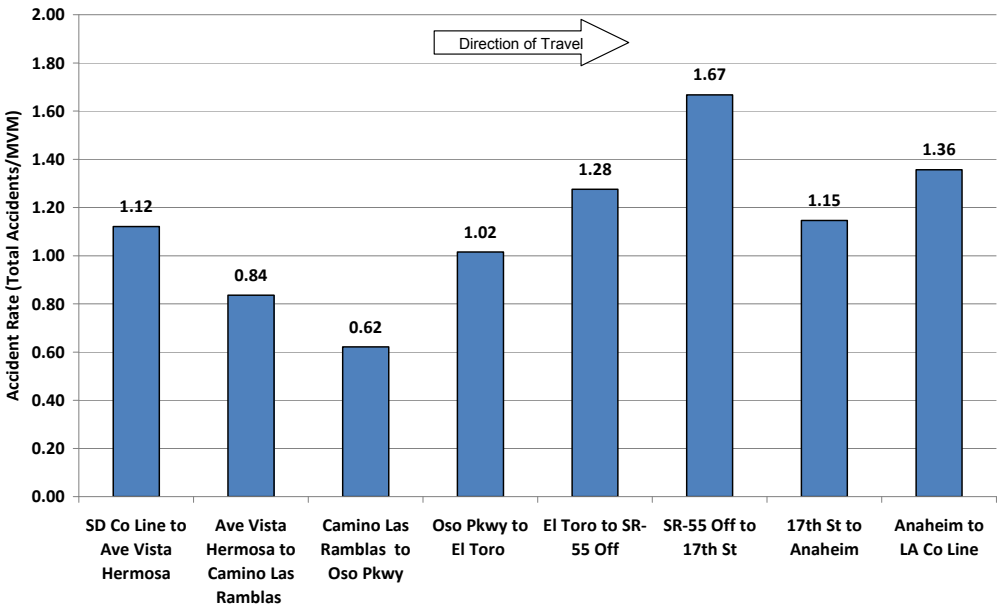
Source: Caltrans Traffic Accident Surveillance and Analysis System (TASAS)

Exhibit 4-22: Southbound I-5 Total Accidents (2006-2008)



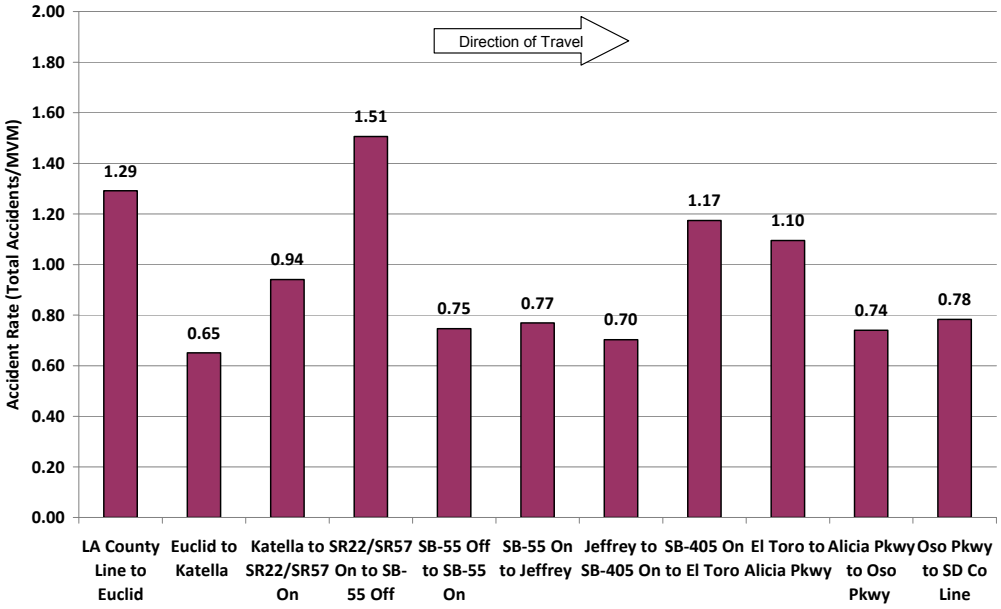
Source: Caltrans Traffic Accident Surveillance and Analysis System (TASAS)

Exhibit 4-23: Northbound I-5 Accident Rates by Bottleneck Area (2008)



Source: Caltrans Traffic Accident Surveillance and Analysis System (TASAS)

Exhibit 4-24: Southbound I-5 Accident Rates by Bottleneck Area (2008)



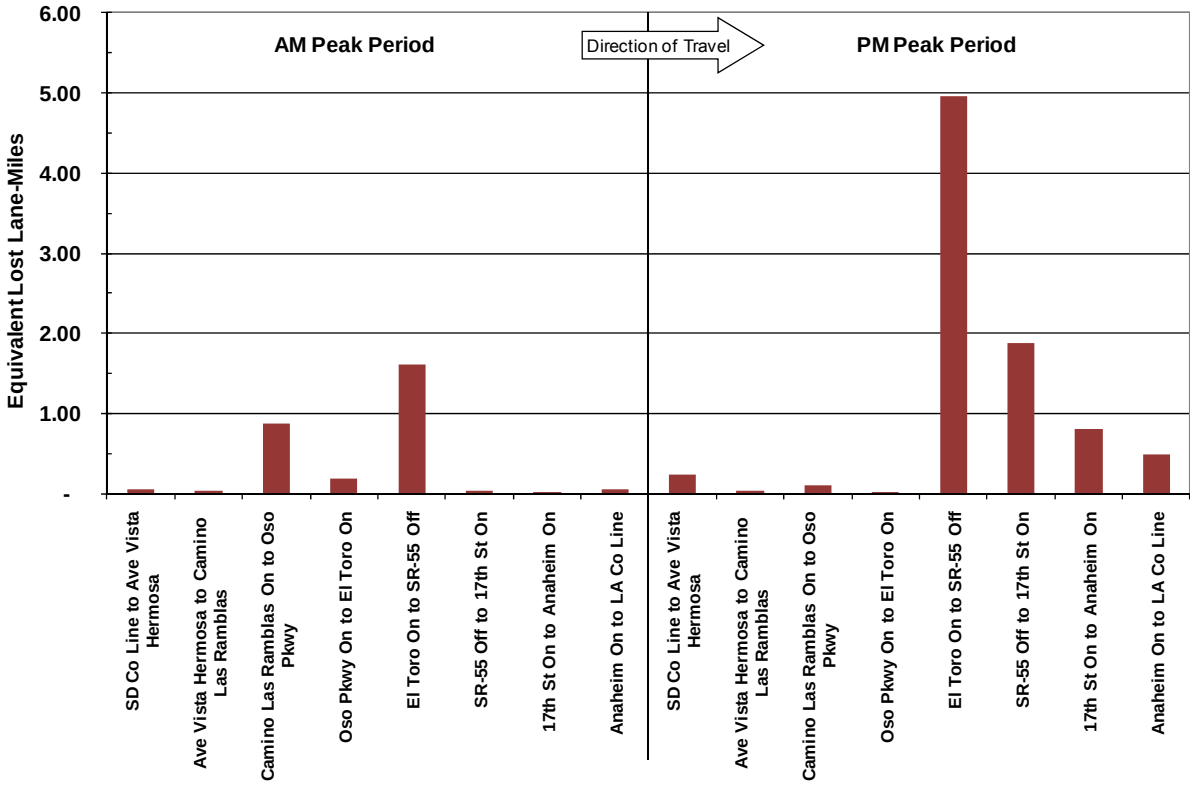
Source: Caltrans Traffic Accident Surveillance and Analysis System (TASAS)

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 4-25 and 4-26 show the productivity losses for both directions of the corridor. In the northbound direction, the segment from El Toro to SR-55 had the worst productivity of any segment on the study corridor. It experienced a productivity loss of almost 1.6 lane-miles during the AM peak and 5.0 during the PM peak.

Exhibit 4-25: Northbound I-5 Equivalent Lost Lane-Miles (2010)

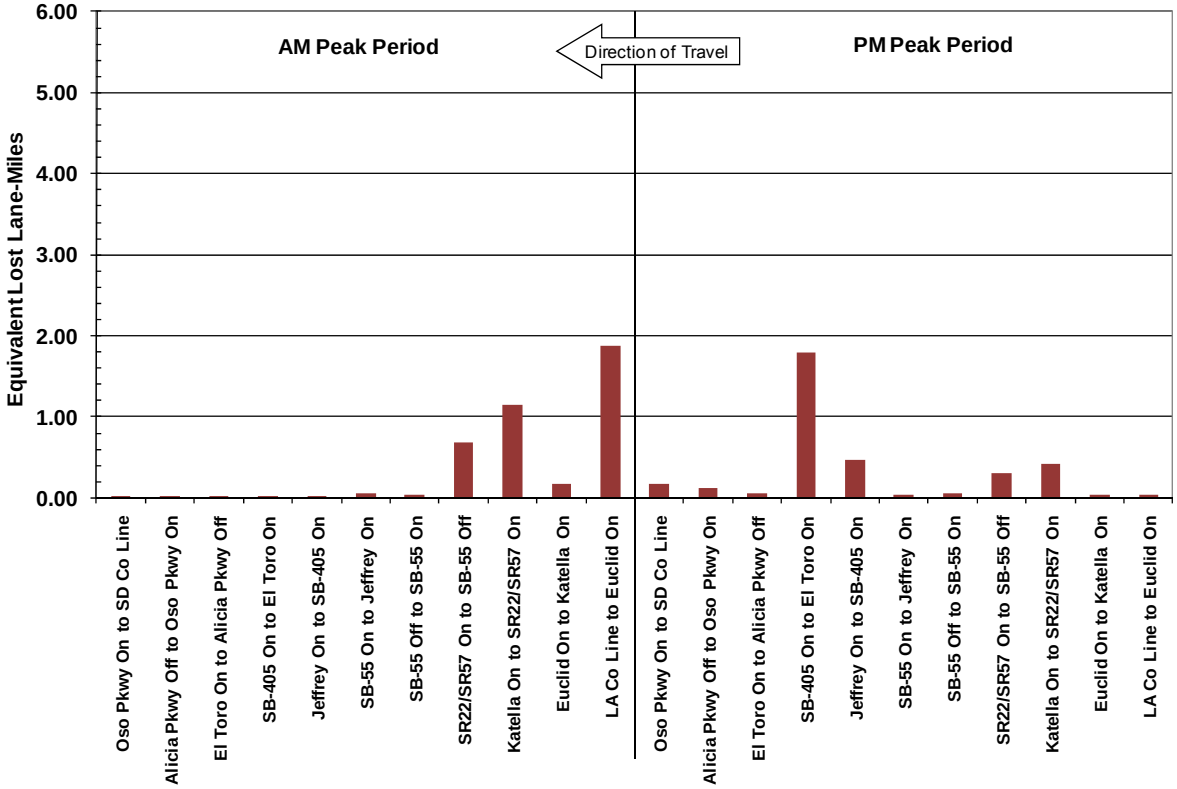


Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

In the southbound direction, the segments that experienced the greatest productivity losses were from the Los Angeles County Line to Euclid Avenue during the AM peak and from I-405 to El Toro Road during the PM peak with both reporting just under 2.0 lost-lane miles.

Note that the segments of the corridor with the highest productivity losses correspond to the same segments that experience the greatest annual vehicle-hours of delay.

Exhibit 4-26: Southbound I-5 Equivalent Lost Lane-Miles (2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

5. BOTTLENECK CAUSALITY ANALYSIS

This section details the causes of the bottlenecks identified in the previous section of this report. Bottlenecks are the primary cause of traffic congestion and lost productivity. It is important to verify the precise location and causes of each bottleneck so that the appropriate operational improvements can be developed to maintain corridor mobility.

The location of each bottleneck was verified by multiple field observations on separate weekdays in June and July 2011. The causes of each bottleneck were also identified by field observations and additional traffic data analysis.

By definition, a bottleneck is a condition where traffic demand exceeds the capacity of 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 on and off-ramps. On the demand side, surges in demand, often from on-ramps added to the mainline freeway already at or near the threshold level, can be greater than a roadway can accommodate. In many cases, it is a combination of increased demand and capacity reductions.

Exhibit 5-1 summarizes the bottleneck locations and their main causes. Details of each bottleneck location and the cause(s) are presented.

Exhibit 5-1: Summary I-5 Bottleneck Causes

Northbound

No.	Major Bottleneck Location	Hidden Bottleneck Location	Causality
NB1A		Avenida Pico	Merging, uphill grade, lane drop at Ave Vista Hermosa Off
NB1	Ave Vista Hermosa		Merging consecutive ramps
NB2	Camino Las Ramblas		Uphill grade, roadway curve, sight distance, lane drop, merging
NB3A		Crown Valley On	Merging
NB3	Oso Pkwy On		Merging (consecutive ramps)
NB4B		La Paz On	Merging (loop ramp)
NB4A		Alicia Pkwy On	Merging (1 mile aux lane lost at El Toro)
NB4	El Toro On		Limited sight dist (vert), merging (loop ramp - short taper)
NB5E		Sand Canyon On	Merging
NB5D		Jeffrey On	Merging
NB5C		Jamboree On	Merging
NB5B		Tustin Ranch On	Merging
NB5A		Red Hill/Newport On	Merging, weaving (with SR55 off), uphill grade, +1000 vph on
NB5	NB-55 Off		Weaving (w/Red Hill On), number of lanes reduction
NB6C		NB-55 On	Merging, high demand
NB6B		4th On	Merging, grade, roadway curve, limited sight dist, clearance
NB6A		Grand Off	HOV lane drop congestion, merging from out of aux In
NB6	17th Street On		HOV exit merging, weaving (SR22/57), uphill grade, rdwy curve
NB7A		SR-22 Off (Main St)	Weaving, traffic backing up from SR22/SR57
NB7	Anaheim On		Uphill grade, merging (Katella/Ball), 5th lane ends at Katella
NB8A		Ball Road	Merging
NB8	Los Angeles County		Loss of lanes at Carmenita IC

Southbound

No.	Major Bottleneck Location	Hidden Bottleneck Location	Causality
SB1	Euclid On		Merging
SB2	Katella On (Disney Wy)		Merging (first ramp)
SB3	SR22/SR57 On (Main)		Merging, lane drop
SB4C		Penn On (17th St)	Merging, short aux lane (less than 800 feet)
SB4B		Grand On	Merging
SB4A		First On	Weaving (w/SR55 off), merging
SB4	SB-55 Off		Queue backup to m/l, weaving (w/1st on), no of lanes reduced
SB5	SB-55 On		Merging, high demand
SB6	Jeffrey On		Merging
SB7A		SR-133	Lane drop
SB7	SB-405 On		Merging, lane drop
SB8B		Truck bypass On	Merging with trucks (Bake On)
SB8A		Lake Forest On	Merging - truck bypass aux lane (1-mile long) ends at El Toro
SB8	El Toro On		Merging (consecutive), backup to m/l
SB9	Alicia Parkway Off		Queue backup to m/l
SB10	Oso Parkway On		Merging (consecutive ramps)
	None		

NOTES:

Causality was verified with multiple field observations and video taping during June and July 2011.

Hidden bottlenecks are bottlenecks hidden by queuing from downstream bottleneck.

Northbound Mainline Facility

Avenida Pico

The bottleneck condition at this location is often hidden by the congestion and queuing from the larger downstream bottleneck at Avenida Vista Hermosa, and occurs mainly during the AM peak period. The main causes of this bottleneck location are the uphill grade and the lane drop just past the Avenida Vista Hermosa off-ramp. The capacity of the roadway is further affected by the merging from the Avenida Pico on-ramp traffic.

Avenida Vista Hermosa

Avenida Vista Hermosa is a major bottleneck location that occurs mainly during the AM peak period but sometimes occurs during midday and PM peak hours. Although the bottleneck condition at this location does not occur every day, it occurs often. The main cause of this bottleneck location is the merging of traffic from consecutive on-ramps at Avenida Vista Hermosa, along with a lane drop in this area. Traffic volume entering the freeway from the two consecutive ramps is three times greater than the traffic exiting the freeway at Avenida Vista Hermosa.

Camino Las Ramblas

Camino Las Ramblas is also a major bottleneck location that occurs mainly during the AM peak period. Although the bottleneck condition at this location does not occur every day, it occurs often. The main cause of the bottleneck condition at this location is the uphill grade, sharp roadway curve to the right that reduces sight distance, lane drop, and the traffic merge from the Camino Las Ramblas on-ramp that occurs on the curve and uphill grade.

Crown Valley Parkway

The bottleneck condition at this location is sometimes hidden by the congestion and queuing from the larger downstream bottleneck at Oso Parkway, and occurs mainly during the AM peak period but sometimes also occurs during the PM peak period. The main cause of this bottleneck is the traffic merging from the eastbound Crown Valley Parkway loop on-ramp and the heavy demand from the westbound on-ramp. Combined, traffic entering the freeway is nearly 2,000 vehicles per hour during the AM peak period.

Oso Parkway

Oso Parkway is a major bottleneck location that occurs mainly during the AM peak period but sometimes occurs during the PM peak hours. The main cause of this bottleneck is the traffic merging from the consecutive on-ramps at Oso Parkway.

La Paz Road

The bottleneck condition at La Paz Road is typically hidden by the congestion and queuing from the larger downstream bottleneck at El Toro Road, and occurs mainly during the AM peak period. The main cause of this bottleneck is the traffic merging from the eastbound La Paz Road loop on-ramp and the heavy demand from the westbound on-ramp. Combined, the traffic entering the freeway often exceeds 1,700 vehicles per hour as compared to less than 300 exiting the freeway at La Paz Road during the AM peak period. La Paz Road is currently being upgraded and construction is in process.

Alicia Parkway

The bottleneck condition at Alicia Parkway is typically hidden by the congestion and queuing from the larger downstream bottleneck at El Toro Road, and occurs mainly during the AM peak period. The main cause of this bottleneck is the heavy traffic merging from the Alicia Parkway on-ramps and the termination of the long auxiliary lane (over 1 mile) at the El Toro Road exit.

El Toro Road

El Toro Road is a major bottleneck location that occurs mainly during the AM peak period but often also occurs during the PM peak period. The main cause of this bottleneck is the limited sight distance from the grade over the interchange and the merging from the eastbound El Toro Road loop on-ramp with a short taper. Exhibit 5-2 presents an aerial view of the interchange and the merge location, and an inset photograph of the limited sight distance.

Exhibit 5-2: Northbound I-5 Bottleneck at El Toro Road

Source: System Metrics Group, Inc./Google Earth

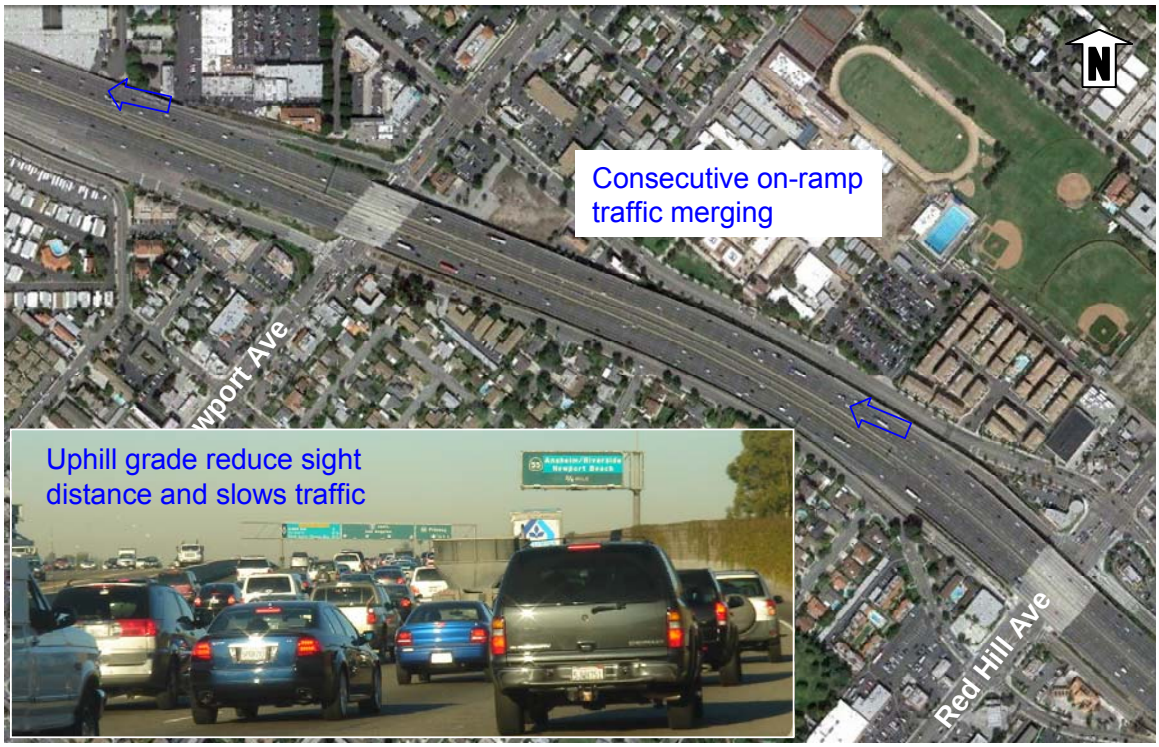
<u>Sand Canyon Avenue, Jeffrey Road, Jamboree Road, Tustin Ranch</u>

The bottleneck condition at these four interchange locations are typically hidden by the larger downstream bottleneck at the SR-55 Interchange, and occurs in the PM peak period. The main cause of these bottlenecks is the merging from the on-ramps. Typically, there is much more traffic getting on to the freeway than getting off at these interchanges. The combination of the additional demand from the ramps and the effect of the merging on to the freeway traffic stream often result in a bottleneck condition.

Red Hill Avenue/Newport Avenue

The bottleneck condition at this location is typically hidden by the larger downstream bottleneck at the SR-55 Interchange, and occurs in the PM peak period. The main cause of this bottleneck is the merging from the consecutive on-ramps, at Red Hill and Newport interchanges, compounded by the steep uphill grade that slows traffic. Exhibit 5-3 presents an aerial view of this location and an inset photograph of the steep uphill grade.

Exhibit 5-3: Northbound I-5 Bottleneck at Red Hill/Newport Avenue



Source: System Metrics Group, Inc./Google Earth

Exit to Northbound and Southbound SR-55

This is a major bottleneck location that occurs mainly during the PM peak period but often also occurs during AM peak period. The main cause of this bottleneck is the weaving of the exiting traffic against the on-ramp traffic from Red Hill and Newport Avenues and the loss of a mainline lane to the SR-55 Interchange, reducing the total number of through lanes on the freeway. Back up also caused by the SB 55 traffic which would fill up the connector slowing down the NB 5 traffic. Exhibit 5-4 presents an aerial view of this location.

Exhibit 5-4: Northbound I-5 Bottleneck at SR-55

Source: System Metrics Group, Inc./Google Earth

Source: System Metrics Group, Inc./Google Earth

Northbound SR-55 to Northbound I-5

The bottleneck at Northbound SR-55 to Northbound I-5 is typically hidden by the downstream bottleneck at the 17th Street Interchange, and occurs in the PM peak period. Although this is considered a hidden bottleneck, it can be a significant bottleneck. Its impact is lessened by the upstream bottleneck at the exit to SR-55, limiting the demand to this location. The main cause of the bottleneck at this location is the heavy platoon merging from the northbound SR-55 connector to northbound I-5. Back up is also caused by the southbound SR-55 traffic queuing on the connector, thereby slowing down the northbound I-5.

4th Street

The bottleneck condition at 4th Street is typically hidden by the larger downstream bottleneck at the 17th Street Interchange, and occurs in the PM peak period. The main cause of the bottleneck at this location is the roadway curve that reduces sight distance, uphill grade, and the merging from the 4th Street on-ramp.

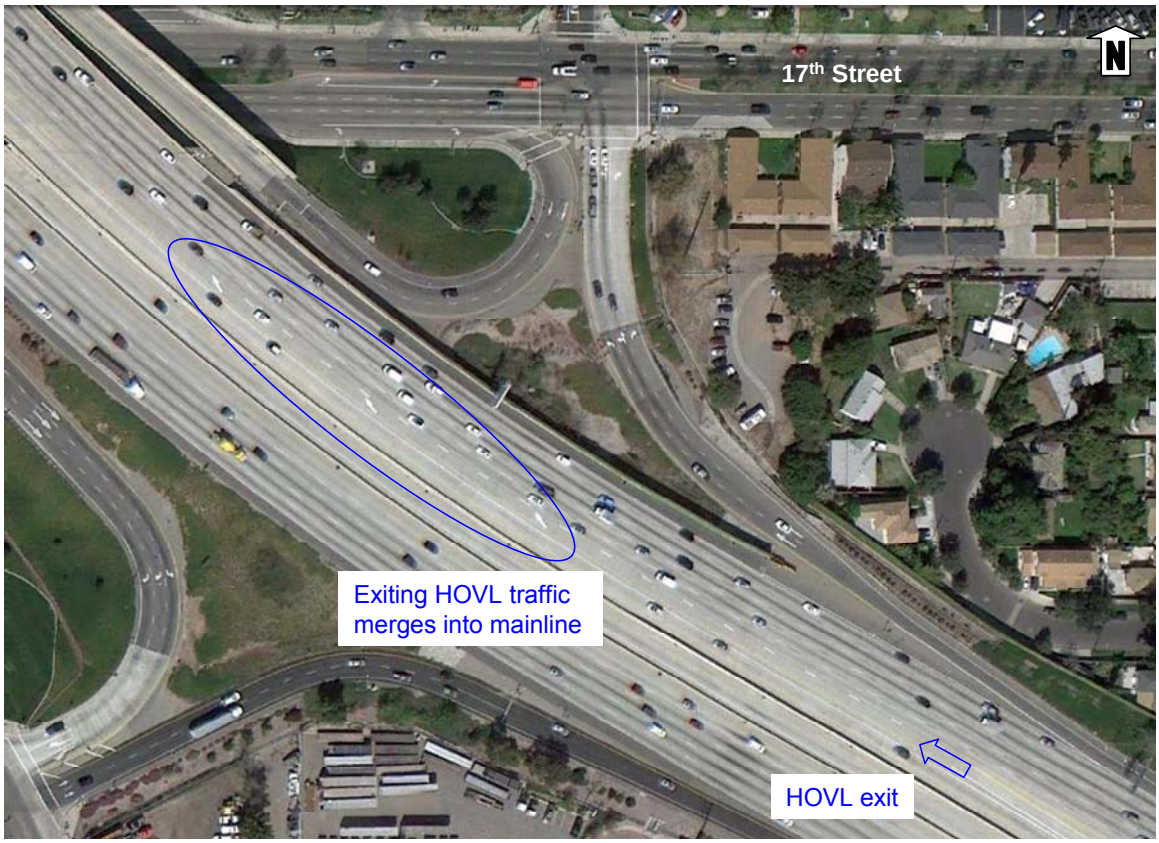
Grand Avenue

The bottleneck condition at Grand Avenue is typically hidden by the larger downstream bottleneck at the 17th Street Interchange, and occurs in the PM peak period. The main cause of this bottleneck is the congestion occurring in the HOV lane that affects the mainline speeds and the merging traffic out of the terminating auxiliary lane at Grand Avenue.

17th Street

This is a major bottleneck location that occurs in the PM peak period. The main cause of this bottleneck is the merging HOV traffic from the inside lane, compounded by the uphill grade, roadway curve, and the weaving of exiting traffic at SR-22/SR-57. Exhibit 5-5 presents an aerial view of this location.

Exhibit 5-5: Northbound I-5 Bottleneck at 17th Street



Source: System Metrics Group, Inc./Google Earth

Exit to SR-22/SR-57

The bottleneck condition at this location is typically hidden by the downstream bottleneck at Anaheim Way, and occurs in the PM peak period. The main cause of this bottleneck is the weaving of the exiting traffic and the queue at the connector exit to SR-22, which backs up the mainline. The total number of through lanes is reduced with the eventual loss of a fifth mainline lane to SR-57, causing traffic to squeeze into the fourth lane.

Anaheim Way

Anaheim Way is a major bottleneck location that occurs in the PM peak period. The main cause of this bottleneck is the merging from the Ball Road/Katella Avenue on-ramp, uphill grade, and the loss of a mainline lane at Katella Avenue, reducing the total number of through lanes on the freeway.

Ball Road

Ball Road is a minor bottleneck that sometimes occurs in the PM peak period. Although it occurs infrequently and was not observed in any of the field visits, data analysis suggests that it does occur from time to time for a brief period. The main cause is likely to be the merging from the Ball Road on-ramp when the demand is high on the freeway and on the on-ramp. Typically, the Ball Road on-ramp carries about 600 vehicles per hour. There is no exit ramp at Ball Road.

Los Angeles County (Carmenita Road)

Although this bottleneck is not at the County line but rather in Los Angeles County, near the Carmenita Road Interchange, the resulting traffic congestion and queuing often extends back into Orange County. The main cause is the reduction of the total number of through lanes. The fifth lane is dropped at the Artesia Boulevard Interchange and the fourth lane ends at the Valley View Avenue exit in Los Angeles County.

Southbound Mainline Facility

Euclid Street

Euclid Street is a major bottleneck that occurs in the AM peak period. The main cause of this bottleneck is the merging from the Euclid Street on-ramp.

Katella Avenue/Disney Way

This is a major bottleneck location that occurs in the AM peak period. The main cause of this bottleneck is the merging from the Disney Way on-ramp.

SR-22/SR-57 to Southbound I-5 (Main Street)

This is a major bottleneck location that occurs mainly in the AM peak period but also often occurs in the PM peak period. The main cause of the bottleneck at this location is the heavy traffic demand and merging from consecutive connectors at southbound SR-57 to southbound I-5 and from the eastbound SR-22 collector-distributor (CD) to southbound I-5, and the loss of a lane. The two-lane CD is eventually joined with the I-5 freeway, making it into a six-lane mainline facility. The sixth lane (second CD lane) is then dropped, squeezing traffic into five through lanes.

Penn Way (17th Street)

The bottleneck condition at Penn Way is typically hidden by the larger downstream bottleneck at the SR-55 Interchange, and occurs mainly in the AM peak period, but sometimes occurs in the PM peak period. The main cause of the bottleneck is the merging from the Penn Way on-ramp. The auxiliary lane from the Penn Way on-ramp to the Santa Ana Boulevard off-ramp is very short at less than 800 feet.

Grand Avenue (Santa Ana Boulevard)

The bottleneck condition at Grand Avenue is typically hidden by the larger downstream bottleneck at the SR-55 Interchange, and occurs in the AM peak period. The main cause of this bottleneck is the merging and weaving from the Santa Ana Boulevard on-ramp. As the outside lanes become fully congested and start queuing back from the exit to SR-55, the on-ramp traffic from Santa Ana merges and weaves its way over to the left, faster, inside lanes.

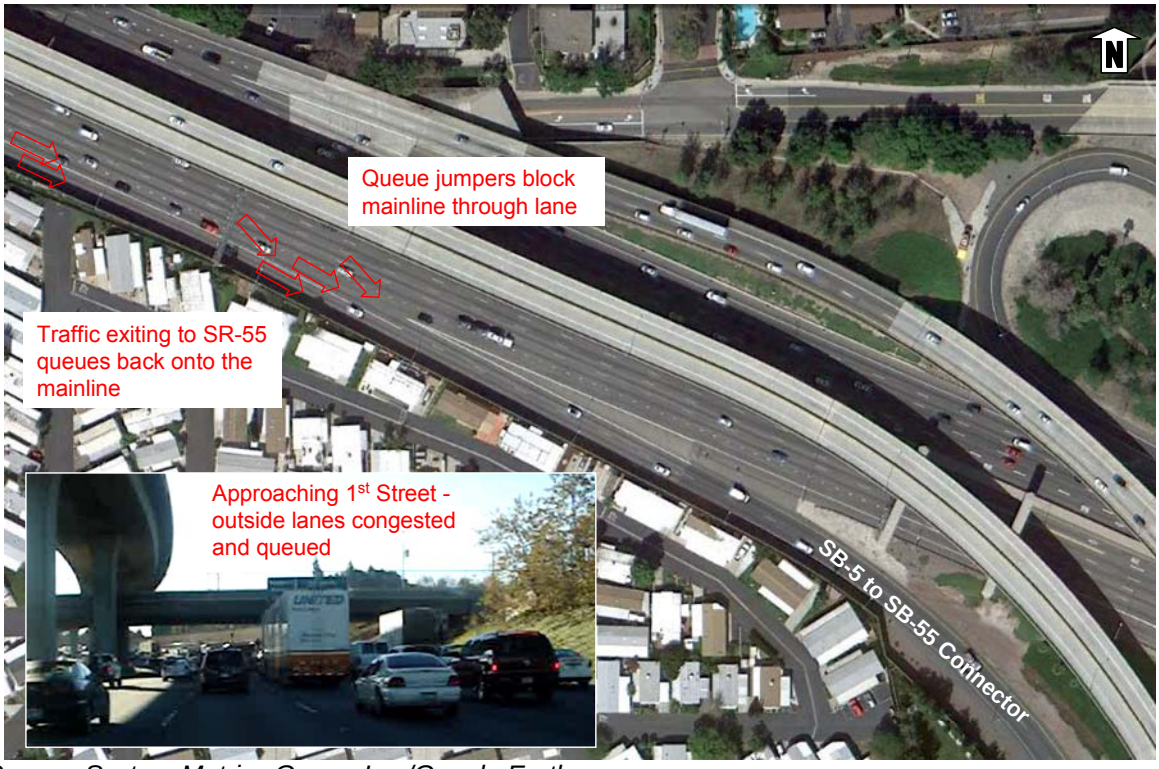
1st Street

The bottleneck condition at 1st Street is typically hidden by the larger downstream bottleneck at the SR-55 Interchange, and occurs in the AM peak period. The main cause of this bottleneck is the merging and weaving from the 1st Street on-ramp. As the outside lanes become fully congested and queue back from the exit to SR-55, the on-ramp traffic from 1st Street merges and weaves its way over to the left, faster, inside lanes against the exiting traffic to southbound SR-55. The traffic from 1st Street often exceeds over 1,000 vehicles per hour during the AM peak hours.

Exit to Southbound SR-55

This is a major bottleneck location that occurs mainly in the AM peak period but also occurs in the PM peak period. The main cause of this bottleneck is the weaving of the exiting traffic against the 1st Street traffic and the queuing caused by the exit connector backing up onto the freeway mainline. In addition, queue jumpers often occupy and queue/stop in the third mainline lane, forcing through traffic to squeeze into two left lanes. Exhibit 5-6 presents an aerial view of this location and inset photograph of this bottleneck condition.

Exhibit 5-6: Southbound I-5 Bottleneck at SR-55



Source: System Metrics Group, Inc./Google Earth

Northbound and Southbound SR-55 to Southbound I-5

This is a major bottleneck location that occurs mainly in the AM peak period but also often occurs in the PM peak period. The main cause of the bottleneck at this location is the merging of the northbound SR-55 to southbound I-5 connector and the heavy demand from SR-55 entering southbound I-5 traffic. When the I-5 mainline traffic density is high, the additional demand can overwhelm the facility capacity, resulting in a bottleneck condition.

Jeffrey Road

Jeffrey Road is a minor bottleneck that sometimes occurs in the AM peak period. Although it occurs infrequently and was not observed in any of the field visits, data analysis suggests that it does occur from time to time for a brief period. The main cause is likely to be the merging from the Jeffrey Road on-ramp when the demand is high on the freeway and on the on-ramp.

SR-133

The SR-133 Interchange is a potential bottleneck location that seldom occurs in the PM peak period. Although it occurs very infrequently and was not observed in any of the field visits, data analysis suggests that it can be a major bottleneck if the mainline demand reaches its threshold level. The likely cause is the lane drop on the mainline facility just south of the SR-133 Interchange.

Southbound I-405 to Southbound I-5

This is a major bottleneck location that occurs mainly in the PM peak period. The main cause of the bottleneck at this location is the heavy demand from I-405 entering the southbound I-5 traffic, the merging, and the lane drop of the outside lane south of the Bake Parkway Overcrossing. Exhibit 5-7 presents an aerial view of this location.

Exhibit 5-7: Southbound I-5 Bottleneck at Southbound I-405 to I-5

Source: System Metrics Group, Inc./Google Earth

Truck Bypass/Bake Parkway

The bottleneck condition at Truck Bypass/Bake Parkway is typically hidden by the larger downstream bottleneck at the El Toro Road Interchange, and occurs in the PM peak period. The main cause of this bottleneck is the merging from the on-ramp, typically truck traffic, from the Truck Bypass and Bake Parkway.

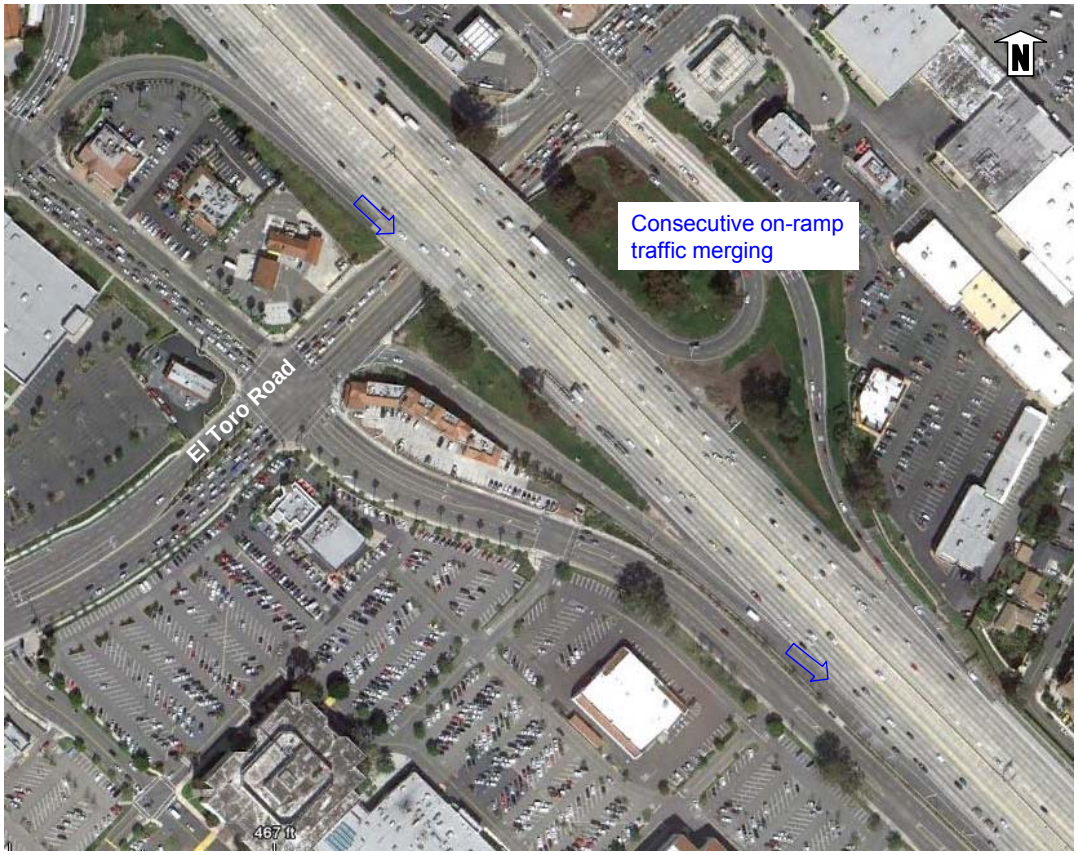
Lake Forest Drive

The bottleneck condition at Lake Forest Drive is typically hidden by the larger downstream bottleneck at the El Toro Road Interchange, and occurs in the PM peak period. The main cause of this bottleneck is the merging from the consecutive Lake Forest on-ramps, compounded by the termination of the long auxiliary lane (over one mile long) at the El Toro Road Interchange, which forces through traffic to merge left.

El Toro Road

El Toro Road is major bottleneck location that occurs in the PM peak period. The causes of this bottleneck are the merging from the El Toro Road Interchange consecutive on-ramps, the merging from the first on-ramp at Avenida De La Carlota, the traffic back up on the freeway beyond the off-ramp gore, and the uphill grade over the Interchange that reduces sight distance. Exhibit 5-8 presents an aerial view of this location and the inset photograph that shows the bottleneck condition.

Exhibit 5-8: Southbound I-5 Bottleneck at El Toro Road



Source: System Metrics Group, Inc./Google Earth

Alicia Parkway

Alicia Parkway is a major bottleneck location that sometimes occurs in the PM peak period. The main cause of this bottleneck is the queuing from the Alicia Parkway exit ramp backing up onto the mainline freeway. When queue jumpers block the outside through lane to get into the exit ramp ahead of the backed up queue, a bottleneck occurs and congestion forms.

Oso Parkway

Oso Parkway is a major bottleneck location that occurs during the PM peak. The main cause of this bottleneck is the traffic merging from the Oso Parkway consecutive on-ramps.

Northbound HOV Facility

HOV bottlenecks also exist along the I-5 corridor. For most of the HOV bottlenecks, the main cause is the congested slow speeds in the adjacent mainline lane. Motorists traveling on the HOV lane tend to slow down out of caution when the adjacent mainline lane experiences a significant reduction in speed. The bottlenecks for the northbound and southbound HOV facility are presented herein:

Crown Valley Parkway and Oso Parkway

The HOV bottlenecks at Crown Valley Parkway and Oso Parkway are minor bottleneck locations that occur in the AM peak period when speeds typically slow to 30 to 40 miles per hour.

Sand Canyon Avenue, Jeffrey Road, and Jamboree Road

These are major bottleneck locations that occur in the PM peak period when speeds typically slow to below 30 miles per hour.

Red Hill Avenue/Newport Avenue

The HOV bottlenecks at Red Hill and Newport occur in the PM peak period when speeds typically fall below 30 miles per hour.

SR-55

These are two major bottleneck locations, at the I-5 exit to SR-55 and I-5 entrance from northbound SR-55, that occur in the PM peak period when speeds typically fall below 30 miles per hour.

4th Street

This is a major bottleneck location that occurs in the PM peak period when speeds typically slow to below 30 miles per hour. The main cause of this bottleneck is the congested slow speeds in the adjacent mainline lane, the uphill grade, roadway curve, and limited sight distance. Motorists traveling on the HOV lane tend to slow down out of caution when the adjacent mainline lane experiences a significant reduction in speed.

Grand Avenue

This is a major bottleneck location that occurs in the PM peak period when speeds typically slow to below 20 miles per hour. The main cause of the bottleneck at this location is the merge (and lane drop) of the northbound SR-55 HOV direct connector lane, compounded by the roadway curve and uphill grade. Exhibit 5-9 presents an aerial view of this location.

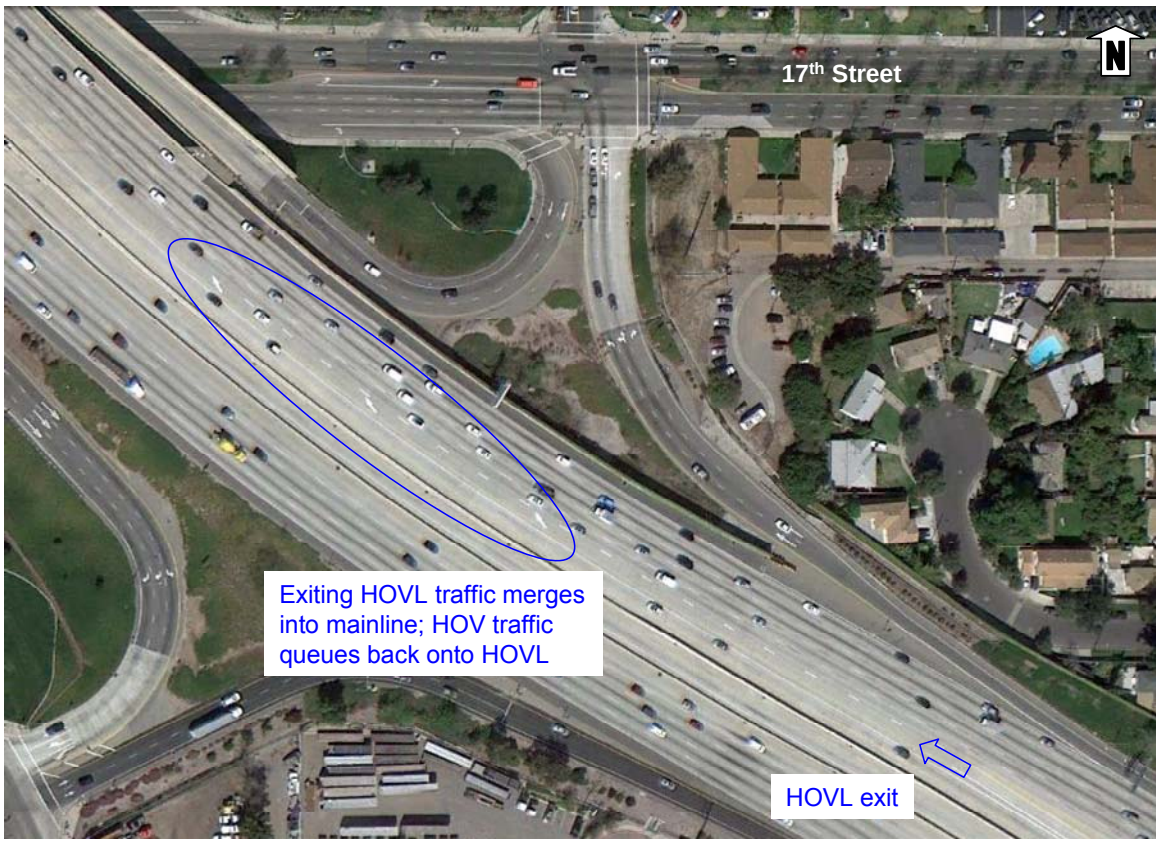
Exhibit 5-9: Northbound HOV Bottleneck at Grand Avenue

Source: System Metrics Group, Inc./Google Earth

17th Street

This is a major bottleneck location that occurs in the PM peak period when speeds typically slow to below 30 miles per hour. The main cause of this bottleneck is the merging of the HOV lane exit into the mainline which often backs up onto the HOV lane. Exhibit 5-10 presents an aerial view of this location.

Exhibit 5-10: Northbound HOV Bottleneck at 17th Street



Source: System Metrics Group, Inc./Google Earth

Broadway

This is a major bottleneck location that occurs in the PM peak period when speeds typically slow to below 30 miles per hour. The main cause of this bottleneck is the merging of the direct HOV on-ramp from Main Street. Exhibit 5-11 presents an aerial view of this location.

Exhibit 5-11: Northbound HOV Bottleneck at Broadway

Source: System Metrics Group, Inc./Google earth

Southbound HOV Facility

SR-57

This is a major bottleneck location that occurs mostly in the AM peak period but sometimes also occurs in the PM peak period when speeds typically slow to below 20 miles per hour. The main cause of the bottleneck at this location is the merge of the southbound SR-57 HOV direct connector lane. Exhibit 5-12 presents an aerial view of this location.

Exhibit 5-12: Southbound HOV Bottleneck at SR-57

Source: System Metrics Group, Inc./Google Earth

Jeffrey Road and I-405

These are minor bottleneck locations that occur in the PM peak period where speeds typically slow to 30 to 40 miles per hour.

El Toro Road

El Toro Road is a minor bottleneck location that occurs in the PM peak period when speeds typically slow to below 30 miles per hour. The main cause of the bottleneck is the lane drop of one of the two HOV lanes. Exhibit 5-13 presents an aerial view of this location.

Exhibit 5-13: Southbound HOV Bottleneck at El Toro Road

Source: System Metrics Group, Inc./Google Earth

Crown Valley Parkway

Crown Valley Parkway is a minor bottleneck location that occurs in the PM peak period when speeds typically slow to 30 to 40 miles per hour.

6. SCENARIO DEVELOPMENT AND MICRO-SIMULATION

The previous sections presented the diagnostic part of the CSMP. They describe the corridor, examine its performance trends, and pinpoint its bottleneck locations and related causes. This section describes the improvement evaluation component of the CSMP effort. It describes the logic behind the scenario development framework using the Paramics micro-simulation model. It also summarizes the overall benefit-cost analysis results conducted to compare costs to benefits. The following steps are discussed in more detail below:

- Developing a traffic model based on current and medium-term demands
- Combining projects in a logical manner into "scenarios" for modeling and testing
- Evaluating model scenario outputs and summarizing results
- Conducting a benefit-cost assessment of scenarios

Traffic Model Development

In order to evaluate the effectiveness of the proposed projects, the modeling team developed an I-5 traffic model using Paramics micro-simulation software.

It is important to note that micro-simulation models are complex to develop and calibrate for large congested urban corridors such as the I-5 Corridor. However, it is one of the only tools capable of providing a reasonable approximation of bottleneck formation and queue development. Such tools help quantify the impacts of operational strategies, which traditional travel demand models cannot.

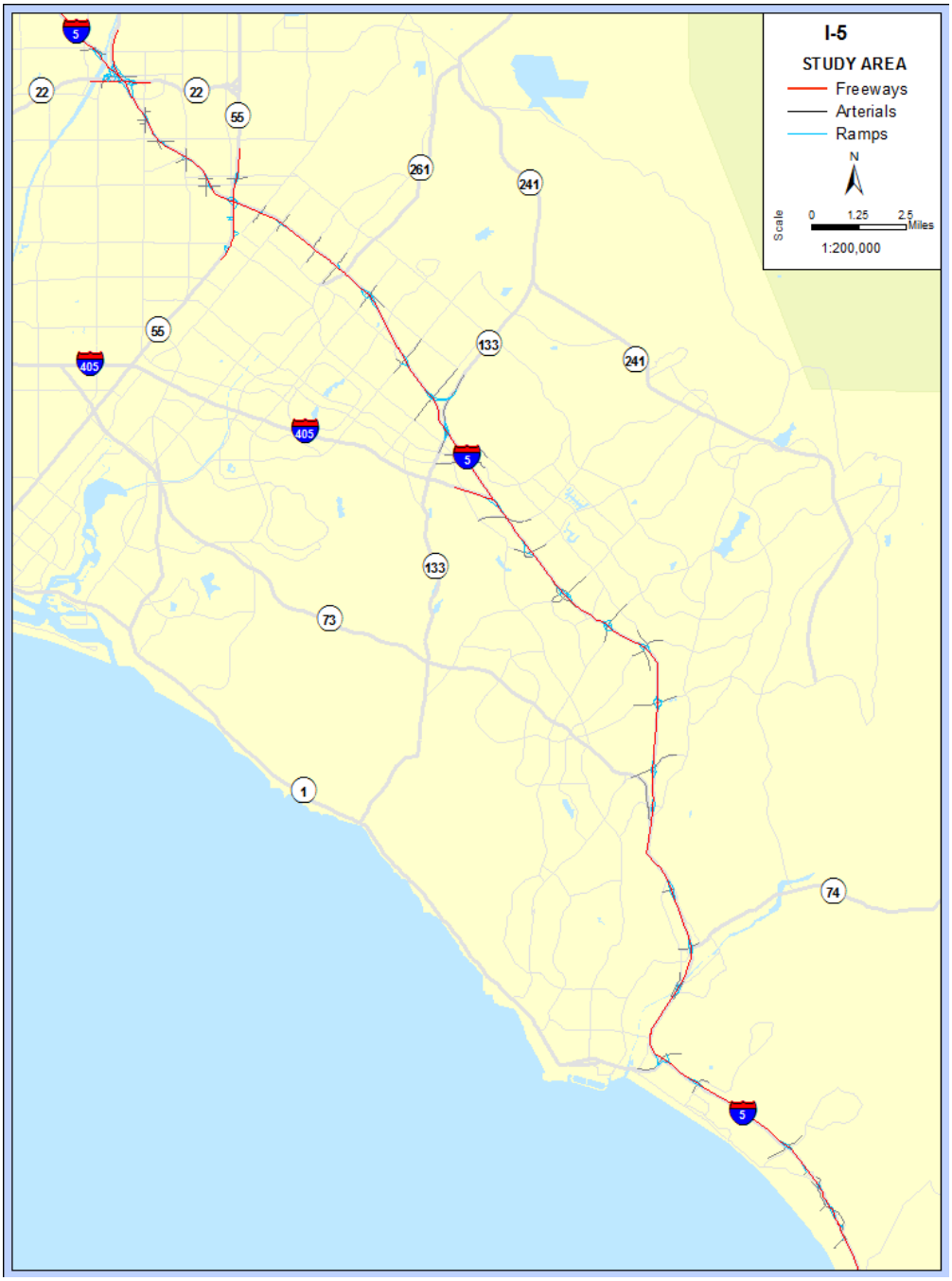
Micro-simulation models should typically start and end at areas with stable flow conditions in order to better estimate the demands of the model and replicate vehicles' releasing patterns during simulation. Exhibit 6-1 shows the roadway network included in the I-5 model that extends from the San Diego County line to north of the SR-22/SR-57 interchange. The model includes all freeway interchanges, arterial sections leading to these interchanges, and on- and off-ramps.

The model was calibrated against 2010 conditions. This was a resource intensive effort, requiring several review cycles until the model reasonably matched bottleneck locations and relative severity. The Model Calibration Report is included under separate cover. Once the calibrated 2010 base year model was approved, a 2020 model was developed based on the Orange County Transportation Authority's (OCTA) travel demand model demand projections. Caltrans agreed to 2020 as the Horizon Year since micro-simulation models are better suited for short- to medium-term forecasting. Based on the growth projections extracted from the OCTAM model,

congestion on I-5 was projected to grow significantly, more than any other CSMP corridor. The analysis does not account for latent demand beyond the OCTA demand forecast.

After calibration, these two models were used to evaluate different scenarios (combinations of projects) and quantify the associated congestion relief benefits. The results allowed the study team to compare the total benefits from each scenario with the associated project costs to assess the cost-effectiveness of improvements.

Exhibit 6-1: I-5 Micro-Simulation Model Network



Source: Paramics Simulation Model

Scenario Development Framework

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

- Fully programmed and funded projects were combined separately from projects not yet funded.
- Short-term projects (typically delivered by 2014) were used to develop scenarios tested with the 2010 and 2020 models.
- Long-term projects (delivered after 2014, but before or close to 2020) were used to develop scenarios tested only with the 2020 model.

The study assumes that the 2010 base year model could support reasonable evaluations of projects developed before 2014. The 2020 horizon year for the I-5 Corridor was extrapolated from the OCTA regional travel demand model origin-destination matrices. When OCTA updates its travel demand model and when the Southern California Association of Governments (SCAG) updates the Regional Transportation Plan (RTP), Caltrans may wish to update the micro-simulation model with revised demand projections.

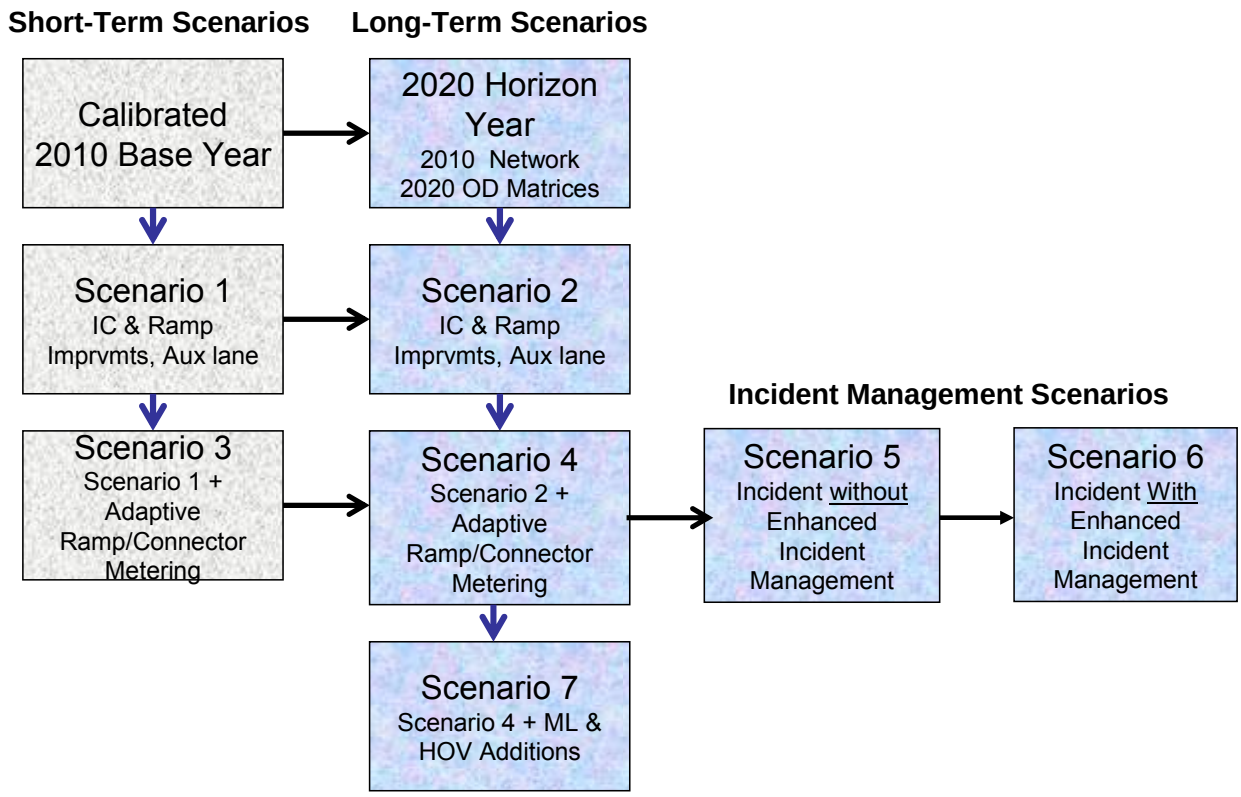
The study team developed projects using project lists obtained from the Regional Transportation Improvement Program (RTIP), the Regional Transportation Plan (RTP), Measure M2, Transportation Corridor Agencies (TCA) improvements, Caltrans Planning, and other sources (e.g., special studies). Projects that do not affect mobility directly were eliminated. For instance, sound wall, landscaping, or minor arterial improvement projects were not evaluated since the primary (non-mobility) benefits of these projects are not captured in micro-simulation models. Projects outside the micro-simulation model limits, such as the I-5 Gateway and the Gene Autry Bridge widening projects, could also help improve corridor conditions.

Scenario testing performed for the I-5 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. This contrasts with the CSMP approach. For the I-5 CSMP, scenarios build on previous scenarios as long as the incremental scenario results show an acceptable level of performance improvement. This incremental scenario evaluation approach is important since CSMPs are new and are often confused with alternatives studies.

Exhibit 6-2 summarizes the I-5 modeling approach and the scenarios tested. While several more scenarios were tested, this exhibit shows only the most promising

scenarios that provide positive benefits. The exhibit also contains general descriptions of the projects included in the 2010 and 2020 micro-simulation runs. Appendix C provides a detailed list of the projects included in each scenario.

Exhibit 6-2: Micro-Simulation Modeling Approach



Scenario Evaluation Results

Exhibits 6-3 and 6-4 show the delay results by facility type and peak period for all scenarios evaluated using the 2010 base year model. Exhibits 6-5 and 6-6 show the results for the 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 - 1). The impacts of strategies differ based on factors, such as traffic flow, available ramp storage, bottleneck locations, and congestion.

For each scenario, the modeling team produced results by facility type (i.e., mainline, HOV, and ramps) and vehicle type (SOV, HOV, trucks) as well as speed contour diagrams. The study team scrutinized these results to ensure consistency with general traffic engineering principles.

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

Exhibit 6-3: 2010 AM Peak Micro-Simulation Delay by Scenario

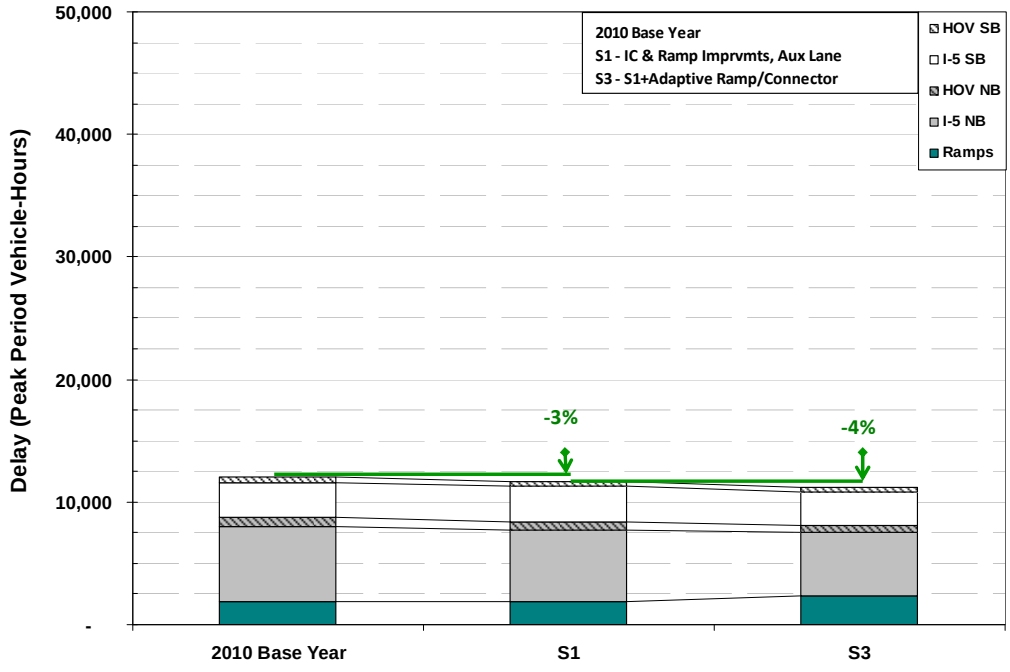


Exhibit 6-4: 2010 PM Peak Micro-Simulation Delay by Scenario

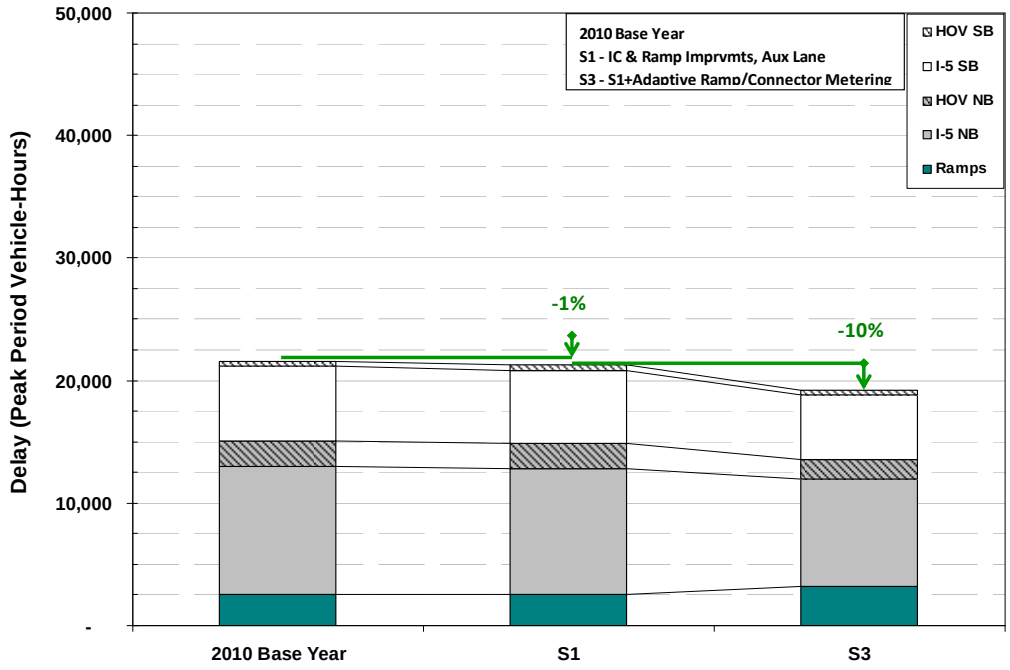


Exhibit 6-5: 2020 AM Peak Micro-Simulation Delay by Scenario

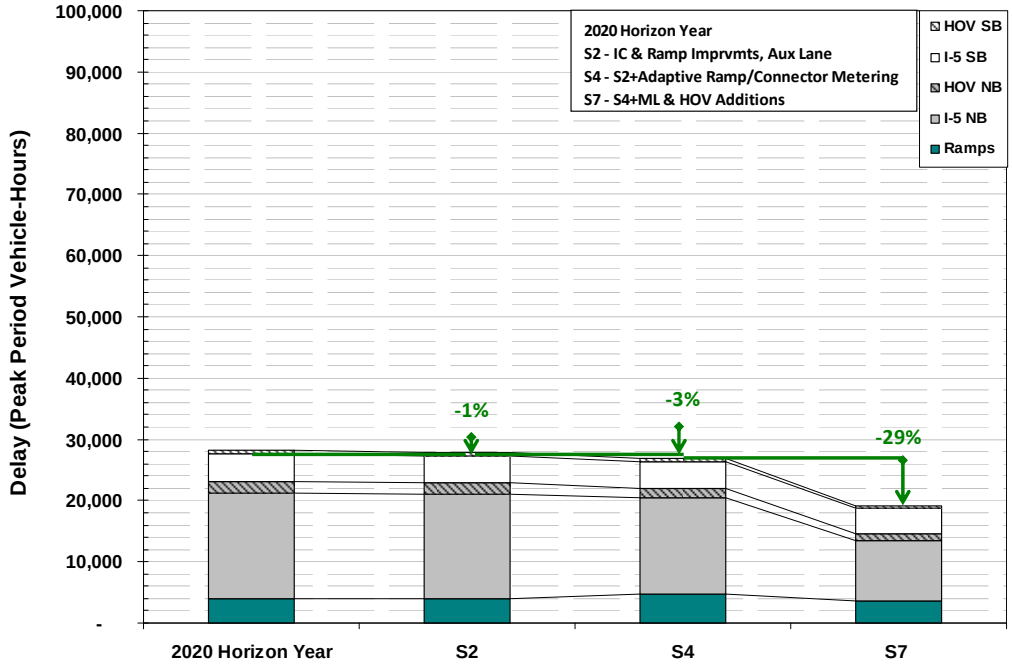
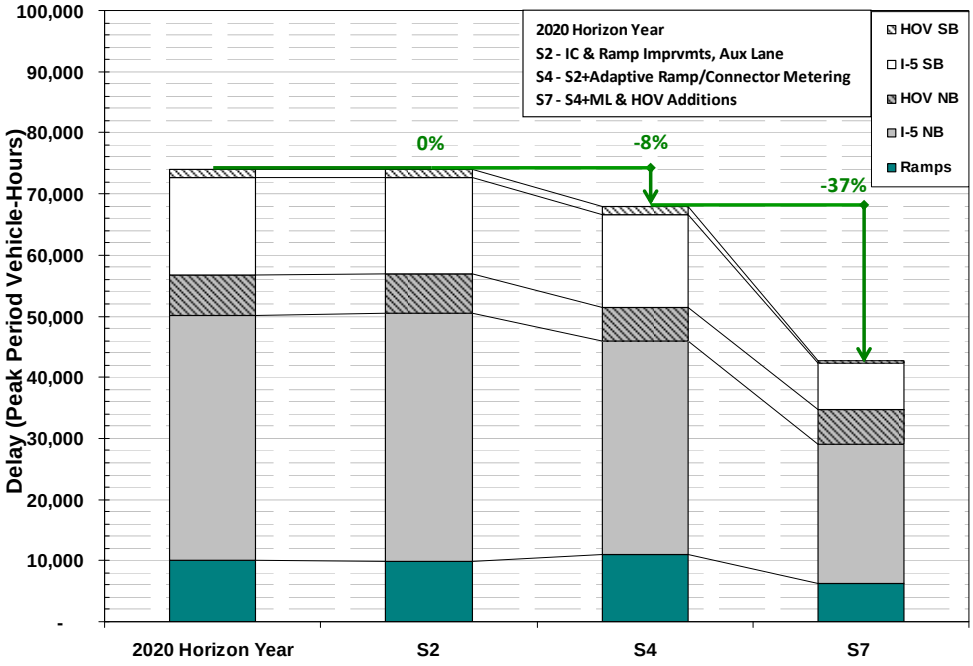


Exhibit 6-6: 2020 PM Peak Micro-Simulation Delay by Scenario



Exhibits 6-7 through 6-10 summarize the delay results from the 2010 base year model by bottleneck area, direction (northbound or southbound), and peak period (AM or PM). Exhibits 6-11 through 6-14 report comparable delay results from the 2020 horizon year model.

Exhibit 6-7: 2010 Northbound AM Delay by Scenario and Bottleneck Area

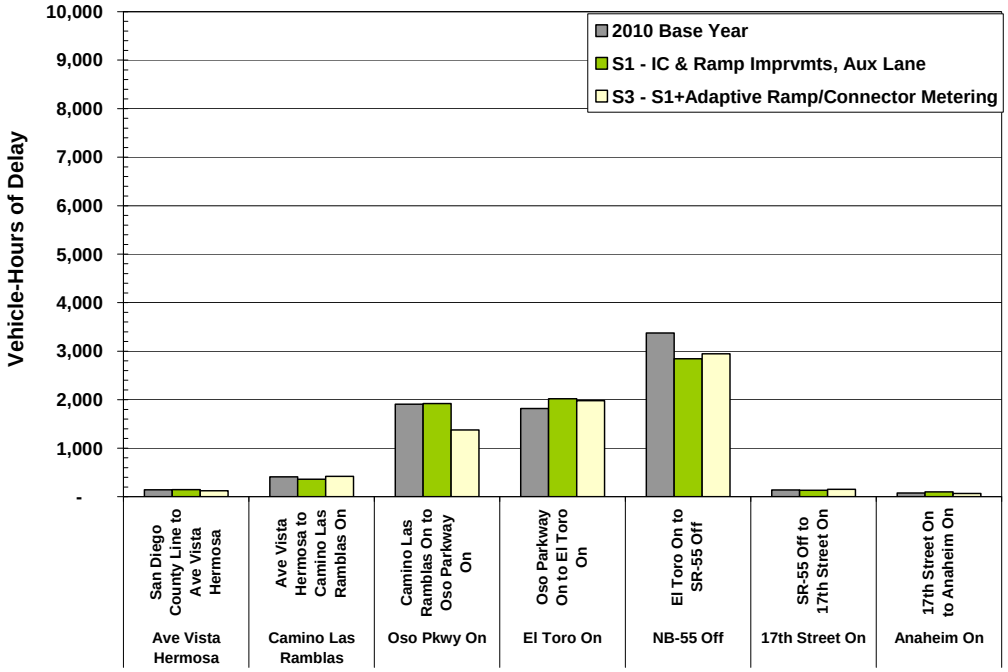


Exhibit 6-8: 2010 Northbound PM Delay by Scenario and Bottleneck Area

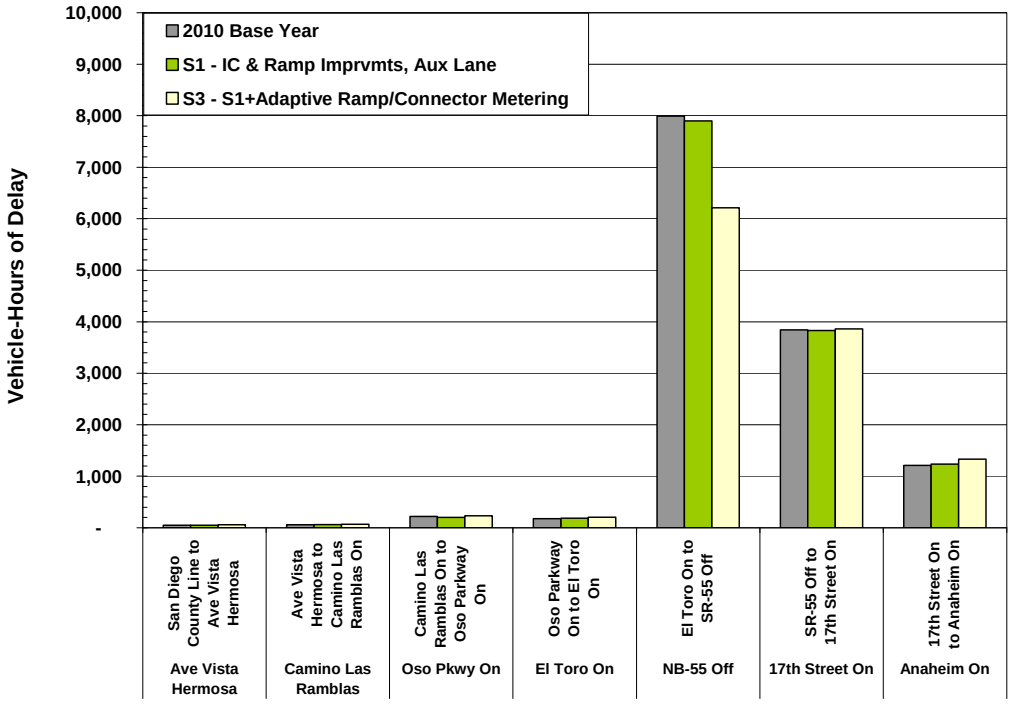


Exhibit 6-9: 2010 Southbound AM Delay by Scenario and Bottleneck Area

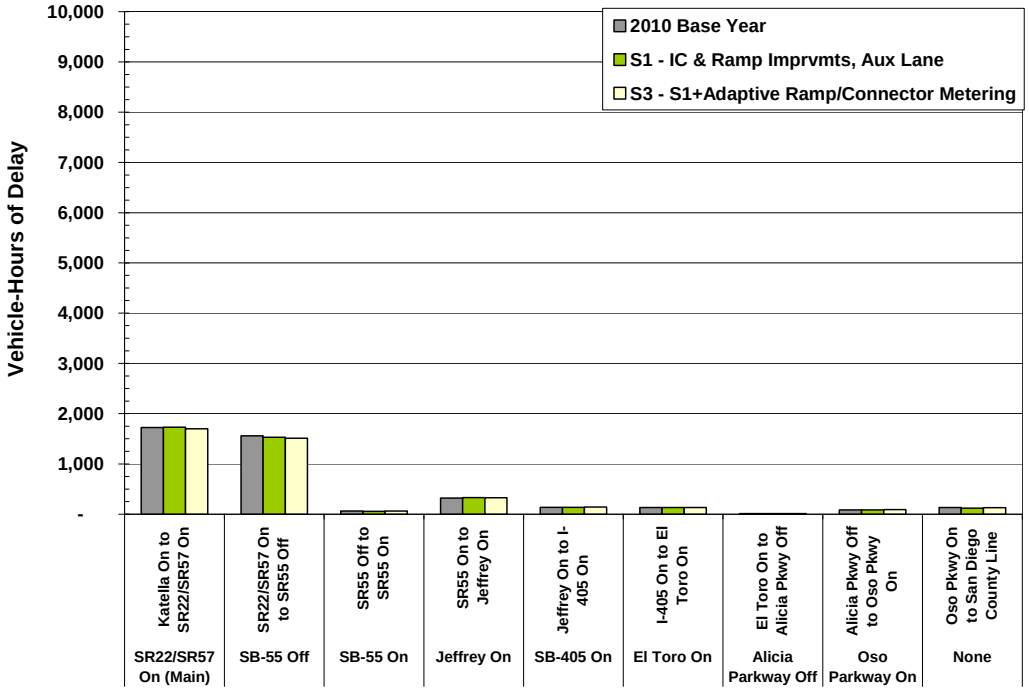


Exhibit 6-10: 2010 Southbound PM Delay by Scenario and Bottleneck Area

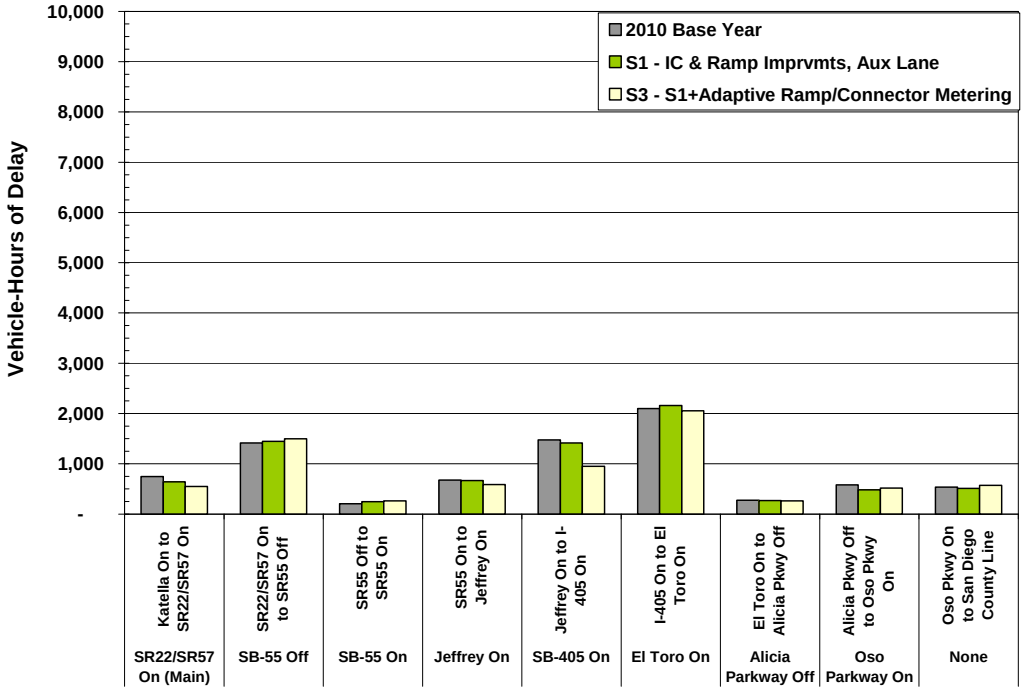


Exhibit 6-11: 2020 Northbound AM Delay by Scenario and Bottleneck Area

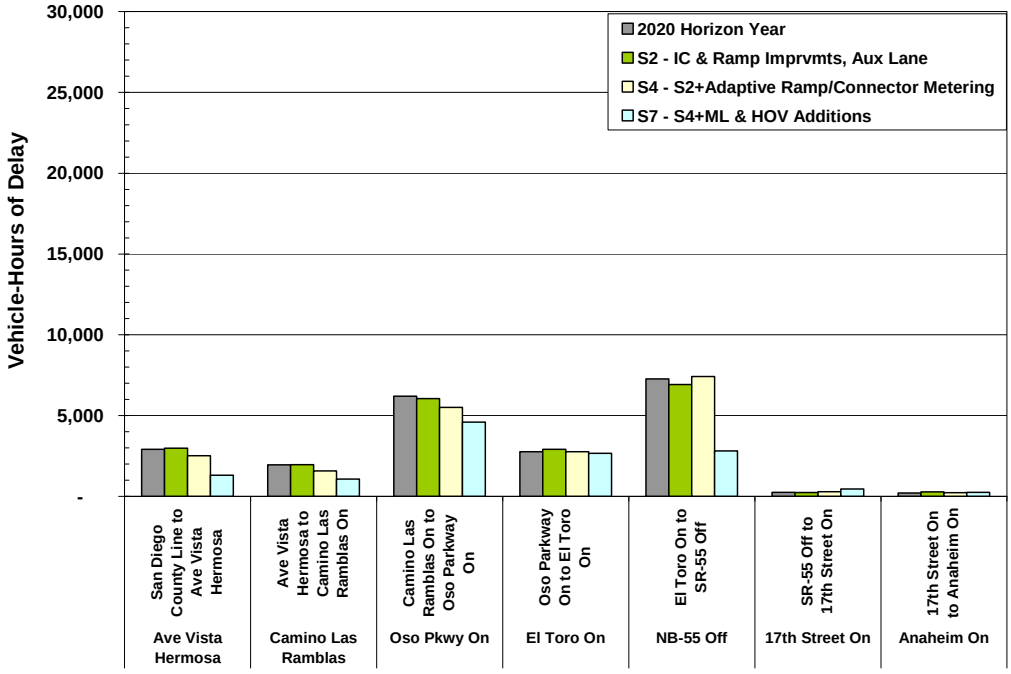


Exhibit 6-12: 2020 Northbound PM Delay by Scenario and Bottleneck Area

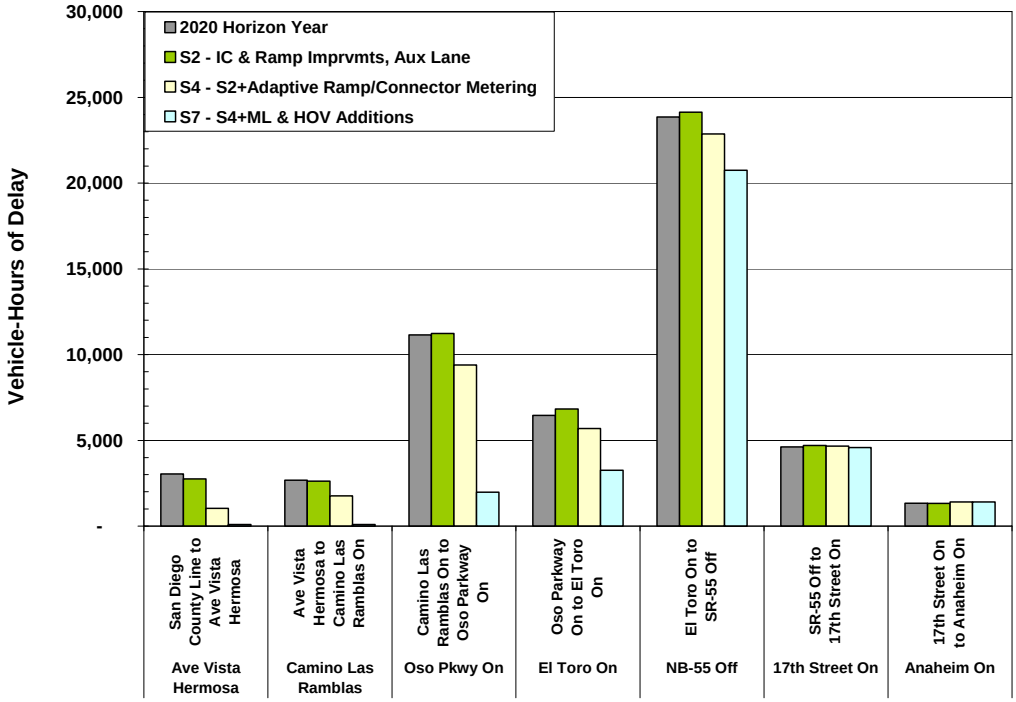


Exhibit 6-13: 2020 Southbound AM Delay by Scenario and Bottleneck Area

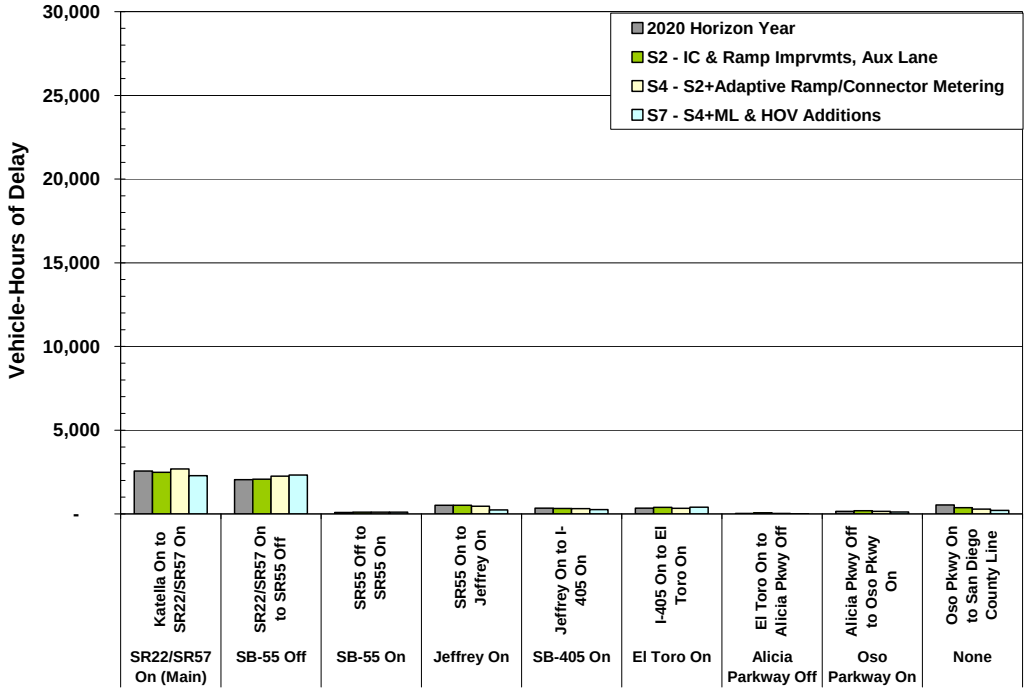
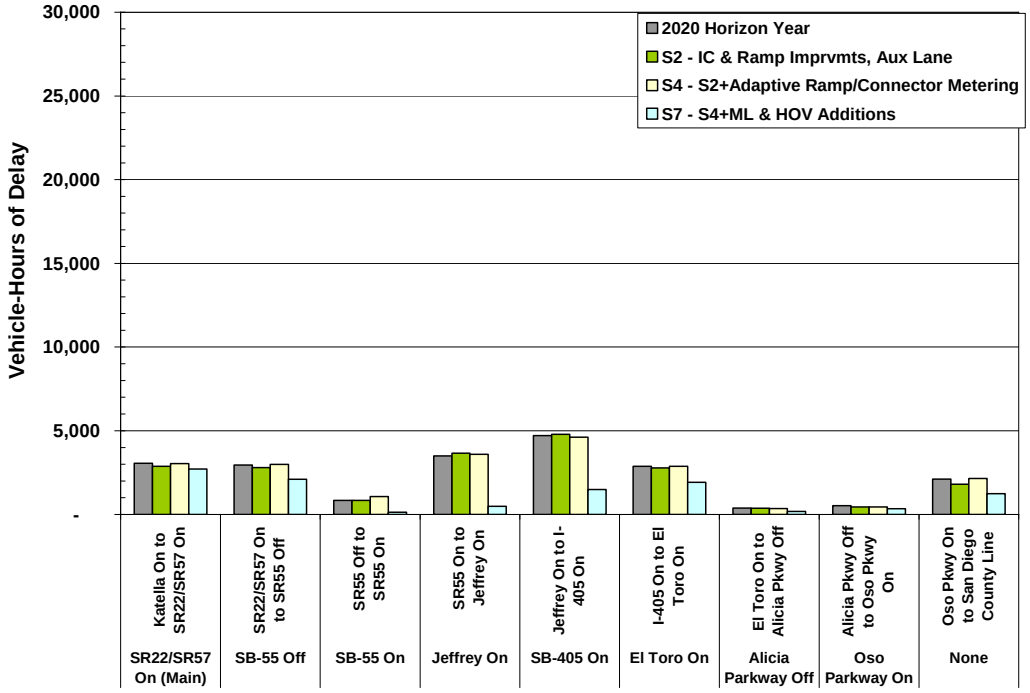


Exhibit 6-14: 2020 Southbound PM Delay by Scenario and Bottleneck Area



The following describes findings for each scenario tested by the study team:

Base Year and "Do Minimum" Horizon Year

Absent any physical improvements, the study team estimates that by 2020, total delay (mainline, HOV, and ramps) will increase by more than 300 percent compared to 2010 (from a total of around 33,600 hours daily to over 102,000 hours) in the AM and PM peak hours. These forecasts do not reflect the economic conditions of the past few years and may overestimate the demand actually experienced in 2020. However, demand is expected to grow over time and may eventually reach these levels. As described further below, the short-term programmed projects lead to significant decreases and improved mobility on the corridor, regardless of when the anticipated growth in demand materializes.

Scenarios 1 and 2 (Interchange and Ramp Improvements, Auxiliary Lane)

The first two scenarios include fully funded and programmed projects that are operations related and slated for completion by 2014. These projects include:

- Converting a northbound HOV lane to continuous access from Tustin Ranch Road to Red Hill Avenue in the City of Tustin.
- Widening southbound Camino de Estrella off-ramp from one lane to two lanes and widening the overcrossing from five lanes to seven lanes in the City of San Clemente.
- Widening southbound Camino Capistrano off-ramp from two lanes to three lanes
- Expanding La Paz Road from four lanes to six lanes and extending the associated on-ramp.
- Constructing a southbound auxiliary lane and widening a southbound off-ramp from one lane to two lanes at Jamboree Road. Widening eastbound undercrossing to create a left turn lane to northbound on ramp.
- Reconstructing the I-5/SR-74 interchange in the City of San Juan Capistrano.

The 2010 model estimates that the projects included in the first scenario (S1) will reduce delay on the corridor by approximately three percent in the AM peak period and by one percent in the PM peak period. In total, this scenario estimates a reduction of almost 650 hours of daily delay. The majority of the delay reduction occurs in the northbound direction during the AM peak period at the El Toro On Ramp to SR-55 Off Ramp bottleneck area. Mobility improves as a result of more opportunities for HOV and mainline vehicles to merge due to the continuous access HOV conversion project.

The 2020 model estimates that the same set of projects will reduce delay on the corridor by one percent in the AM peak period and less than one percent in the PM peak period. With demand increases in 2020, these operational improvement projects provide only minor benefits near the project areas only. The level of congestion

expected by year 2020 suggests that bigger, more beneficial projects would be needed to address these bottlenecks.

Scenarios 3 and 4 (Advanced Ramp Metering, Connector Metering)

Scenarios 3 and 4 also test advanced ramp and connector metering on Scenarios 1 and 2. A series of several ramp and connector metering projects were tested as part of the scenarios:

- Implementing advanced ramp metering with queue control.
- Metering the northbound SR-55 to northbound and southbound I-5 connector ramps. Metering the southbound SR-55 to southbound I-5 connector ramp.
- Metering the eastbound SR-91 to southbound I-5 and westbound SR-91 to northbound I-5 connector ramps.
- Metering the southbound SR-57 to southbound I-5 connector ramp.
- Metering the eastbound SR-22 to northbound and southbound I-5 connector ramps.

There are several types of advanced ramp metering systems deployed around the world. For modeling purposes, the study team used one called Asservissement Lineaire d'Entrée Autoroutiere (ALINEA). This algorithm has been deployed in Europe and Asia and the software was readily available for modeling. However, this algorithm is used as a proxy, so its use is not a recommendation for the I-5 Corridor. Caltrans should evaluate different algorithms and implement the one it deems most beneficial.

The 2010 model indicates that the projects will improve delay in the AM peak by four percent and PM peak by ten percent. The 2020 model shows that the projects will improve delays in the AM and PM peaks by three and eight percent, respectively. Although the mainline facility experienced an improvement in delay during both the AM and PM peak hours, the ramps and connectors experienced an overall delay increase. This results in a modest improvement for the corridor overall in both the 2010 and 2020 models. Advanced ramp and connector metering are estimated to reduce delay by over 2,500 vehicle-hours for the 2010 model and by almost 7,000 vehicle-hours of delay for the 2020 model.

Scenarios 5 and 6 (Enhanced Incident Management)

Two incident scenarios were tested upon Scenario 4 to evaluate the non-recurrent delay reductions resulting from enhanced incident management strategies. In the first scenario, Scenario 5, one collision incident with one outside lane closure was simulated in the southbound direction in the AM peak period model and in the northbound direction in the PM peak period model. The incident simulation location and duration was selected based on review of the 2011 actual incident data, at one of the high frequency locations. The following are the scenario details:

- Northbound AM peak period starting at 7:00 AM, close outermost mainline lane for 45 minutes at Post Mile 18.685 (at El Toro Road).
- Southbound PM peak period starting at 5:00 PM, close outermost mainline lane for 35 minutes at Post Mile 18.685 (at El Toro Road).

As a result, the modeling represents a typical or moderate incident at one location during a peak period in each direction. 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 require upgrading or enhancing the current Caltrans incident management system to include the 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 6, the same collision incident is simulated with a reduction in duration by 15 minutes in the northbound direction and ten minutes in the southbound direction to determine the benefits of an enhanced incident management system.

Exhibits 6-15 and 6-16 show the delay results by facility type and peak period for the enhanced incident management scenarios evaluated using the 2020 model. Without enhanced incident management, the first scenario produced a two percent increase in congestion in the AM peak and a 31 percent increase in the PM peak over Scenario 6 — a total increase of over 21,600 vehicle-hours of delay. The results indicate enhanced incident management would have little effect in the AM peak, but eliminate over 19,000 vehicle-hours of delay in the PM peak using 2020 demand. While these results capture benefits during the peak direction in the peak period, additional benefits could be realized during off-peak hours and in the off-peak direction.

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

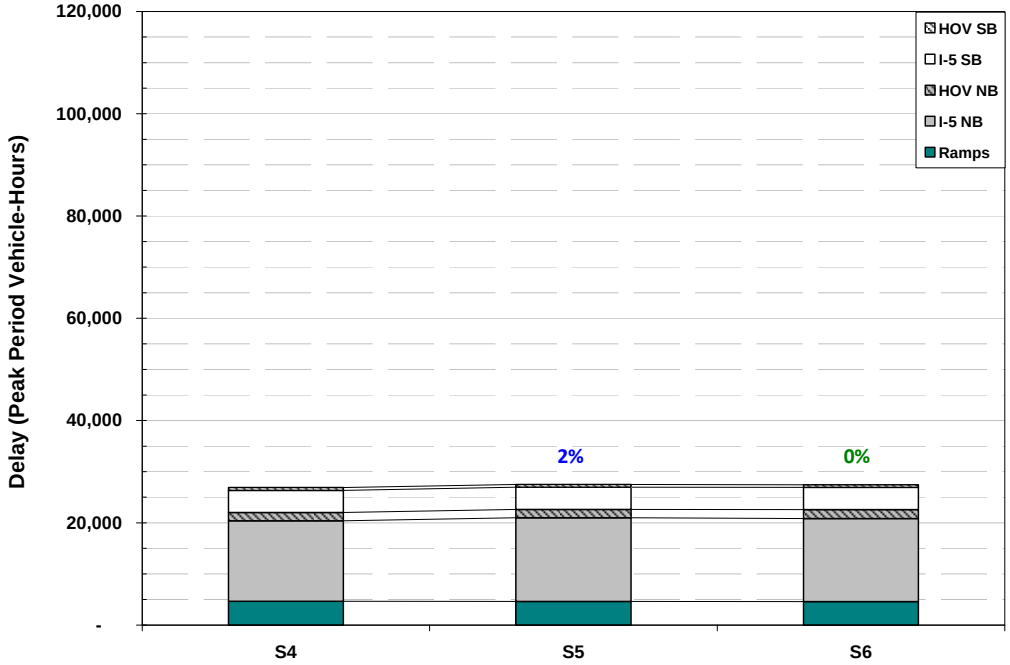
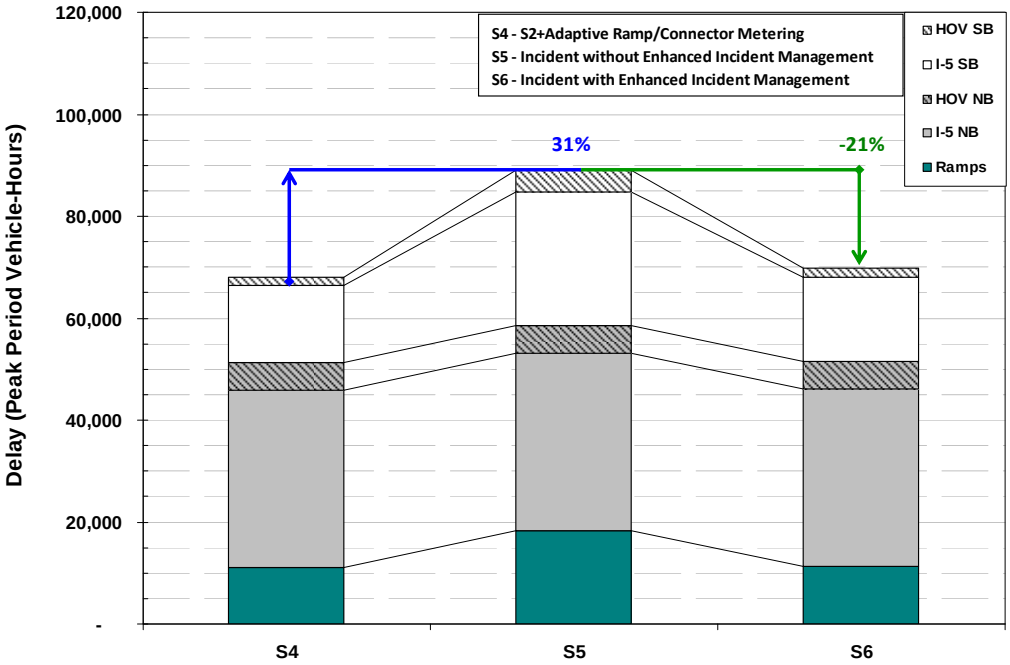


Exhibit 6-16: 2020 PM Delay Results for Enhanced Incident Management



Scenario 7 (HOV and Mainline Lane Additions)

Scenario 7 adds several funded projects to the alternative modeled in Scenario 4:

- Providing a second HOV lane in each direction in the Cities of Tustin and Santa Ana. This is a Measure M2 funded project.
- Providing new lanes in both directions and improving the interchange at the Y (El Toro) from SR-55 to El Toro Interchange. This is a Measure M2 funded project.
- Adding mainline, HOV, and auxiliary lanes and reconfiguring interchanges from El Toro Interchange in Lake Forest to Junipero Serra in San Juan Capistrano. This is a Measure M2 funded project.
- Adding an HOV lane in each direction from Avenida Pico to San Juan Creek Road. Reconfiguring Avenida Pico interchange.

The 2020 model shows that the combination of these projects will produce a 29 percent reduction in delay in the AM peak period and a 37 percent reduction in delay in the PM peak period. Although the combination of these projects produce a significant benefit on the corridor, the delay in the AM and PM peak periods still totals almost 62,000 vehicle-hours after Scenario 7.

Post Scenarios 1-7 Conditions

After the completion of Scenarios 1 through 7, the 2020 model reveals that significant residual congestion (almost 62,000 vehicle-hours) remains to be addressed through additional improvements. However, the OCTAM model forecasts do not reflect the economic conditions of the past few years and may overestimate the demand actually experienced in 2020. Even without any improvements to the corridor, congestion is expected to be triple due to the high future demand in 2020 according to the OCTAM model. Given such high demand forecasts, the modeled conditions after Scenarios 1 through 7 represent an overall reduction in delay of almost 40 percent from the 102,000 vehicle-hours of delay expected in 2020 if no improvements are made.

Benefit-Cost Analysis

Following an in-depth review of model results, the study team performed a benefit-cost analysis (BCA) 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 the benefits after the 20-year lifecycle

or other benefits, such as the reduction in congestion outside the peak periods, safety benefits, and improvements 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 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 B/C greater than 1.0 means that a scenario's projects return greater benefits than they cost to construct or implement. It is important to consider the total benefits that a project brings. For example, a large capital expansion project such as adding new mainline lanes in each direction from SR-55 to El Toro has a high capital construction cost, which reduces the B/C ratio, but brings much higher absolute benefits to I-5 users. Exhibit 6-17 illustrates typical benefit-cost ratios that can be expected for different project types.

The benefit-cost analysis for the I-5 Corridor is summarized in Exhibit 6-18.

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

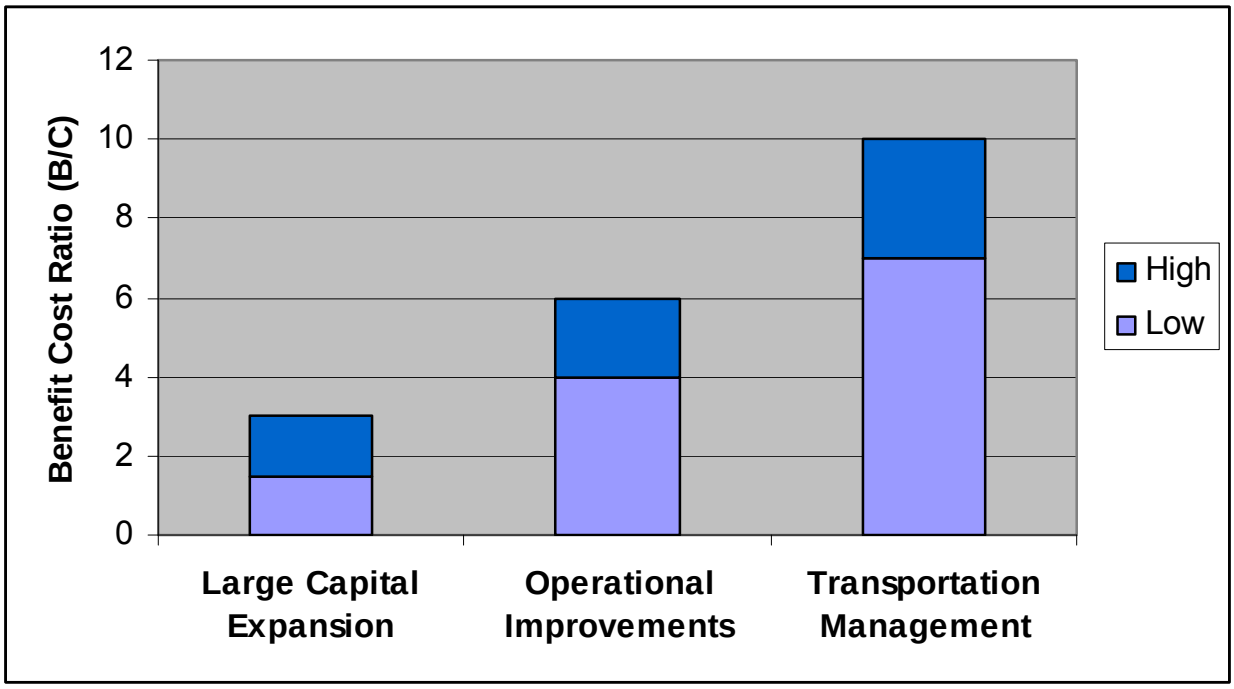
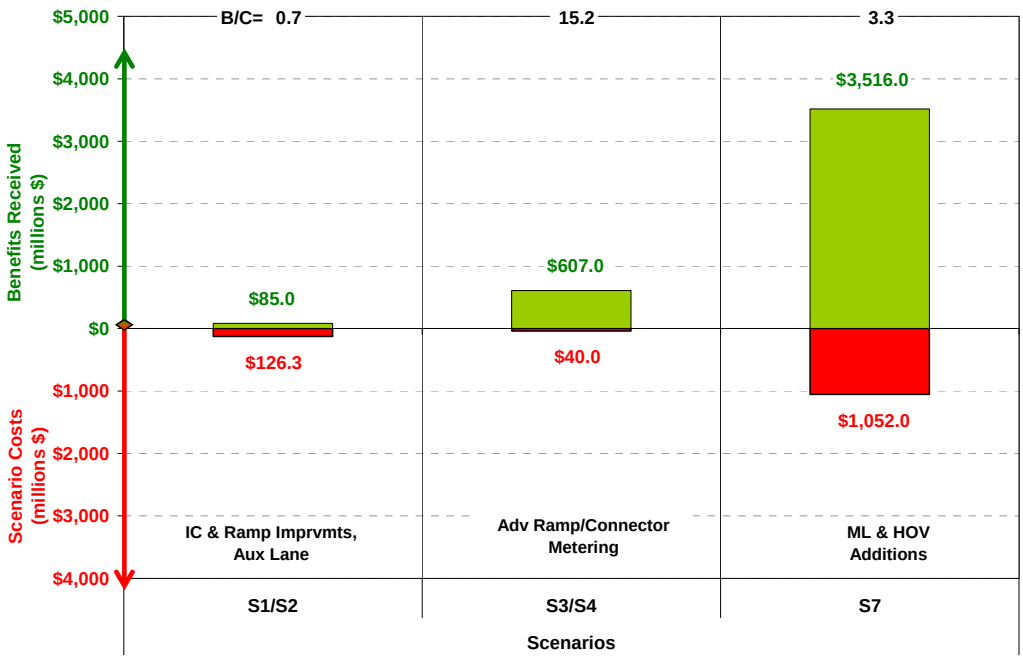


Exhibit 6-18: Scenario Benefit/Cost (B/C) Results



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

- Scenario 1 and Scenario 2 (interchange and ramp improvements, auxiliary lane at southbound Jamboree Road) produces a low benefit-cost ratio of about 0.7, but these operational improvements are critical before advanced ramp metering can be completed in Scenarios 3 and 4.
- Scenarios 3 and 4 (advanced ramp/connector metering) produce a very high benefit-cost ratio of over 10. Combined with Scenarios 1 and 2, these scenarios produce an aggregate benefit-cost ratio of 4.2.
- Scenario 7 (mainline and HOV lane additions) produces an average benefit-cost ratio of 3.3.
- The combined benefit-cost ratio of Scenarios 1, 2, 3, 4, and 7 is 3.5, which is a compelling investment result despite the remaining congestion on the corridor. If all the projects are delivered at current cost estimates, the public will get over three dollars of benefits for each dollar expended. In current dollars, costs add to over $1.2 billion whereas the benefits are estimated to be over $4.2 billion.
- The projects also alleviate CO_2 greenhouse gas emissions by three million tons over 20 years, avoiding more than 150,000 tons per year. These emission impacts are estimated in Cal-B/C using data from the California Air Resources Board (CARB) EMFAC model.

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

7. CONCLUSIONS AND RECOMMENDATIONS

This section summarizes the conclusions and recommendations of the I-5 CSMP based on the analysis presented in this report. It is important to note that many of these conclusions are based primarily on the micro-simulation model results, which was based on the best data available at the time. The study team believes that both the calibration and the scenario results are reasonable given the demand forecasts in the OCTAM model. However, caution should always be used when making decisions based on modeling alone, especially complex models such as this one. Project decisions are based on a combination of regional and inter-regional plans and needs. Regional and local acceptance for a project, availability of funding, as well as planning and engineering requirements are all critical for the successful implementation of a project.

Based on the results of the analyses presented herein, the study team offers the following conclusions and recommendations:

- The short-term operational improvements produce a low benefit on the corridor. However, these projects can be implemented within a short timeframe and can result in minor spot improvements. In addition, these improvements are necessary to support advance ramp metering in later steps, which produces a high benefit.

- Subsequent adaptive ramp metering and connector metering deployment provides a high benefit-cost ratio due to the low costs to implement such improvements.

- The capacity-enhancing projects included in Scenario 7 (e.g., mainline lane and HOV lane additions) generate a significant improvement in operations of the corridor. Even with the high cost of implementing these projects, they produce a very compelling benefit-cost ratio of 3.3.

- The I-5 corridor is an example of an extremely congested urban corridor that benefits from operational strategies, however, it requires expansion to significantly improve mobility.

- After these improvements are completed, congestion is still expected to double what it is today due to increases in demand. As a result, the public may not fully appreciate the delay savings achieved (since they never experience the congestion that “would have been”). To address these concerns, Caltrans must consider additional operational and capacity enhancing projects to reduce congestion further.

- Enhanced incident management shows promise as well. With an average delay savings of over 10,000 vehicle-hours per incident, the corridor would experience significant delay savings.

Speed contour maps illustrate how the modeled scenarios can change performance on the corridor. Exhibits 7-1 and 7-2 show speed contour maps for the 2020 “do minimum” horizon year with the growth in congestion before any improvements. Exhibits 7-3 and 7-4 show the conditions at the conclusion of Scenario 9, the final scenario tested. A comparison of these charts shows that the tested scenarios reduce the extent and duration of congestion. While the scenarios reduce congestion by almost 40 percent compared to no improvements, considerable congestion remains.

Exhibits 7-3 and 7-4 show the remaining residual congestion and bottleneck locations. In the northbound direction, much of the southern corridor congestion has been eliminated, but the El Toro, SR-55, and SR-22/SR-57 bottleneck locations remain. In the southbound direction, the residual bottlenecks occur at the I-405 and SR-22/SR-57. These bottlenecks should be the target of future improvements on the corridor.

Exhibit 7-1: 2020 Northbound PM Peak Model Speed Contours Before Improvements

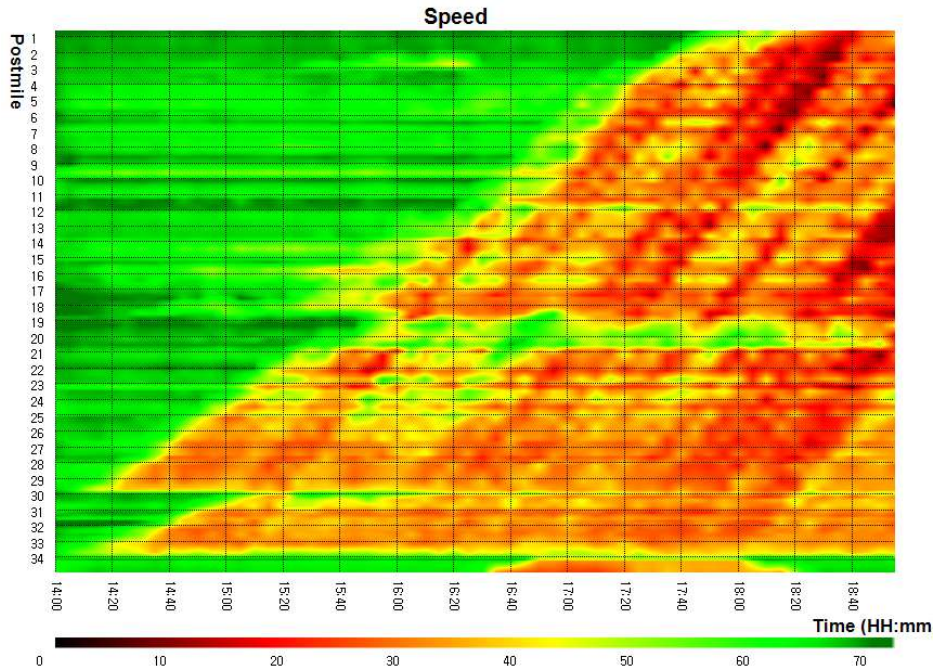


Exhibit 7-2: 2020 Southbound PM Peak Model Speed Contours Before Improvements

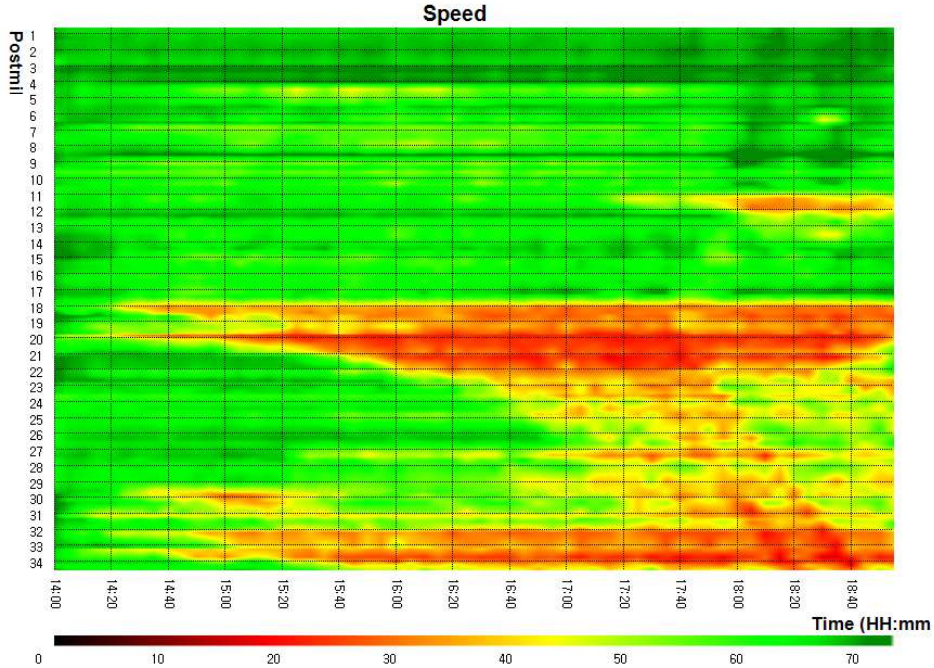


Exhibit 7-3: 2020 Northbound PM Peak Model Speed Contours After Improvements

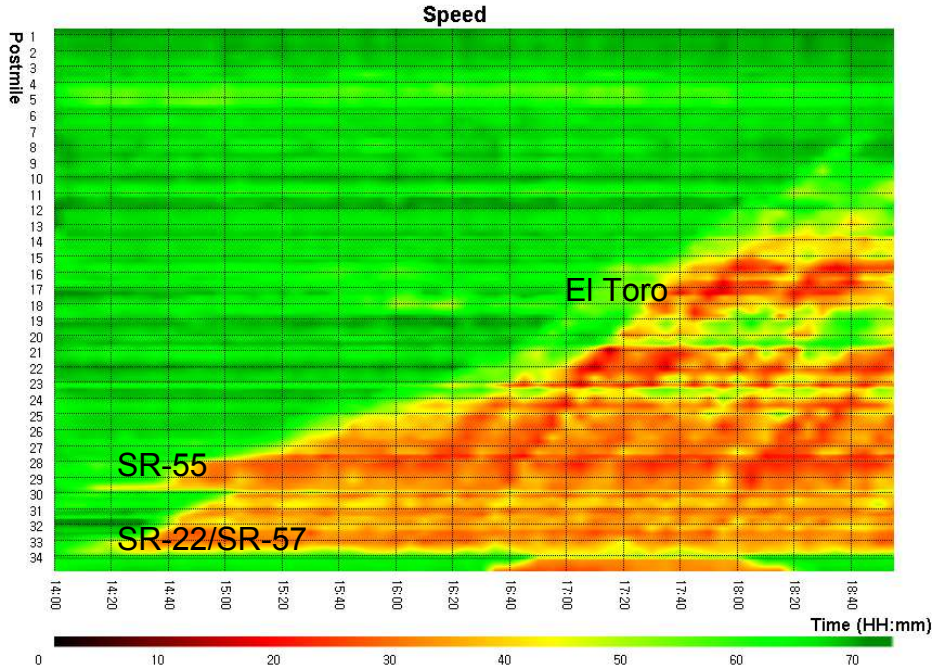
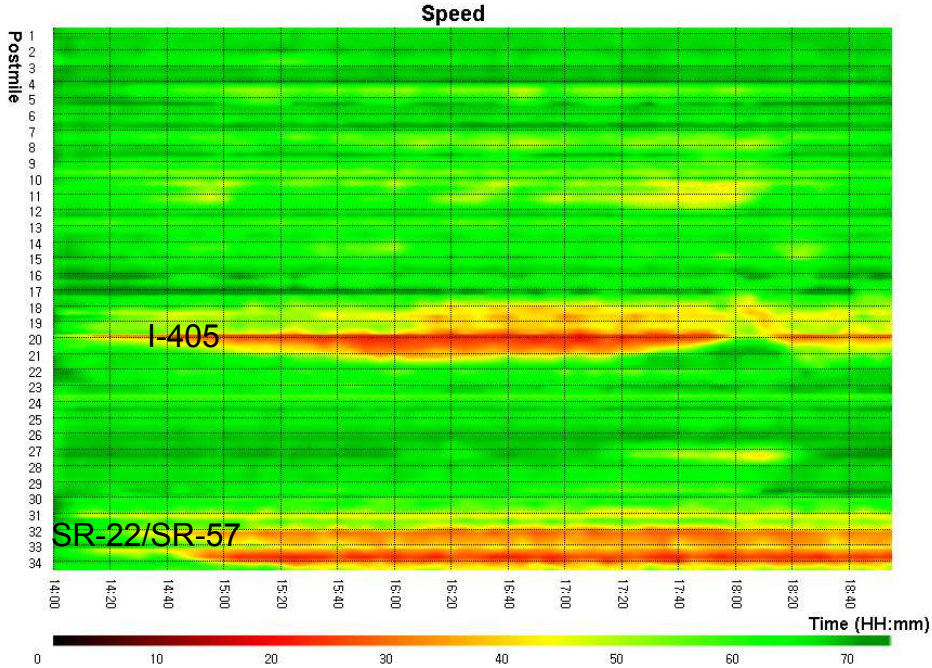


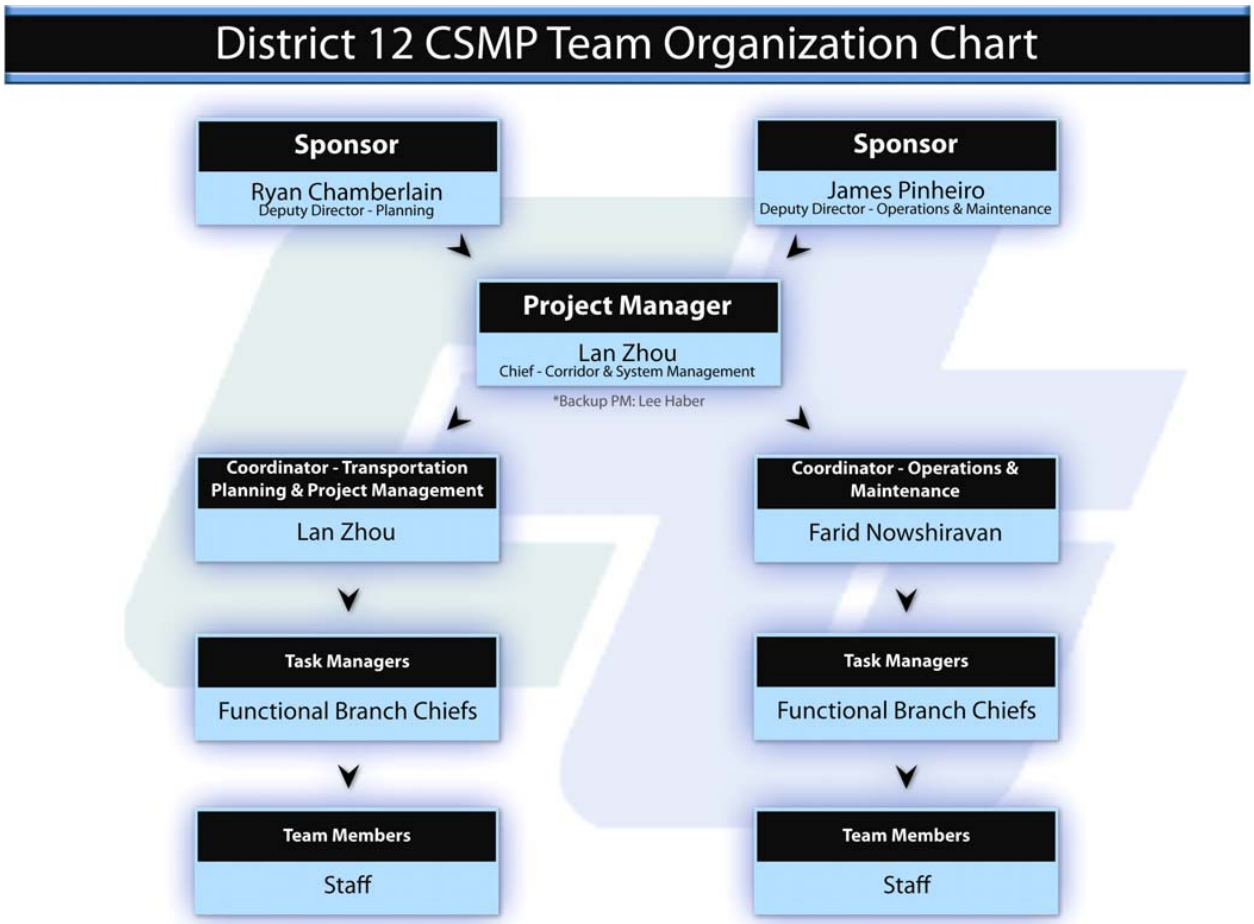
Exhibit 7-4: 2020 Southbound PM Peak Model Speed Contours After Improvements



This is the first generation CSMP for the I-5 Corridor. It is important to stress that CSMPs should be updated on a regular basis. 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 ones estimated in this document so that models can be further improved.

CSMPs, or a variation thereof, should become a normal course of business that is based on 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 the productivity of the current system. A traffic report with all the speed contours is available under separate cover.

Appendix A: District 12 CSMP Team Organization Chart



Appendix B: Weekend Performance Assessment and Bottleneck Identification

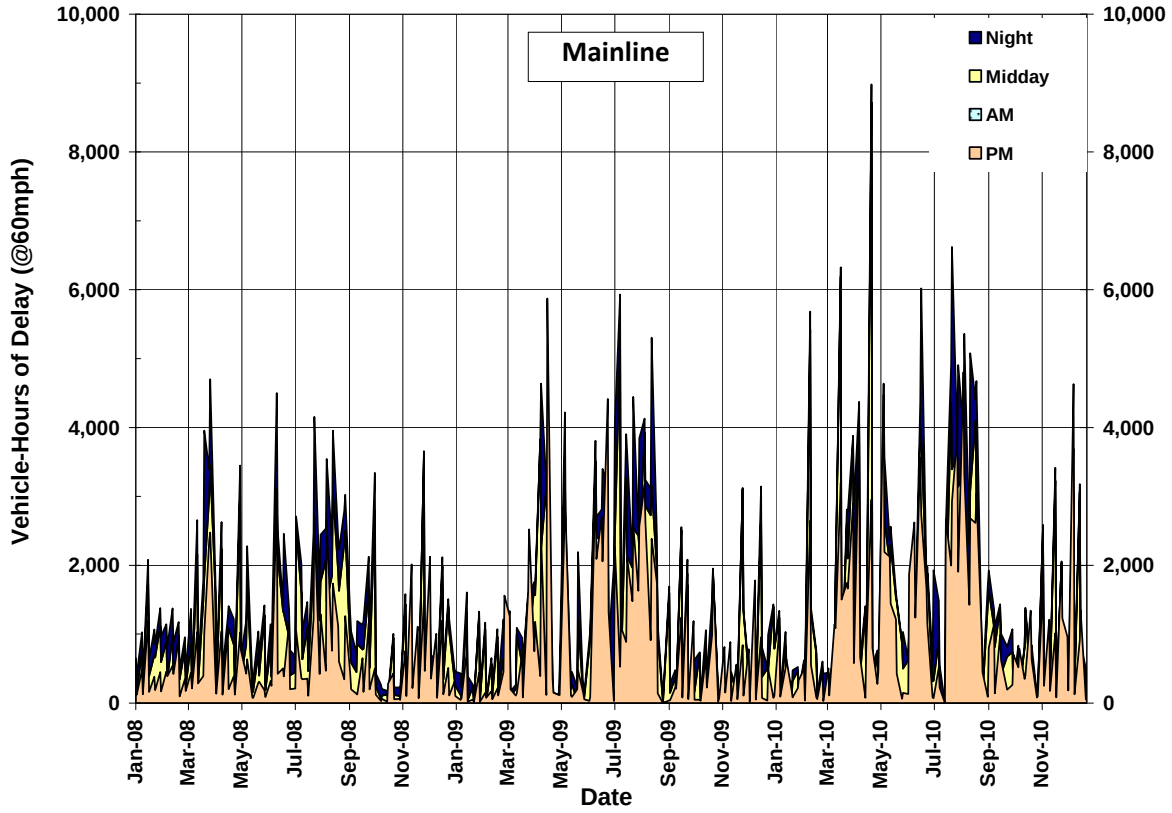
The weekend performance assessment includes three years of automatic detector data: 2008, 2009, and 2010. Delay presented herein represent the difference in travel time between actual conditions and free-flow conditions at 60 miles per hour, applied to the actual output flow volume collected from a vehicle detector station.

Exhibits B-1 through B-4 illustrate the delay experienced on weekends for the study corridor. Exhibits B-1 and B-2 report delay on the mainline facility while Exhibits B-3 and B-4 report delay on the HOV facility. Total delay along the study 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).

As indicated in Exhibits B-1 and B-2, weekend delay on the mainline facility was greater in the northbound direction with larger delays experienced during the Midday period. Northbound total delay increased yearly from 2008 to 2010 while southbound total delay decreased from 2008 to 2009 but increased from 2009 to 2010. 2010 had the highest total delay of the three-year period, with almost 300,000 vehicle-hours in the northbound direction and over 180,500 vehicle-hours in the southbound direction.

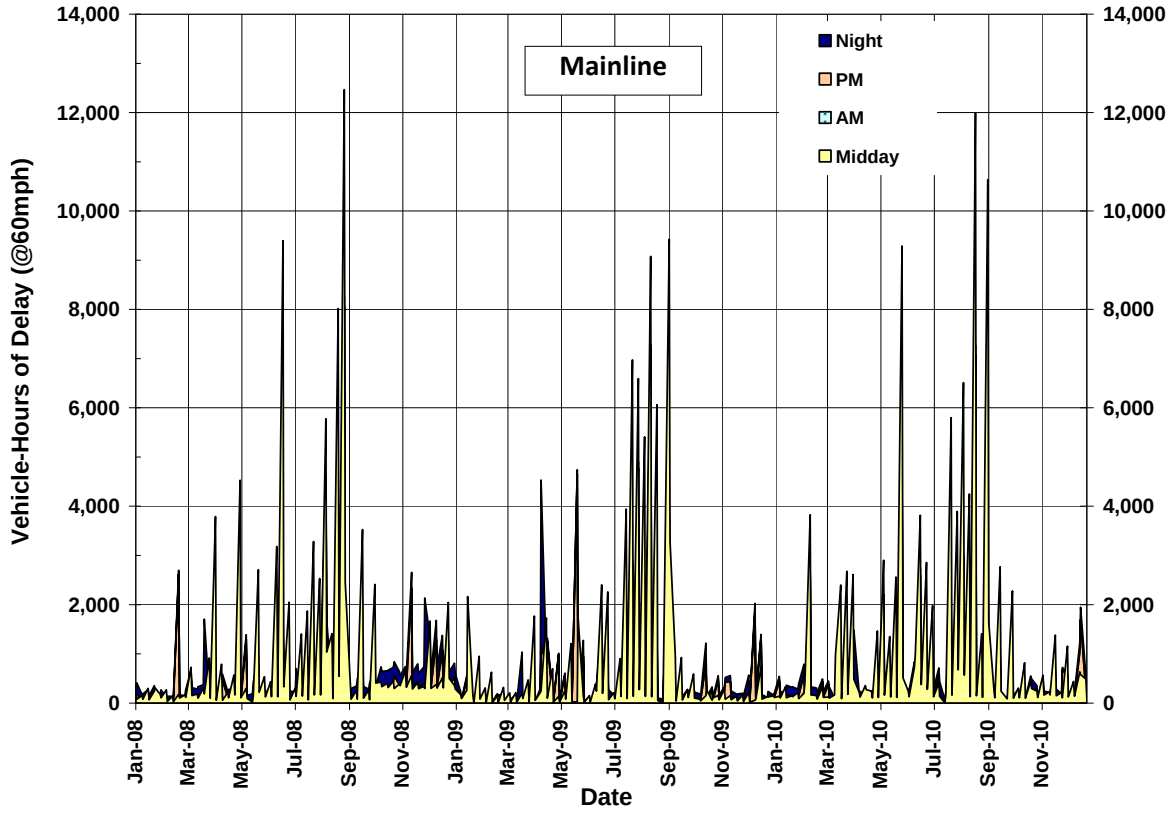
Exhibits B-3 and B-4 show the weekend delay on the HOV facility for the same three-year period. Similar to the mainline, delay in the southbound direction was highest in the Midday period, however, delay in the northbound direction was highest in the PM period, followed closely by Midday. Similar to mainline delays, northbound total delay increased yearly from 2008 to 2010 while southbound total delay decreased from 2008 to 2009 but increased from 2009 to 2010. HOV delay was also highest in 2010 out of the three-year period, with over 95,000 vehicle-hours in the northbound direction and almost 135,000 vehicle-hours in the southbound direction.

Exhibit B-1: Northbound I-5 ML Weekend Average Delay by Time Period (2008-2010)



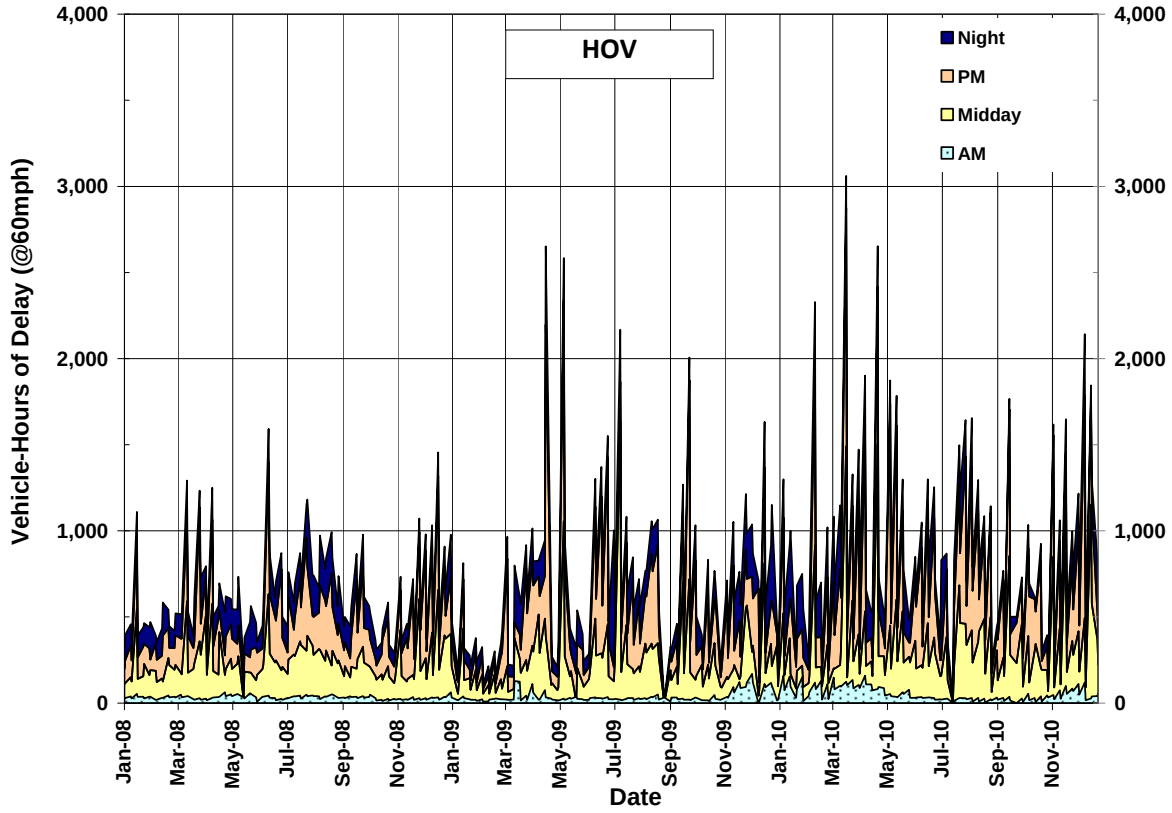
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-2: Southbound I-5 ML Weekend Average Delay by Time Period (2008-2010)



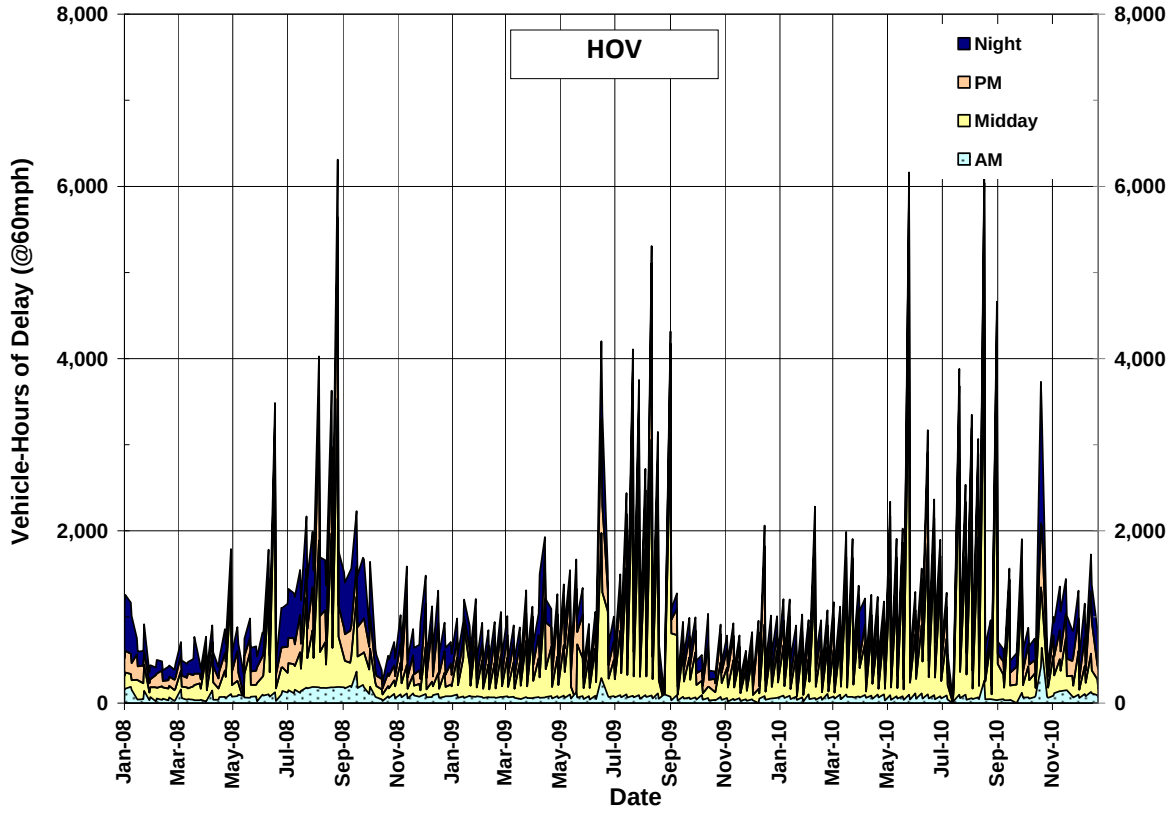
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-3: Northbound I-5 HOV Weekend Average Delay by Time Period (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

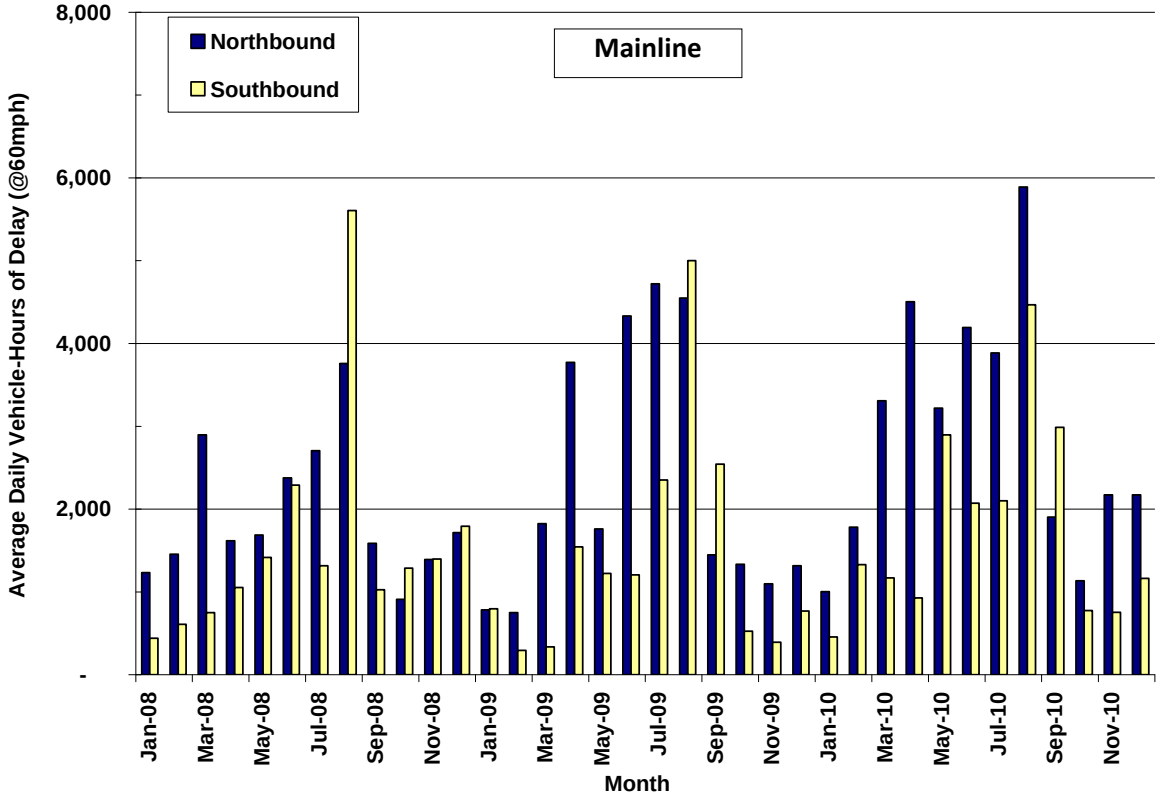
Exhibit B-4: Southbound I-5 HOV Weekend Average Delay by Time Period (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-5 shows the weekend average vehicle-hours of delay for each month between 2008 and 2010 for the mainline facility. This exhibit shows that northbound delay exceeded southbound delay for almost every month during the three-year period while delay in both directions was generally higher during the summer months. In addition, northbound monthly delays increased more than southbound delays for almost every month in 2009 and 2010.

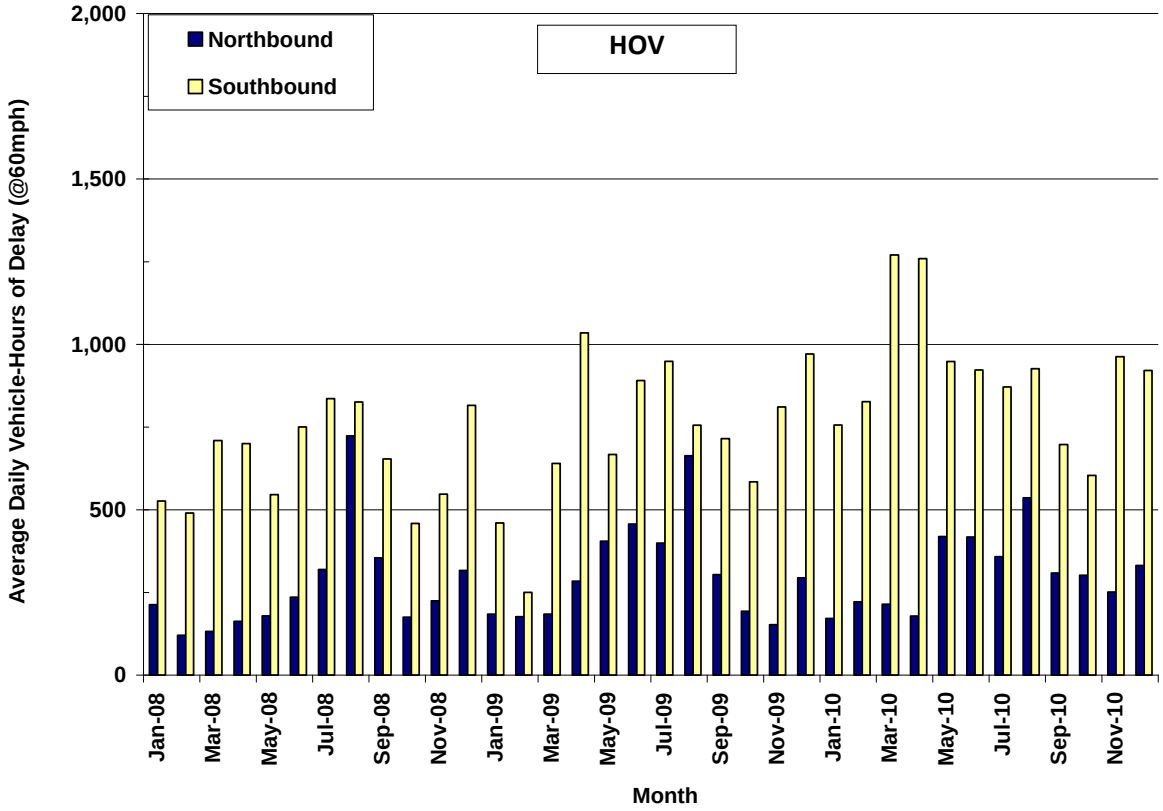
Exhibit B-5: I-5 ML Weekend Average Delay by Month (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-6 shows the weekend average vehicle-hours of delay for each month between 2008 and 2010 for the HOV facility. This exhibit shows that southbound delay exceeded northbound delay for every month during the three-year period.

Exhibit B-6: I-5 HOV Weekend Average Delay by Month (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Delays presented to this point represent the difference in travel time between "actual" conditions and free-flow conditions at 60 miles per hour. This delay can be segmented into two components as shown in the following two exhibits:

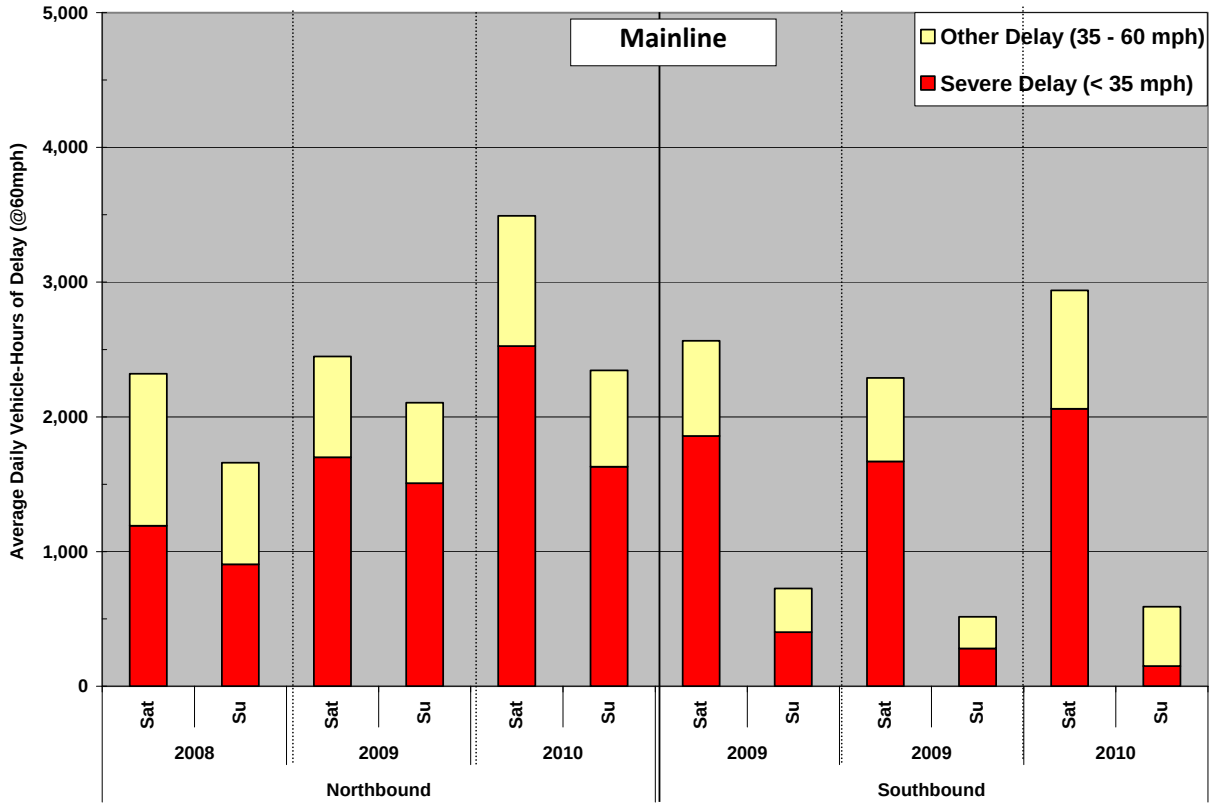
- Severe delay – delay occurring when speeds are below 35 miles per hour
- Other delay – delay occurring when speeds are between 35 and 60 miles per hour.

Severe delay represents breakdown conditions and is the focus of most congestion mitigation strategies. "Other" delay represents conditions approaching the breakdown congestion, leaving the breakdown conditions, or areas that cause temporary slowdowns rather than widespread breakdowns.

Exhibit B-7 shows weekend average severe and other vehicle-hours of delay by Saturdays and Sundays for the mainline facility. As depicted in the exhibit, Saturdays experienced the highest delays in both the northbound and southbound directions.

Delay was highest in 2010 compared to previous years, and greater in the northbound direction than the southbound.

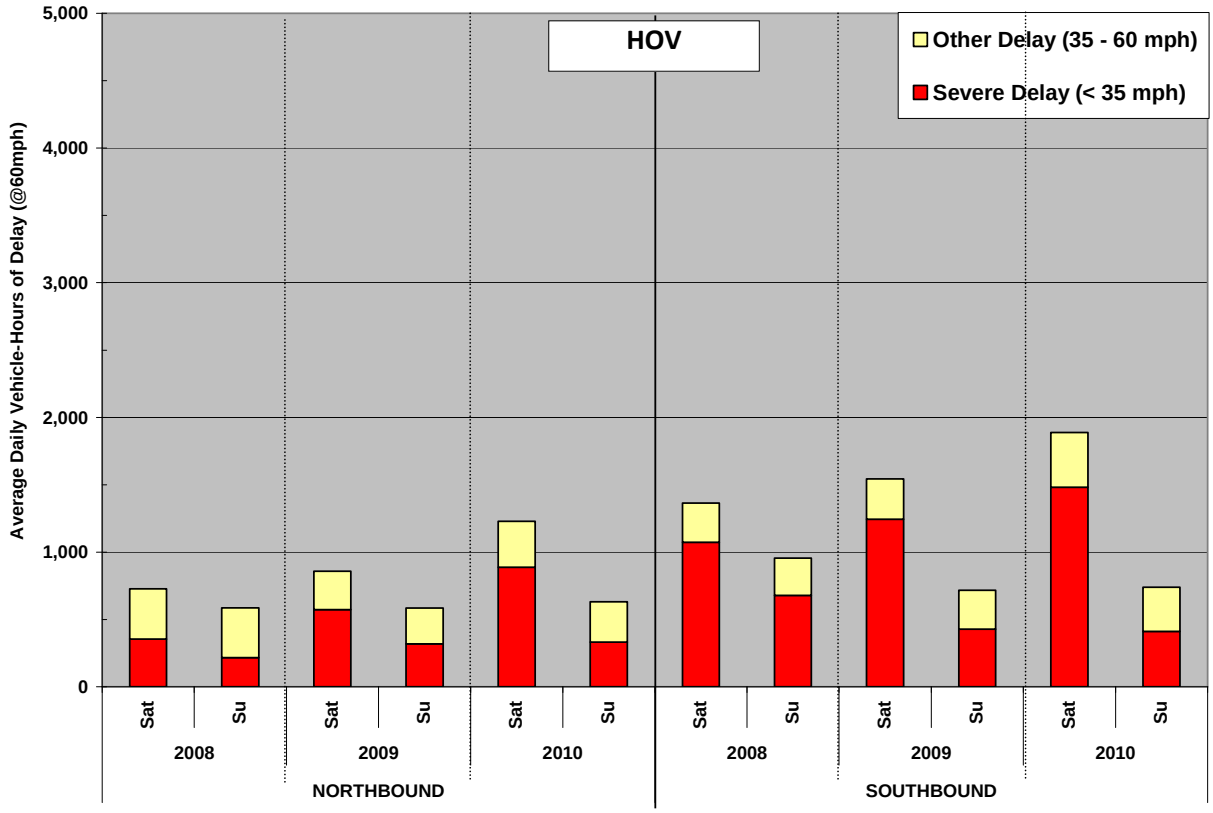
Exhibit B-7: I-5 ML Weekend Average Delay by Day of Week by Severity (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-8 summarizes the weekend severity of delay trend for the HOV facility. Saturdays also experienced the highest delay in both directions of travel. Delay in the southbound direction however, was higher than delay in the northbound direction during all three years.

Exhibit B-8: I-5 HOV Weekend Average Delay by Day of Week by Severity (2008-2010)

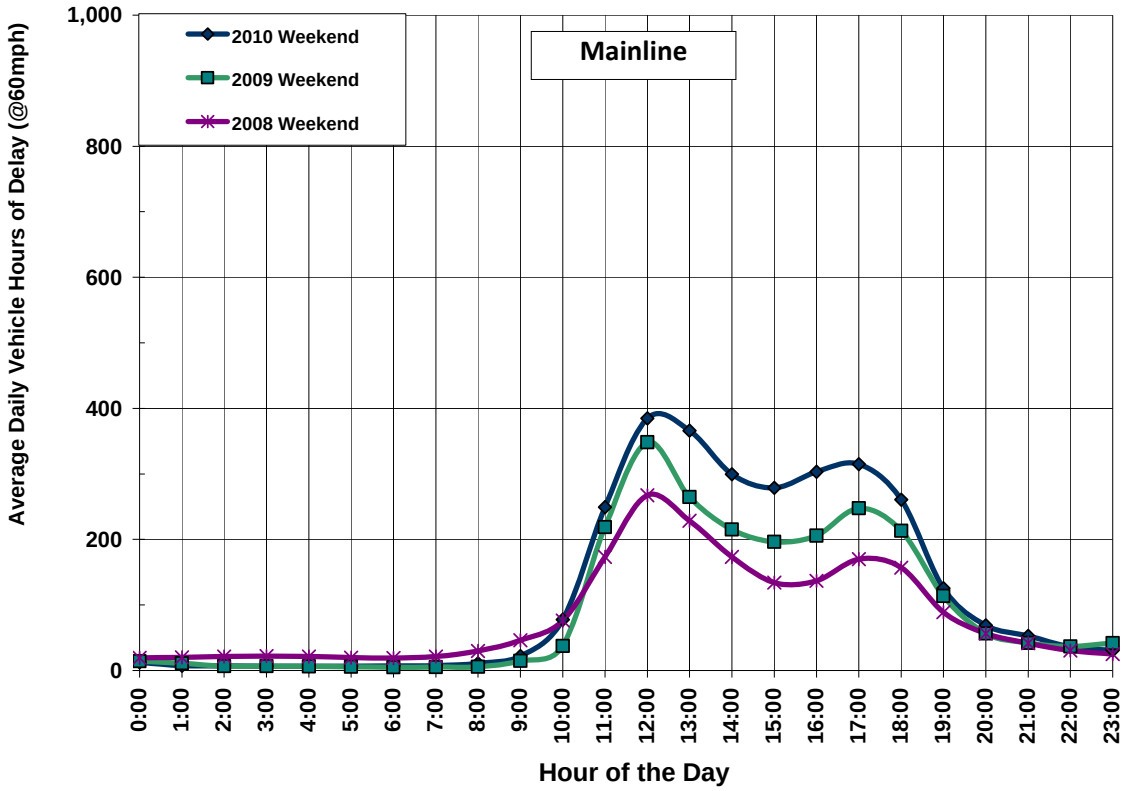


Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Another way to understand the characteristics of congestion and related delays is to examine average weekend delays by hour. The following exhibits summarize average weekend hourly delay for each year over the three-year period from 2008 to 2010. Exhibits B-9 and B-10 depict the mainline facility, while Exhibits B-11 and B-12 show the HOV facility. Each point represents the total delay for the hour. For example, the 7:00 AM point is the sum of delay from 7:00 AM to 8:00 AM. The exhibits show the peaking characteristics of congestion and how the peak period changes over time.

In both the northbound and southbound directions of the mainline, delay in the Midday period exceeded delay in any other period. Exhibit B-9 shows that in the northbound direction, delay during the Midday hour of 12:00 PM was the highest. In addition to Midday delays, PM delays also occurred in the northbound direction with the peak delay experienced during the 5:00 PM peak hour.

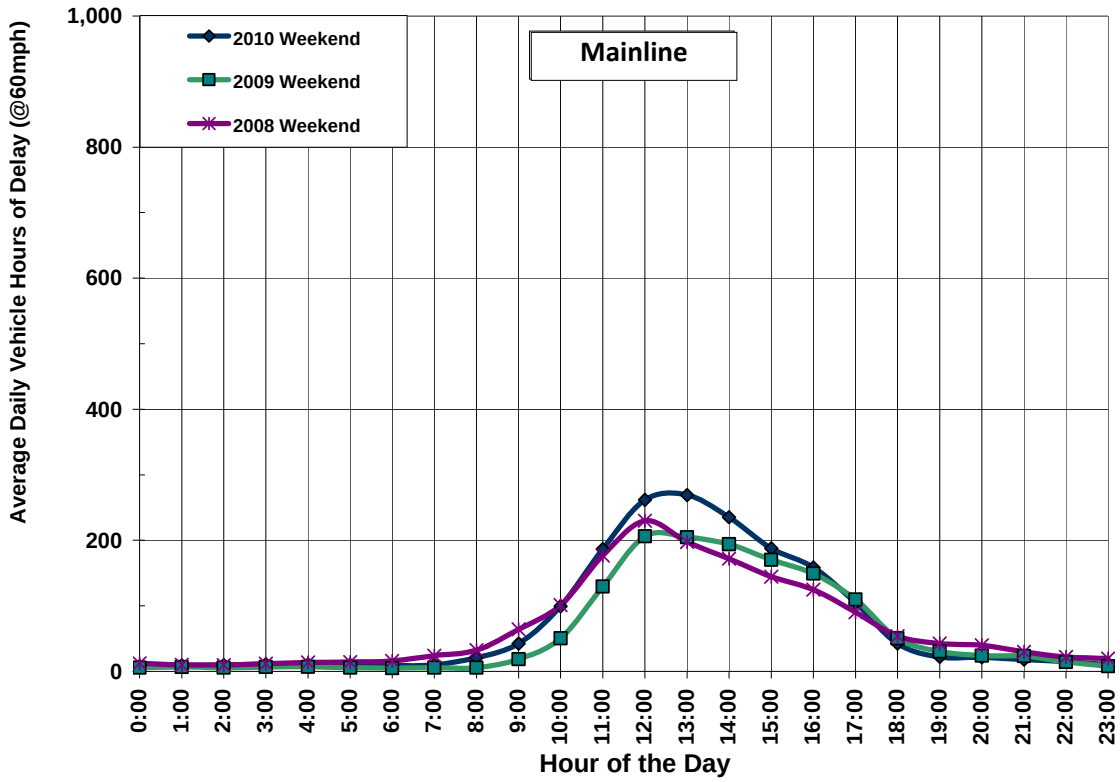
Exhibit B-9: Northbound I-5 ML Weekend Average Hourly Delay (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-10 shows the hourly delay profile for the southbound direction of the mainline facility, which is similar to the northbound direction. Again, the biggest delays occurred during the Midday period at 12:00 PM.

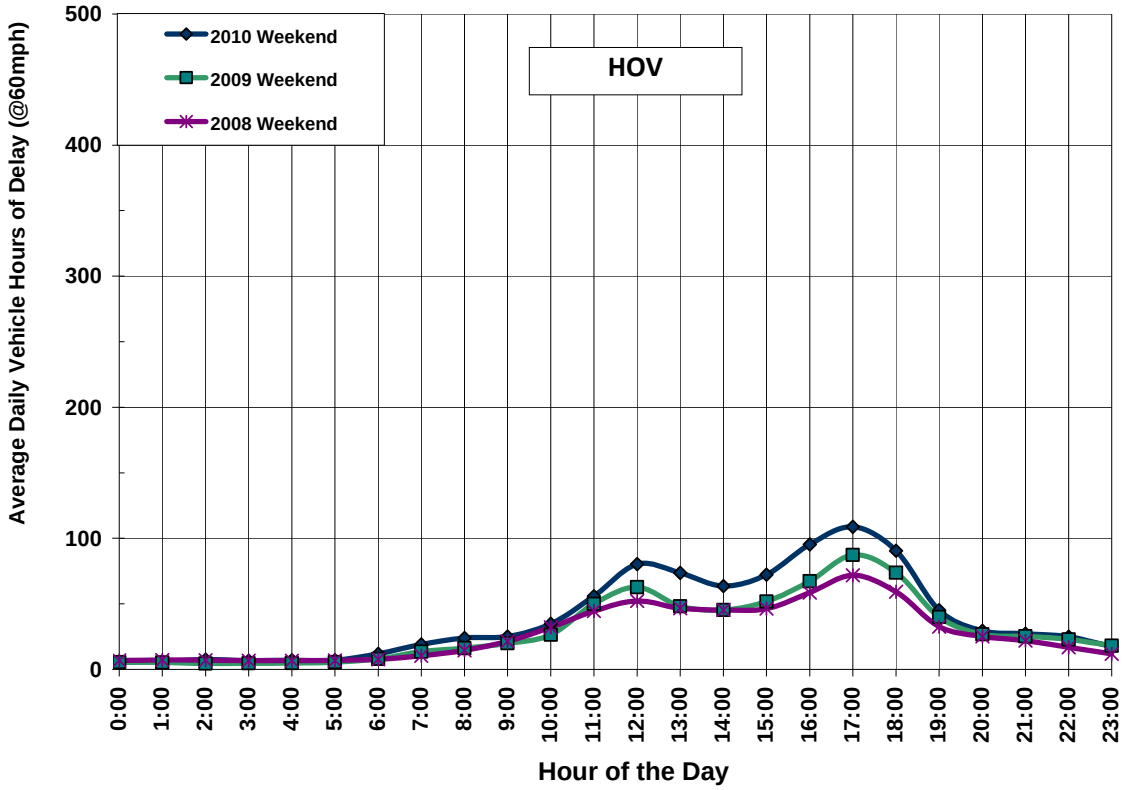
Exhibit B-10: Southbound I-5 ML Weekend Average Hourly Delay (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

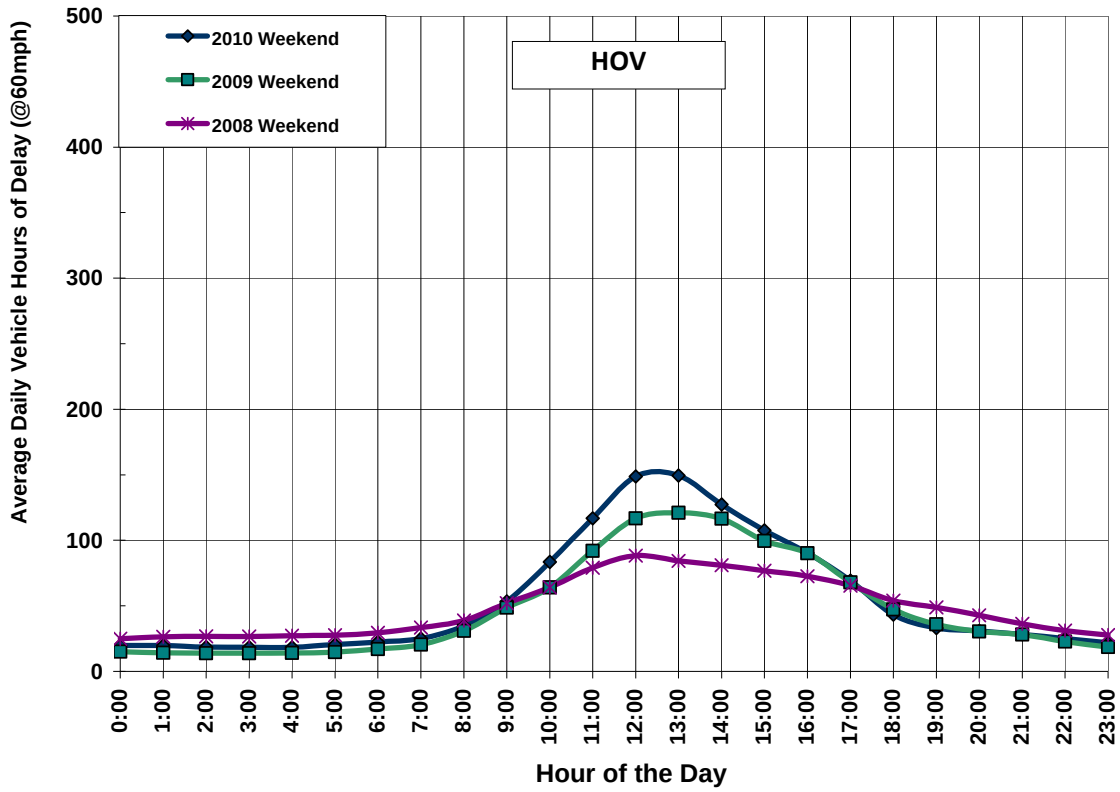
Exhibit B-11 shows the northbound HOV hourly delay trend. Although the northbound HOV lane experienced the most congestion during the Midday and PM peak periods, PM peak period delays exceeded Midday period delays. In the southbound HOV, as shown in Exhibit B-12, the hourly delay trend was the same as the southbound mainline facility: delays peaked during the Midday period at 12:00 PM.

Exhibit B-11: Northbound I-5 HOV Weekend Average Hourly Delay (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-12: Southbound I-5 HOV Weekend Average Hourly Delay (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

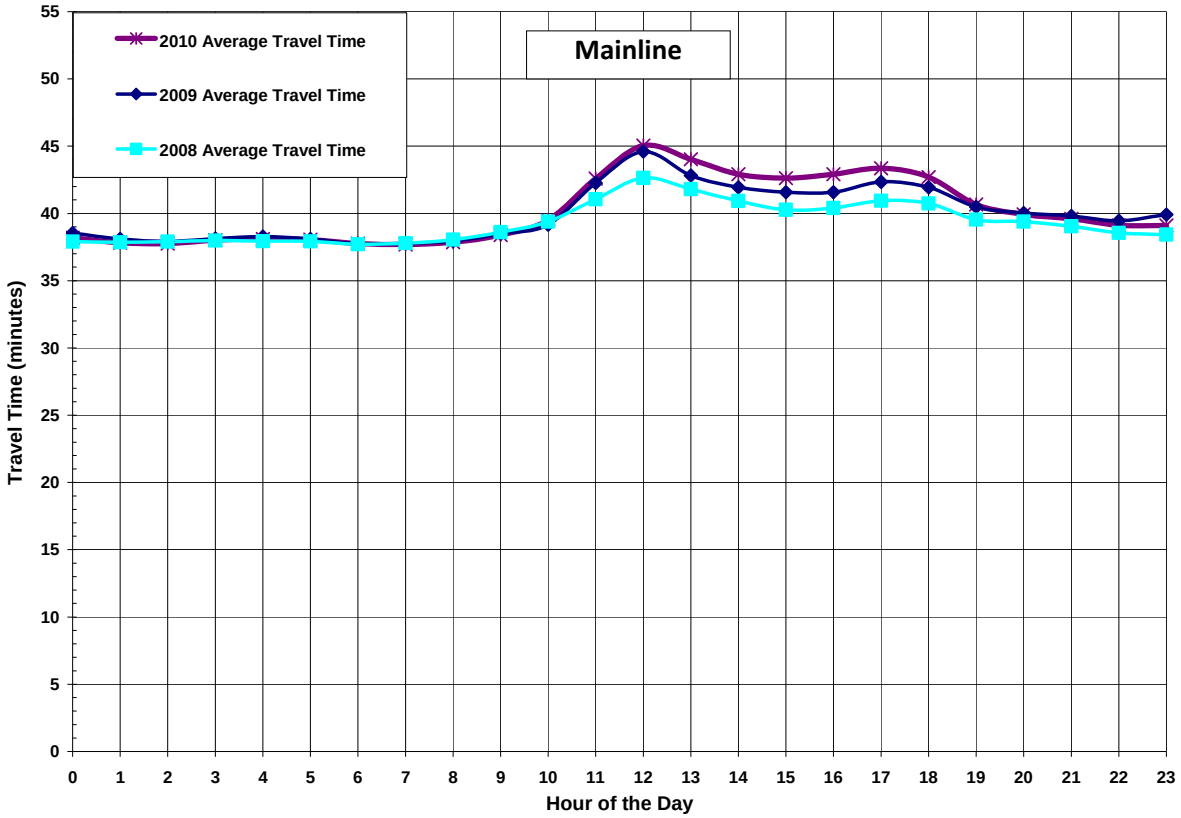
Travel Time

Travel time is reported as the amount of time it takes a vehicle to travel between two points on a corridor, as estimated using automatic detector data in this analysis. To travel the entire 44 miles of the mainline facility, it takes approximately 44 minutes traveling at 60 mph. Travel time on parallel arterials is not included in the analysis.

Exhibits B-13 and B-14 summarize average annual travel times estimated for the mainline facility by hour of day for the years 2008 through 2010. Similar to delay trends, travel times were highest in 2010 compared to the prior two years.

As shown in Exhibit B-13, the northbound direction of the mainline had travel times ranging from 42 to 45 minutes during the Midday period.

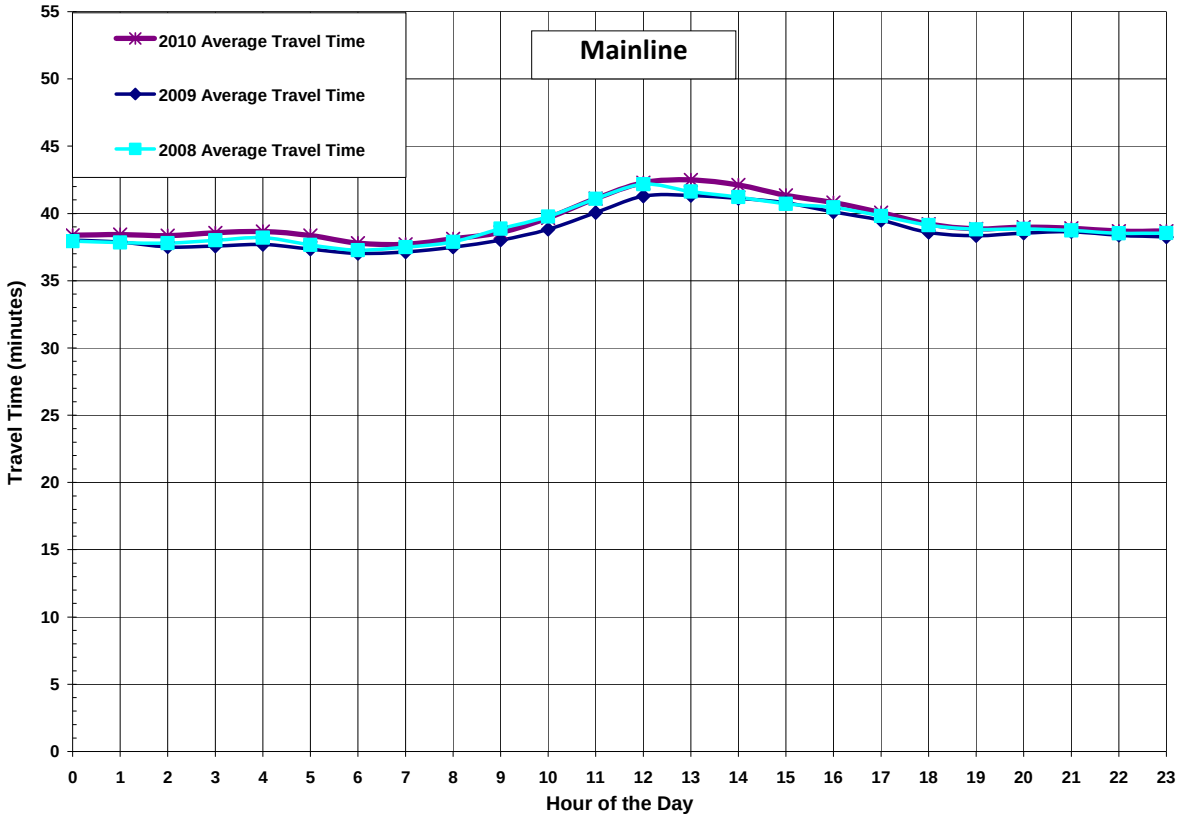
Exhibit B-13: Northbound I-5 ML Weekend Travel Time by Hour (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

As shown in Exhibit B-14, the southbound direction had travel times of approximately 41 to 42 minutes during the Midday period. Travel times decreased slightly from 2008 to 2009, and increased from 2009 to 2010. Travel times were higher in 2010 compared to the prior two years.

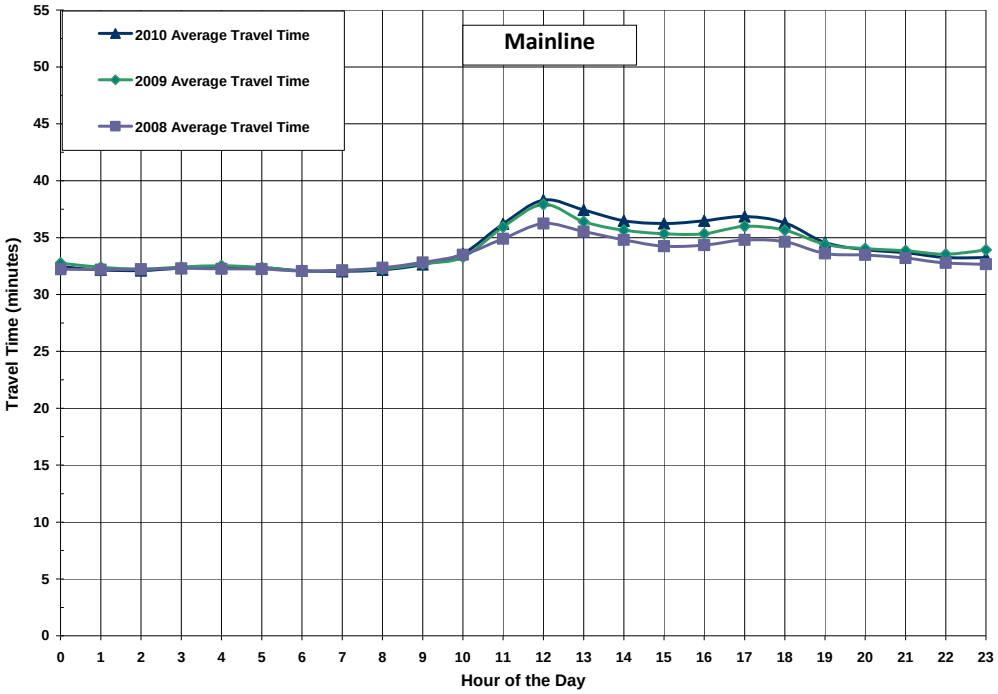
Exhibit B-14: Southbound I-5 ML Weekend Travel Time by Hour (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

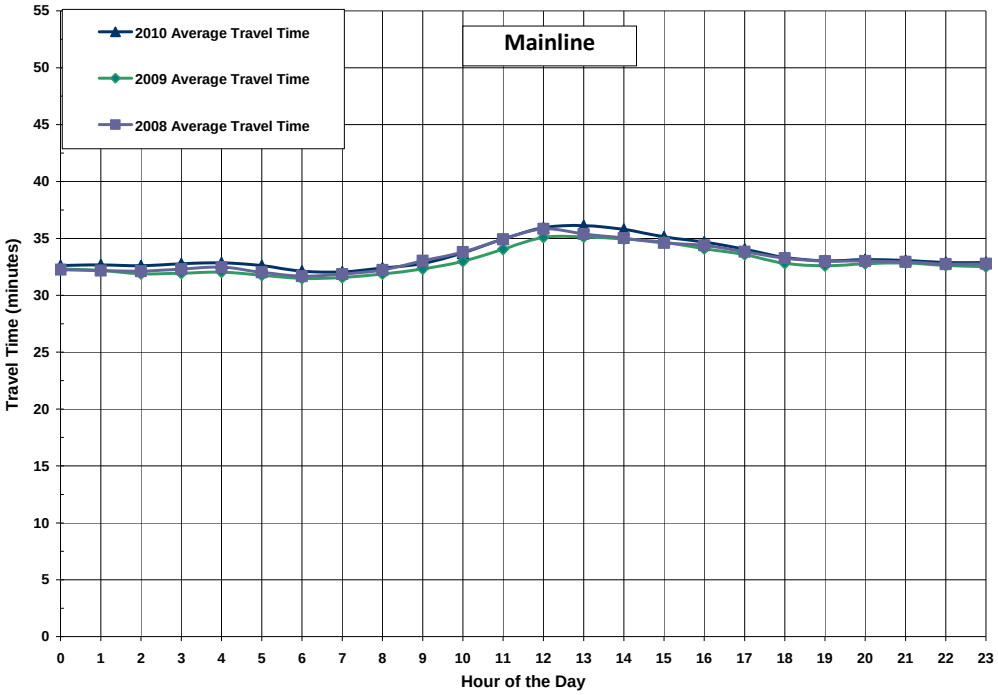
Exhibits B-15 and B-16 show travel times for the mainline facility within the HOV limits while Exhibits B-17 and B-18 illustrate travel times for the HOV facility. To travel the entire 38 miles of the HOV facility, it takes approximately 38 minutes traveling at 60 mph. As shown in Exhibit B-15, the 12:00 PM hour has slightly higher travel times than the 5:00 PM hour (38 minutes compared to 37 minutes). For the HOV facility, shown in Exhibit B-17, the 5:00 PM hour had the peak travel time (approximately 39 minutes to 42 minutes). The trend in the southbound direction of the HOV facility differs as the peak is experienced during the midday only (as shown in Exhibits B-16 and B-18). During the 12:00 PM peak hour, travel times are highest in 2010 for both the mainline and HOV facility. Overall, 2010 experiences the highest travel times from 2008 through 2010 in both directions of travel.

Exhibit B-15: Northbound I-5 ML (HOV Limits) Weekend Travel Time by Hour (2008-2010)



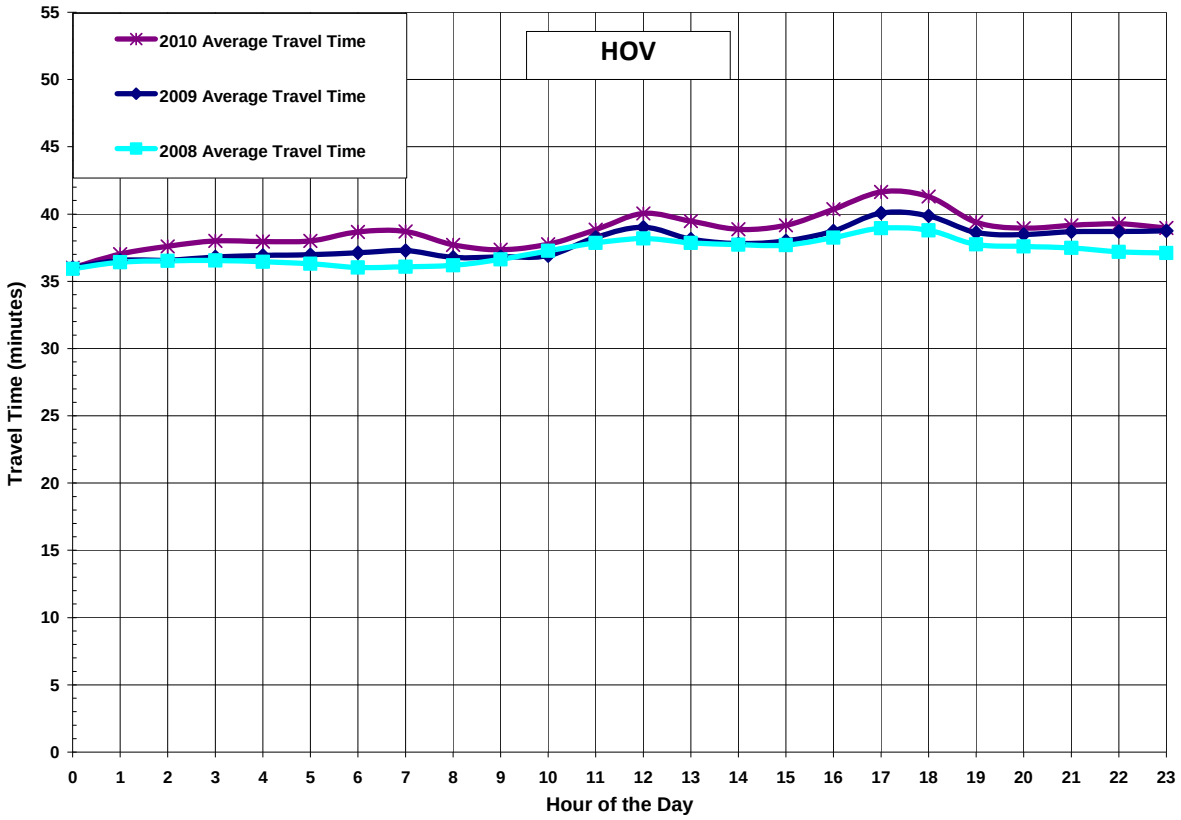
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-16: Southbound I-5 ML (HOV Limits) Weekend Travel Time by Hour (2008-2010)



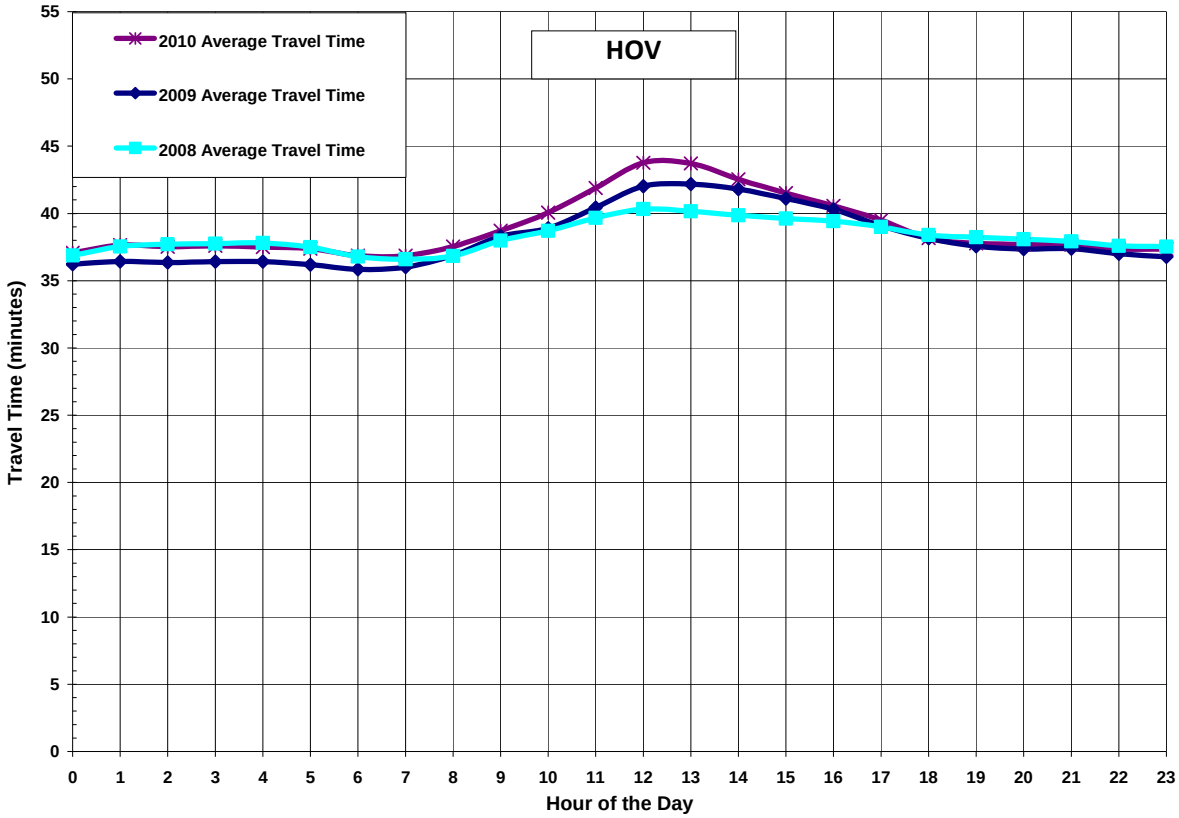
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-17: Northbound I-5 HOV Weekend Travel Time by Hour (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-18: Southbound I-5 HOV Weekend Travel Time by Hour (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

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 and efforts to accomplish this include incident management, traveler information, and special event planning.

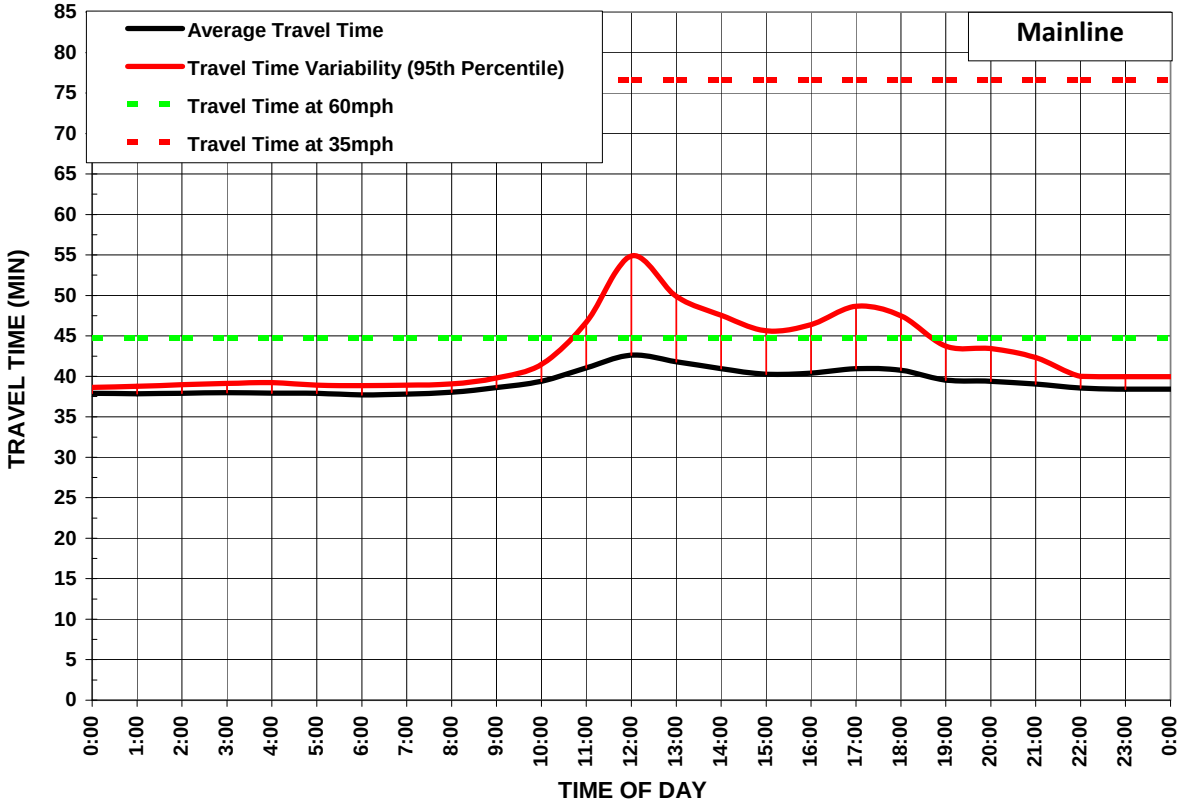
To measure reliability, the study team used automatic detector data to estimate the "buffer index." The buffer index reflects the additional time required (over and beyond the average) to ensure an on-time arrival 95 percent of the time. In other words, if a person must be on time 95 days out of 100 (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 B-19 through B-30 on the following pages illustrates the variability of travel time along the I-5 Corridor on weekends for the years 2008 through 2010.

Exhibits B-19 through B-24 present travel time variability for the mainline facility. In the northbound direction, the 12:00 PM hour was the most unreliable in addition to being the slowest hour. In 2008 (shown in Exhibit B-19), motorists driving the entire length of the 44-mile corridor had to add 12 minutes to an average travel time of 43 minutes (for a total travel time of 55 minutes) to ensure that they arrived on time 95 percent of the time. This is over 10 minutes longer than the 44-minute travel time at 60 mph. The time needed to arrive on time 95 percent of the time increased from 55 minutes in 2008 to 57 minutes in 2009 (shown in Exhibit B-20) and 62 minutes in 2010 (shown in Exhibit B-21).

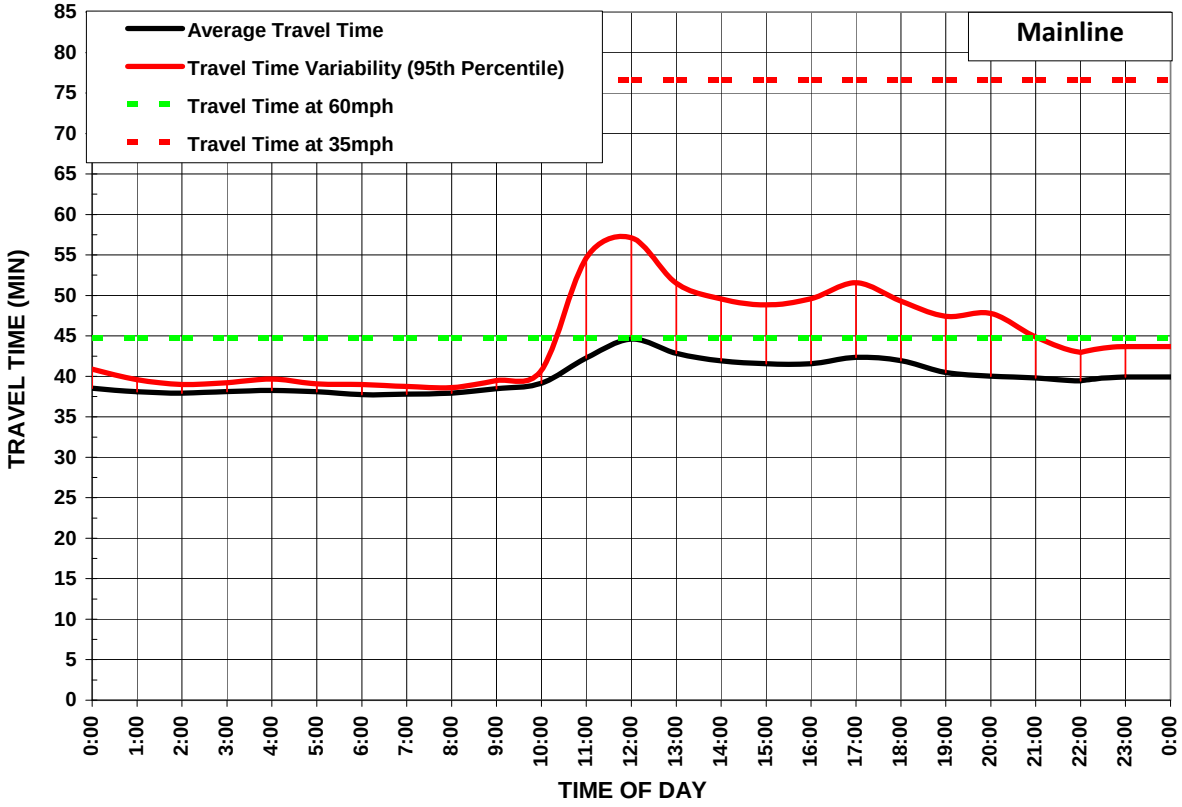
In the southbound direction of the mainline facility, the most unreliable hour was also centered around 12:00 PM. In 2008 (Exhibit B-22), the time needed to arrive on time 95 percent of the time was 58 minutes. Variability in travel times decreased in 2009 (Exhibit B-23) to 56 minutes and increased to 60 minutes in 2010 (Exhibit B-24).

Exhibit B-19: Northbound I-5 ML Weekend Travel Time Variation (2008)



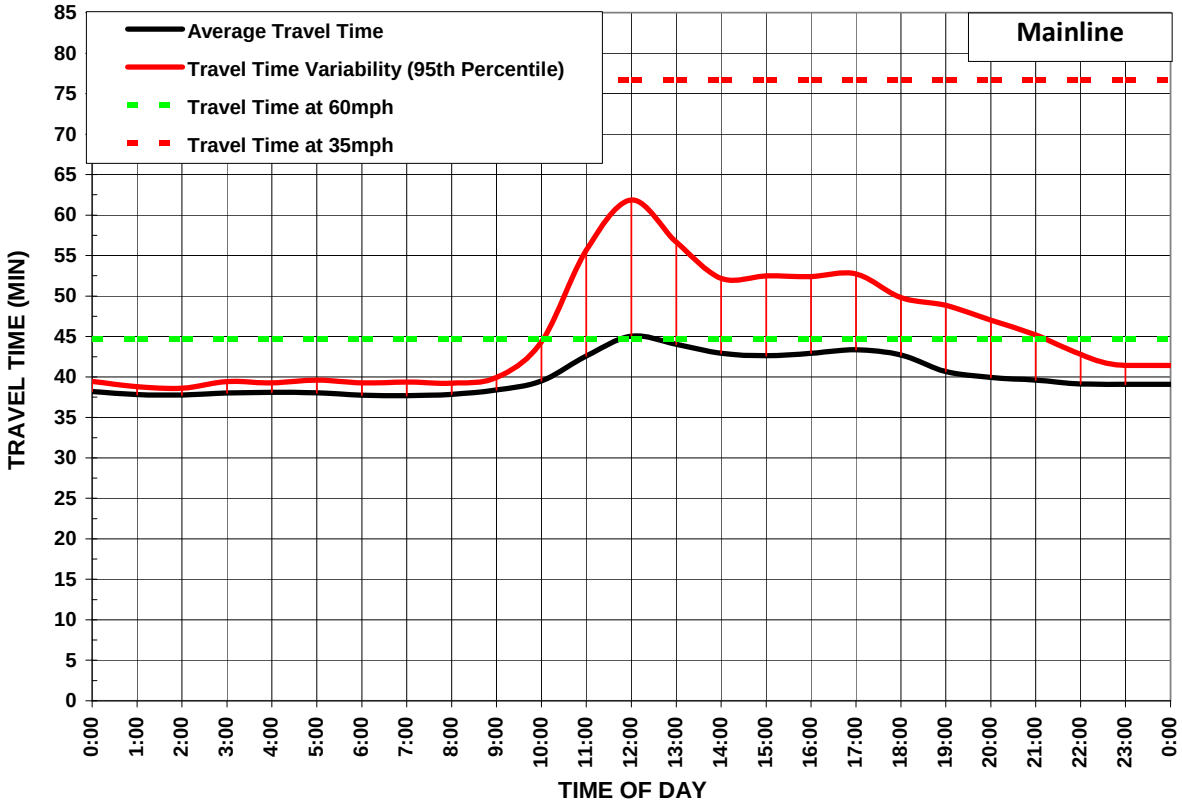
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-20: Northbound I-5 ML Weekend Travel Time Variation (2009)



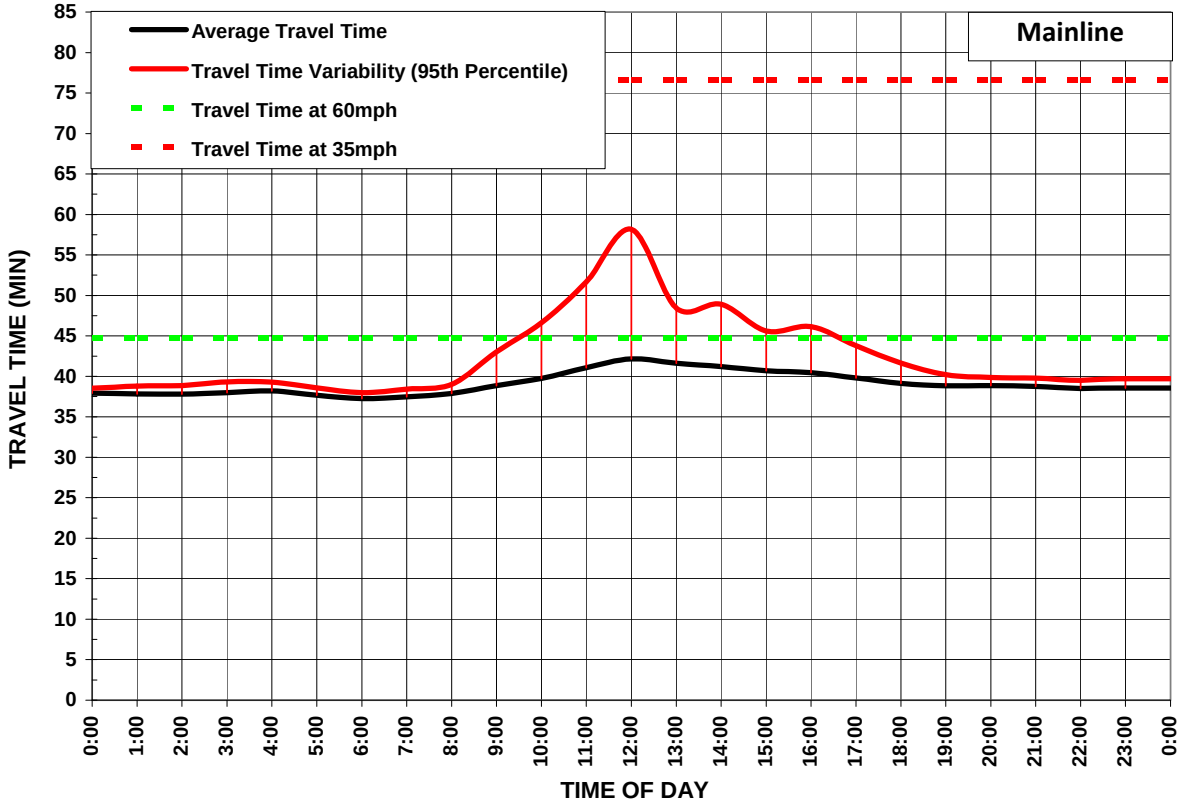
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-21: Northbound I-5 ML Weekend Travel Time Variation (2010)



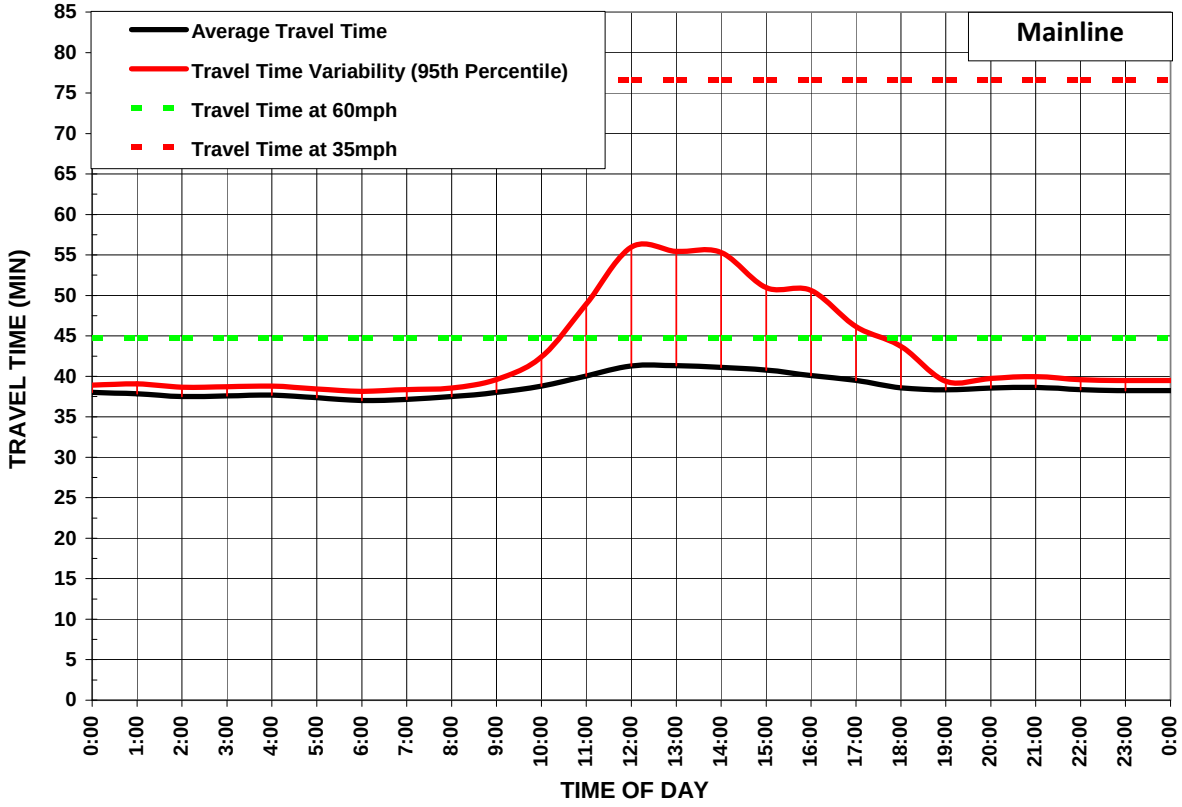
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-22: Southbound I-5 ML Weekend Travel Time Variation (2008)



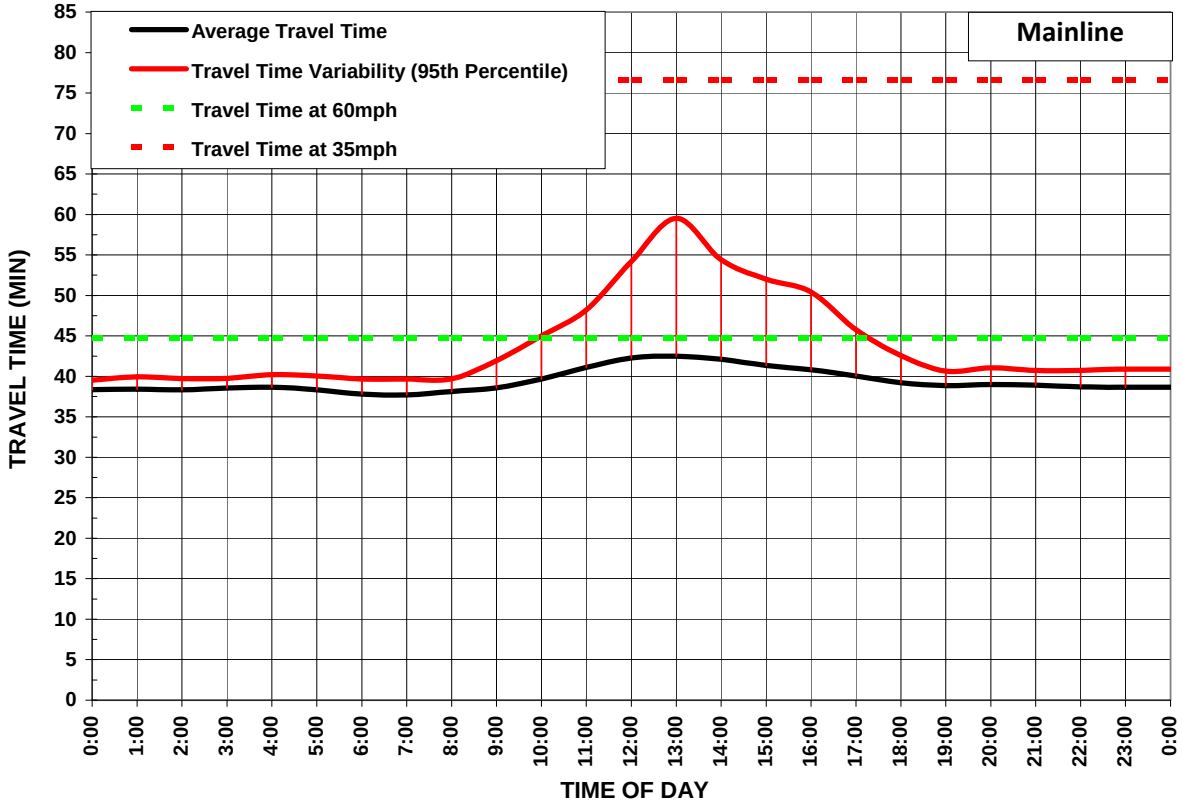
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-23: Southbound I-5 ML Weekend Travel Time Variation (2009)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-24: Southbound I-5 ML Weekend Travel Time Variation (2010)

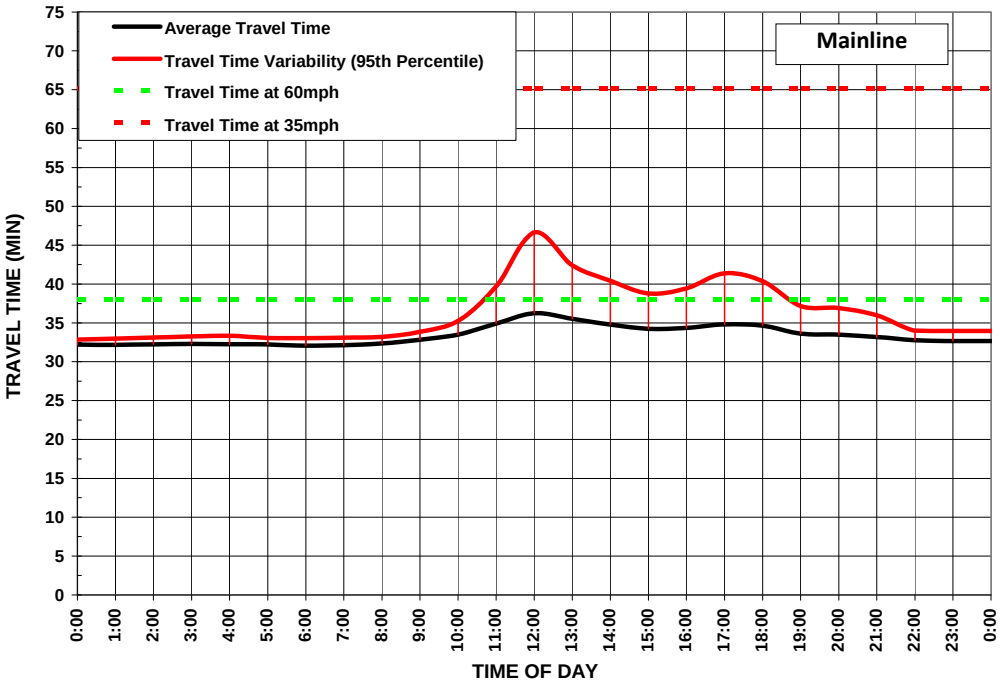


Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibits B-25 through B-30 present travel time variability for the mainline facility within the HOV limits and Exhibits B-31 through B-36 present travel time variability for the HOV facility. For the HOV facility, the 5:00 PM hour is the most unreliable and slowest hour while for the mainline facility within the same limits, the 12:00 PM is the most reliable and slowest hour. The time needed to arrive on time 95 percent of the time during the PM peak hour of travel for the HOV facility ranges from 45 to 52 minutes. The travel time needed to arrive on time 95 percent of the time during the midday peak hour of travel for the mainline facility ranges from 47 to 53 minutes.

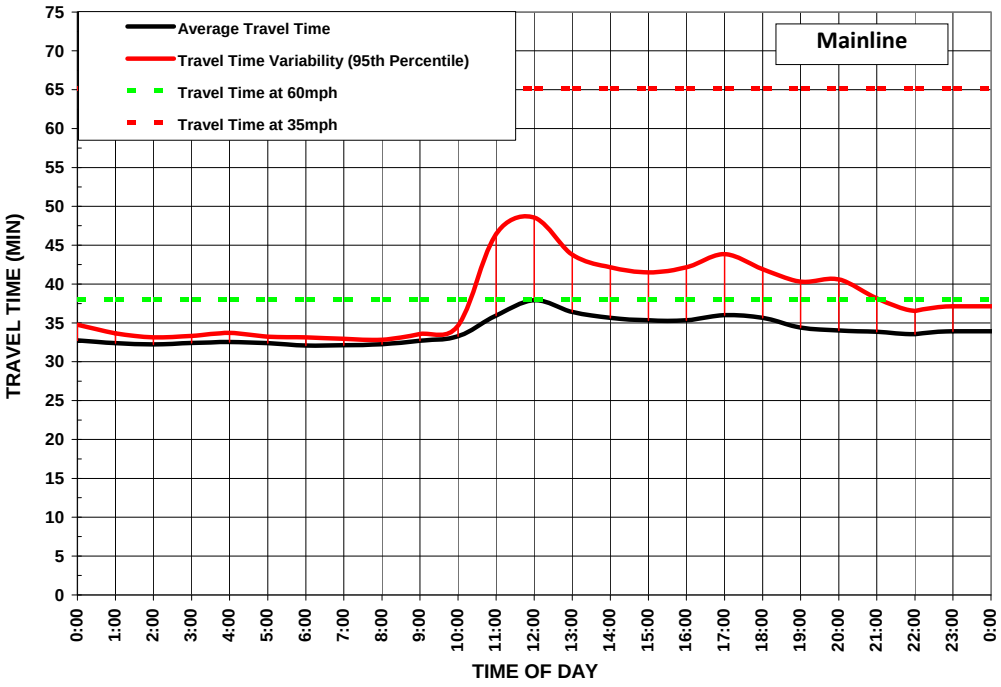
In the southbound direction for both the HOV and mainline facilities within the same limits, the most unreliable hour is 12:00 PM for 2008 and 2009 and 1:00 PM for 2010. The travel time needed to arrive on time 95 percent of time for the HOV facility ranges from 52 to 65 minutes compared to 48 to 51 minutes for the mainline facility within the same limits. Overall, 2010 has the most reliable travel time for the midday peak hour.

Exhibit B-25: Northbound I-5 ML (HOV Limits) Weekend Travel Time Variation (2008)



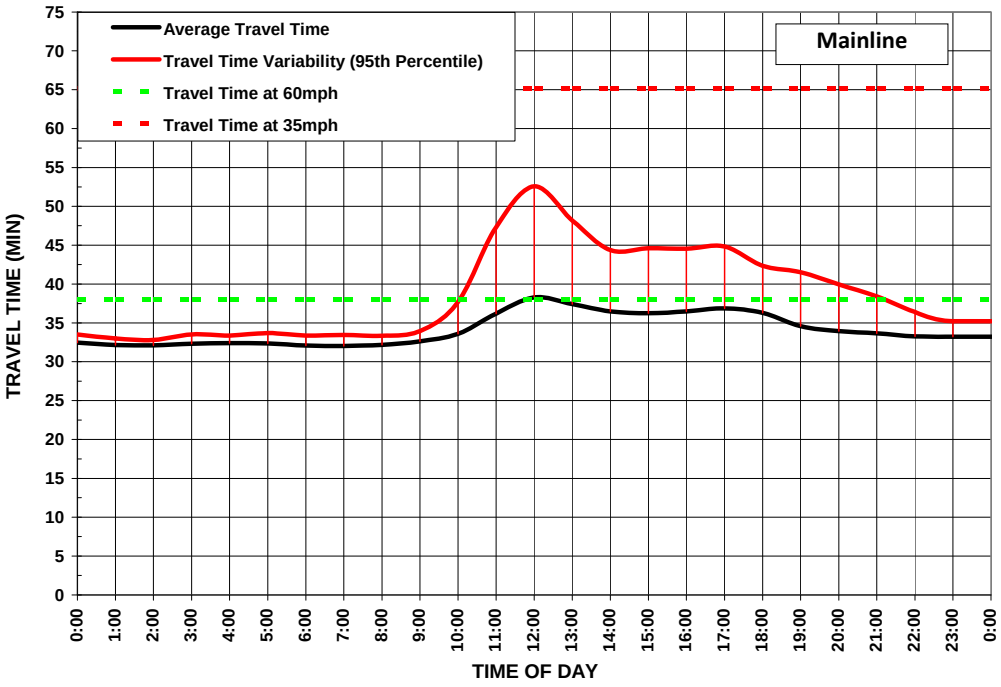
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-26: Northbound I-5 ML (HOV Limits) Weekend Travel Time Variation (2009)



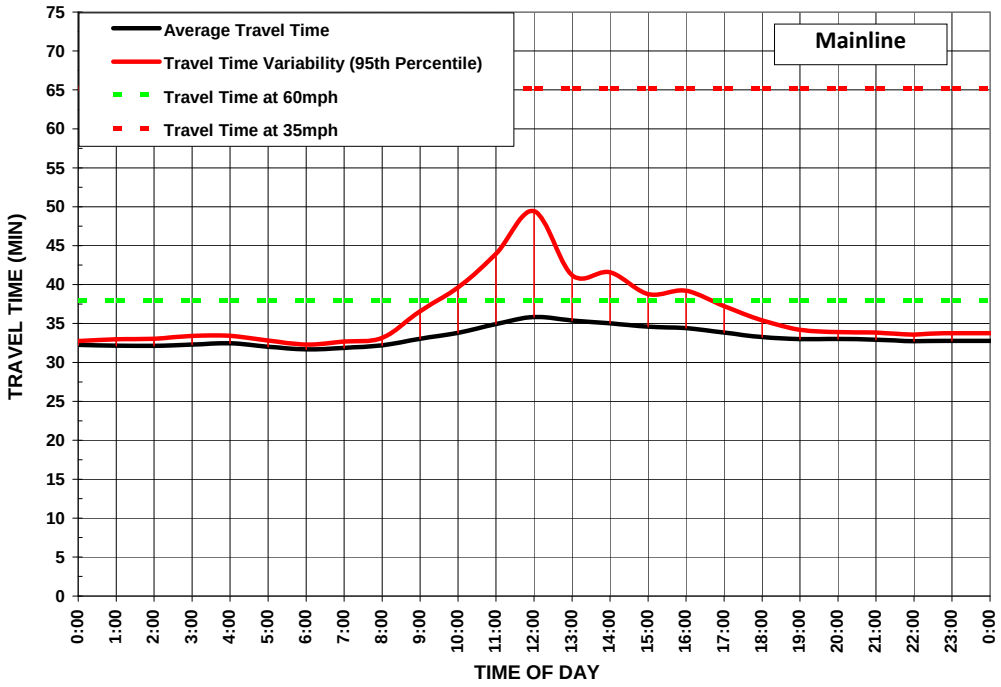
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-27: Northbound I-5 ML (HOV Limits) Weekend Travel Time Variation (2010)



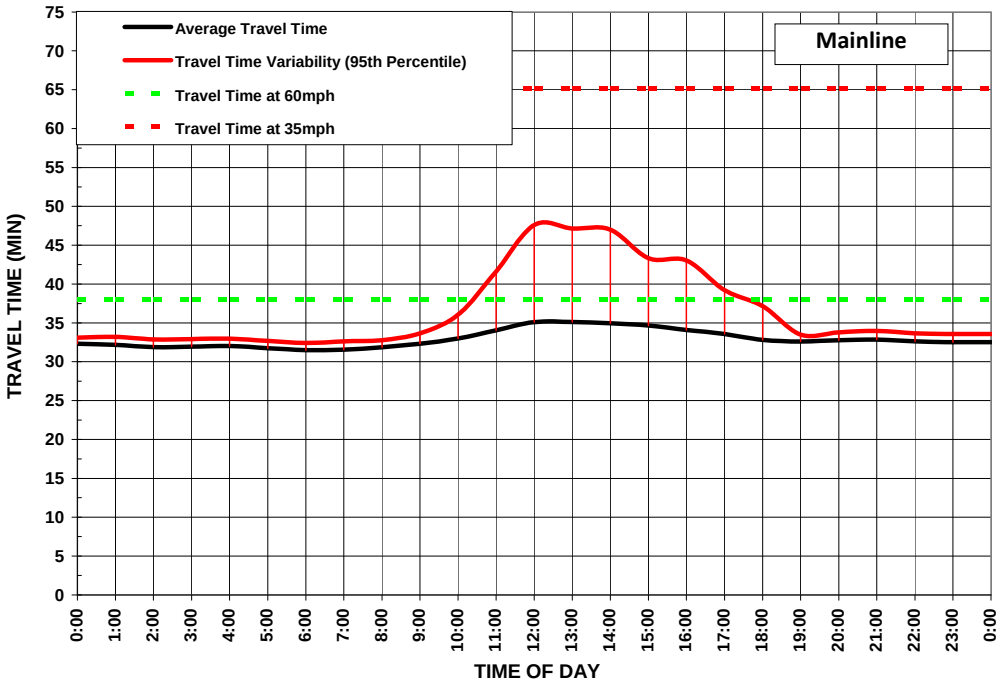
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-28: Southbound I-5 ML (HOV Limits) Weekend Travel Time Variation (2008)



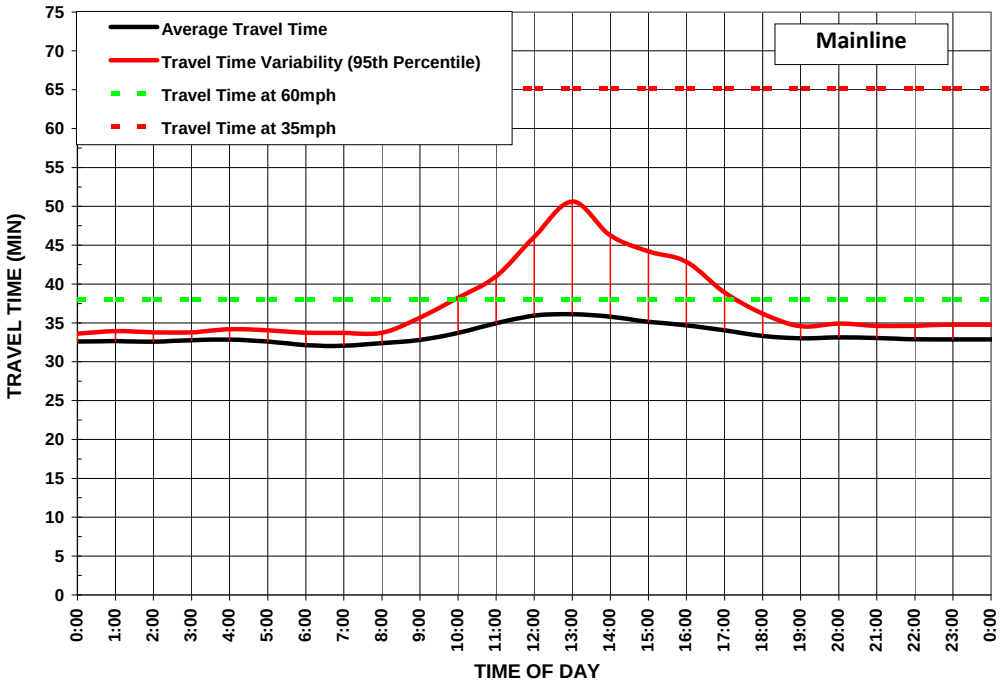
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-29: Southbound I-5 ML (HOV Limits) Weekend Travel Time Variation (2009)



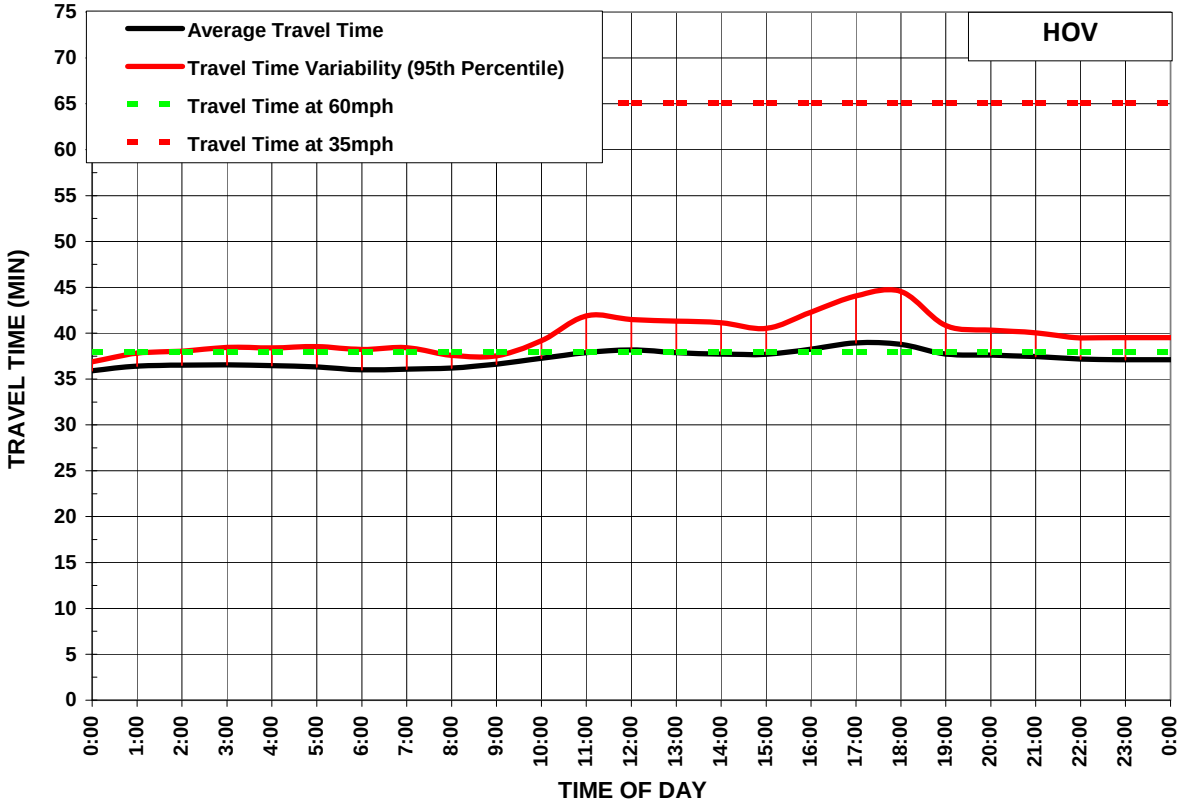
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-30: Southbound I-5 ML (HOV Limits) Weekend Travel Time Variation (2010)



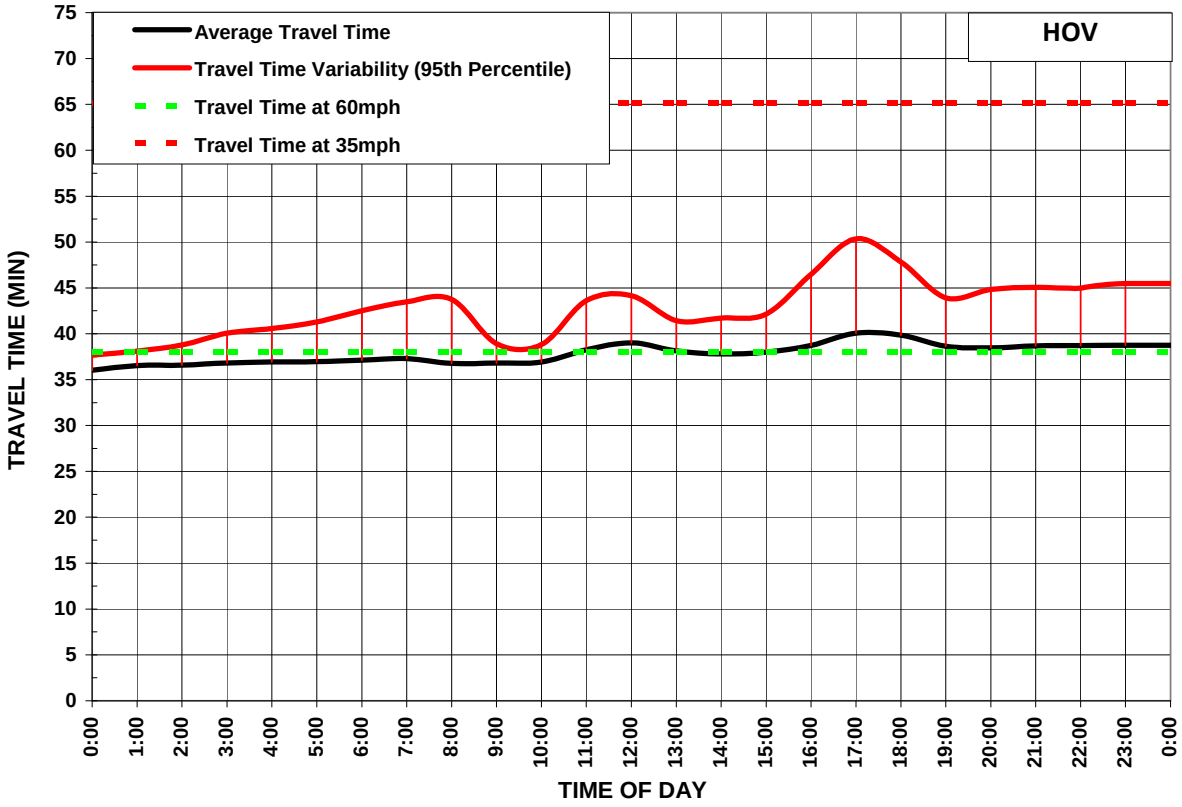
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-31: Northbound I-5 HOV Weekend Travel Time Variation (2008)



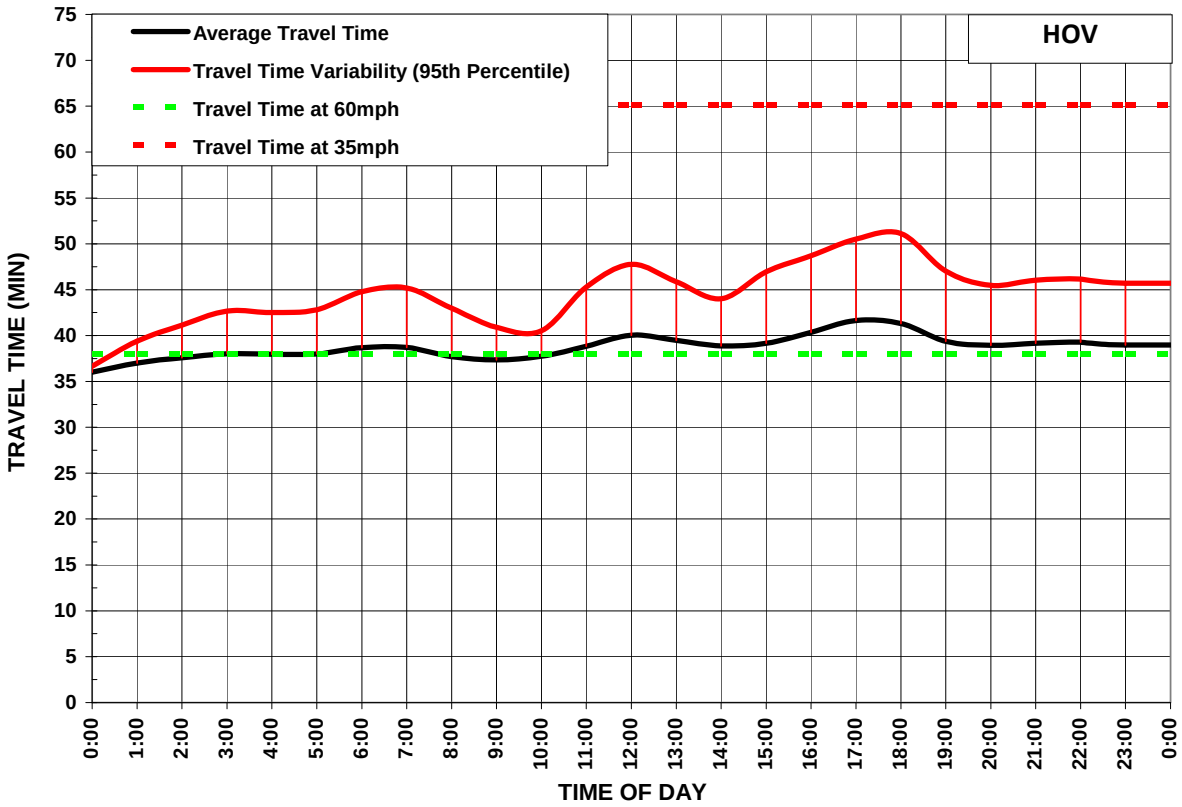
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-32: Northbound I-5 HOV Weekend Travel Time Variation (2009)



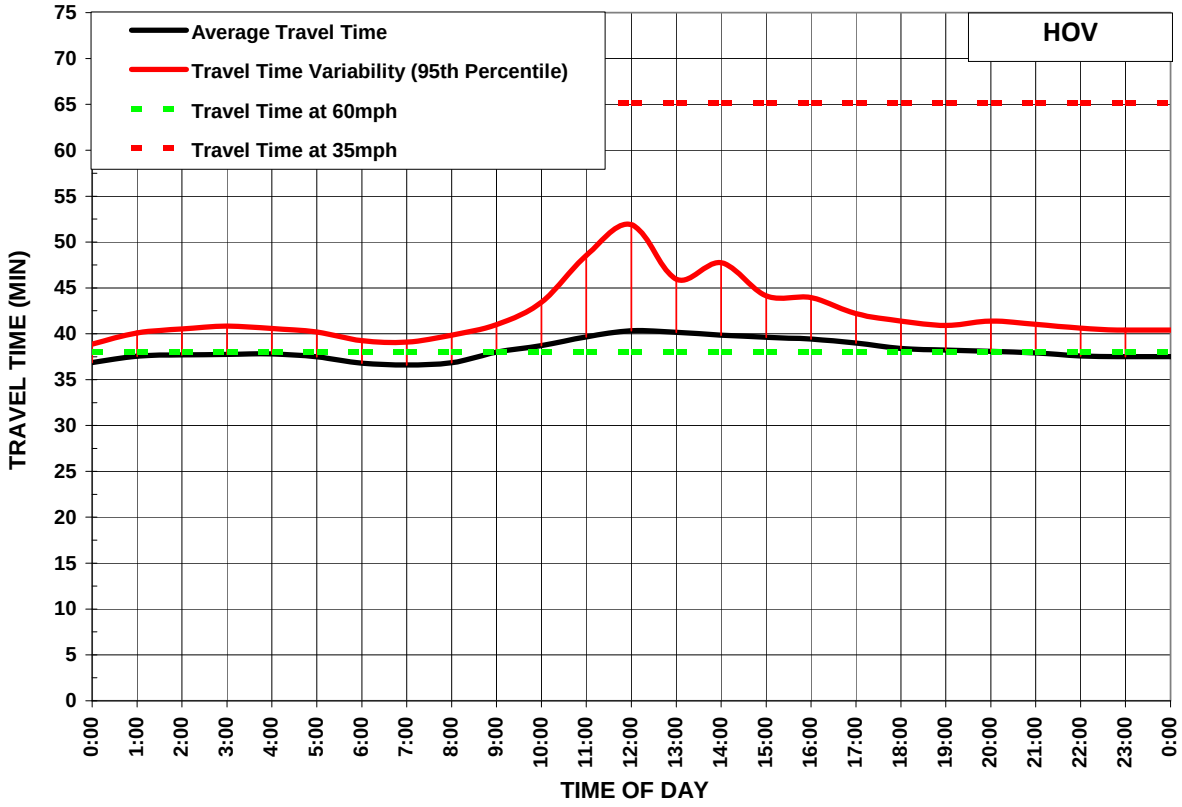
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-33: Northbound I-5 HOV Weekend Travel Time Variation (2010)



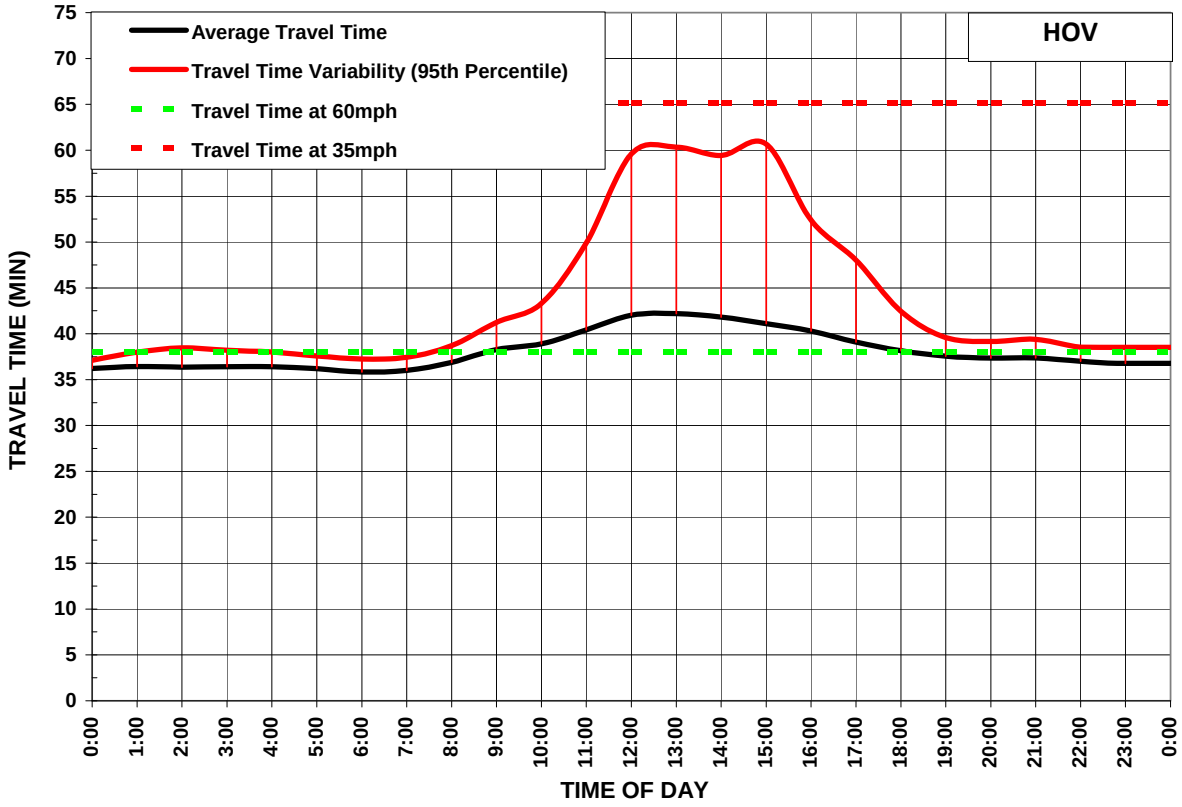
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-34: Southbound I-5 HOV Weekend Travel Time Variation (2008)



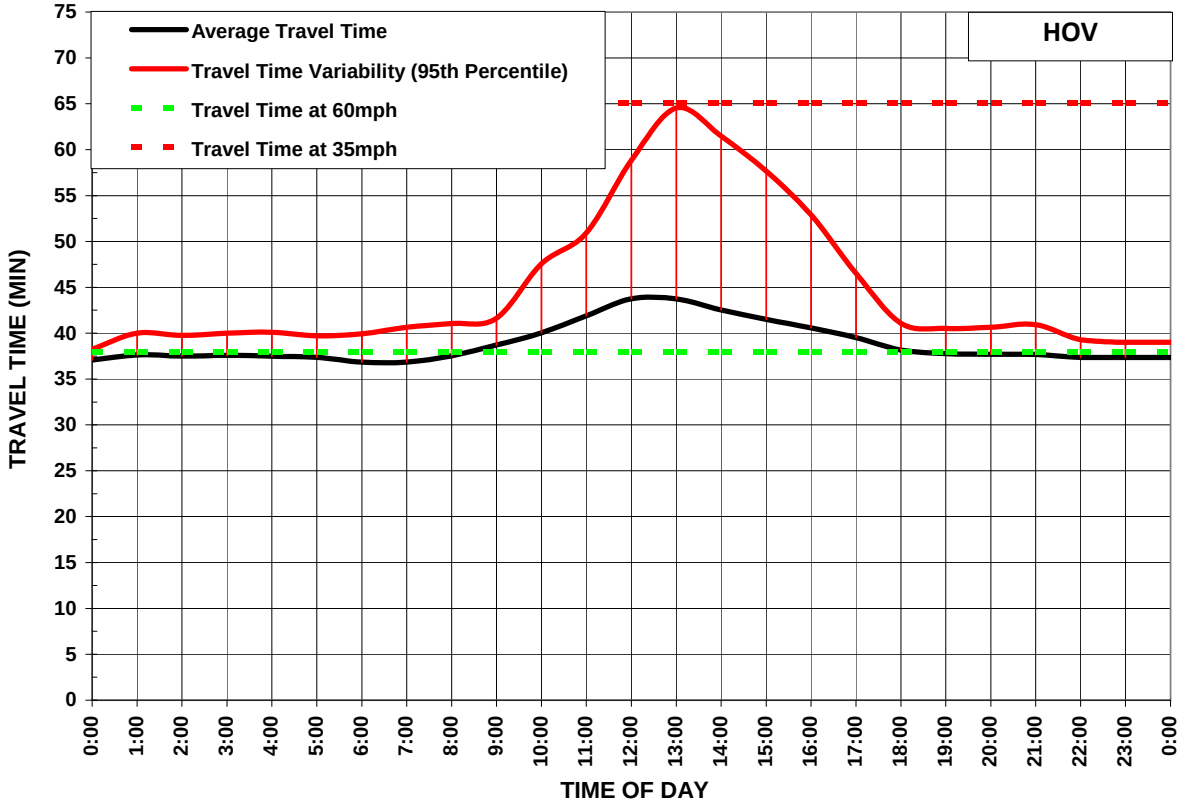
Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-35: Southbound I-5 HOV Weekend Travel Time Variation (2009)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-36: Southbound I-5 HOV Weekend Travel Time Variation (2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Productivity

Productivity is a system efficiency measure used to analyze the capacity of the corridor, and is defined as the ratio of output (or service) per unit of input. In the case of transportation, productivity is the percent utilization of a facility or mode under peak congested conditions.

For highways, it is the number of vehicles compared to the capacity of the roadways 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.

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." Equivalent lost lane-miles is computed as follows (for congested locations only):

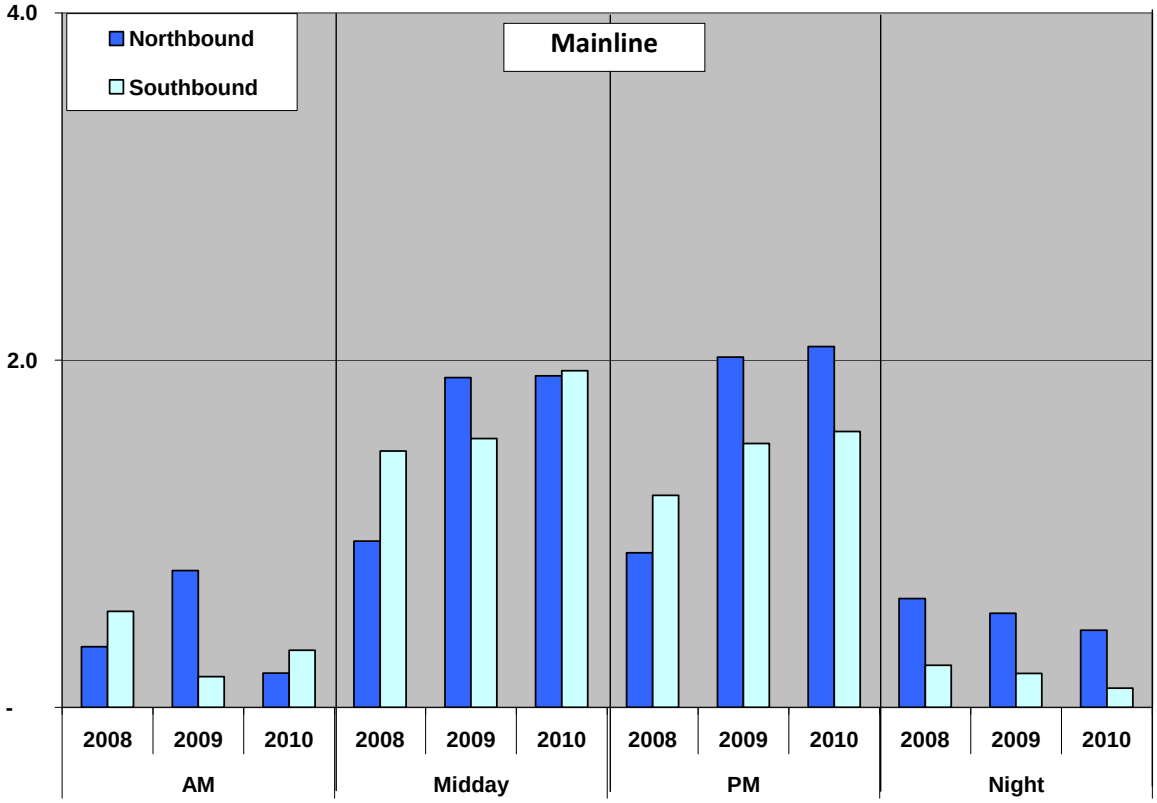
$$LostLaneMiles = \left(1 - \frac{ObservedLaneThroughput}{2000vphpl}\right) \times Lanes \times CongestedDistance$$

Strategies to combat such productivity losses are primarily related to operations. These strategies include: building new or extending auxiliary lanes, developing more aggressive ramp metering strategies without negatively influencing the arterial network, and improving incident clearance times.

Exhibit B-37 summarizes the productivity losses on the mainline from 2008 to 2010. The largest productivity losses occurred during the PM peak period in the northbound direction (as noted by the taller blue shaded bars). During the PM peak period in 2010, the northbound direction lost over two equivalent lane-miles, which is a slight increase from 2009 and a larger increase from 2008. The southbound direction of the mainline (aqua shaded bars) also experienced productivity losses during the PM peak, but experienced the highest loss in productivity during the Midday period of almost two equivalent lane-miles in 2010.

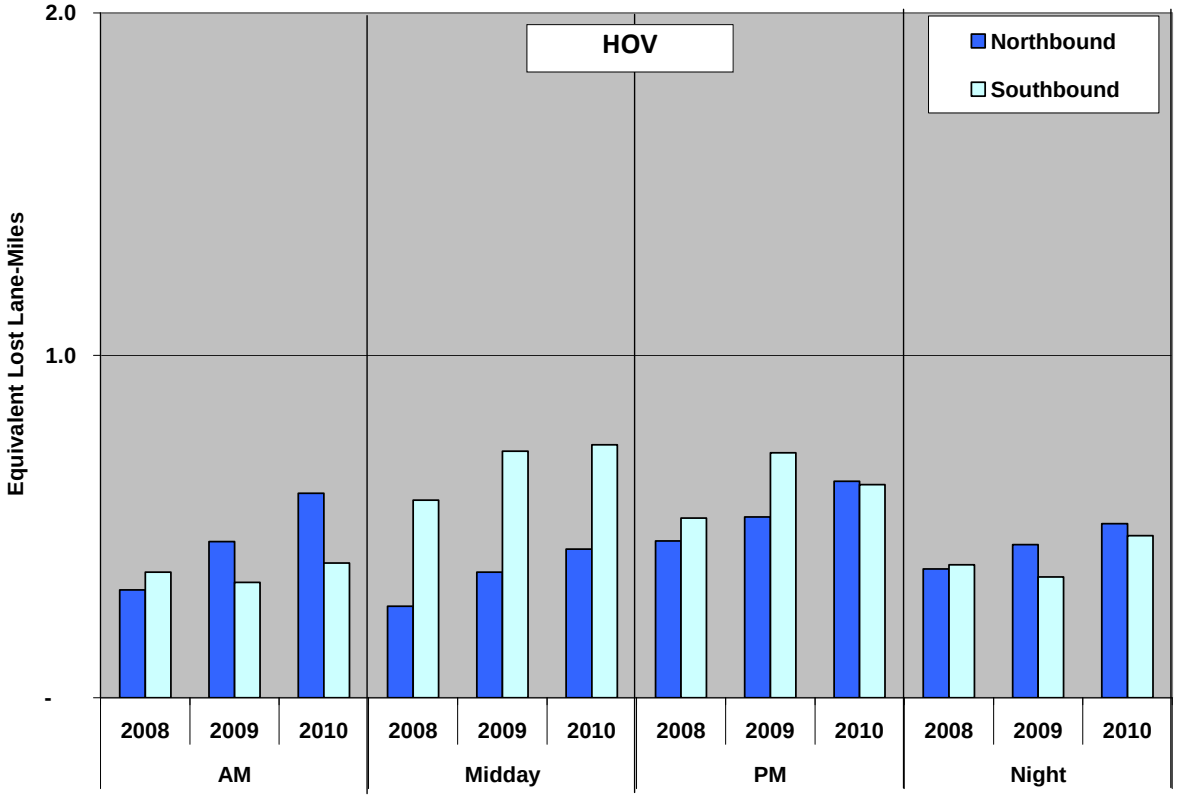
Exhibit B-38 summarizes the productivity losses on the HOV facility during the same period. Unlike the mainline facility, productivity losses were higher in the northbound direction during the Midday and PM peak periods. However, productivity losses during the AM and night time periods were higher in the southbound direction. Overall, the HOV facility experienced less than one equivalent lost lane-mile.

Exhibit B-37: I-5 ML Weekend Lost Lane-Miles by Direction and Period (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Exhibit B-38: I-5 HOV Weekend Lost Lane-Miles by Direction and Period (2008-2010)



Source: SMG analysis of Caltrans Performance Measurement System (PeMS) data

Weekend Bottleneck Identification

Bottleneck identification analysis was also conducted for weekend days, as the I-5 Corridor is a heavily traveled corridor on weekends, providing access to San Diego, Los Angeles, and other destinations to the north. The study team downloaded detector data from PeMS to conduct the weekend bottleneck 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.

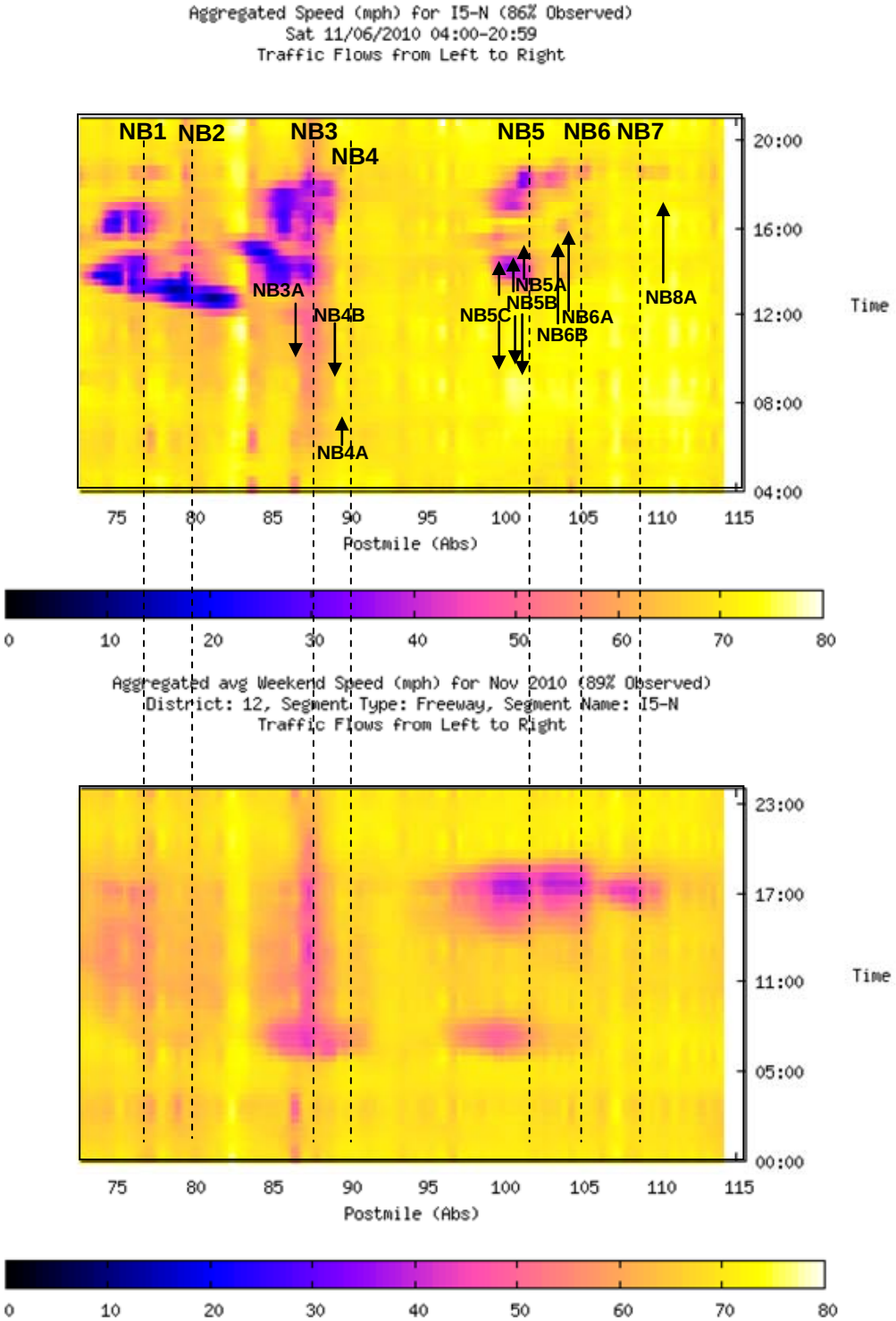
Northbound I-5 Mainline Facility

Speed contour plots were analyzed for different weekend days in November 2010 for the northbound mainline facility. Aggregate average speed contours of weekends in November 2010 were also examined.

Exhibit B-39 illustrates the speed contour plots for a sample weekend day in November 2010 and an aggregate average of November 2010 weekends used to analyze the northbound direction of the corridor (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 San Diego County Line to the Los Angeles County Line.

As shown, the dark blue blotches indicate slow speeds and congestion. The vertical dotted lines identify the actual weekend bottleneck location, which is currently labeled with a bottleneck number as listed in Exhibit 4-1 for typical weekdays. As indicated, essentially the same bottlenecks appear on the weekend days as the weekdays, only fewer and with less congestion. There was no noticeable new bottleneck, either in the data analysis or in the field observations, in the weekend days that did not appear in the weekdays.

Exhibit B-39: Northbound I-5 Speed Contour Plots (November 2010)



Source: Caltrans Performance Measurement System (PeMS) data

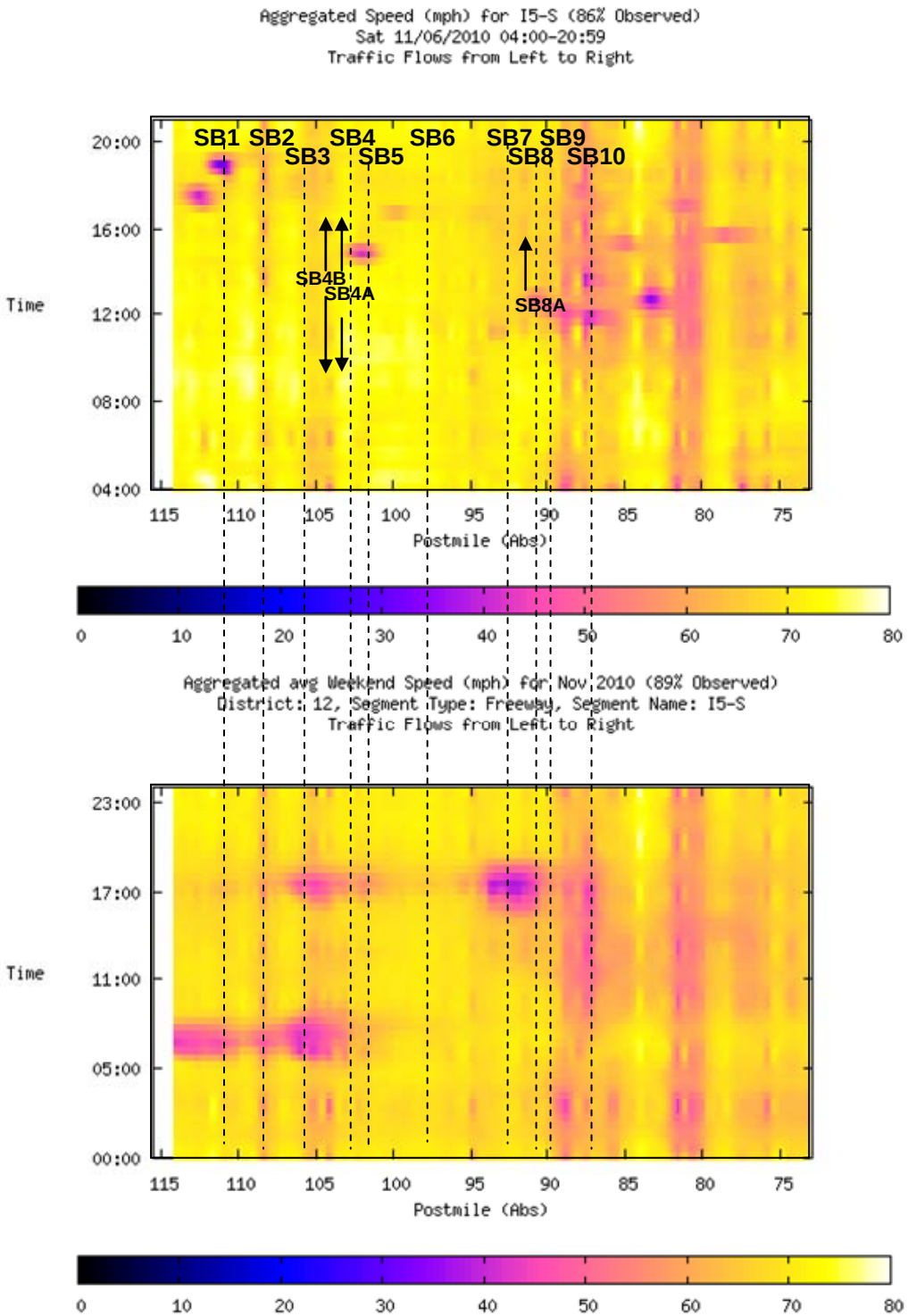
Southbound I-5 Mainline Facility

Likewise, speed contour plots were also analyzed for different weekend days in November 2010 for the southbound mainline facility. Aggregate average speed contours of weekends in November 2010 were also examined.

Exhibit B-40 illustrates the speed contour plots for a sample weekend day in November 2010 and an aggregate average of November 2010 weekends used to analyze the southbound direction of the corridor (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 Los Angeles County Line to the San Diego County Line.

As shown, the dark blue blotches indicate slow speeds and congestion. The vertical dotted lines identify the actual weekend bottleneck location, which is currently labeled with a bottleneck number as listed in Exhibit 4-1 for typical weekdays. Similar to the northbound facility, as indicated in Exhibit B-40, essentially the same bottlenecks appear on the weekend days as the weekdays, only fewer and with less congestion. There was no noticeable new bottleneck, either in the data analysis or in the field observations, in the weekend days that did not appear in the weekdays.

Exhibit B-40: Southbound I-5 Speed Contour Plots (November 2010)



Source: Caltrans Performance Measurement System (PeMS) data

Appendix C: I-5 Detailed Scenario Descriptions

This appendix describes the scenarios and the projects from the Regional Transportation Improvement Program (RTIP), the Regional Transportation Plan (RTP), Measure M2, Transportation Corridor Agencies (TCA) improvements, and other sources (e.g., special studies) that are used to build the scenarios to be tested using the Paramics micro-simulation model.

Exhibit C-1 shows the scenarios for both the 2010 Base Year and 2020 Horizon Year forecast.

Exhibit C-1: Project Lists for Micro-Simulation Scenarios

Scenarios	Proj ID	Improvement	Lead Agency	Expected Completion Date	Est Project Cost, $ (in $1,000's)
1 (2010-1) 2 (2020-1)	EA 0L2501	From Tustin Ranch to Red Hill, continuous access HOV (PM 28.3 - 29.0)	Caltrans	2011	$81
	FTIP ORA030602 EA 0F060	In San Clemente - SB Camino de Estrella - Widen off-ramp from 1 to 2 lanes and widen overcrossing from 5 to 7 lanes (1 WB left turn lane & 1 EB lane) (PM 5.8)	Caltrans	2012	$13,493
	FTIP ORA020109	I-5 at Camino Capistrano intersection improvement. Widen SB off-ramp from 2 to 3 lanes (PM 8.4-8.7)	OCTA	2012	$13,200
	FTIP ORA000122	I-5 at La Paz interchange improvements. Expand La Paz Road from 4 to 6 lanes total. On-ramp extension lanes (PM 16.5)	Laguna Hills	2012	$8,942
	FTIP ORA120359	I-5 at Jamboree - Construct aux lane on I-5 SB; widen SB off-ramp from 1 to 2 lanes; widening Jamboree Rd EB undercrossing to create a turn lane to NB on-ramp (PM 27.5-28.1)	Caltrans	2012	$8,533
	FTIP ORA120326	Reconstruct I-5/SR-74 interchange on Route 74 from I-5 to east of city San Juan Capistrano city limit (PM 9.6)	Caltrans/ San Juan Capistrano	2014	$82,063
3 (2010-2) 4 (2020-2)	Proposed (SMG)	Advanced ramp metering with queue control	CALTRANS		$10,000
	Proposed (SMG)	Connector metering on SR-57, SR-22, SR-55 interchanges	CALTRANS		$30,000
5 (2020-3) 6 (2020-4)	Proposed (SMG)	Enhanced Incident Management System - incident clearance time reduction from current and with improvements (2020 Model Only)	CALTRANS		
7 (2020-5)	FTIP ORA990929/ ORA111002/ ORA111001 EA 0F960	Add 1 HOV lane in each direction from Avenida Pico to San Juan Creek Road & reconfigure Avenida Pico interchange (PM 3.0-8.7)	Caltrans	2019	$244,087
	EA 0C890	Provide a second HOV lane in both directions in the City of Tustin and Santa Ana; reconstruct the First St/Fourth St interchange on SB I-5 to increase weaving length to standard (extend merge lanes by 100 ft) (PM 30.3 to 34) (M2)	OCTA	2017	$45,000
	EA 0K670	Provide new lanes in both directions and improve the interchange at the Y (El Toro) on I-5 from SR-55 to El Toro IC (PM 18.5-30.3) (M2)	OCTA	2019	$236,753
	EA 0K020	Operational Improvements that include ML lane addition, HOV, aux lane, & interchange reconfiguration on I-5 from the El Toro Road IC in Lake Forest to Junipero Serra in San Juan Capistrano (PM 11-18.5) (M2)	OCTA	2021	$526,124

Appendix D: Benefit-Cost Analysis Results

This appendix provides more detailed Benefit-Cost Analysis (BCA) results than found in Section 6 of the I-5 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*.

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 D-1: BCA Results – S1/S2 – Interchange & Ramp Improvements, Auxiliary Lane
- Exhibit D-2: BCA Results – S3/S4 – S1/S2+Ramp/Connector Metering
- Exhibit D-3: BCA Results – S7 – Mainline & HOV Lane Additions
- Exhibit D-4: Cumulative BCA Results

Exhibit D-1: BCA Results - S1/S2 – Interchange and Ramp Improvements, Auxiliary Lane

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INVESTMENT ANALYSIS
SUMMARY RESULTS

Life-Cycle Costs (mil. $)	$126.3
Life-Cycle Benefits (mil. $)	$85.0
Net Present Value (mil. $)	-$41.3
Benefit / Cost Ratio:	0.7
Rate of Return on Investment:	0.6%
Payback Period:	20 years

ITEMIZED BENEFITS (mil. $)	Average Annual	Total Over 20 Years
Travel Time Savings	$3.7	$74.2
Veh. Op. Cost Savings	$0.4	$7.8
Accident Cost Savings	$0.0	$0.0
Emission Cost Savings	$0.2	$3.0
TOTAL BENEFITS	$4.3	$85.0
Person-Hours of Time Saved	472,364	9,447,270
Additional CO_2 Emissions (tons)	-1,919	-38,381
Additional CO_2 Emissions (mil. $)	-$0.1	-$1.1

Incremental Costs (mil. $)	$126.3
Incremental Benefits (mil. $)	$85.0
Incremental Benefit / Cost Ratio:	0.7

Exhibit D-2: BCA Results – S3/S4 – S1/S2+Ramp/Connector Metering

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INVESTMENT ANALYSIS
SUMMARY RESULTS

Life-Cycle Costs (mil. $)	$166.3
Life-Cycle Benefits (mil. $)	$692.0
Net Present Value (mil. $)	$525.7
Benefit / Cost Ratio:	4.2
Rate of Return on Investment:	23.8%
Payback Period:	5 years

ITEMIZED BENEFITS (mil. $)	Average Annual	Total Over 20 Years
Travel Time Savings	$29.7	$594.9
Veh. Op. Cost Savings	$3.5	$70.9
Accident Cost Savings	$0.0	$0.0
Emission Cost Savings	$1.3	$26.2
TOTAL BENEFITS	$34.6	$692.0
Person-Hours of Time Saved	3,950,074	79,001,481
Additional CO_2 Emissions (tons)	-14,908	-298,164
Additional CO_2 Emissions (mil. $)	-$0.5	-$9.5

Incremental Costs (mil. $)	$40.0
Incremental Benefits (mil. $)	$607.0
Incremental Benefit / Cost Ratio:	15.2

Exhibit D-3: BCA Results – S7 – Mainline & HOV Lane Additions

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INVESTMENT ANALYSIS
SUMMARY RESULTS

Life-Cycle Costs (mil. $)	$1,052.0
Life-Cycle Benefits (mil. $)	$3,516.0
Net Present Value (mil. $)	$2,464.0
Benefit / Cost Ratio:	3.3
Rate of Return on Investment:	24.4%
Payback Period:	5 years

ITEMIZED BENEFITS (mil. $)	Average Annual	Total Over 20 Years
Travel Time Savings	$136.2	$2,724.9
Veh. Op. Cost Savings	$29.5	$590.1
Accident Cost Savings	$0.0	$0.0
Emission Cost Savings	$10.1	$201.0
TOTAL BENEFITS	$175.8	$3,516.0
Person-Hours of Time Saved	16,851,280	337,025,610
Additional CO_2 Emissions (tons)	-136,042	-2,720,836
Additional CO_2 Emissions (mil. $)	-$4.1	-$82.6

Exhibit D-4: Cumulative BCA Results

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INVESTMENT ANALYSIS
SUMMARY RESULTS

Life-Cycle Costs (mil. $)	$1,203.3
Life-Cycle Benefits (mil. $)	$4,208.0
Net Present Value (mil. $)	$3,004.7
Benefit / Cost Ratio:	3.5
Rate of Return on Investment:	n/a
Payback Period:	n/a

ITEMIZED BENEFITS (mil. $)	Average Annual	Total Over 20 Years
Travel Time Savings	$166.0	$3,319.8
Veh. Op. Cost Savings	$33.0	$661.0
Accident Cost Savings	$0.0	$0.0
Emission Cost Savings	$11.4	$227.2
TOTAL BENEFITS	$210.4	$4,208.0
Person-Hours of Time Saved	20,801,355	416,027,091
Additional CO_2 Emissions (tons)	-150,950	-3,019,000
Additional CO_2 Emissions (mil. $)	-$4.6	-$92.2