CORRIDOR SYSTEM MANAGEMENT PLAN (CSMP)
RIVERSIDE COUNTY SR-91

FINAL REPORT

June 10, 2011

System Metrics Group, Inc.

State Route 91

Corridor System Management Plan

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EXECUTIVE SUMMARY

This is the Riverside State Route 91 (SR-91) Final Corridor System Management Plan II (CSMP) developed on behalf of the California Department of Transportation (Caltrans). This report analyzes the existing conditions of the SR-91 corridor with the latest available data. It also analyzes improvement scenarios using a calibrated Vissim micro-simulation model and a benefit-cost analysis that would maintain the mobility gains achieved by implementing projects partially funded by Proposition 1B. This Final CSMP is a culmination of previous deliverables and represents the final milestone of developing a Corridor System Management Plan.

Background

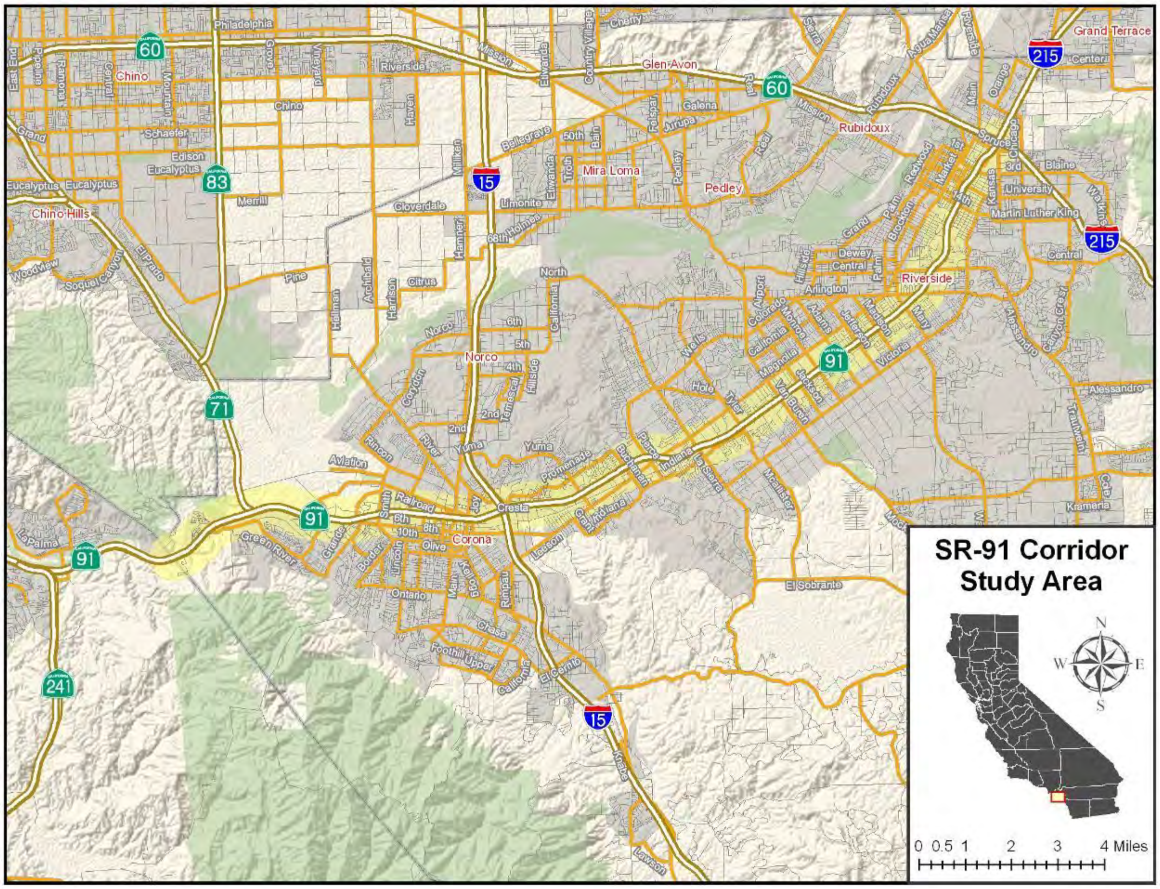
This CSMP is the direct result of the November 2006 voter-approved Proposition 1B (The Highway Safety, Traffic Reduction, Air Quality, and Port Security Bond Act of 2006). This ballot measure included a funding program deposited into a Corridor Mobility Improvement Account (CMIA). The CMIA will fund the construction of the High Occupancy Vehicle (HOV) lanes from Adams Street to the SR-60/I-215 interchange, and an eastbound auxiliary lane from SR-241 to SR-71 in Orange and Riverside Counties. As a requirement to obtain CMIA funding for this project, Caltrans District 8 is developing this Riverside SR-91 CSMP to be submitted to the California Transportation Commission (CTC). This document assesses the existing conditions of the corridor and discusses the final results of the scenarios of projects that were evaluated with a calibrated Vissim micro-simulation model and benefit-cost analyses.

Corridor Description

Caltrans and the CTC defined the Riverside SR-91 study corridor as the 22-mile stretch from the Orange/Riverside County line (CA PM 0.0) to the I-215/SR-60 interchange (CA PM 21.7) in Riverside. The corridor passes through the cities of Corona and Riverside. The corridor is a six to ten-lane freeway with a High Occupancy Vehicle (HOV) lane in each direction. In the eastbound direction, the HOV lane terminates west of the Madison interchange. In the westbound direction, the HOV lane starts at the Arlington interchange and continues throughout the study corridor. The corridor has three major freeway-to-freeway interchanges at SR-71 (Chino Valley Freeway), I-15 (Corona Freeway), and I-215/SR-60.

As the only corridor that connects the Inland Empire to the commercial centers of the Greater Los Angeles area, SR-91 has become one of the most congested freeways in Southern California. In 2009, nearly 240,000 vehicles per day used the corridor near the Riverside-Orange County Line. The western part of the corridor (west of McKinley) was used by fewer vehicles at around 150,000. Traffic is forecasted to increase about 50 percent by 2030. This will further exacerbate congestion. The growing population and relatively affordable housing market in Riverside County, coupled with increasing employment opportunities in the Greater Los Angeles area, have increased demand on the corridor in the last decade.

Exhibit ES-1: SR-91 Study Corridor



Corridor-Wide Performance and Trends

In order to identify how well or poorly the corridor is performing, the existing conditions of the SR-91 corridor were analyzed using the performance measures of mobility, reliability, productivity, and safety. These performance measures were based on data from 2005 to 2009 with a focus on the 2008 base model year. The following discussion briefly summarizes the results of each performance measure. The detailed discussion can be found in Section 3 of this document, *Comprehensive Performance Assessment*.

- Mobility – a directional pattern of delay appeared in both the mainline and HOV facilities. The westbound direction experienced greater congestion during the AM peak period, and the eastbound direction experienced more congestion during the PM peak period. In 2008, eastbound delay on the mainline (1,260,000 vehicle-hours) exceeded westbound delay (680,000 vehicle-hours) by 45 percent. Similarly, eastbound delay on the HOV lane (240,000 vehicle-hours) was nearly 50 percent greater than westbound delay (122,000 vehicle-hours) in 2008. Travel times for both mainline and HOV facilities experienced an overall decline between 2005 and 2009.

- Reliability – this measure captures the degree of predictability in travel time and focuses on how travel time varies from day to day. The variability of peak hour travel time declined overall between 2006 and 2009 on both mainline and HOV facilities. During the 5 PM peak hour in 2008, motorists driving the entire length of the eastbound mainline facility had to add 6 minutes to an average travel time of 28 minutes (for a travel time of 34 minutes) to ensure they would arrive on time most days (95 percent of the time). This is 14 minutes longer than the 20 minutes it would take to travel the same distance at 60 mph. In the westbound direction of the mainline facility during the 6 AM peak hour, a driver needed to add 8 minutes to an average travel time of 24 minutes to ensure an on-time arrival 95 percent of the time. The driver in effect had to plan for a total travel time of 32 minutes.

- Productivity – this measure reflects the reduction in effective capacity due to merging and weaving activities in equivalent lost lane-miles. Just as delay on the corridor decreased from 2006 to 2009, so did the unit of lost lane-miles, signifying an increase in corridor productivity. On the mainline facility, productivity of the corridor improved as lost lane-miles declined from 16.8 in 2007 to 13.9 in 2008 and 13.0 in 2009. The same occurred on the HOV lanes as lost lane-miles fell from 2.4 in 2007 to 2.1 in 2008 and 1.7 in 2009.

- Safety – reported accident data must be used for this measure and the latest year of available data is 2008. The safety measure is not separated by mainline or HOV lanes. The number of accidents that occurred on the corridor remained steady from 2005 to 2007 with about 1,100 in the eastbound direction and 900 in the westbound direction. However, in 2008, the number of accidents on the corridor declined about 13 percent to approximately 970 in the eastbound direction and 800 in the westbound. From 2006 to mid-2009, the rate of fatalities and injuries for this corridor is lower compared to other state highway facilities with similar operating characteristics, particularly in the westbound direction. The accident rate for westbound SR-91 (0.88) is lower than the rate on similar facilities (between 1.15 and 1.26)

Exhibit ES-2: SR-91 Corridor-Wide Analysis

MAINLINE FACILITY										
	Mobility				Reliability		Safety		Productivity	
	Total Annual Delay (Vehicle Hours)[1]		Average Peak Hour Travel Time (Minutes)[2]		Peak Hour Travel Time Variability (Percent)[2]		Annual Accidents[3,4]		Average Daily Lost Productivity (Lane-Miles)[1]	
	EB	WB	EB	WB	EB	WB	EB	WB	EB	WB
2005	1,275,127	1,084,570	30	30	33%	65%	1,186	907	9.1	9.2
2006	1,289,732	953,514	30	31	52%	55%	1,189	900	9.4	7.1
2007	1,216,297	886,125	28	29	37%	57%	1,131	893	8.9	7.9
2008	1,264,187	682,703	27	24	44%	52%	970	781	7.9	6.0
2009	1,069,520	658,029	27	25	35%	51%	n/a	n/a	7.0	6.0

HIGH OCCUPANCY VEHICLE (HOV) FACILITY										
	Mobility				Reliability		Safety		Productivity	
	Total Annual Delay (Vehicle Hours)[1]		Average Peak Hour Travel Time (Minutes)[2]		Peak Hour Travel Time Variability (Percent)[2]		Annual Accidents[3,4]		Average Daily Lost Productivity (Lane-Miles)[1]	
	EB	WB	EB	WB	EB	WB	EB	WB	EB	WB
2005	232,786	172,572	28	31	25%	46%	1,186	907	1.2	1.5
2006	240,014	150,719	30	32	47%	57%	1,189	900	1.5	0.9
2007	251,210	144,397	28	31	37%	50%	1,131	893	1.5	1.0
2008	241,967	122,492	27	25	42%	28%	970	781	1.3	0.8
2009	198,325	65,627	26	24	33%	31%	n/a	n/a	1.1	0.6

[1] Accounts for weekdays during peak and non-peak periods
[2] Accounts for weekdays only
[3] Accounts for weekdays and weekends
[4] Represents total accidents on both mainline and HOV facilities. Accidents are not separated by facility type

Bottleneck Identification and Causality Analysis

Exhibits ES-3 and ES-4 show a map of the SR-91 corridor with the bottleneck locations identified in this study for AM and PM peak periods. The bottleneck locations that occur during the AM peak period mostly concentrate in the westbound direction, west of I-15. During the PM, the bottlenecks occur throughout the eastbound direction. This finding is consistent with the directional pattern of travel from Orange County and Los Angeles.

By definition (HCM2000), a bottleneck is a road element in which traffic demand exceeds the capacity of the roadway facility. In other words, a location where traffic demand able to reach a section of roadway is greater than the section can handle, because there are too many vehicles or not enough road, or both (*Caltrans Freeway Operations Academy Manual*). In most cases, the cause of bottlenecks is related to a sudden reduction in capacity (such as roadway geometry, heavy merging and weaving, and driver distractions) or a surge in demand (from ramps or connectors) that the facility cannot accommodate. The cause of each bottleneck along the corridor was identified through numerous field visits in December 2008 and January 2009. These causes are summarized in Exhibit ES-5.

A detailed description of each bottleneck location is provided in Section 3 of this report. It should be noted that many of the bottlenecks visible in 2006 and early part of 2007 have now disappeared with the reduction in demand associated with higher gas prices and the depressed economy. However, should mainline traffic growth reach 2006 levels, these bottlenecks are likely to reoccur.

Exhibit ES-3: AM Bottleneck Locations

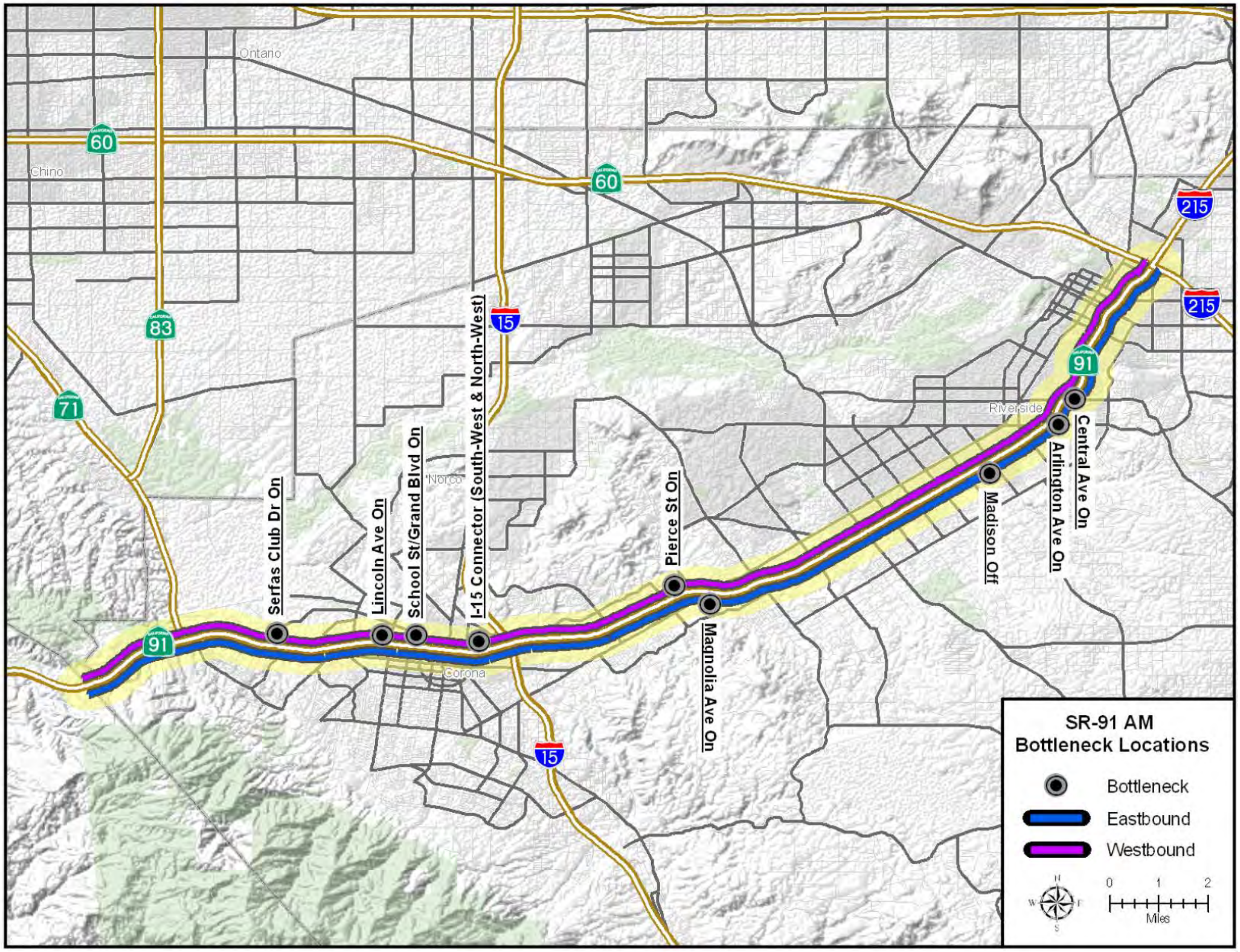


Exhibit ES-4: PM Bottleneck Locations

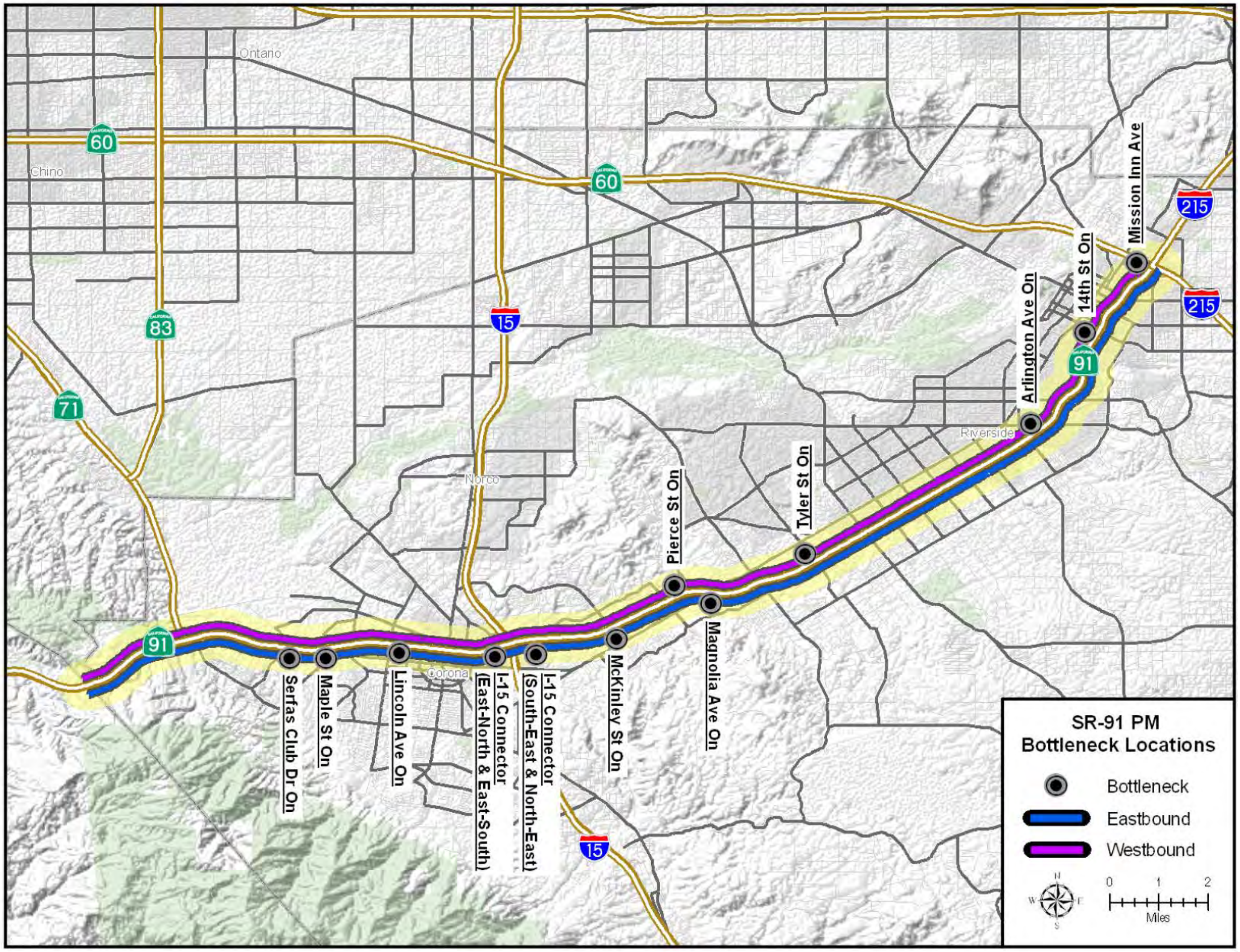


Exhibit ES-5: Summary of Bottleneck Causes

EASTBOUND BOTTLENECKS

Abs	CA	Bottleneck Location	Active Period AM	Active Period PM	Causality Summary
41.1	R3.8	Serfas Club Dr Off/On		✓	On-ramp demand and merging; cross-weaving of SR-71 traffic
41.6	4.2	Maple St On		✓	Merging and weaving
42.9	5.5	Lincoln Ave On		✓	On-ramp demand and merging from Lincoln
44.4	7.0	I-15 Connectors (East-North & East-South)		✓	Demand to I-15 causes queuing at I-15 and merging from Main Street on-ramp
45.0	7.6	I-15 Connectors (South-East & North-East)		✓	Connector demand and merging from I-15
46.5	9.2	McKinley St On		✓	Consecutive merging from McKinley and uphill grade
48.0	10.6	Magnolia Ave On	✓	✓	On-ramp demand and merging from Magnolia
53.9	16.5	Madison Off	✓		Lane drop due to HOV termination
55.4	18.0	Arlington Ave On	✓		On-ramp demand and merging from Arlington; curve to the left; short aux lane
55.9	18.6	Central Ave On	✓		On-ramp demand and merging from Central; curve to the left

WESTBOUND BOTTLENECKS

Abs	CA	Bottleneck Location	Active Period AM	Active Period PM	Causality Summary
58.5	21.1	Mission Inn Avenue		✓	Reduction in capacity at approach to Mission Inn Ave
57.3	19.8	14th St On		✓	On-ramp demand and merging from 14th
55.1	17.6	Arlington Ave On		✓	On-ramp demand and merging from Arlington
50.3	12.9	Tyler St On		✓	Weaving from Tyler On-ramp and HOV ingress/egress
48.0	10.6	Pierce St	✓	✓	Geometric roadway curve to left; ramp merge at crest
45.2	7.8	I-15 Connectors (South-West & North-West)	✓		High demand from I-15 NB connector to WB-91 and lane drop
43.3	5.9	School St/Grand Blvd On	✓		Merging from the School Street On-ramp
42.7	5.3	Lincoln Ave On	✓		On-ramp demand and merging from Lincoln
40.9	R3.5	Serfas Club Dr On	✓		On-ramp demand and merging from Serfas Club Dr
37.2	0.0	Green River Road On	✓		Combination of merging and diverging traffic from the ending of the HOV Lane and beginning of the Toll Lanes

Planned Corridor System Management Strategies

As one of the most congested corridors in Southern California, SR-91 has been the focus of many efforts to identify potential alternatives for improving the corridor. Projects on the state highway system with funding are identified in the Southern California Association of Government's (SCAG's) Regional Transportation Improvement Program (RTIP) and State Highway Operations Protection Program (SHOPP). The RTIP is a listing of all capital transportation projects proposed over a six-year period for the SCAG region. Along the SR-91 corridor, projects with funding in the RTIP include:

- An eastbound lane addition between SR-241 and SR-71
- Ramp widening and reconstruction of the Van Buren Boulevard interchange
- Extension of the HOV lane from Adams to the SR-60/I-215 interchange
- Replacement of the eastbound SR-91 to northbound SR-71 connector with a direct flyover
- The SR-91 Corridor Improvement Project.

After planned corridor improvements were identified, a framework was developed to combine projects into scenarios and test them in a micro-simulation model. Following the testing in the model, a benefit-cost analysis (BCA) was performed for each scenario to evaluate how well the scenario would maintain the mobility gains achieved by the CMIA-funded project.

This framework combines projects using a number of rules, including:

- Operations projects were combined separately from expansion projects to distinguish their benefits. Operations projects improve mobility without expanding the capacity of the facility. These projects include auxiliary lanes, ramp metering, and interchange improvements.
- Projects that were fully programmed and funded were combined separately from projects that were not.
- Short-term projects (delivered by 2015) were used to develop scenarios for testing in the 2008 model.
- Medium-term projects (delivered by 2020) were used to develop scenarios for testing in the 2020 model.

1. INTRODUCTION

This report is the Riverside State Route 91 (SR-91) Final Corridor System Management Plan II (CSMP). The document is required by the California Transportation Commission (CTC) for corridors that received funding from the Corridor Mobility Improvement Account (CMIA) approved by voters in 2006. The CMIA will partially fund the construction of High Occupancy Vehicle (HOV) lanes from Adams Street to the SR-60/I-215 interchange.

This report presents performance measurement findings, identifies bottlenecks leading to degraded freeway performance, and diagnoses the causes for these bottlenecks in detail. It also discusses recent and future improvements on the corridor as well as the sequence and organization of projects that were tested with the Vissim micro-simulation model.

This report provides an assessment of corridor conditions using the latest available data. It also presents the framework used to test projects using the Vissim micro-simulation model. Micro-simulation modeling is a tool that evaluates alternative investment strategies and helps determine their relative benefits.

This report and associated CSMP should be updated on a periodic basis since corridor performance can vary dramatically over time due to changes in demand patterns, economic conditions, and delivery of projects and strategies. Such changes could influence the conclusions of the CSMP and the relative priorities in investments. This document has been updated twice since the Preliminary Performance Assessment was written to reflect the most current corridor conditions.

What is a Corridor System Management Plan (CSMP)?

A CSMP is a comprehensive, integrated management plan for increasing transportation options, decreasing congestion, and improving travel times in a transportation corridor. The California Department of Transportation (Caltrans) is developing CSMPs for all major urban corridors in the state to improve mobility and optimize the use of taxpayer dollars. The document identifies the recommended system management strategies for a given State Highway System facility based on comprehensive performance assessment and evaluation. The strategies are phased and include both operations and long-range capital expansion strategies. The strategies take into account transit usage, projections, and interactions with the arterial network. This corridor system management plan serves as a “first cut” template that integrates the overall concept of system management into Caltrans’ planning and decision-making processes. Moving away from the traditional approach that often focuses on expensive capital improvements to localized freeway problem areas; this plan follows a corridor management approach, which emphasizes performance assessments and operations strategies that yield higher benefit-cost results.

A CSMP includes all travel modes in a defined corridor -- highways and freeways, parallel and connecting roadways, and public transit. Although individual districts are ultimately responsible for completing each CSMP, these plans are developed and implemented in partnership with regional and local transportation agencies. 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 of CSMP, this report is more focused on reducing congestion and increasing mobility through capital and operations strategies. The future, more matured CSMP network will further address pedestrian, bicycle and transit components and seek to manage and improve the whole network as an interactive system.

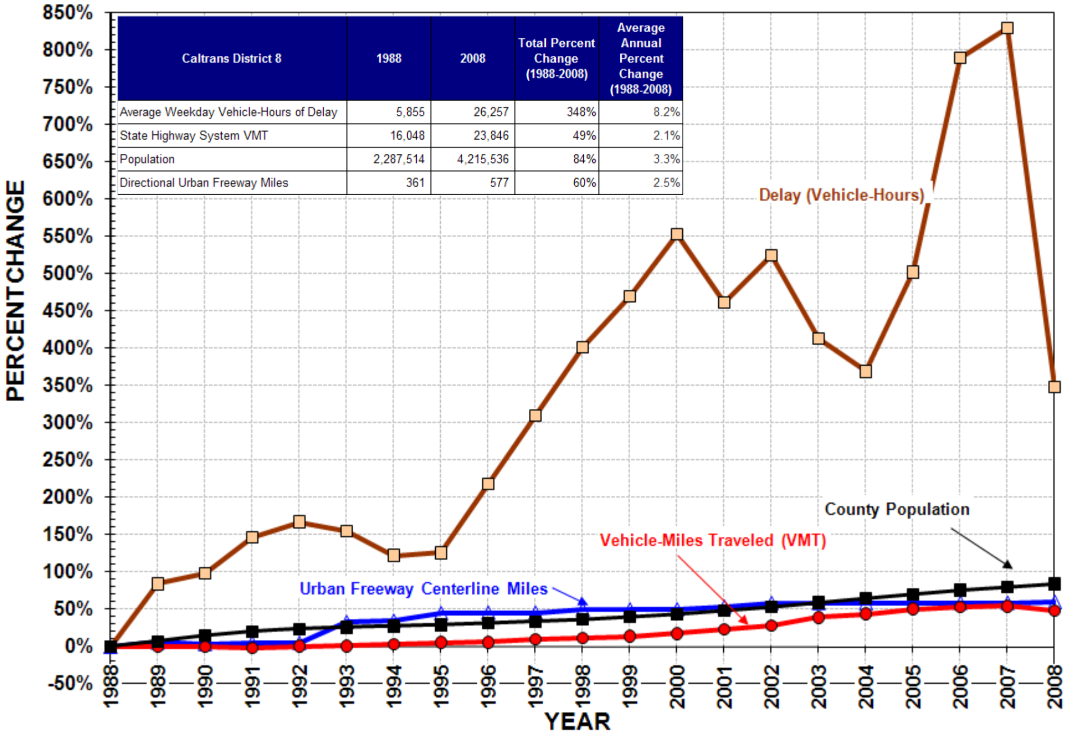
What is System Management?

The system management philosophy begins by defining how the system performs, understanding why it is performing that way, and then evaluating different strategies, including operations-oriented strategies, to address deficiencies.

Exhibit 1-1 shows Riverside and San Bernardino congestion (measured by average weekday recurring vehicle-hours of delay), VMT, population, and urban freeway mileage between 1988 and 2008. Over that 20-year period, congestion increased by more than 300 percent from 1988 levels (just over 8 percent per year). Over the same period, VMT and population rose by 49 percent and 84 percent, respectively. Between 1995 and 2004, urban freeway miles grew dramatically, but since then virtually no miles have been added.

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

Exhibit 1-1: District 8 Growth Trends (1988-2008)



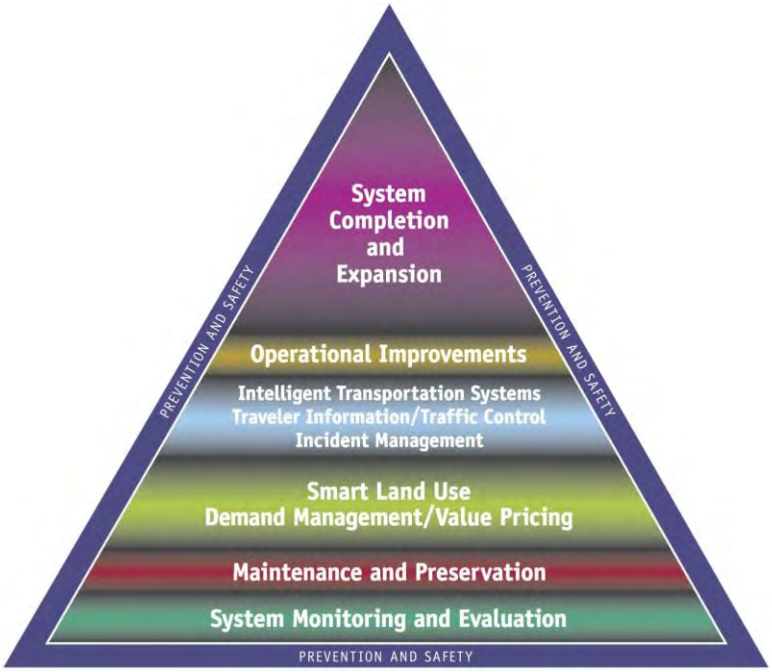
Caltrans District 8	1988	2008	Total Percent Change (1988-2008)	Average Annual Percent Change (1988-2008)
Average Weekday Vehicle-Hours of Delay	5,855	26,257	348%	8.2%
State Highway System VMT	16,048	23,846	49%	2.1%
Population	2,287,514	4,215,536	84%	3.3%
Directional Urban Freeway Miles	361	577	60%	2.5%

Sources: *HICOMP data*
Caltrans Traffic Operations
California Department of Finance
Caltrans Division of Transportation System Information (TSI)

Caltrans recognized this emerging need as it adopted a “One Vision/One Mission” statement to improve mobility across California. It specifies a revised set of goals to help guide the State towards that new approach: productivity, reliability, flexibility, safety, and performance. The first three goals are new and call for improving the efficiency of the transportation system, reducing traveler delays due to incidents and road work, and making transit a more practical travel option. The last two goals are traditional, but critical, ensuring the public’s safety and delivering projects efficiently.

System Management (SM) is the wave of the future and is being touted at the federal, state, regional and local levels. The SM “pyramid” shown in Exhibit I-2 illustrates how Caltrans and its partners need to address both transportation demand and supply to maximize system performance. In the end, it is critical that the *productivity of our system increases* to make up with the past and likely future difference (deficiency) between supply and demand increases.

Exhibit 1-2: System Management Pyramid

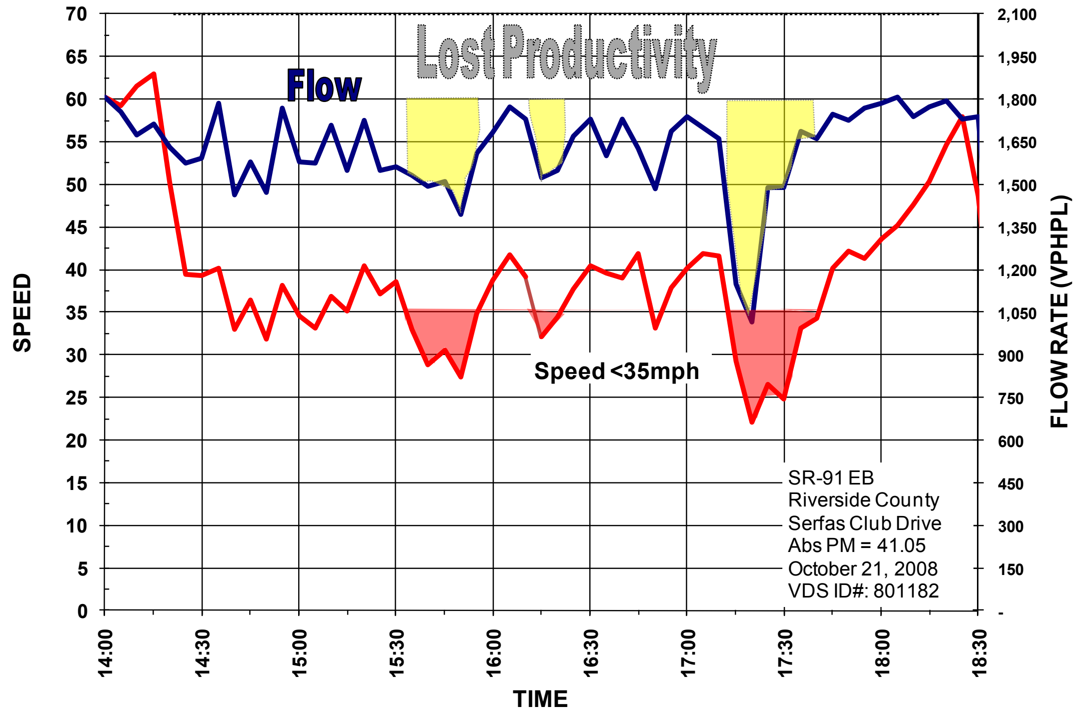


What is Productivity?

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

Exhibit 1-3 illustrates how congestion leads to lost productivity. The exhibit was created using observed SR-91 data from sensors for a typical October afternoon peak period (Tuesday, October 21, 2008). It shows speeds (in red) and flow rates (in blue) on eastbound SR-91 at Serfas Club Drive, which is one of the most congested locations on the corridor.

Exhibit 1-3: Productivity Loss during Congestion



As shown in the exhibit, flow rates (measured as vehicles per hour per lane, or vphpl) averaged around 1,800 vphpl at Serfas Club Drive around 2:00 PM. This is slightly less than a typical maximum flow rate for a peak period.

However, flow rates higher than approximately 2,000 vphpl cannot be sustained for a significant time. Once volumes exceed this maximum flow rate, traffic breaks down and speeds plummet to below 35 or 45 miles per hour (mph). Rather than being able to accommodate the same number of vehicles, flow rates also drop and vehicles back up, creating what most people know as recurrent congestion. Recurrent congestion occurs at regular times at a specific location and can be anticipated by road users that normally use the route during those times. At the location shown in Exhibit 1-3, throughput drops by nearly 20 percent on average during the peak period. Since this is a five-lane road, it is as if one lane were taken away during rush hour. Stated differently, just when the corridor needed the most capacity, it performed in the least productive manner and effectively, lost lanes.

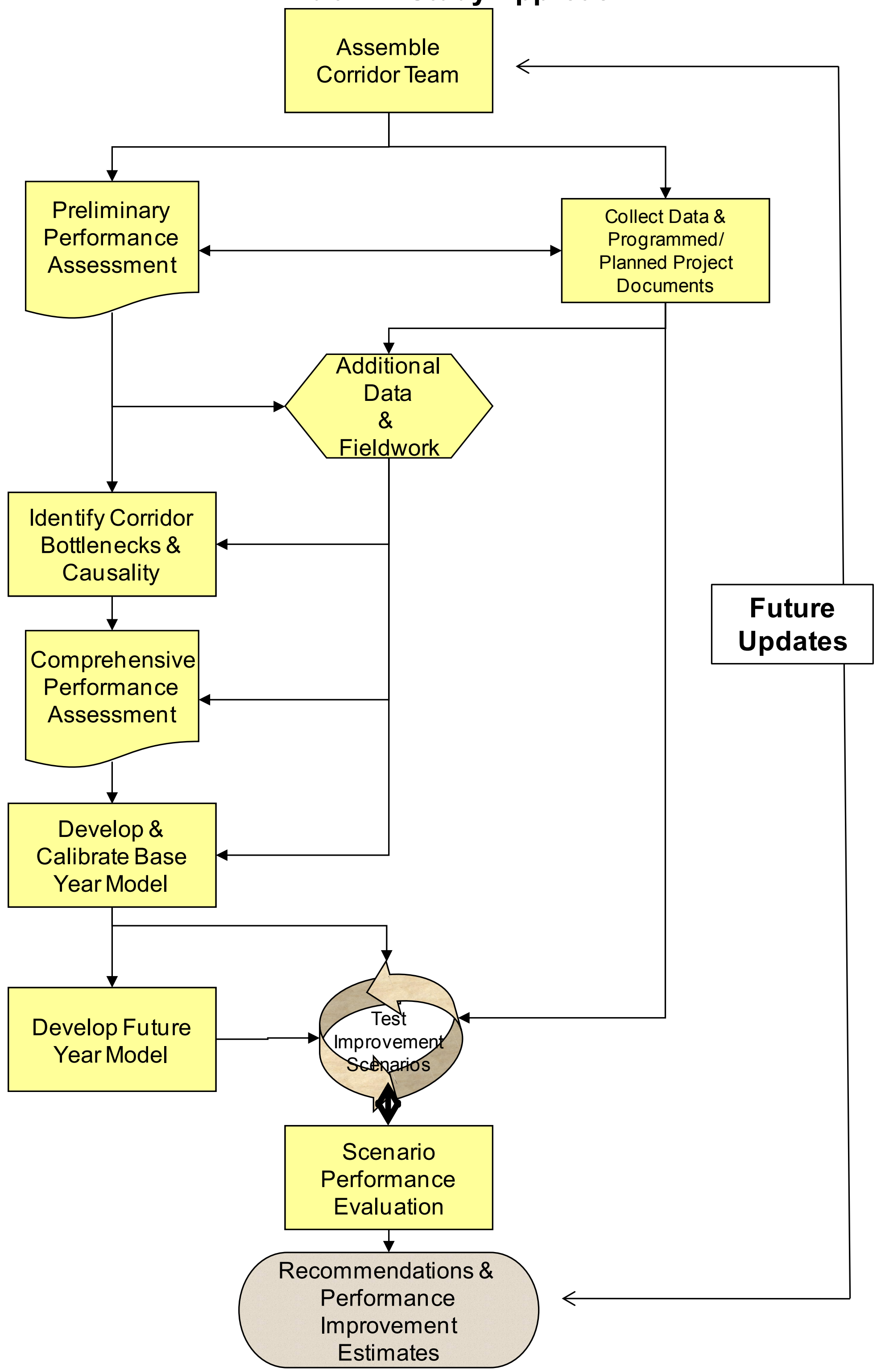
This lost productivity is a major cost of congestion that is rarely discussed or understood. Where there is sufficient automatic detection, the loss in throughput can be quantified and presented as “Equivalent Lost-Lane-Miles”. As discussed in more detail later in the report, productivity losses on eastbound SR-91 exceeded 4.0 lane-miles during the PM peak period in 2009. This means that several hundred million dollars of previous investments on SR-91 were idle when demand was at its highest.

Infrastructure expansion, although still an important strategy, cannot be the only strategy for addressing the mobility needs of Californians. System management is needed to get the most out of the current system and must be an important consideration as Caltrans and its partners evaluate the need for facility expansion investments. **The system management philosophy begins by defining how the system performs, understanding why it is performing that way, and then evaluating different strategies, including operations-oriented strategies, to address deficiencies.** These strategies can then be evaluated using different tools to estimate benefits and determine whether the benefits are worthy of the associated costs.

Study Approach

The SR-91 study approach follows system management principles by emphasizing performance monitoring and evaluation (the base of the pyramid in Exhibit 1-2) and the use of lower cost operations improvements to maintain system productivity. The flow chart in Exhibit 1-4 illustrates this approach.

Exhibit 1-4: Study Approach



Document Organization

Subsequent to the introduction, this report is organized into four sections:

2. *Corridor Description*
   This section describes the corridor, including the roadway facility, major interchanges and relative demands at these interchanges, rail and transit services along the freeway facility, major intermodal facilities around the corridor, and special event facilities and trip generators. This section has been expanded since the Comprehensive Performance Assessment milestone to include a discussion on traffic operations systems as well as park and ride facilities.

3. *Comprehensive Performance Assessment*
   This section presents multiple years of performance data for the CSMP-defined freeway facility, including mobility, reliability, productivity, and safety performance measures. It has been updated to include performance through December 2009. This section also identifies the locations of bottlenecks, or choke points, on the freeway facility and reports performance results for delay, productivity, and safety by major "bottleneck area." This addition allows bottlenecks to be prioritized relative to their contribution to corridor performance degradation. A discussion diagnosing the causes of each bottleneck is included in this section.

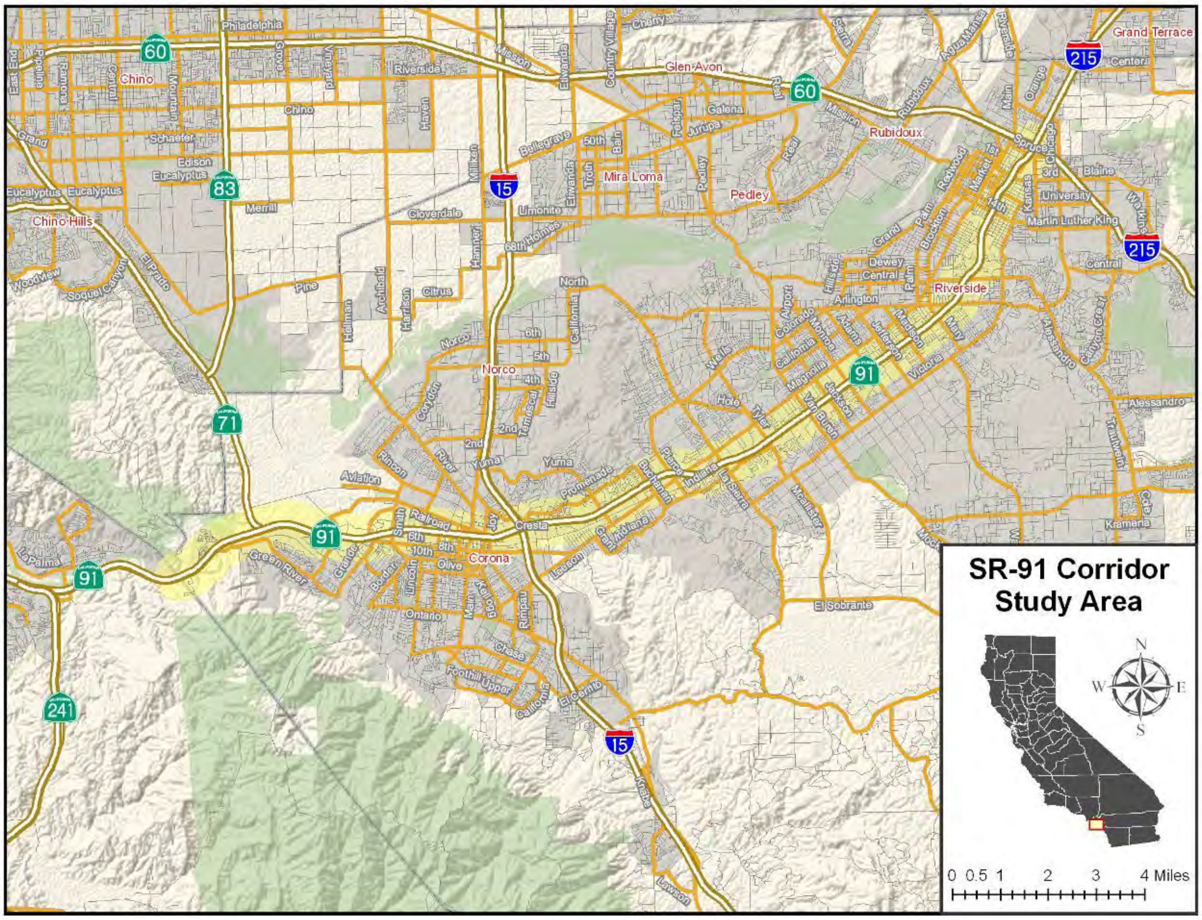
4. *Planned Corridor System Management Strategies*
   This section introduces various improvements planned for the corridor, including those ready for implementation in the next few years and conceptual projects. The section identifies bottlenecks that may improve with implementation of these projects. It also presents the framework that developed for combining projects into scenarios and the results of the modeling and benefit-cost analysis.

5. *Next Steps and Expected Outcomes*
   The last section of this report discusses the outcomes of the current plan and strategies based on the analyses conducted.

2. CORRIDOR DESCRIPTION

Exhibit 2-1 highlights the Riverside SR-91 study area in yellow. The Riverside County SR-91 CSMP corridor begins at the Orange County/Riverside County line (CA post mile 0.0) and terminates at the I-215/SR-60 junction (post mile 21.659), extending approximately 22 miles. Riverside SR-91 traverses the cities of Corona and Riverside.

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



Corridor Roadway Facility

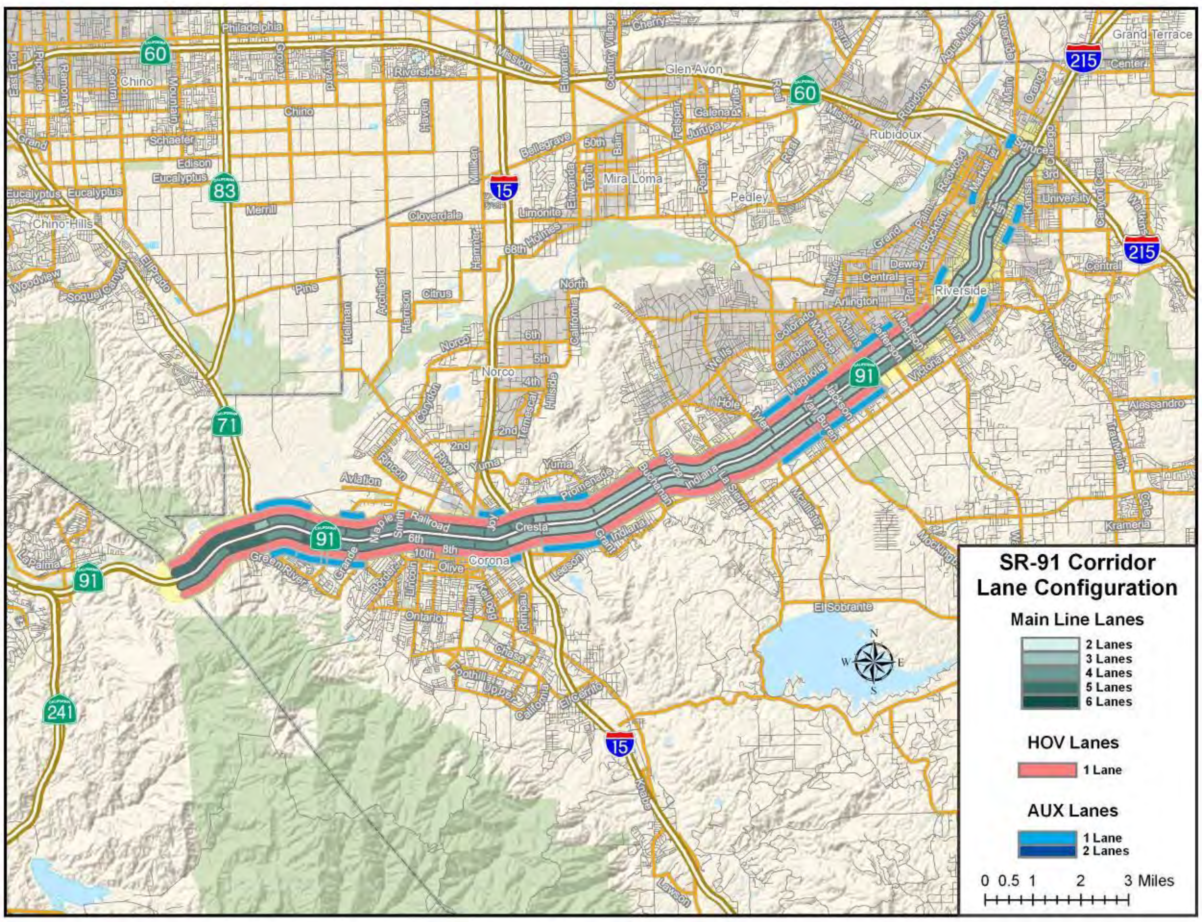
The corridor has three major freeway-to-freeway interchanges:

- SR-71 (Chino Valley Freeway), which provides north-south access from Corona to Chino Hills and Pomona
- I-15 (Corona Freeway), which provides north-south access from Riverside County to San Bernardino County

- I-215/SR-60 interchange, which provides east-west access from Los Angeles/Orange County to Riverside County.

As depicted in Exhibit 2-2, SR-91 is a six to ten-lane freeway with a concrete median barrier that separates eastbound and westbound traffic. Note that Exhibit 2-2 lists the lanes in each direction, so five lanes is equivalent to a ten-lane freeway. There are auxiliary (aux) lanes along many sections of the corridor, but they are neither continuous nor available on both sides of the freeway. There are also continuous High Occupancy Vehicle (HOV) lanes on the corridor except east of the Mary Street interchange. Metered ramps Single Occupancy Vehicle (SOV) and HOV bypass lanes are also present along the study corridor.

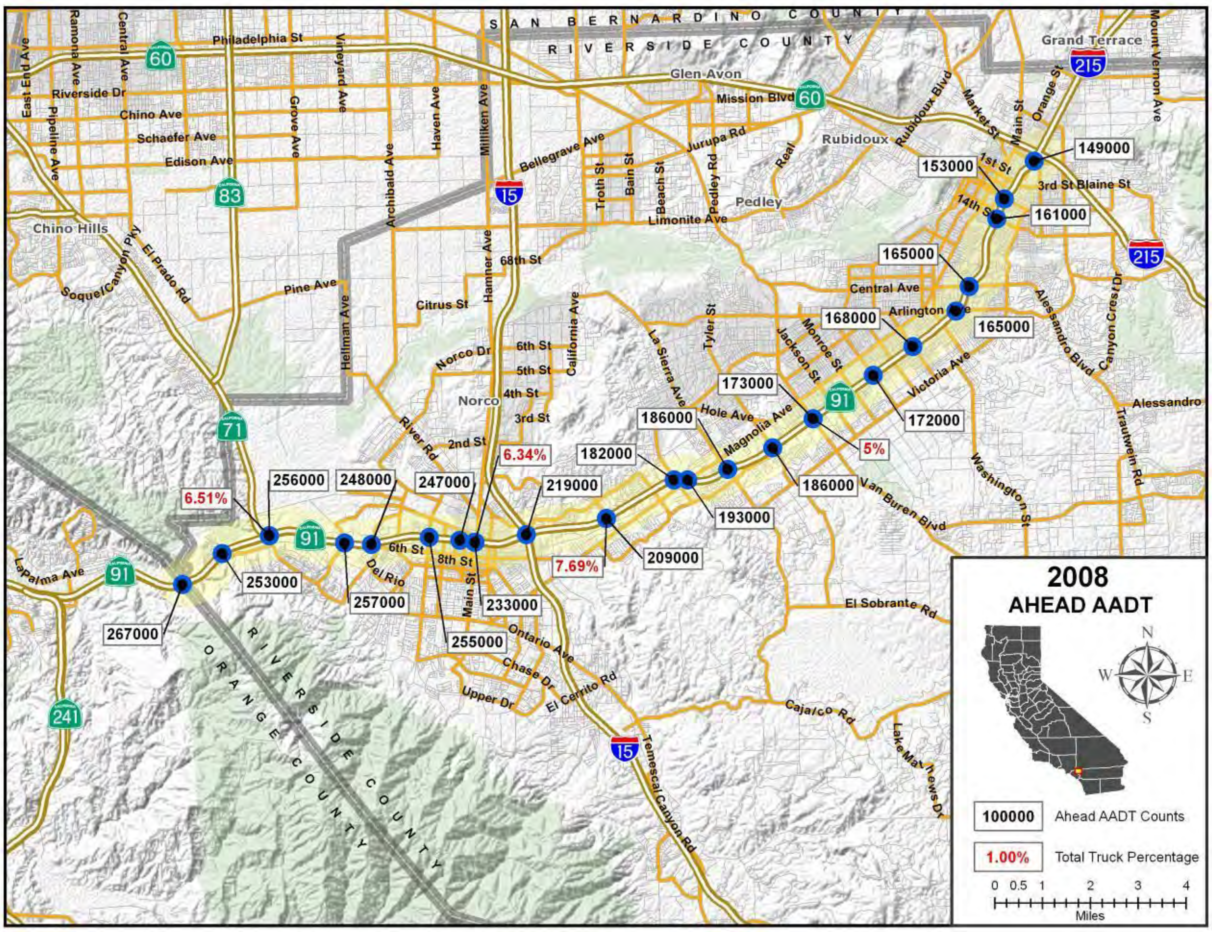
Exhibit 2-2: SR-91 Corridor Lane Configuration



According to the 2008 Caltrans Annual Traffic Volumes Report, the SR-91 Corridor carries between 153,000 and 267,000 annual average daily traffic (AADT)[1] as shown in Exhibit 2-3. The highest AADT was reported near the Orange County/Riverside County line.

SR-91 is designated as a Surface Transportation Assistance Act (STAA) route, which means that trucks may operate on the corridor as shown in Exhibit 2-4. Exhibit 2-4 also identifies trucks as a percentage of AADT (listed as total truck percentage). According to the 2008 Annual Average Daily Truck Traffic on the California State Highway System published by Caltrans in 2009 this corridor's daily truck traffic ranges from 5 percent to 7.7 percent of total daily traffic.

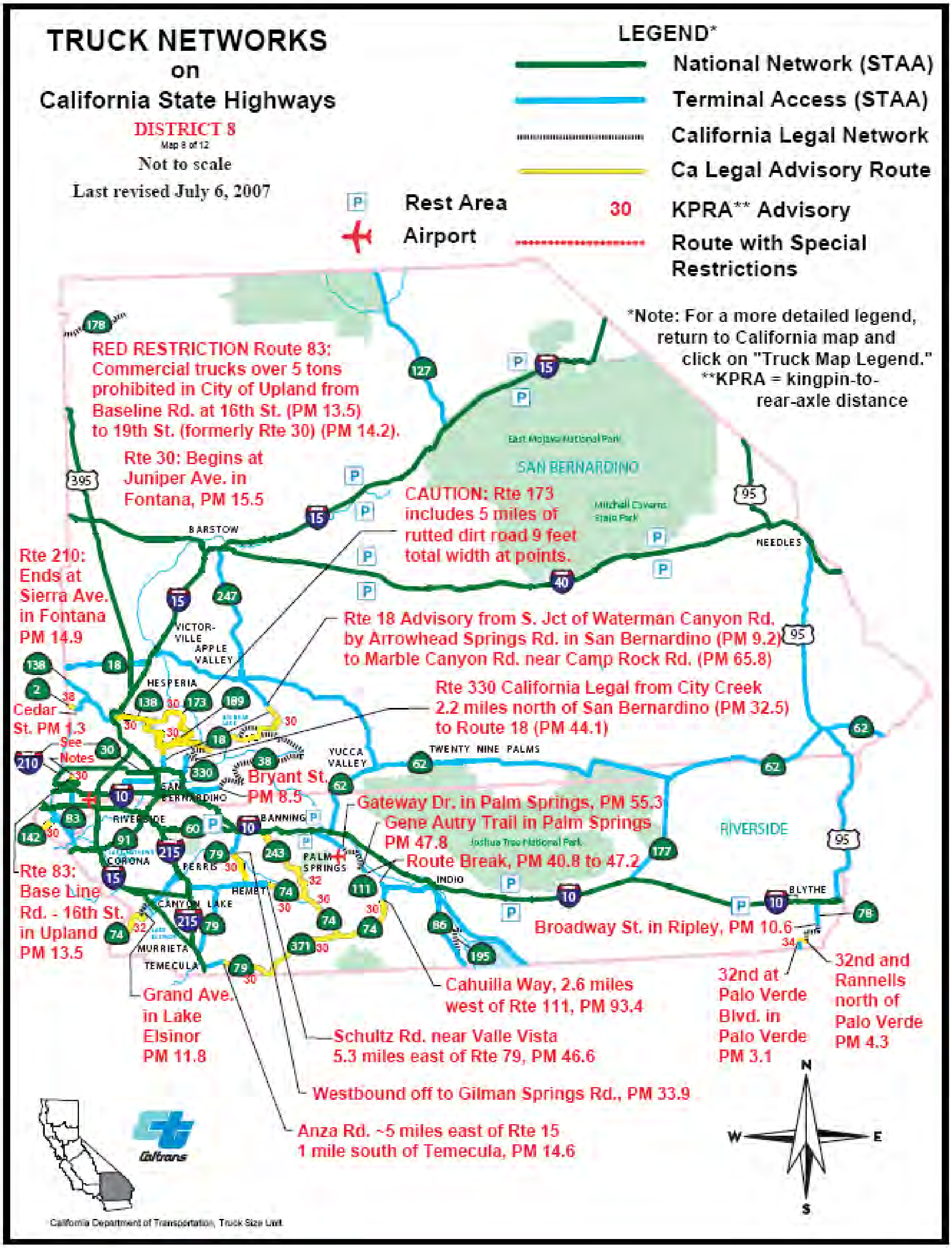
Exhibit 2-3: AADT and Truck Percentages along the SR-91 Corridor



Source: AADT and truck percentages are from the Caltrans Traffic and Vehicle Data Systems Unit

[1] AADT is the daily volume of vehicles averaged over a year.

Exhibit 2-4: San Bernardino/Riverside County Truck Networks



Recent Roadway Improvements

Along the corridor, several roadway improvements have been recently completed or are currently under construction:

- The SR-91 auxiliary lane project began in late October 2007 and opened to traffic in March 2008. This project added an auxiliary lane on eastbound SR-91 from SR-71 to the Serfas Club Drive interchange.
- The I-15/SR-91 connector pavement rehabilitation project began in late November 2007. The project included repairing and resurfacing of bridge decks on the northbound I-15 to the westbound SR-91 connector and the bridges over Temescal Wash.
- The La Sierra interchange project replaced the freeway and railroad bridges with six-lane structures, including dual left-turn lanes and widened freeway ramps. It was completed late in 2009.
- The reconstruction and ramp widening at the Van Buren Boulevard interchange is currently under construction and expected to be completed in 2012.
- The Green River Road interchange project, which replaced the existing bridge, was completed in December 2008.
- A landscaping and paving project at the Lincoln Avenue interchange in the City of Corona involved local closures at Lincoln Avenue.
- The SR-60/SR-91/I-215 improvement project was completed in December 2008. Among the major improvements are: four miles of HOV lanes and widened freeways on I-215, SR-60, and SR-91; major structural improvements at eight local interchanges; two sweeping „flyover' connectors between the I-215/SR-60 and SR-91 to create a new elevation for the SR-91 freeway in both the eastbound and westbound directions; and a new truck bypass connector leading from the southbound I-215 to the eastbound SR-60.
- A bi-county project with Caltrans District 8, Orange County, and Riverside County to construct a continuous lane on eastbound SR-91 from the SR-241 Toll Road interchange in Orange County to SR-71 in Riverside County was open to traffic on December 3, 2010.

Transit

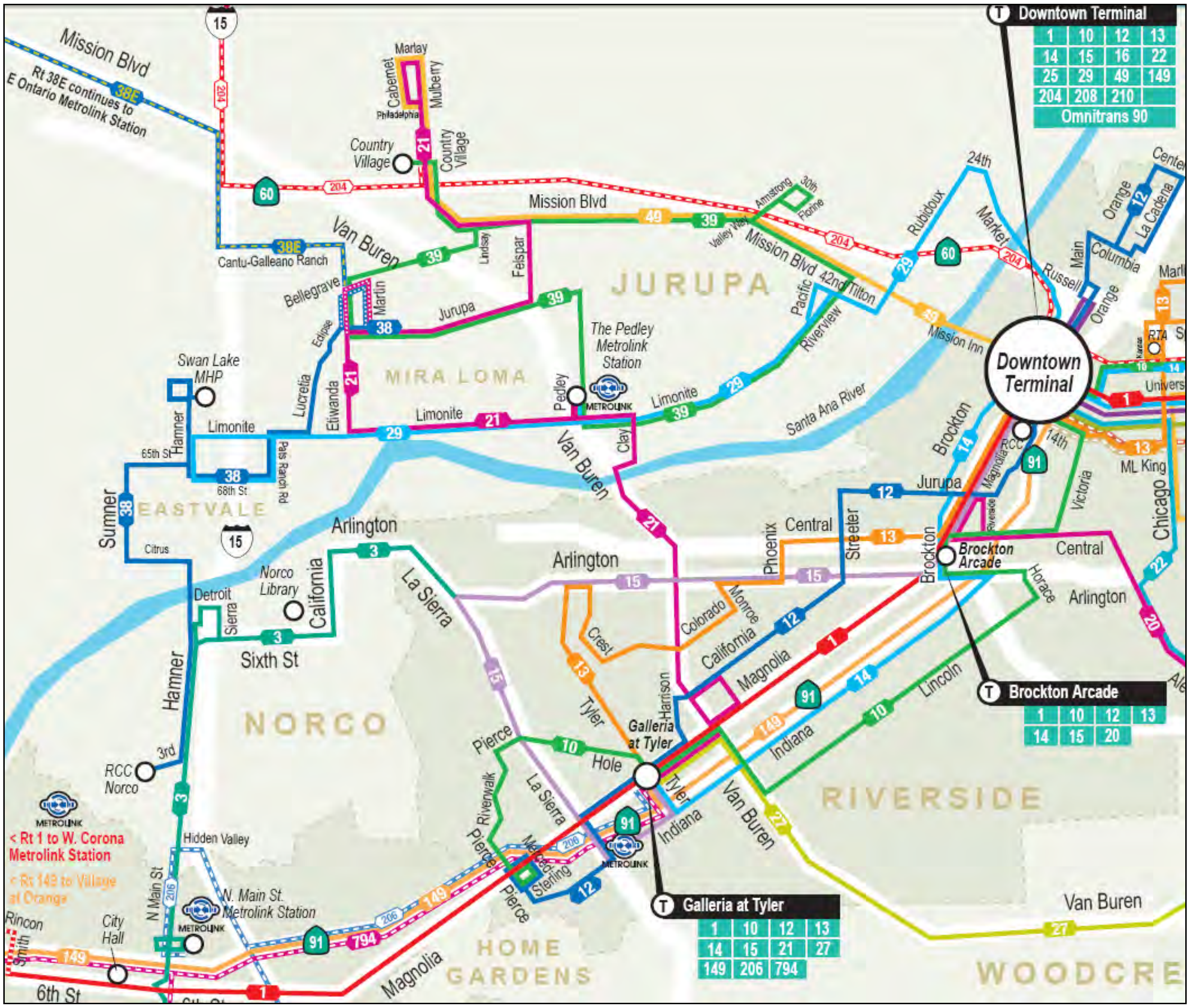
Major transit operators within the SR-91 study corridor include the Riverside Transit Agency (RTA), Omnitrans, and Metrolink commuter rail service

RTA provides 38 fixed routes, five commuter routes, and Dial-A-Ride services in western Riverside County. RTA bus service links communities in Riverside County and Orange County along SR-91. Exhibit 2-5 graphically illustrates the transit lines which serve the SR-91 study corridor area:

- Route 149 travels along SR-91 between the Downtown Terminal in Riverside to the Village at Orange in Anaheim. It provides both weekday and weekend service.
- Route 794 is a limited-stop express service that also travels along the SR-91, and connects the Galleria at Tyler Mall in the City of Riverside to the City of Corona and the South Coast Metro area in Orange County.
- Route 1 is a local service line that operates along Sixth Street and Magnolia Avenue and connects the University of California, Riverside to the Corona Metrolink station.
- Other local routes that operate within close proximity to the study corridor include routes 3, 10, 12, 13, 14, and 15.

Omnitrans is a joint powers authority that represents the County of San Bernardino and the 15 cities served by Omnitrans. It also offers bus service within the vicinity of the SR-91 Corridor. Route 215 connects San Bernardino to Riverside via the I-215 and SR-91. It provides service from the Fourth Street Transit Mall in San Bernardino to the RTA Downtown Terminal in Riverside.

Exhibit 2-5: RTA Map Servicing the SR-91 Corridor



The Southern California Regional Rail Authority (SCRRA) is a joint powers authority that operates the Metrolink regional rail service throughout Southern California. Three lines service the areas along the study corridor:

- The Riverside Line provides service from the Los Angeles Union Station to downtown Riverside with stops in Montebello/Commerce, Industry, Pomona, Pedley, and Ontario. This line operates 12 trains on the weekdays and averages nearly 5,200 riders per day, which is roughly a 9 percent increase from 2006.

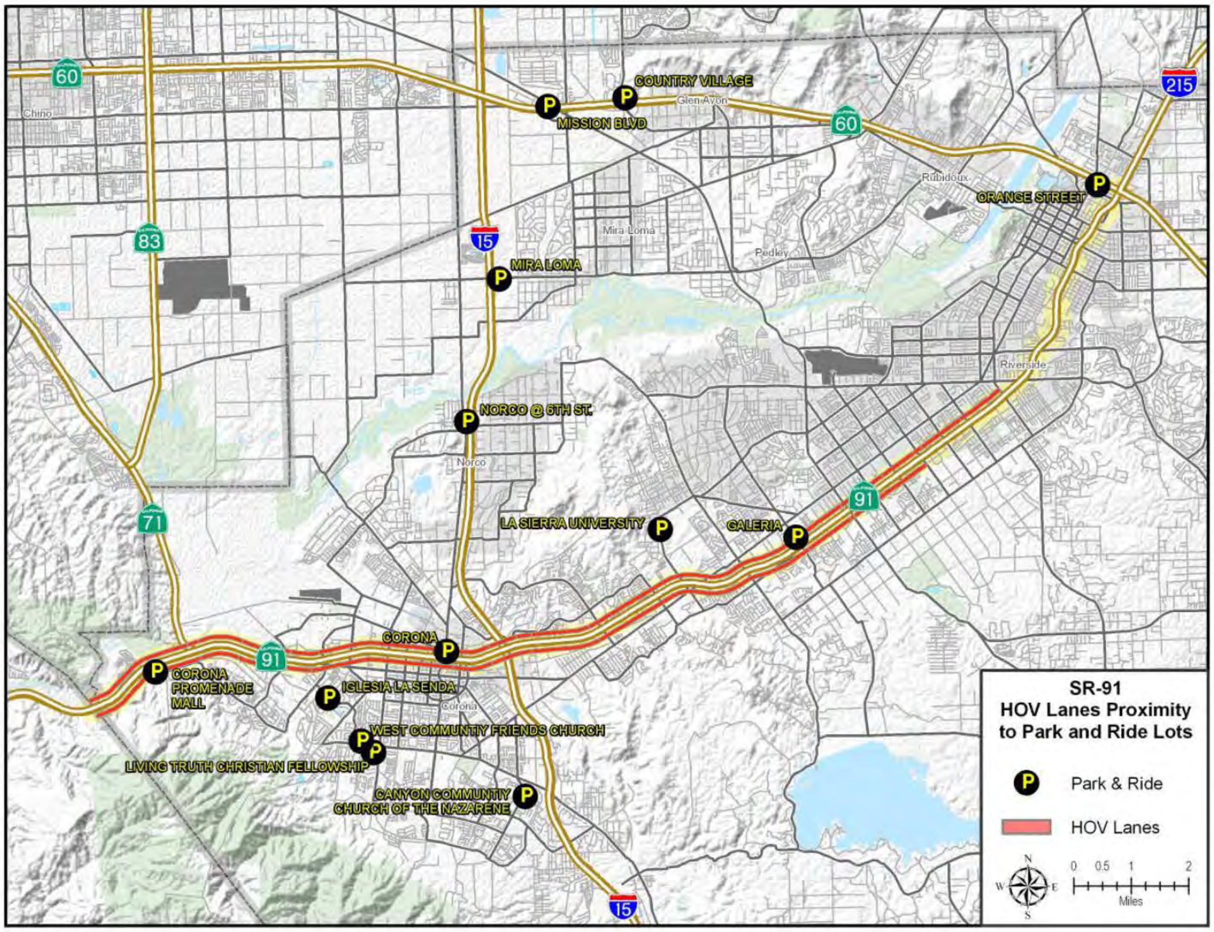
- The 91 Line provides service from the Los Angeles Union Station to downtown Riverside with stops in Commerce, Norwalk/Santa Fe Springs, Fullerton, Corona, and Riverside at La Sierra. This line operates nine trains on the weekdays and averages over 2,250 riders per day, which reflects an increase of approximately 9 percent from 2006.

- The Inland Empire-Orange County Line connects the city of San Bernardino in San Bernardino County to the City of San Juan Capistrano in San Diego County. There are a total of 14 stations for this line with various stops in the cities of Riverside, Corona, and Orange County. This line operates 16 trains on the weekdays, six trains on Saturdays, and four trains on Sundays. Average weekday ridership in 2007 was slightly above 4,800, which reflects a growth of 7 percent since 2006.

Exhibit 2-6: Metrolink System Map

There are several park and ride lots near the SR-91 corridor that provide motorists the opportunity to use an alternative mode of travel.

Exhibit 2-7: Park and Ride Lots



Intermodal Facilities

Two small airports operate within the vicinity of the SR-91 study corridor, the Corona and Riverside Municipal Airports. The Corona Municipal Airport is located less than one-mile north of the study corridor between Serfas Club Drive and Lincoln Avenue. It has one runway and no control tower. In 2004, the airport experienced roughly 68,000 aircraft operations, all of which were general aviation.

Exhibit 2-8: Corona Municipal Airport

The Riverside Municipal Airport is located approximately two-miles north of the study corridor between Van Buren Boulevard and Central Avenue. It serves the Inland Empire area with over 110,000 annual flight operations. It is tower-controlled with full-service runways.

Exhibit 2-9: Riverside Municipal Airport

In addition to the Corona and Riverside Municipal Airports, the March Joint Air Reserve Base is located about seven miles east of the study corridor between the cities of Riverside and Moreno Valley and adjacent to the I-215 corridor. In addition to multiple units of the Air Force Reserve Command supporting Air Mobility Command, Air Combat Command and Pacific Air Forces, March ARB is also home to units from the Army Reserve, Navy Reserve, Marine Corps Reserve and the California Air National Guard.

Trip Generators

Major special event facilities can generate significant trips on the SR-91 Corridor. A number of these facilities are shown in Exhibit 2-10. A trip generator is a venue that produces substantial trips to and from the site. Although the list of trip generators identified in this report is not exhaustive, it provides an indication of the types of businesses and facilities near the study corridor.

One category of trip generators is educational institutions. These include:

- The University of California, Riverside is the largest four-year university in Riverside County. It is located approximately 1.75 miles southeast of the SR-60/I-215 interchange. In 2006, it had a student enrollment of almost 17,000 and it offers both graduate and undergraduate degrees.
- Riverside Community College District has campuses in close proximity to the SR-91 Corridor in the cities of Riverside and Norco.
- Riverside City College is located in downtown Riverside at 4800 Magnolia Avenue, adjacent to the SR-91 freeway west of Fourteenth Street. It serves over 40,000 students.
- Riverside Community College Norco Campus is located at 2001 Third Street in Norco within two-miles northwest of the SR-91/I-215 interchange. It serves over 8,500 students.
- La Sierra University is located approximately one-mile north of the SR-91, just west of La Sierra Avenue. It is a private Christian university offering graduate and undergraduate programs. According to the *La Sierra University's Fast Facts 2004-2005*, student enrollment was approximately 2,000.
- California Baptist College is located right off the SR-91 at Adams Street. It is a private Christian university serving over 3,100 students offering both graduate and undergraduate programs.

In addition to educational institutions, hospital facilities can also be a major trip generator.

- The Parkview Community Hospital is situated north of SR-91 between Van Buren Boulevard and Adams Street. It is a 193-bed acute care hospital that has served the community since 1958.
- The Kaiser Foundation Hospital Riverside is located north of SR-91 between Tyler and La Sierra. It is a short-term hospital with 215 total beds.

- The Riverside Community Hospital is located in downtown Riverside and west of SR-91 at Fourteenth Street. It has over 400 physicians on staff and over 1,400 employees.
- Corona Regional Medical Center is located south of SR-91 on Main Street. It is a 240-bed community hospital network comprised of a 160-bed acute care hospital and an 80-bed rehabilitation campus.

Other trip generators include:

- The Galleria at Tyler, a shopping mall and movie complex located immediately off the SR-91 Tyler Street interchange. It offers nearly 175 dining, entertainment, and shopping options.
- The Riverside Plaza, an outdoor shopping mall and movie complex located on Central Avenue in the City of Riverside, west of SR-91.
- The Fender Music of Music and the Arts, a 33,000 square foot museum and education facility houses classrooms, a recording studio, an outdoor amphitheater, and visual arts gallery. It is located on Main Street in the City of Corona near the I-15 and SR-91 junction.

Exhibit 2-10: Major Trip Generators

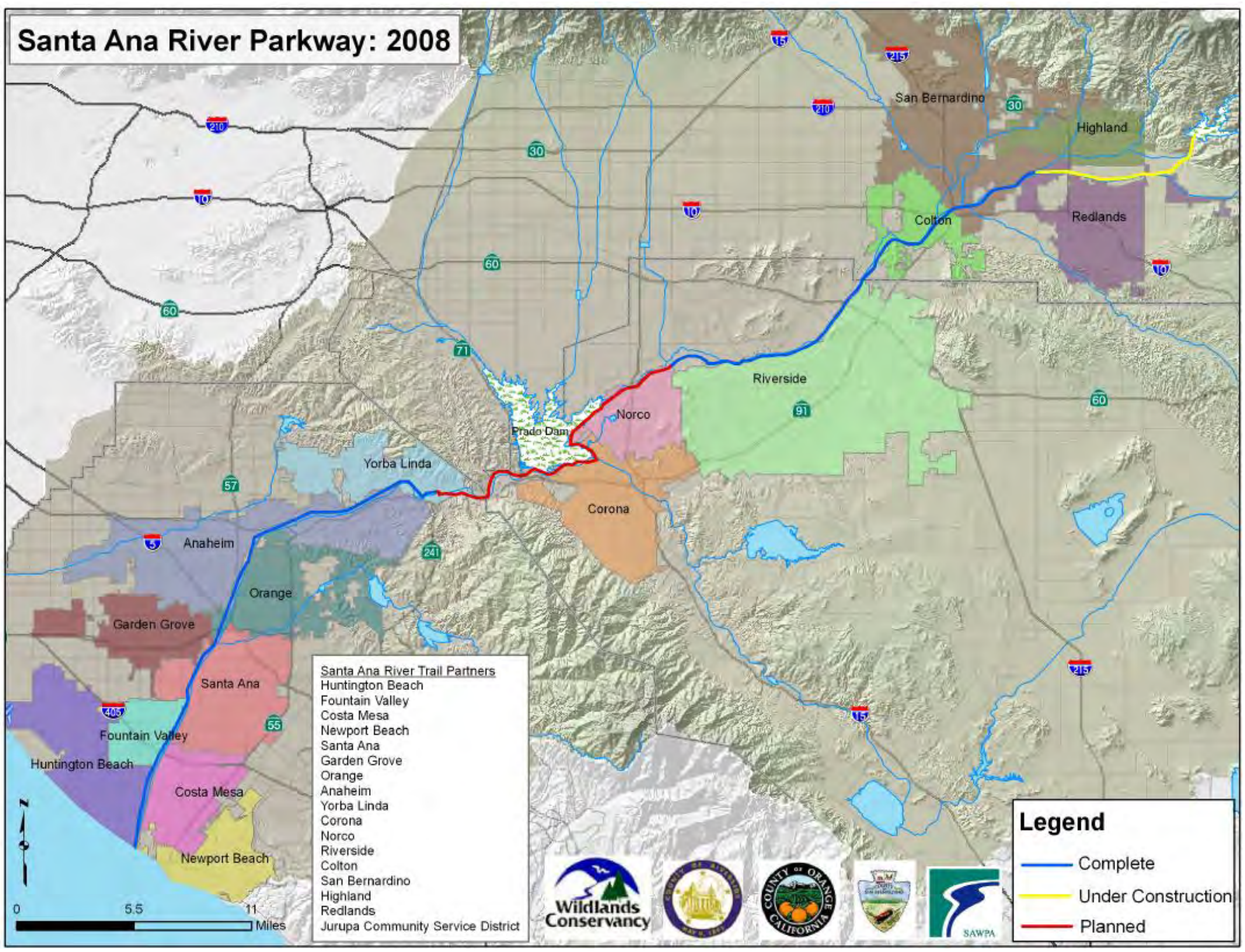
Source: SMG Mapping of Trip Generators

Bicycle/Pedestrian Facilities

The most notable bicycle and pedestrian facility near the study corridor is the Santa Ana River Trail and Parkway. It is a 100-mile long recreational trail that extends from the crest of the San Bernardino Mountains to the coast of the Pacific Ocean. In Riverside County, the trail runs north and parallel to the SR-91 study corridor. Part of the trail is currently under development, as shown in Exhibit 2-11. Specifically, the segment west of I-15 has not yet been completed. The entire trail is approximately 60 percent complete with plans to complete the remaining portions over the next five years.

The variety of geography and park opportunities along the trail allow for a wide range of recreational activities including, but not limited to, hiking, bicycling, walking, running, rock climbing, "geocaching", bird watching, horseback riding, and organized team and individual sports.

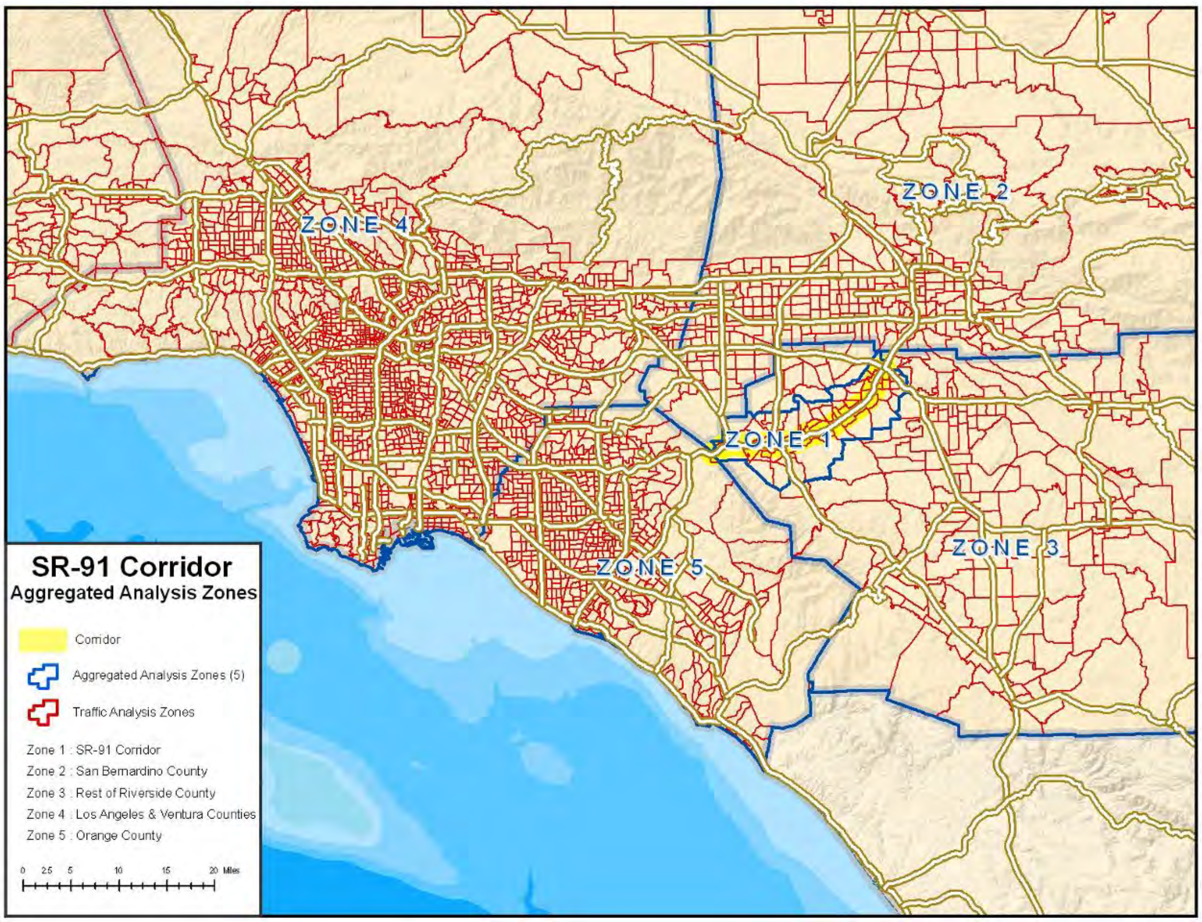
Exhibit 2-11: The Santa Ana River Trail



Demand Profiles

An analysis of origins and destinations was conducted to determine the travel pattern of trips made on the SR-91 study corridor. Based on the Southern California Association of Governments' (SCAG's) travel demand model, this "select link analysis" isolated the SR-91 study 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 five aggregate analysis zones shown in Exhibit 2-12.

Exhibit 2-12: Aggregate Analysis Zones for Demand Profile Analysis



Based on this aggregation, demand on the corridor was summarized by aggregated origin-destination zone as depicted in Exhibits 2-13 and 2-14 for the AM and PM peak periods. This analysis shows that a large number of trips using the SR-91 study corridor represent travel to and from the Greater Los Angeles area, and also within Riverside and San Bernardino Counties.

During the AM peak period, 66 percent of all trips originate in Riverside/San Bernardino Counties and terminate outside those counties. The majority of these trips are destined for Los Angeles and Orange County. The remaining trips depicted in Exhibit 2-13 originate and terminate in Riverside/San Bernardino Counties (19 percent); originate outside Riverside/San Bernardino Counties and terminate outside those counties (11 percent); or originate outside Riverside/San Bernardino Counties and terminate in Riverside/San Bernardino Counties (3 percent). This data suggests that AM congestion is concentrated in the westbound direction with a significant number of trips destined for counties outside of Riverside and San Bernardino, mainly Orange County.

Exhibit 2-13: AM Peak Origin Destination by Aggregated Analysis Zone

		To Zone					
	AM Trips	SR-91 Corridor	San Bernardino County	Rest of Riverside Co	LA and Ventura Counties	Orange County	Outside Zones
From Zone	SR-91 Corridor	1,613	840	11,268	18,710	29,649	412
	San Bernardino County	45	64	5,737	3,140	13,087	114
	Rest of Riverside County	399	417	3,824	6,897	11,879	154
	LA and Ventura Counties	21	0	698	281	1,987	569
	Orange County	353	23	2,675	2,994	6,564	946
	Outside Zones	10	67	183	404	472	117

19.1%	Trips starting and ending in Riverside/San Bernardino Counties
66.4%	Trips starting in Riverside/San Bernardino and ending outside Riverside/San Bernardino
3.2%	Trips starting outside Riverside/San Bernardino and ending in Riverside/San Bernardino
11.3%	Trips starting outside Riverside/San Bernardino and ending outside Riverside/San Bernardino

During the PM peak period (which experiences roughly 30 percent more demand than the AM for travel on SR-91), the picture is slightly different. Roughly 45 percent of trips originate and terminate in Riverside/San Bernardino Counties. The remaining trips originate outside Riverside/San Bernardino Counties and terminate in Riverside/San Bernardino (35 percent); originate in Riverside/San Bernardino Counties and terminate outside those counties (18 percent); or originate and terminate outside Riverside/San Bernardino Counties (3 percent). Of the 35 percent of trips that originate outside Riverside and San Bernardino Counties, 82 percent of those originate in Orange County.

Exhibit 2-14: PM Peak Origin Destination by Aggregated Analysis Zone

		To Zone					
	PM Trips	SR-91 Corridor	San Bernardino County	Rest of Riverside Co	LA and Ventura Counties	Orange County	Outside Zones
From Zone	SR-91 Corridor	24,846	17,871	9,063	4,301	13,076	439
	San Bernardino County	17,476	0	1,171	274	6,754	151
	Rest of Riverside County	7,916	778	541	1,312	5,676	215
	LA and Ventura Counties	6,947	323	2,531	0	362	568
	Orange County	25,764	10,601	14,234	237	0	916
	Outside Zones	841	171	225	906	2,153	205

44.5%	Trips starting and ending in Riverside/San Bernardino Counties
18.0%	Trips starting in Riverside/San Bernardino and ending outside Riverside/San Bernardino
34.5%	Trips starting outside Riverside/San Bernardino and ending in Riverside/San Bernardino
3.0%	Trips starting outside Riverside/San Bernardino and ending outside Riverside/San Bernardino

3. COMPREHENSIVE PERFORMANCE ASSESSMENT

A. Data Sources and Freeway Detection Status

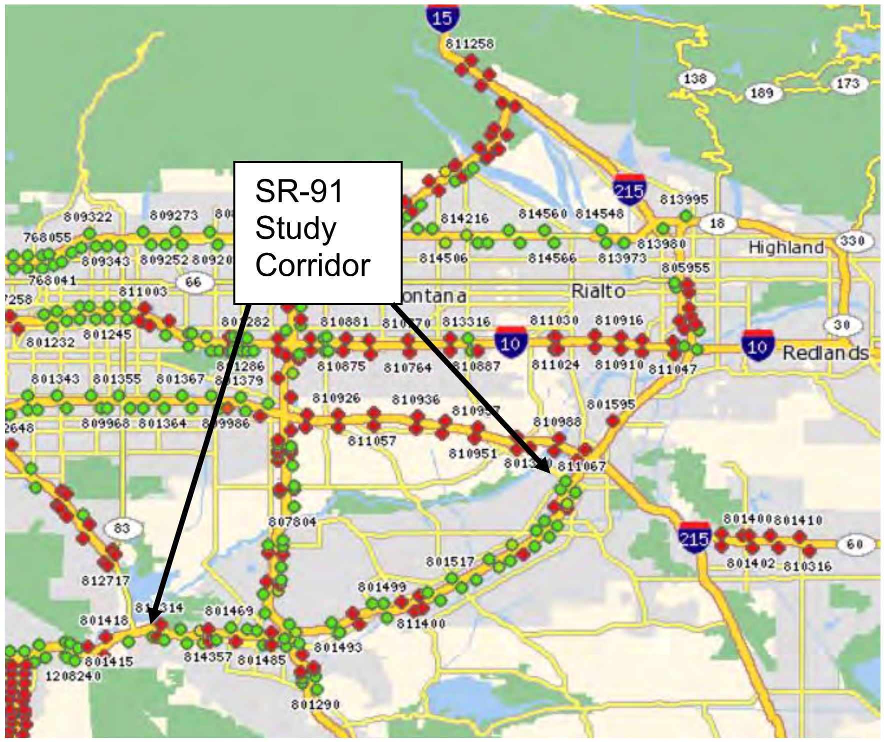
A comprehensive performance assessment was completed in May of 2009. It summarized the numerous data sources used to analyze the existing conditions of the corridor and to identify bottlenecks. These sources include:

- Caltrans Highway Congestion Monitoring Program (HICOMP) report and data files (2006 to 2008)
- Caltrans Freeway detector data
- Caltrans Traffic Accident Surveillance and Analysis System (TASAS) from PeMS
- Various traffic study reports
- Aerial photographs (Google Earth) and Caltrans photologs
- Internet (e.g., RTA, Omnitrans, and Metrolink transit websites).

Details for each data source are provided in the applicable sections of this report. However, given the need for comprehensive and continuous monitoring and evaluation, detection coverage and quality are discussed in more detail here.

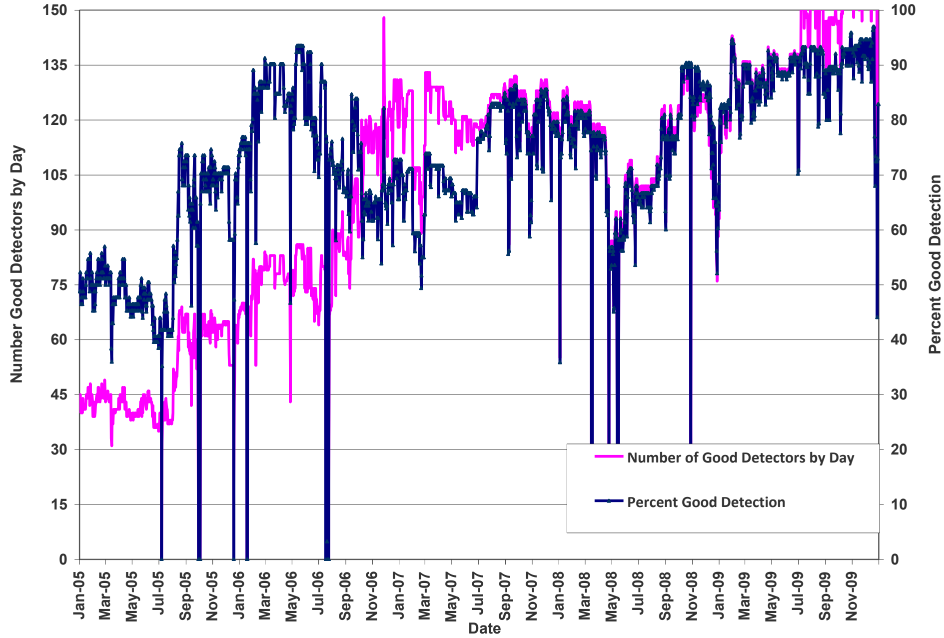
Exhibit 3A-1 depicts the corridor freeway facility with the detectors in place as of December 30, 2008. This data was chosen randomly to provide a snapshot of the detection status. The exhibit shows that there are many detectors on the mainline, the majority functioning well (based on the green color). Furthermore, it illustrates some seemingly small gaps between detectors at some locations.

Exhibit 3A-1: Detector Data Quality (December 30, 2008)



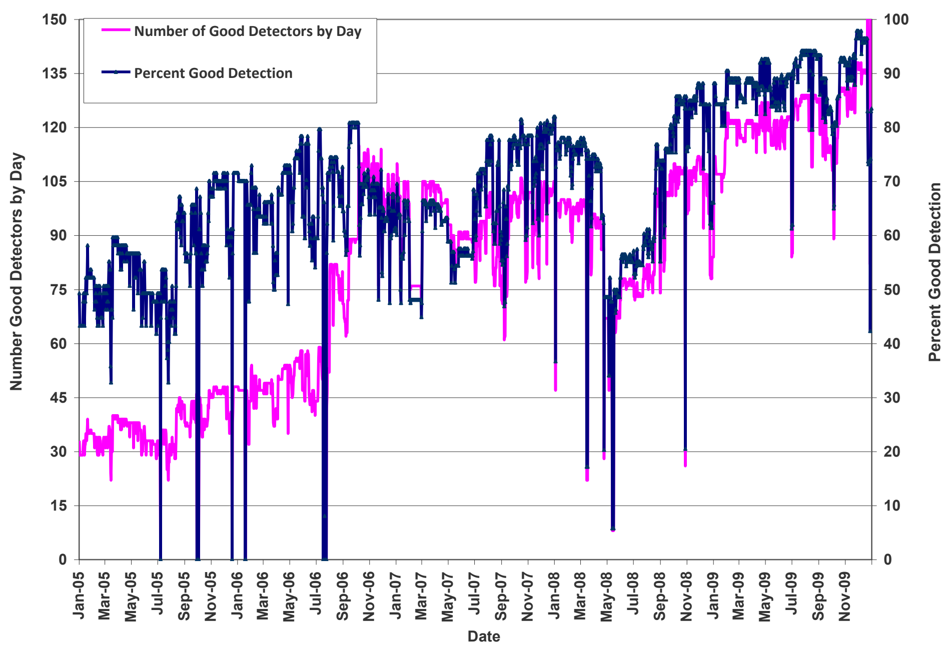
The following exhibits provide a better picture of how the detectors on the corridor performed over a longer period of time. Exhibits 3A-2 and 3A-3 report the number and percentage of daily “good” detectors on the mainline (ML) facility (including ramps) of the Riverside SR-91 Corridor from 2005 to 2009. Exhibits 3A-4 and 3A-5 report the same information for the HOV lane. 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 the eastbound direction was slightly better than the westbound direction since the eastbound direction reported a larger number of good detectors (120) than the westbound direction (105), most notably in the last half of 2007. In the first half of 2008, the quality of detection on the mainline declined in both directions, but recovered in the last half of the year in 2009 to almost 100 percent of reported good data.

Exhibit 3A-2: ML Eastbound SR-91 Number & Percent Daily Good Detectors (2005-2009)



Source: Vehicle detector data

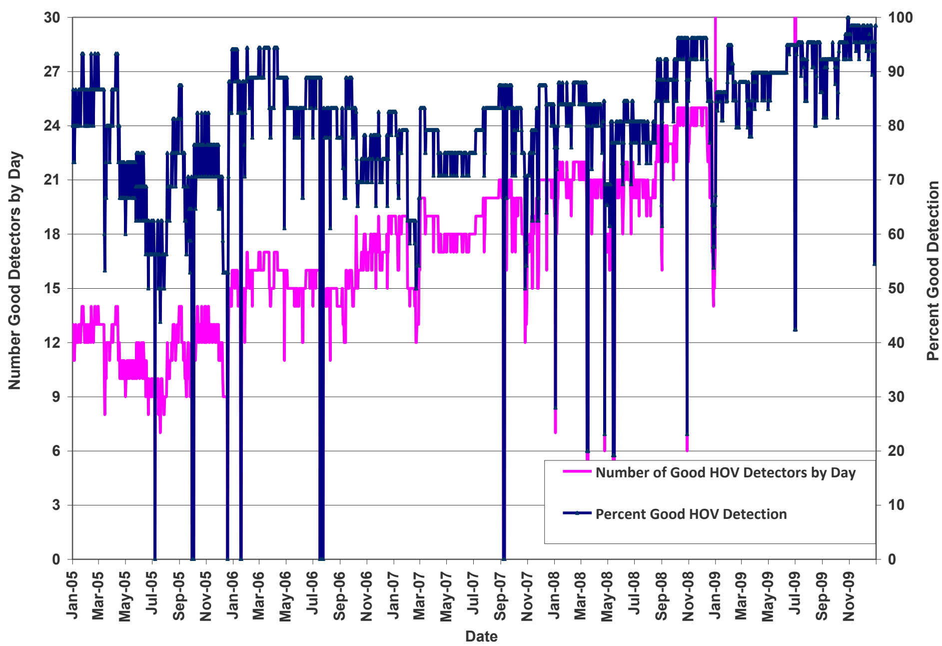
Exhibit 3A-3: ML Westbound SR-91 Number & Percent Daily Good Detectors (2005-2009)



Source: Vehicle detector data

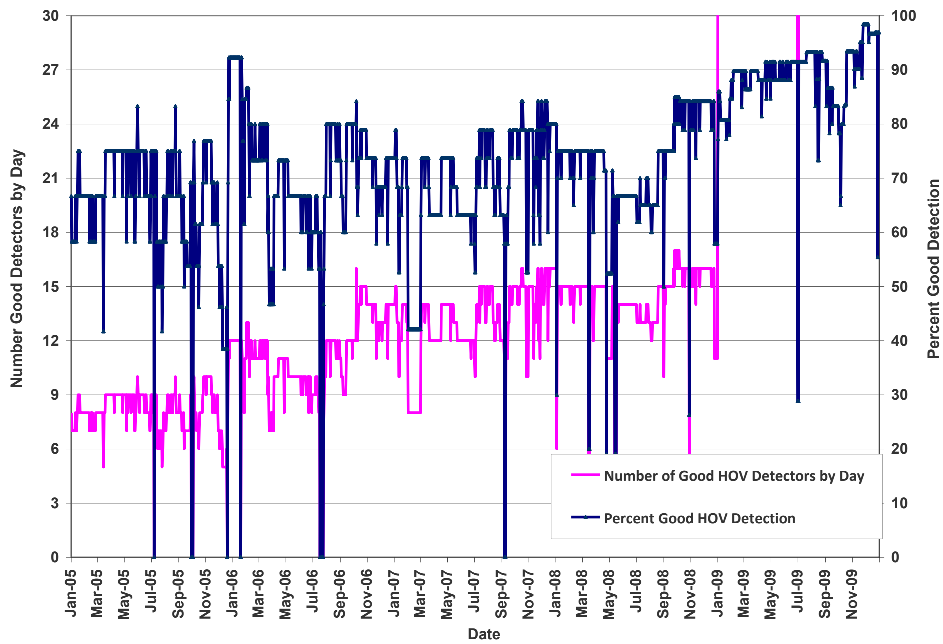
The quality of detection on the HOV lanes was more consistent than the mainline facility, as shown in Exhibits 3A-4 and 3A-5. From 2005 to 2009, the HOV lane experienced a gradual increase of good detectors. Overall, the eastbound HOV lane (Exhibit 3A-4) had better detection than the westbound HOV lane (Exhibit 3A-5). Detectors in the eastbound direction consistently reported around 70 to 90 percent good data, which is higher than the reported 60 to 80 percent good data in the westbound direction. Additionally, the eastbound HOV lane exhibited a greater number of good detectors (roughly 25) than the westbound HOV lane (roughly 15) in the latter half of 2008. However, in 2009 both the eastbound and westbound HOV lane detection quality improved to almost 100 percent.

Exhibit 3A-4: HOV Eastbound SR-91 Number & Percent Daily Good Detectors (2005-2009)



Source: Vehicle detector data

Exhibit 3A-5: HOV Westbound SR-91 Number & Percent Daily Good Detectors (2005-2009)



Source: Vehicle detector data

Part of the increased detection quality in 2009 on the mainline and HOV facilities may be attributed to improved maintenance of the existing detection. Regardless of the reason, this trend is very encouraging and should allow for detailed analysis capabilities now and in the future.

B. Corridor-Wide Performance and Trends

This section summarizes the analysis results of the performance measures used to evaluate the existing conditions of the SR-91 Corridor. The primary objective for having the measures is to provide a sound technical basis for describing traffic performance on the corridor. Data from the mainline (ML) and high-occupancy vehicle (HOV) facilities are analyzed separately under each performance measure. The base year for the analysis and modeling is 2008 for the SR-91 study corridor.

The performance measures focus on four key areas:

- **Mobility** describes how well people and freight move along the corridor
- **Reliability** captures the relative predictability of travel along the corridor
- **Safety** provides an overview of collisions along the corridor
- **Productivity** describes the productivity loss due to traffic inefficiencies

Mobility

The mobility performance measures are both measurable and straightforward for documenting current conditions. They can be forecasted, which makes them useful for future comparisons. Two primary measures are typically used to quantify mobility: delay and travel time.

Delay

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

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

In the formula above, the *Vehicles Affected per Hour* value depends on the methodology used. Some methods assume a fixed flow rate (e.g., 2000 vehicles per hour per lane), while others use a measured or estimated flow rate. The segment length is the distance under which the congested speed prevails. The duration is how long the congested period lasts (measured in hours), with the congested period being the amount of time spent below the threshold speed. The threshold speed is the speed under which congestion is considered to occur. Any speed can be used, but two commonly used threshold speeds are 35 mph and 60 mph.

Caltrans defines the threshold speed as 35 mph and assumes a fixed 2,000 vehicles per hour per lane are experiencing the delay to estimate severe delay for reporting congestion for the statewide Highway Congestion Monitoring Report (HICOMP).

In calculating total delay, Caltrans automatic detectors use the 60 mph threshold speed and the observed number of vehicles reported. The congestion results of HICOMP and automatic detectors are difficult to compare due to these methodological differences, so they are discussed separately in this assessment.

Caltrans HICOMP

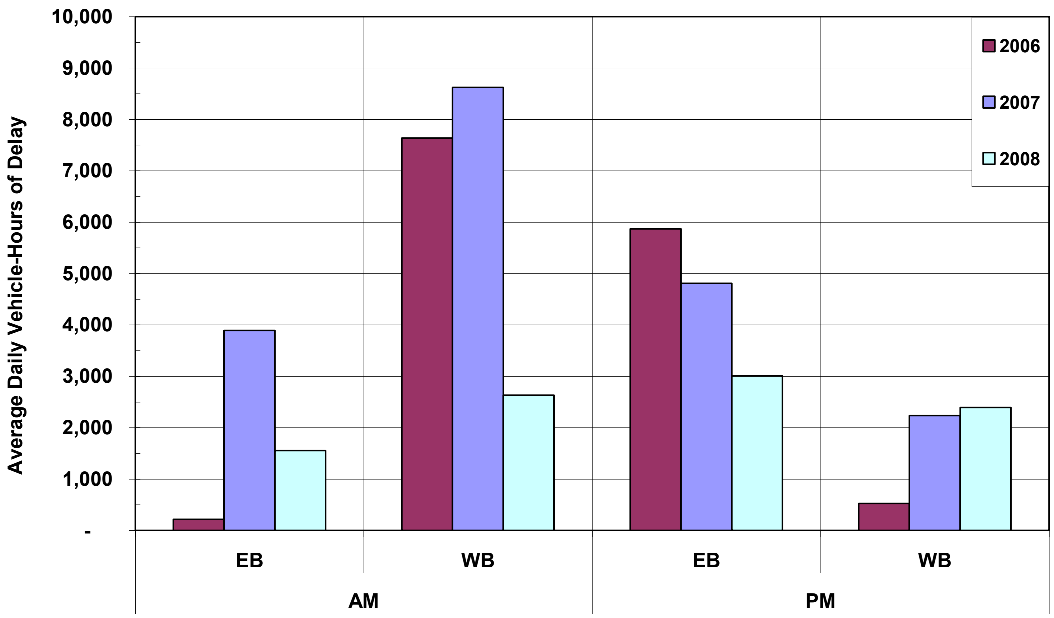
The HICOMP report has been published annually by Caltrans since 1987.[2] Delay is presented as average daily vehicle-hours of delay (DVHD). In HICOMP, Caltrans attempts to capture recurrent congestion during “typical” incident-free weekday peak periods. Recurrent delay is defined in HICOMP as a condition where speeds drop below 35 mph for a period of 15-minutes or longer during weekday AM or PM commute periods.

For the analysis of the SR-91 study corridor, a mix of automatic detection data and probe vehicle (tachometer or “tach” run) data have historically been used. Where “good” detection data is available, it is used; where District 8 staff believes that better results are obtained by manual data collection and field observation, probe vehicle data is used. The most current HICOMP report is available for 2008. HICOMP data is available for the mainline facility only.

Exhibit 3B-1 summarizes HICOMP data for the yearly delay trends from 2006 to 2008 during the AM and PM peak period in both directions of the study corridor. As indicated in the exhibit, congestion is directional – morning congestion occurs in the westbound direction and afternoon congestion occurs in the eastbound direction. It is also important to note that there is substantial congestion in downtown Riverside in the westbound direction during the PM peak period.

[2] Located at <www.dot.ca.gov/hq/traffops/sysmgtpl/HICOMP/index.htm>

Exhibit 3B-1: Average Daily Vehicle-Hours of Delay by Peak Period (2006-2008 HICOMP)



Source: Vehicle detector data

Exhibit 3B-2 shows a complete list of congested segments reported in the HICOMP report for the SR-91 Corridor. A congested segment may vary in distance or size from one year to the next as well as from day-to-day.

Exhibits 3B-1 and 3B-2 reveal that total congestion in 2008 declined by half from 2007 levels. In 2007, total congestion was reported at around 19,600, which dropped to 9,600 in 2008. In 2008, westbound delay during the AM peak was highly concentrated between I-15 and McKinley Boulevard in Corona. This segment alone experienced 2,300 hours of delay during the AM peak, the highest delay of any other segment on the corridor in either direction. The location at the SR-60/I-215 interchange also experienced considerable delay in the westbound direction during the PM peak period with over 2,000 vehicle-hours.

In the eastbound direction, congestion is concentrated in the PM peak period. From 2007 to 2008, congestion decreased from 7,000 vehicle-hours to 5,400 vehicle-hours. The location with the greatest delay was at the Riverside/Orange County Line, which experienced over 2,000 vehicle-hours of delay.

The maps in Exhibits 3B-3 and 3B-4 show the 2008 AM and PM peak period delay listed in Exhibit 3B-2. The approximate locations of the congested segments, the duration of congestion, and the reported recurrent daily delay are shown on the maps.

Exhibit 3B-2: HICOMP Hours of Delay for Congested Segments (2006-2008)

Period	Dir	Potential Bottleneck		Approximate Queue End		2006	2007	2008
		Location (approx)	Ca PM (approx)	Location (approx)	Ca PM (approx)			
AM	EB	Tyler St	13.2	b/n Pierce St & Magnolia Ave	10.6	-	214	-
		Madison St	16.5	b/n Van Buren Ave & Tyler St	13.7	-	-	-
		Central Ave	18.9	b/n Van Buren Ave & Tyler St	14.5	215	-	-
		14th St	19.6	b/n Pierce St & Magnolia Ave	10.6	-	-	1,554
				b/n Van Buren Ave & Tyler St	13.3	-	3,679	-
	WB	RIV/ORA Co Line	-	b/n Serfas Club Dr & SR-71	3.0	189	225	-
		SR-71	2.7	Serfas Club Dr	3.8	-	-	153
				b/n I-15 & McKinley	7.8	5,055	8,254	-
		Serfas Club Dr	3.8	b/n I-15 & McKinley	7.5	-	-	2,325
		I-15	7.5	b/n I-15 & McKinley	9.2	2,227	-	152
		McKinley St	9.2	Pierce St	11.1	-	142	-
				Buchanon St	10.2	-	-	-
		Buchanon St	10.2	b/n La Sierra Ave & Tyler	12.1	164	-	-
					AM PEAK PERIOD CONGESTION	**7,849**	**12,514**	**4,184**
PM	EB	Serfas Club Dr	3.9	RIV/ORA Co Line	-	-	1,419	-
		I-15	7.4	RIV/ORA Co Line	-	3,016	-	2,015
		McKinley St	9.8	Serfas Club Dr	3.9	-	2,955	-
				I-15	7.5	-	-	-
		Pierce St/Magnolia Ave	11.0	I-15	8.0	527	301	649
		Madison St	16.7	b/n Van Buren Ave & Tyler St	13.7	-	-	-
		SR-60/I-215	21.7	b/n 14th St and Central Ave	19.3	-	133	341
				b/n Van Buren Ave & Tyler St	14.0	2,325	-	-
	WB	McKinley St	10.2	b/n La Sierra Ave & Tyler	12.9	307	313	200
		Madison St	17.0	Central Ave	18.5	-	-	100
				SR-60/I-215	21.6	-	1,923	-
		Central Ave	18.3	SR-60/I-215	21.2	217	-	2,094
					PM PEAK PERIOD CONGESTION	**6,392**	**7,045**	**5,399**
					TOTAL CORRIDOR CONGESTION	**14,242**	**19,559**	**9,584**

Exhibit 3B-3: 2008 AM Peak Period HICOMP Congested Segments Map

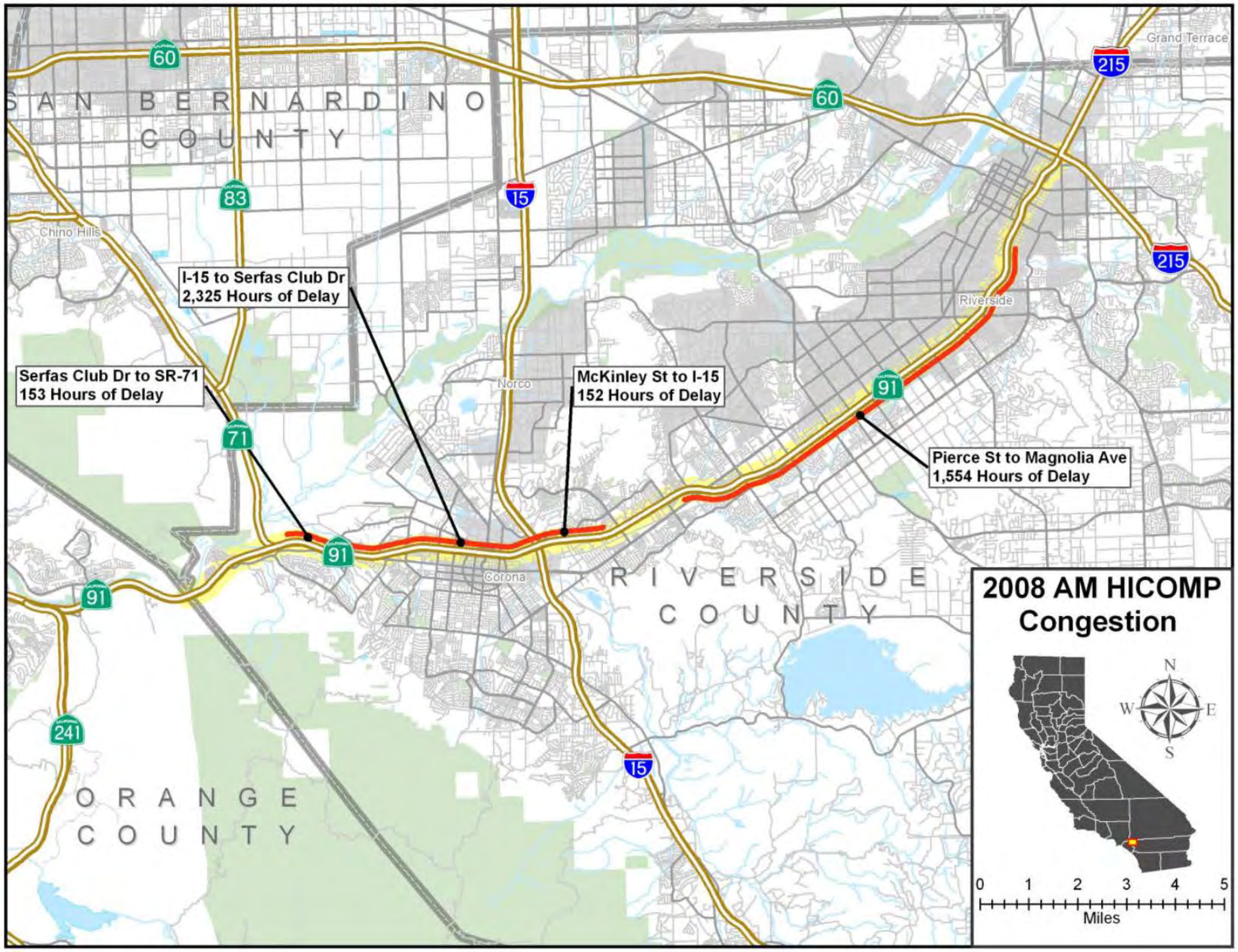
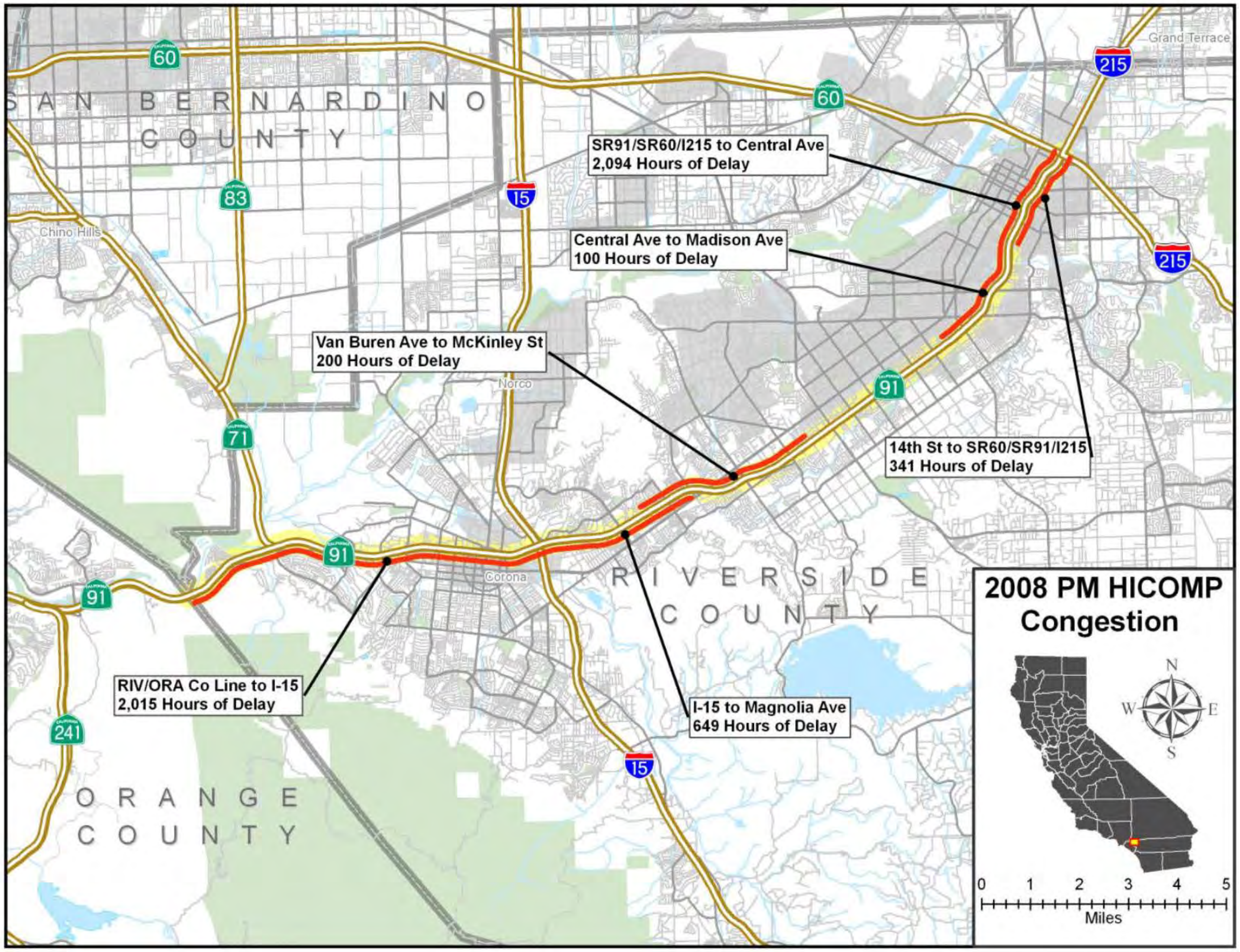


Exhibit 3B-4: 2008 PM Peak Period HICOMP Congested Segments Map



Vehicle Detector Data

Using the freeway detector data accessed via PeMS, delay can be computed for every day and summarized in different ways. This is not possible with probe vehicle data.

Performance assessments were conducted initially for the three-year period between 2005 and 2007. These assessments were recently updated through December 2009. Unlike HICOMP, where delay is only considered and captured for speeds below 35 miles per hour and applied to an assumed output or capacity volume of 2,000 vehicles per hour, delays 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. The total delay by time period for the SR-91 for each direction is shown in Exhibits 3B-5 and 3B-6.

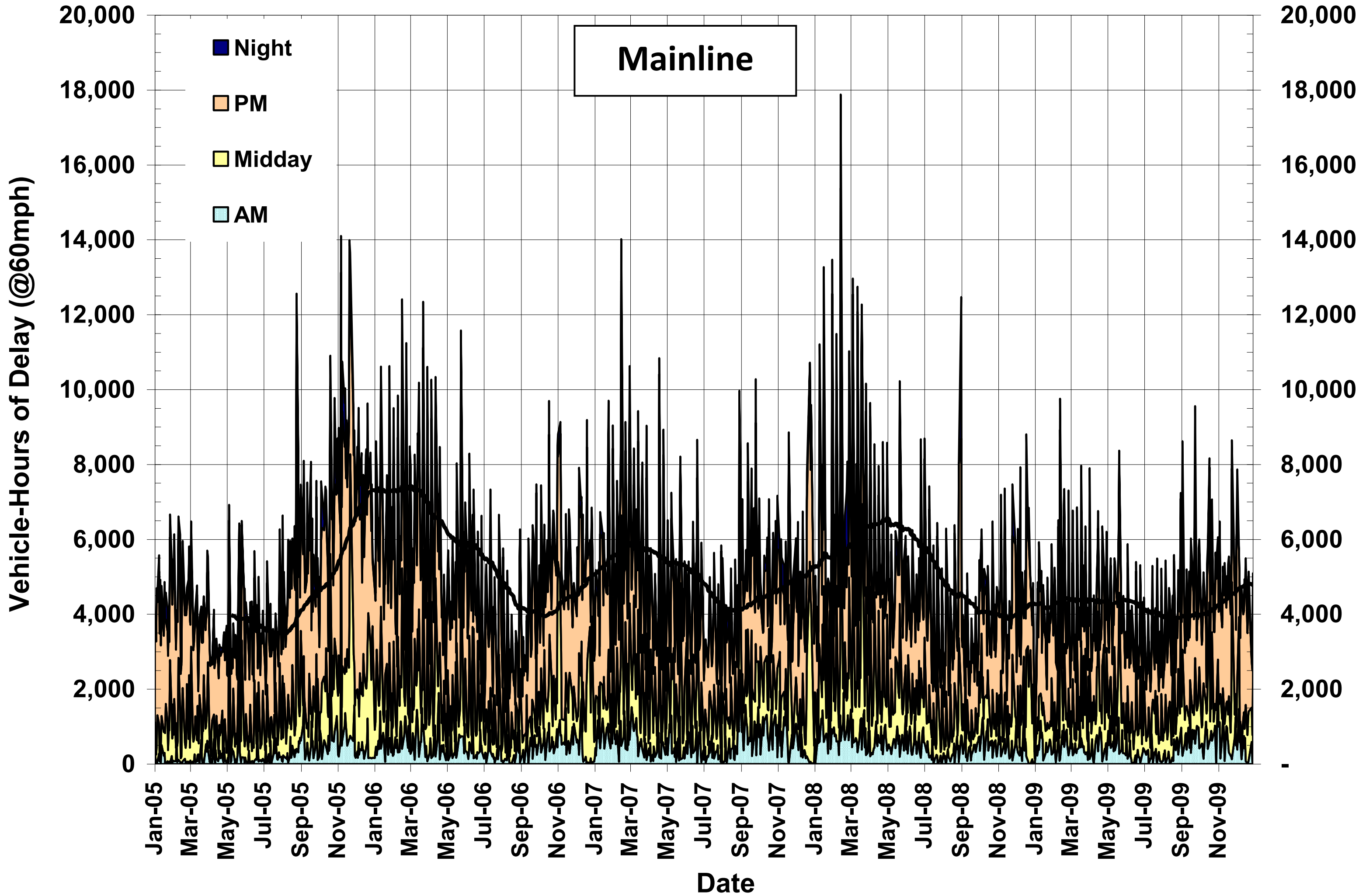
The performance assessment includes five years of automatic detector data filtered to exclude data considered poor quality. Imputed data were used for sensors with sufficient observed data to provide reasonable estimates.

Weekday delay for the mainline facility is presented in Exhibits 3A5 and 3A6 during the five-year period of 2005-2009. Within the exhibit, there is a 90-day moving average to "smooth" out the day-to-day variations and illustrate the seasonal and annual changes in congestion over time. Similar to HICOMP data, Caltrans vehicle detector data shows a directional pattern in delay with the westbound direction experiencing greater congestion during the AM peak and the eastbound direction experiencing more congestion during the PM peak. However, unlike HICOMP data, detector data shows that PM delay is significantly greater than AM delay during all five years analyzed.

Average eastbound delay consistently fluctuated between 4,000 and 6,000 hours (Exhibit 3B-5), with a noticeable decline during the summer months. Delay was noticeably less in the westbound direction than the eastbound direction with average total westbound delay lingering below 4,000 hours (Exhibit 3B-6). A gradual decline in delay occurred westbound starting in March 2007 and continuing through 2009. Out of the five years analyzed, 2005 experienced the greatest delay in both directions of travel. Since 2005, overall delay in the eastbound direction remained consistent while the westbound direction experienced a pattern of decline starting in 2007.

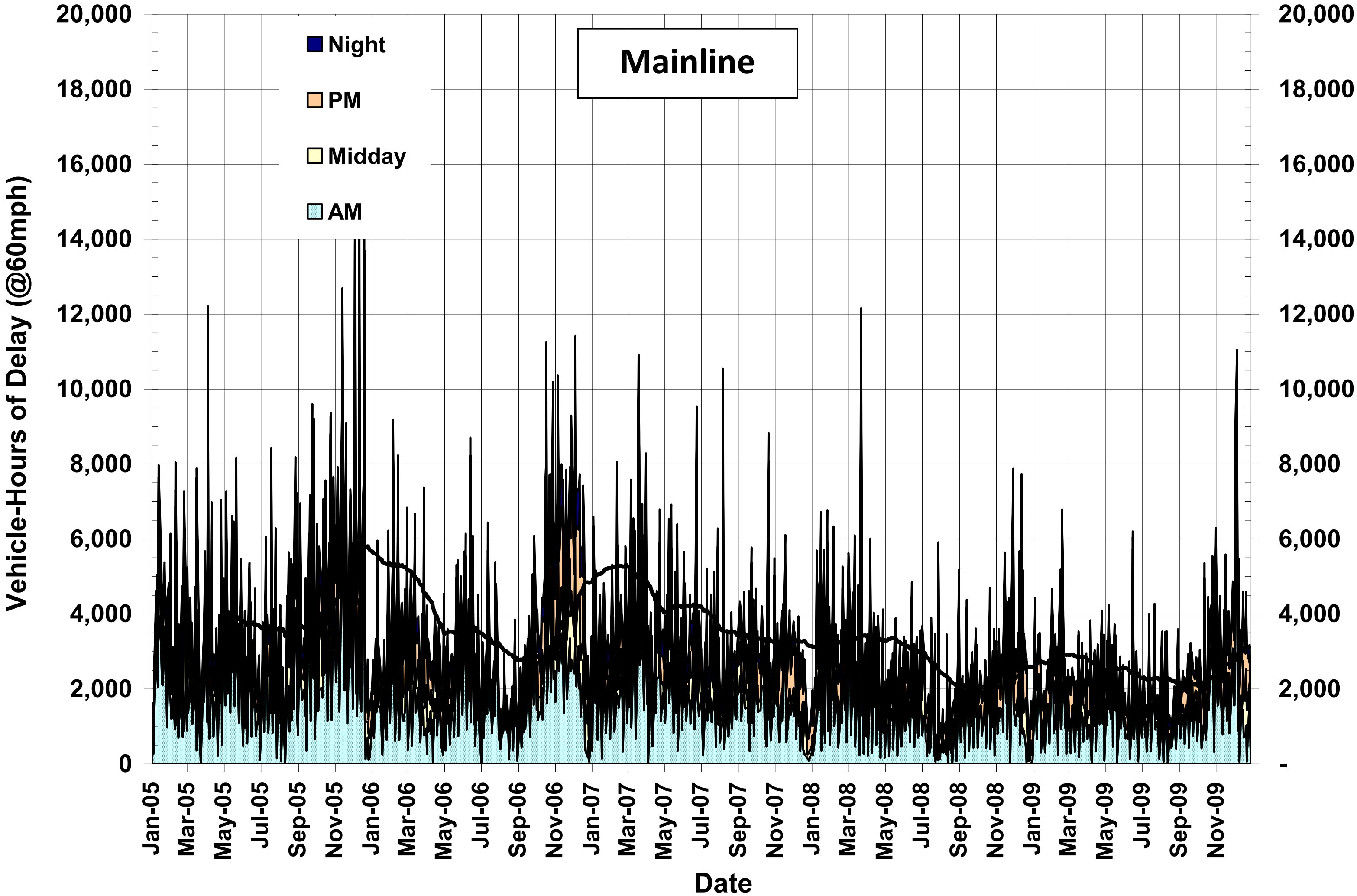
Exhibits 3B-7 and 3B-8 show that delay on the HOV lanes followed the same pattern as the mainline facility with more congestion occurring in the PM for the eastbound direction and in the AM for the westbound direction. Between 2005 and 2009, the average HOV eastbound delay was around 1,000 hours with the highest delay around February 2008. Similar to the mainline trend, the westbound HOV lane experienced less delay than the eastbound facility with an average delay around 600 hours during the same five-year period. The gradual decline of delay experienced on the westbound mainline facility was not as apparent on the HOV westbound facility in 2007 and 2008; however, it declined to around 250 hours in 2009.

Exhibit 3B-5: SR-91 Eastbound Mainline Average Daily Delay by Time Period (2005-2009)



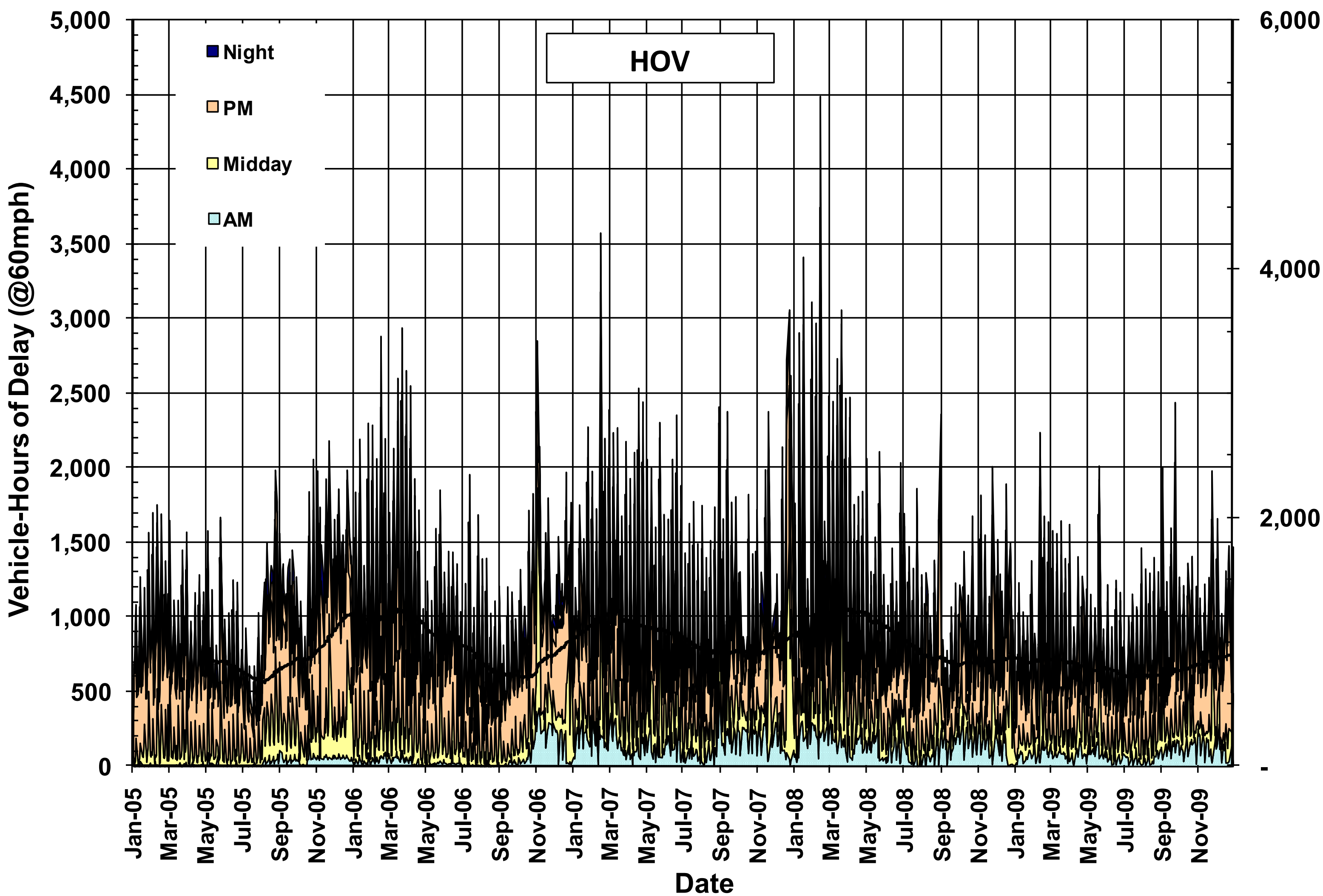
Source: Vehicle detector data

Exhibit 3B-6: SR-91 Westbound Mainline Average Daily Delay by Time Period (2005-2009)



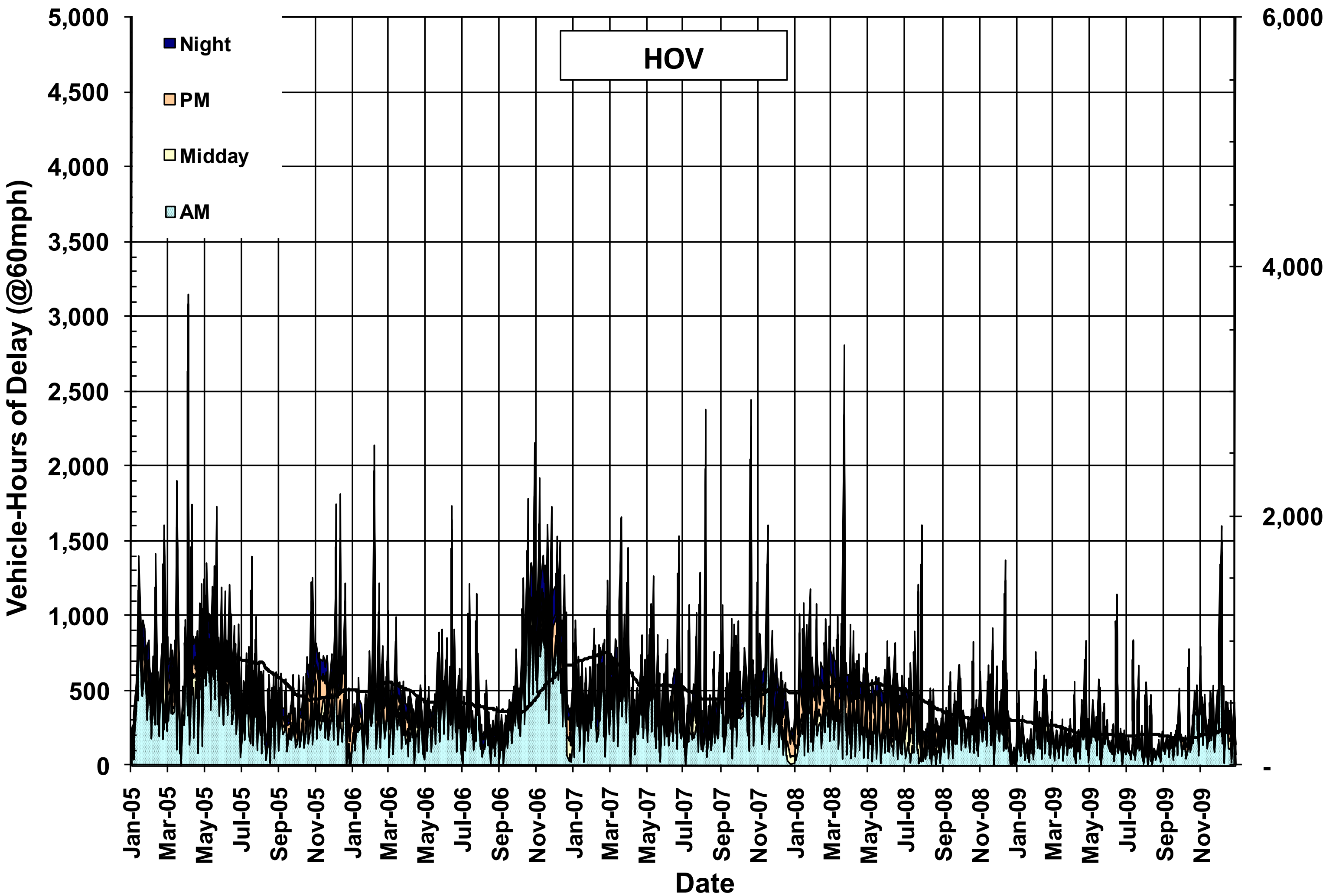
Source: Vehicle detector data

Exhibit 3B-7: SR-91 Eastbound HOV Average Daily Delay by Time Period (2005-2009)



Source: Vehicle detector data

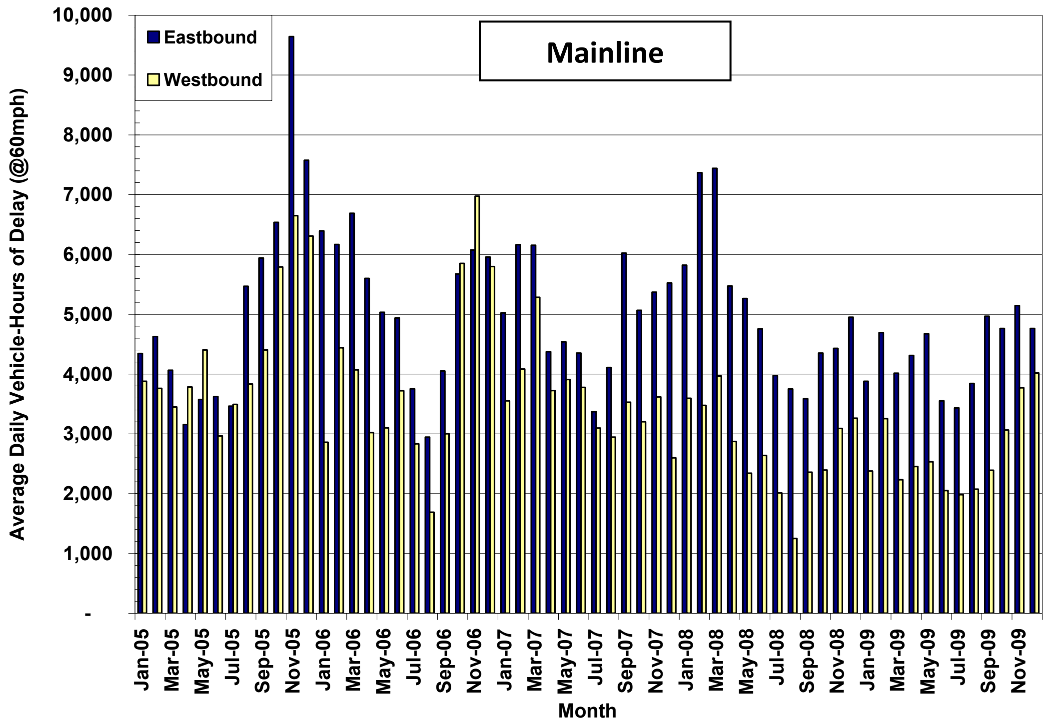
Exhibit 3B-8: SR-91 Westbound HOV Average Daily Delay by Time Period (2005-2009)



Source: Vehicle detector data

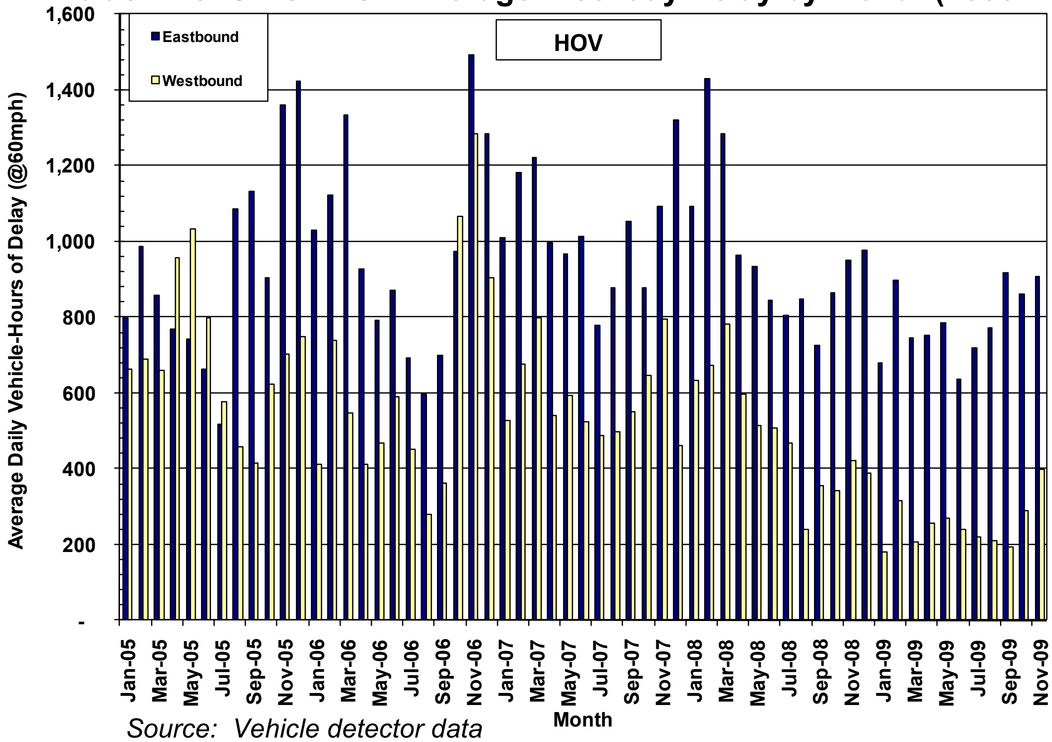
Exhibits 3B-9 and 3B-10 depict the average daily weekday delay by month for the mainline and HOV facilities. Like previous exhibits, these exhibits illustrate that delay is greater in the eastbound direction than the westbound direction. Seasonal dips in delay occur during the summer months for both the mainline and HOV facilities.

Exhibit 3B-9: SR-91 Mainline Average Weekday Delay by Month (2005-2009)



Source: Vehicle detector data

Exhibit 3B-10: SR-91 HOV Average Weekday Delay by Month (2005-2009)



Source: Vehicle detector data

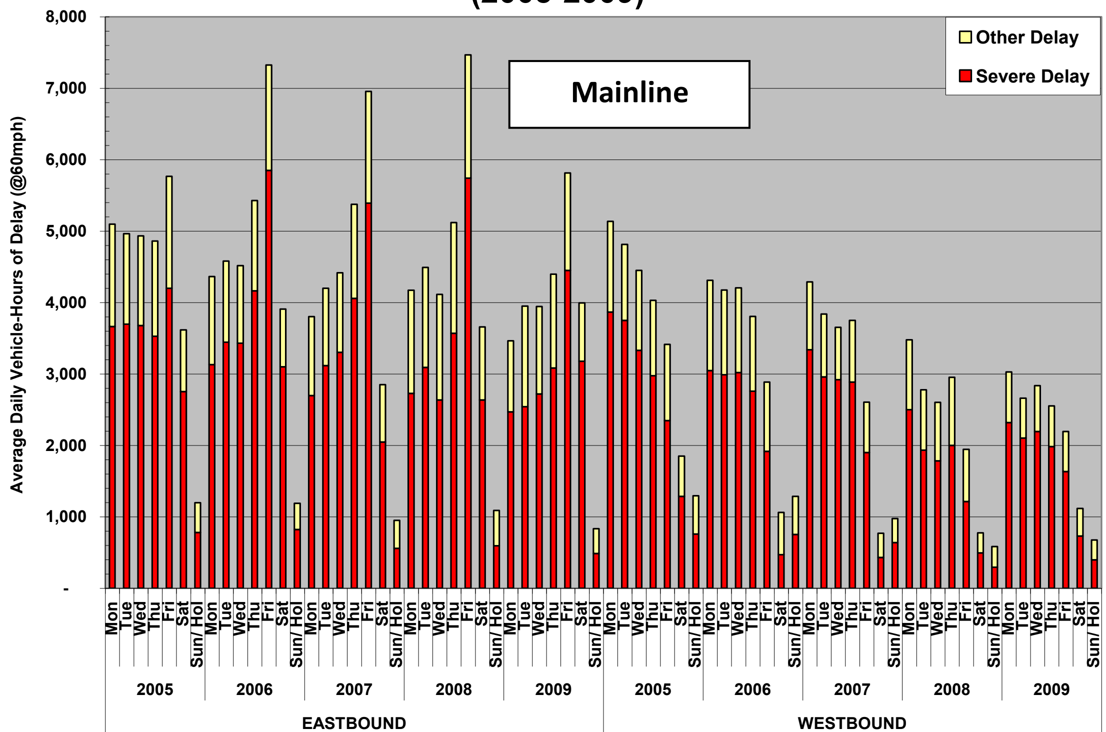
Delays presented to this point represent the difference in travel time between “actual” conditions and free-flow conditions at 60 miles per hour. This delay can be segmented into two components as shown in Exhibits 3B-11 and 3B-12:

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

Severe delay, as depicted in Exhibits 3B-11 and 3B-12, represents breakdown conditions and is generally the focus of congestion mitigation strategies. “Other” delay represents conditions approaching breakdown conditions, vehicles leaving breakdown conditions, or areas that cause temporary slowdowns rather than widespread breakdowns. Exhibit 3B-11 shows that severe delay comprised 75 percent of all weekday delay on the mainline facility during the between 2005 and 2009. In the eastbound direction of the mainline, the level of congestion grew during the workweek and peaked on Fridays. In contrast, the westbound direction of the mainline showed greater delay on Mondays with a gradual decrease as the workweek progressed. Delays were minimal on weekends in both directions of the mainline.

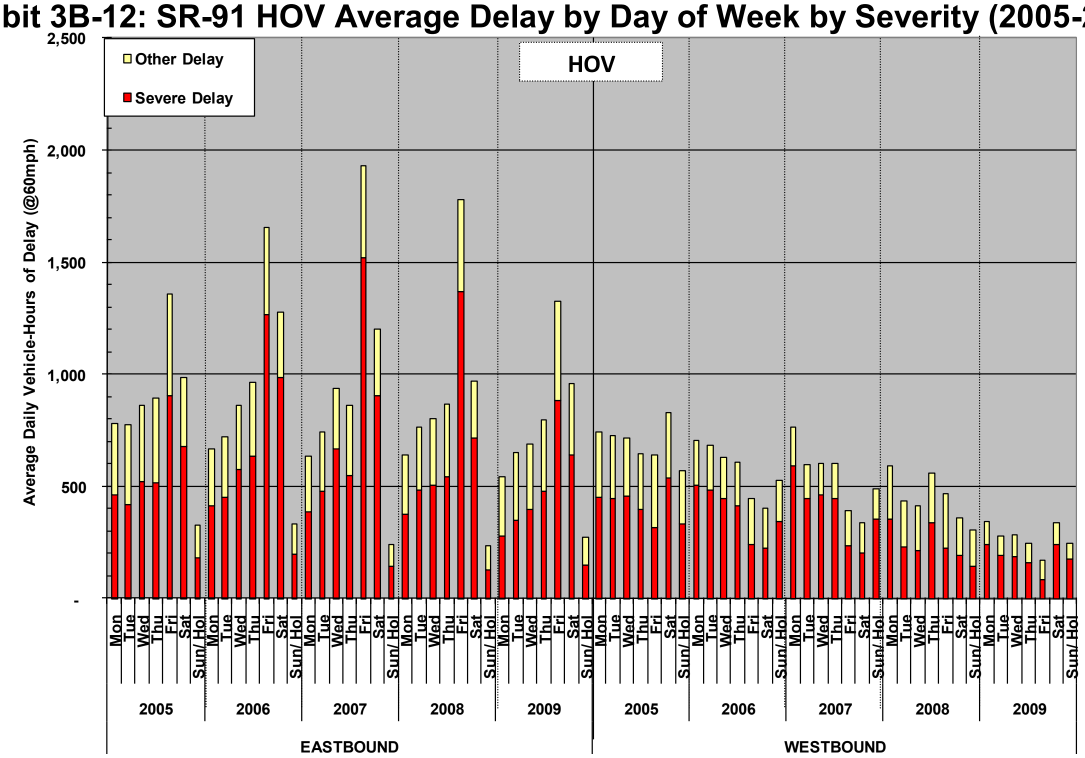
Exhibit 3B-12 shows that severe delay comprised roughly 65 percent of all weekday delay on the HOV lane, which was about 10 percent less than the mainline facility. Similar to the mainline facility, congestion on the eastbound HOV grew during the workweek and peaked on Fridays, whereas congestion on the westbound HOV was highest on Mondays and declined during the workweek.

Exhibit 3B-11: SR-91 Mainline Average Delay by Day of Week by Severity (2005-2009)



Source: Vehicle detector data

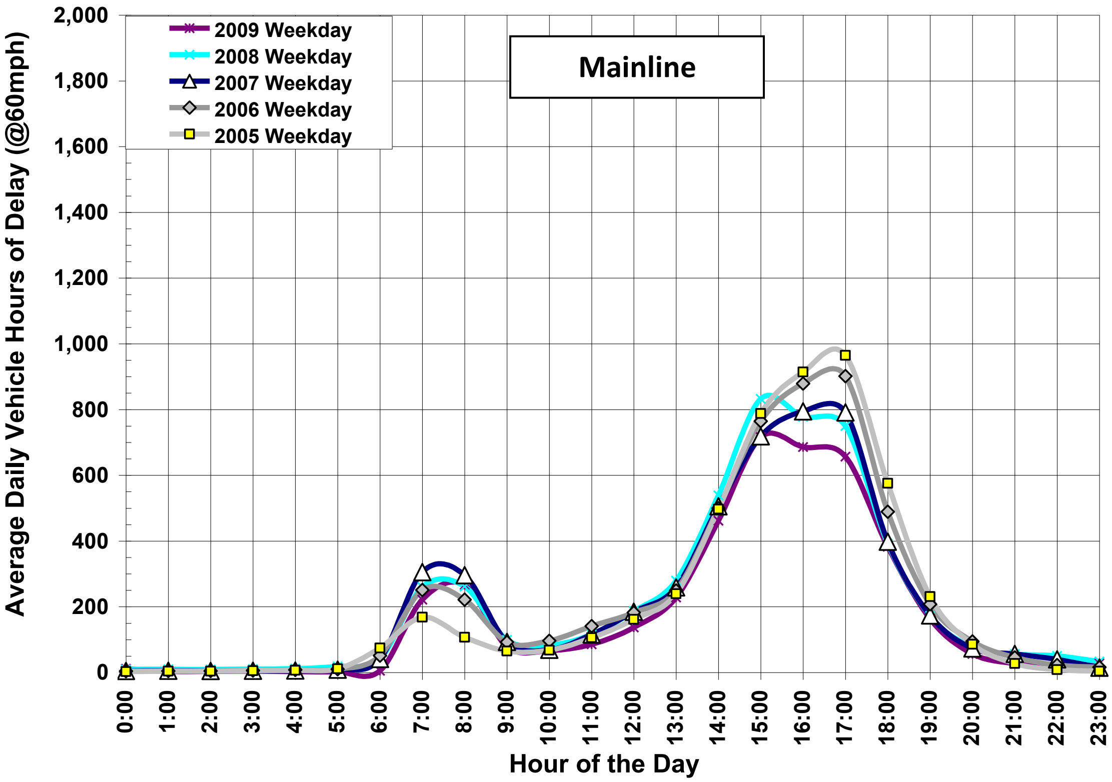
Exhibit 3B-12: SR-91 HOV Average Delay by Day of Week by Severity (2005-2009)



Source: Vehicle detector data

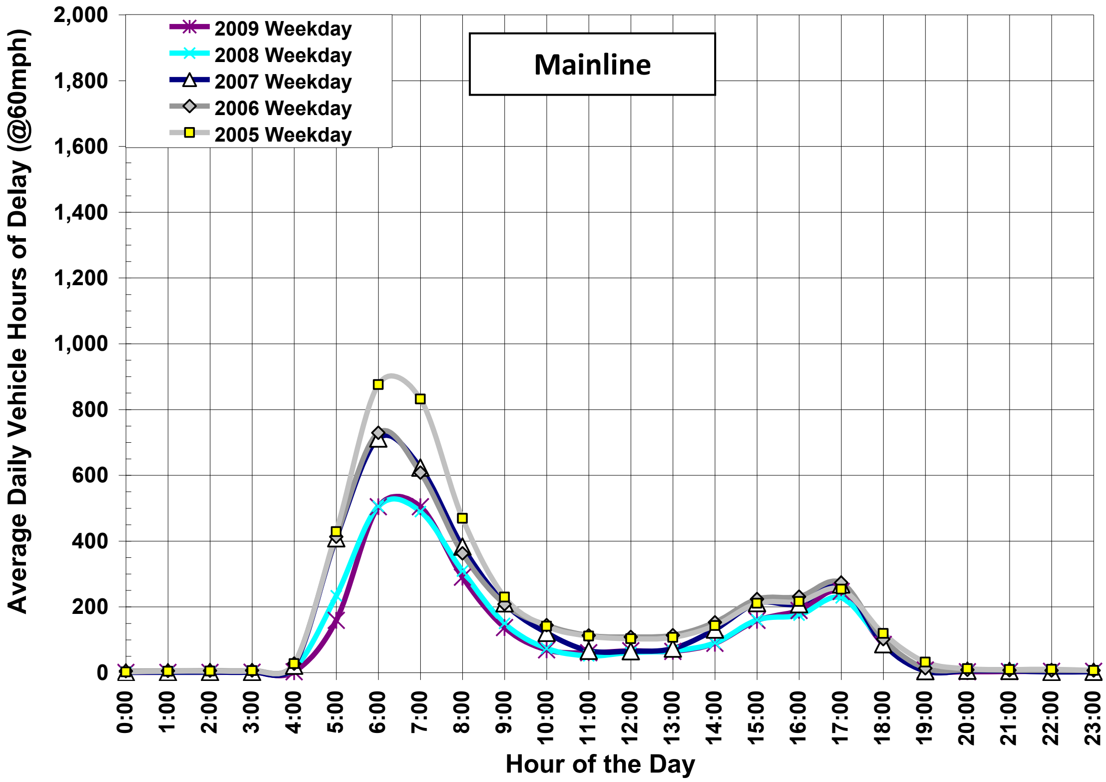
Another way to understand the characteristics of congestion and related delays is shown in Exhibits 3B-13 through 3B-16, which summarize weekday delays by time of day from 2005 through 2009. For the mainline facility in 2007, Exhibit 3B-13 shows that the peak hourly delay in the eastbound direction is approximately 800 vehicle-hours at around 5 PM. Conversely, Exhibit 3B-14 shows that the peak hourly delay in the westbound mainline is about 700 vehicle-hours at around 6 AM. For both directions of the mainline, 2005 experienced the greatest delay and 2009 experienced the least delay during their respective peak period. However, the peak hour in the eastbound mainline appeared to have shifted from 5 PM in the previous years to 3 PM in both 2008 and 2009.

Exhibit 3B-13: Eastbound Mainline Average Weekday Hourly Delay (2005-2009)



Source: Vehicle detector data

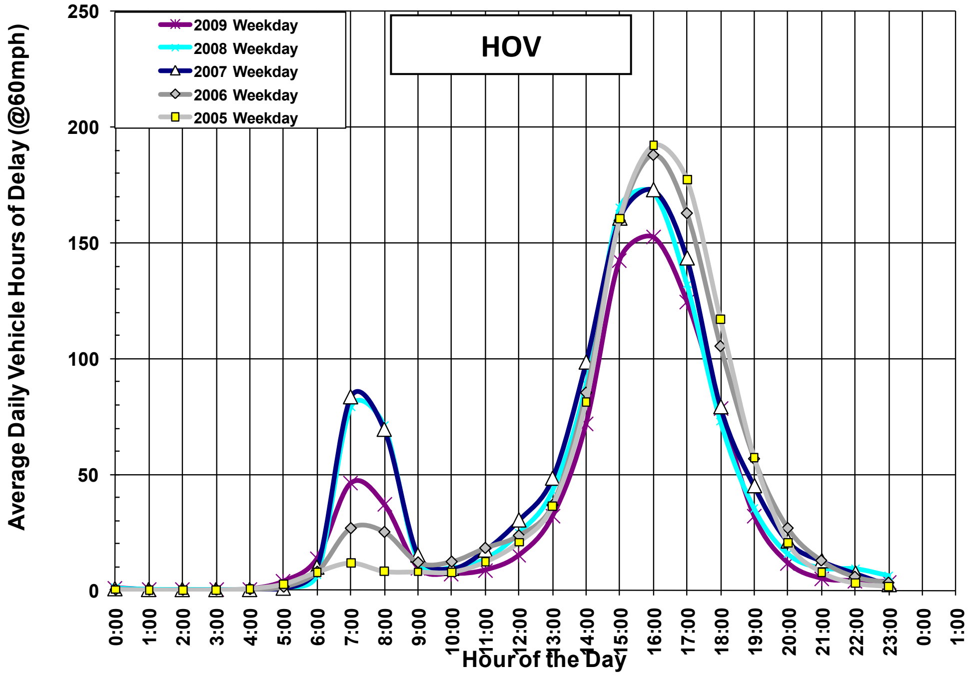
Exhibit 3B-14: Westbound Mainline Average Weekday Hourly Delay (2005-2009)



Source: Vehicle detector data

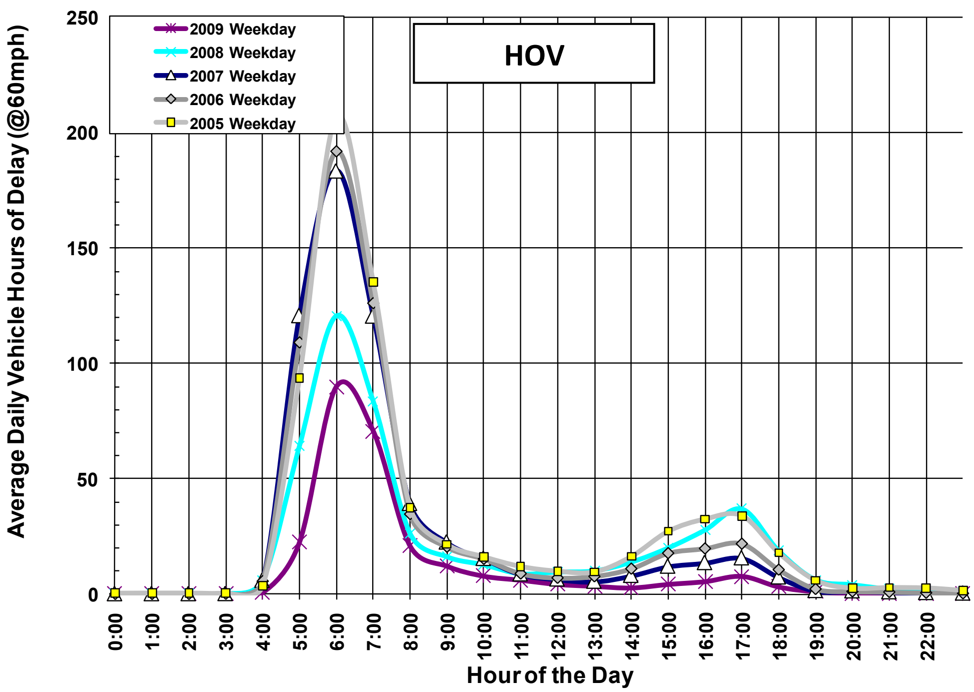
Delay on the HOV lane in Exhibits 3B-15 and 3B-16 reveal a slightly different pattern than the mainline lanes. Exhibit 3B-15 shows that the peak hourly delay in the eastbound HOV lane is approximately 170 vehicle-hours at around 4 PM, which is one hour earlier than the eastbound mainline lanes. Exhibit 3B-16 shows that the peak hourly delay in the westbound mainline is about 180 vehicle-hours at around 6 AM, which is the same peak hour as the mainline westbound facility. Unlike the mainline, the peak hour in the eastbound HOV lane did not shift in 2008 and 2009 but remained the same as the previous years.

Exhibit 3B-15: Eastbound HOV Average Weekday Hourly Delay (2005-2009)



Source: Vehicle detector data

Exhibit 3B-16: Westbound HOV Average Weekday Hourly Delay (2005-2009)



Source: Vehicle detector data

Travel Time

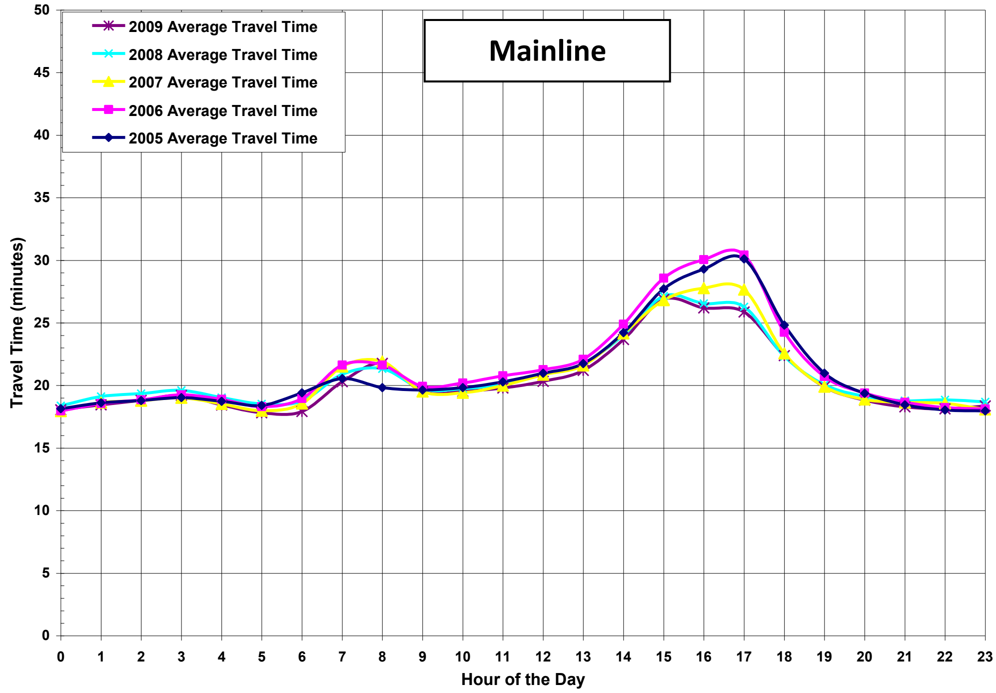
Travel time is reported as the time it takes for a vehicle to travel between two points on the corridor as estimated using automatic detector data. For the SR-91 corridor, this is the time to traverse 22 miles from the Orange County/Riverside County line to the I-215/SR-60 interchange. Travel time on parallel arterials was not included for the analysis.

Exhibits 3B-17 through 3B-20 summarize travel times estimated for the mainline and HOV facilities using automatic detector data. As shown in Exhibits 3B-17 and 3B-18, travel along the mainline takes about 18 minutes during the off-peak periods. This corresponds to a speed of just over 70 mph.

Exhibits 3B-17 and 3B-18 illustrate that travel times for both directions of the mainline have decreased between 2005 and 2009. During the 6 AM peak hour, travel time in the westbound mainline is estimated to have been roughly 24 minutes in both 2008 and 2009 (Exhibit 3B-18). This is lower by 20 percent than the 30 minutes estimated for 2005. During the PM peak hour at 5 PM, travel time for the eastbound mainline is estimated to be 27 minutes in 2008 and 2009, which is 3 minutes less than the 30 minutes estimated in 2005.

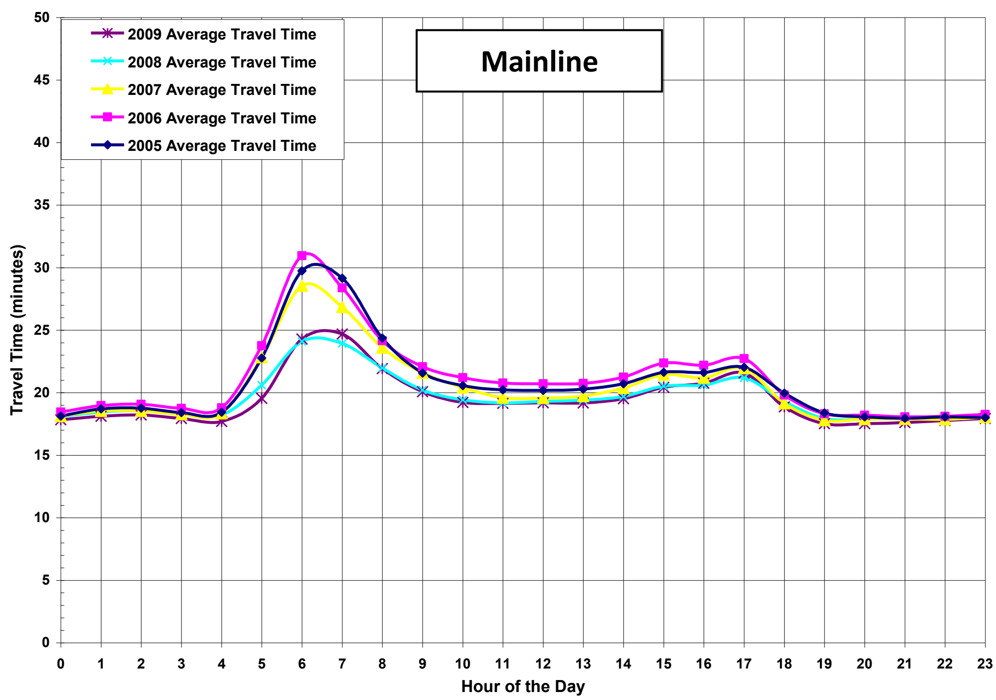
Travel times on the HOV facilities displayed the same characteristics as the mainline facility. Again, travel times on the HOV lanes in both directions are lowest in 2008 and 2009 compared to the earlier three years. This is particularly evident in the westbound direction (Exhibit 3B-18), which shows a travel time of approximately 25 minutes during the 6 AM peak hour. This is at least a 5-minute improvement from the previous years. Exhibit 3B-17 suggests that the peak hour on the eastbound HOV lane occurred one hour earlier (4 PM) than the eastbound mainline facility, which experienced a 5 PM peak hour.

Exhibit 3B-17: Eastbound Mainline Travel Time by Time of Day (2005-2009)



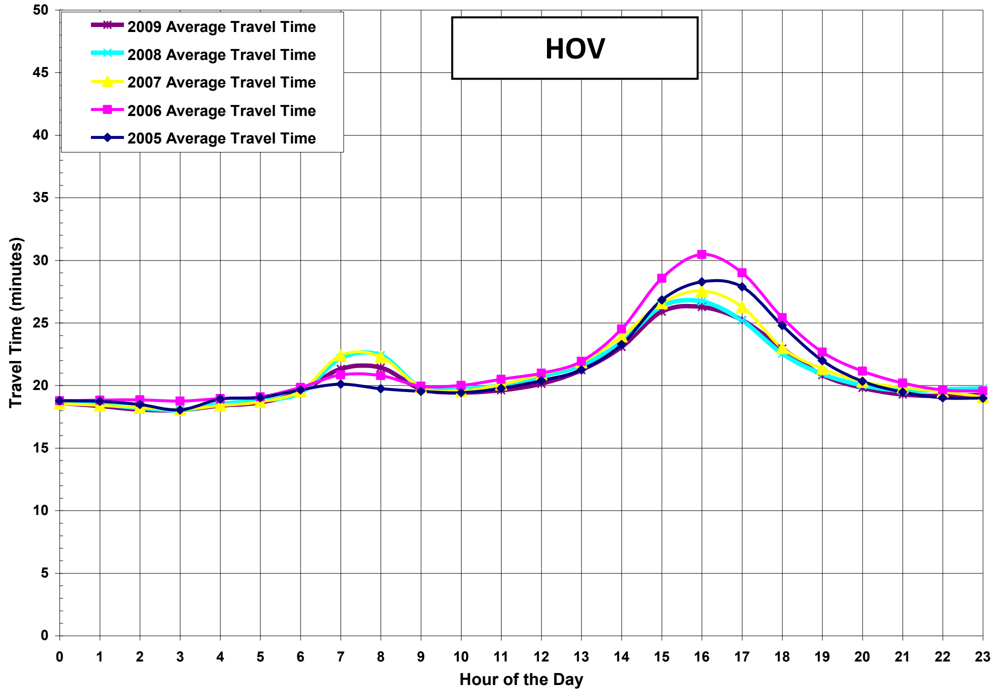
Source: Vehicle detector data

Exhibit 3B-18: Westbound Mainline Travel Time by Time of Day (2005-2009)



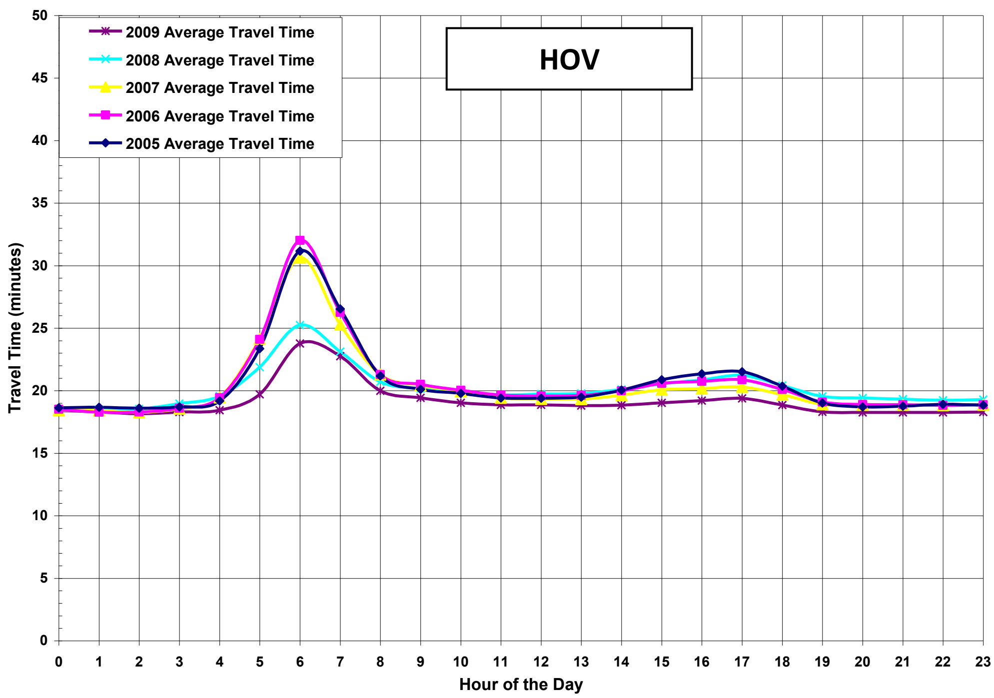
Source: Vehicle detector data

Exhibit 3B-19: Eastbound HOV Travel Time by Time of Day (2005-2009)



Source: Vehicle detector data

Exhibit 3B-20: Westbound HOV Travel Time by Time of Day (2005-2009)



Source: Vehicle detector data

Reliability

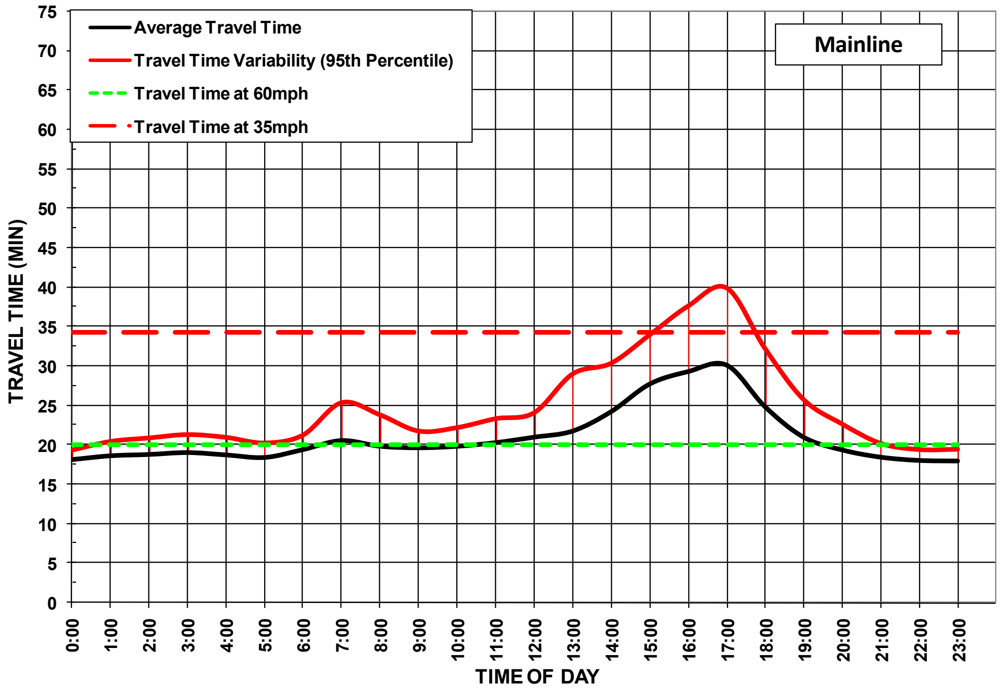
Reliability captures the degree of predictability in the public's travel time. Unlike mobility, which measures the rate of travel, the reliability measure focuses on how travel time varies from day to day. To measure reliability, statistical measures of variability on the travel times estimated from automatic detector data were used. The 95th percentile was chosen to represent the maximum time it would take most people to travel the corridor. Severe events, such as fatal collisions, could cause longer travel times, but the 95th percentile was chosen as a balance between extreme events and a "typical" day.

Exhibits 3B-21 to 3B-40 on the following pages illustrate the variability of travel time along the SR-91 Corridor on weekdays for 2005 through 2009. Exhibits 3B-21 through 3B-30 present travel time variability on the mainline in the eastbound direction followed by the westbound direction. Similarly, Exhibits 3B-31 through 3B-40 show travel time variability on the HOV lanes beginning with the eastbound and followed by the westbound direction.

For the mainline facility, the 5 PM peak hour was the most unreliable hour in the eastbound direction in addition to being the slowest. In 2005 (shown in Exhibit 3B-21), motorists driving the entire length of the corridor had to add 10 minutes to an average travel time of 30 minutes (for a total travel time of 40 minutes) to ensure that they arrived on time 95 percent of the time. This is 20 minutes longer than the 20-minute travel time at 60 mph. In 2006 (Exhibit 3B-22), the time needed to arrive on time 95 percent of the time remained the same, but declined to 36 minutes in 2007 (Exhibits 3B-23). In 2008 (Exhibit 3B-24) and 2009 (Exhibit 3B-25), travel times improved slightly to 34 and 32 minutes, respectively. In the westbound direction on the mainline, the 7 AM peak hour was the most unreliable. In 2005 (Exhibit 3B-25), the time required to arrive on time 95 percent of the time was 48 minutes, which decreased to 44 minutes in 2006 (Exhibit 3B-26), decreased again to 40 minutes in 2007 (Exhibit 3B-27), and further declined to 34 minutes in both 2008 (Exhibit 3B-29) and 2009 (Exhibit 3B-30). Both directions on the mainline experienced a consistent improvement in travel times throughout this four-year period.

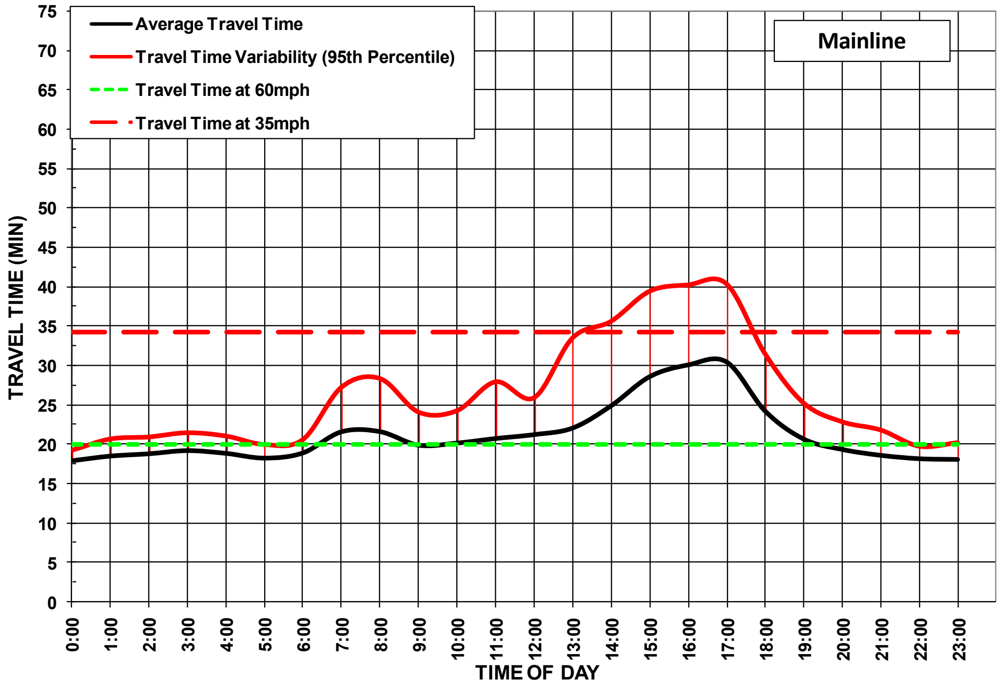
Unlike the mainline facility which experienced a clear improvement in travel times, the HOV lanes witnessed mixed results. During the 4 PM peak hour (Exhibit 3B-31) of the eastbound HOV lane, a driver needed to add 6 minutes to an average travel time of 28 minutes to ensure an on-time arrival of 95 percent on the weekdays in 2005. This corresponds to a total travel time of 34 minutes. In 2006 (Exhibit 3B-32), the time needed to arrive on time 95 percent of the time increased to 41 minutes, but decreased to 34 minutes in 2007 (Exhibit 3B-33). It remained about the same at 35 minutes in 2008 (Exhibit 3B-34) and further decreased to 32 minutes in 2009 (Exhibit 3B-35). In the westbound direction of the HOV lane, the 6 AM peak hour was the most unreliable and the slowest hour. In 2005 (Exhibit 3B-36), the time required to arrive on time 95 percent of the time was 41 minutes, which increased to 50 minutes in 2006 (Exhibit 3B-37), decreased back to 41 minutes in 2007 (Exhibit 3B-38), and decreased again to 32 and 30 minutes in 2008 (Exhibit 3B-39) and 2009 (Exhibit 3B-40), respectively.

Exhibit 3B-21: Eastbound Mainline Travel Time Variability (2005)



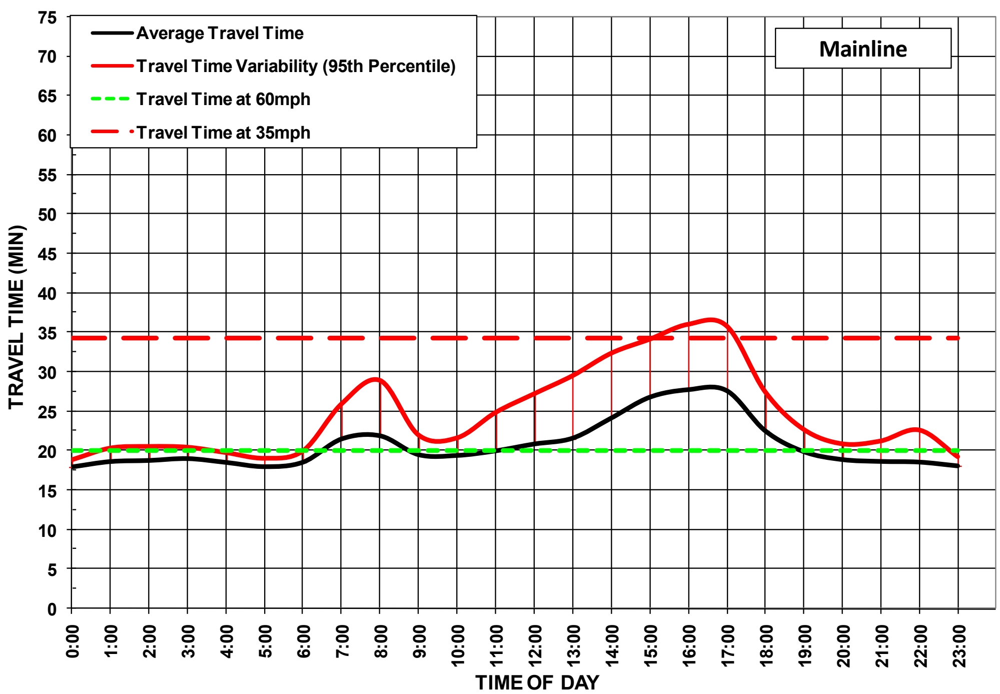
Source: Vehicle detector data

Exhibit 3B-22: Eastbound Mainline Travel Time Variability (2006)



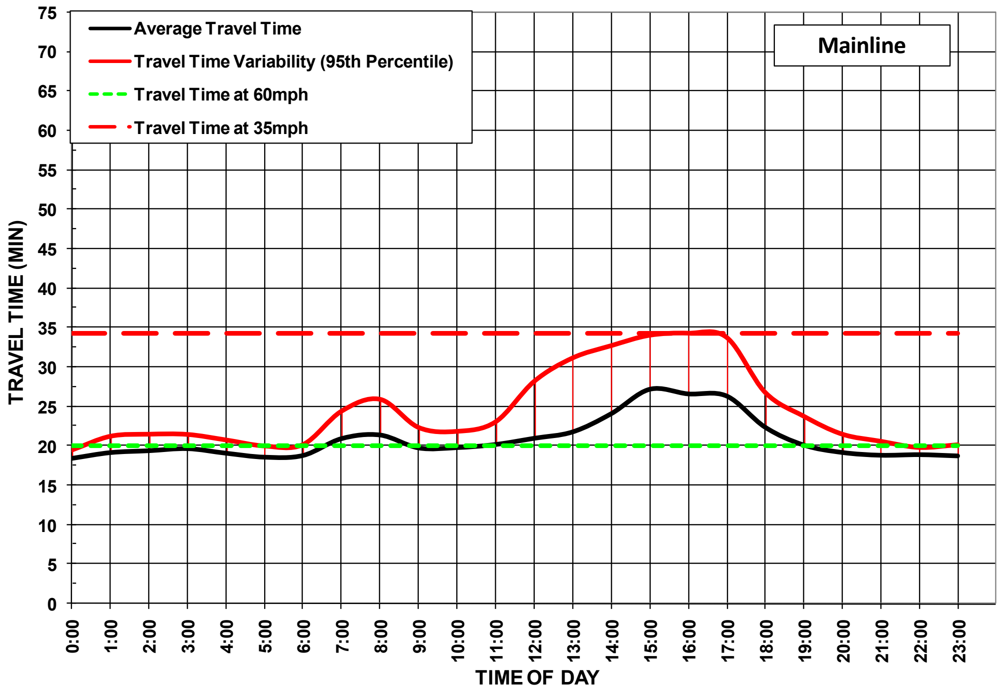
Source: Vehicle detector data

Exhibit 3B-23: Eastbound Mainline Travel Time Variability (2007)



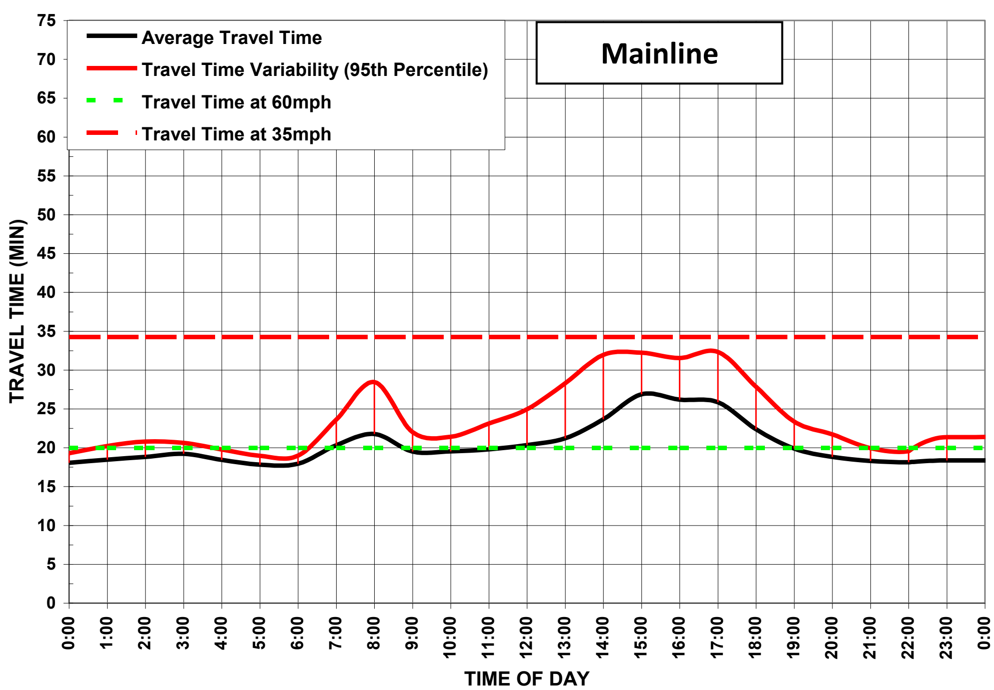
Source: Vehicle detector data

Exhibit 3B-24: Eastbound Mainline Travel Time Variability (2008)



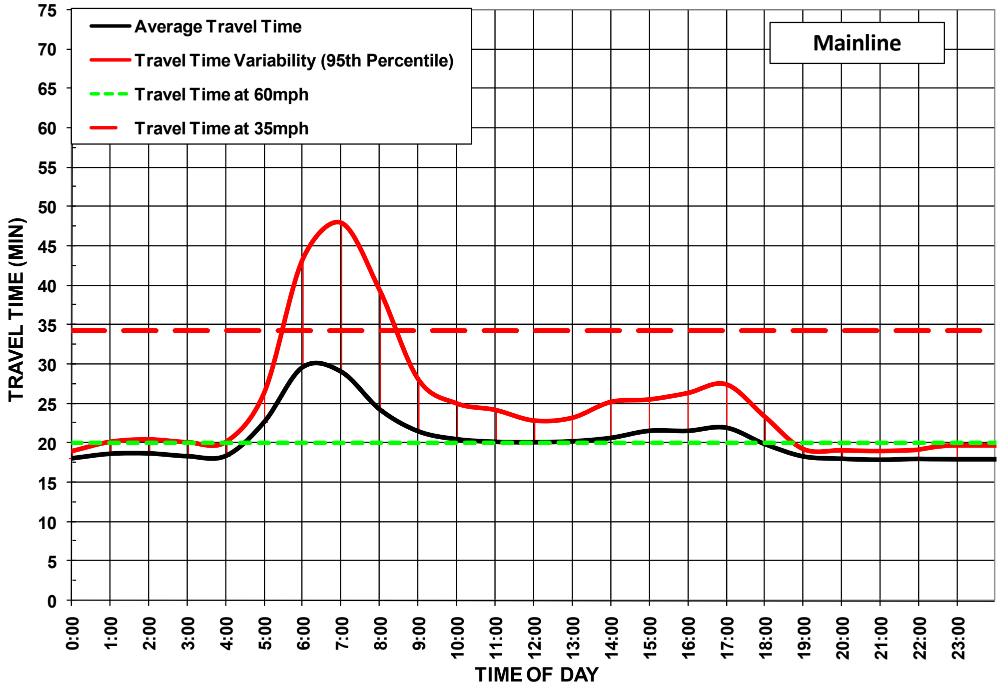
Source: Vehicle detector data

Exhibit 3B-25: Eastbound Mainline Travel Time Variability (2009)



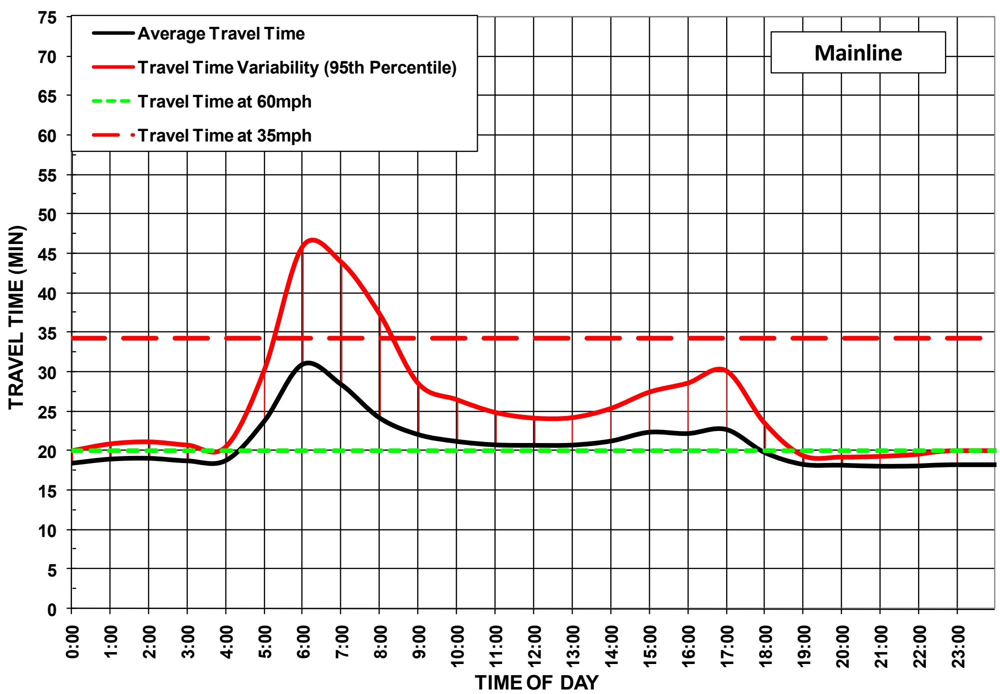
Source: Vehicle detector data

Exhibit 3B-26: Westbound Mainline Travel Time Variability (2005)



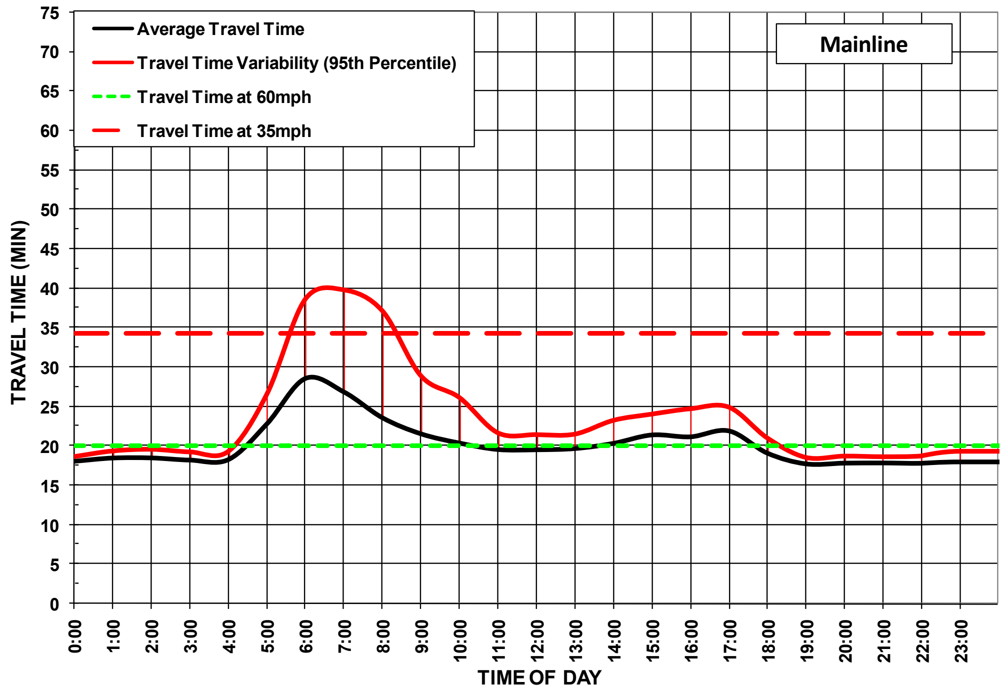
Source: Vehicle detector data

Exhibit 3B-27: Westbound Mainline Travel Time Variability (2006)



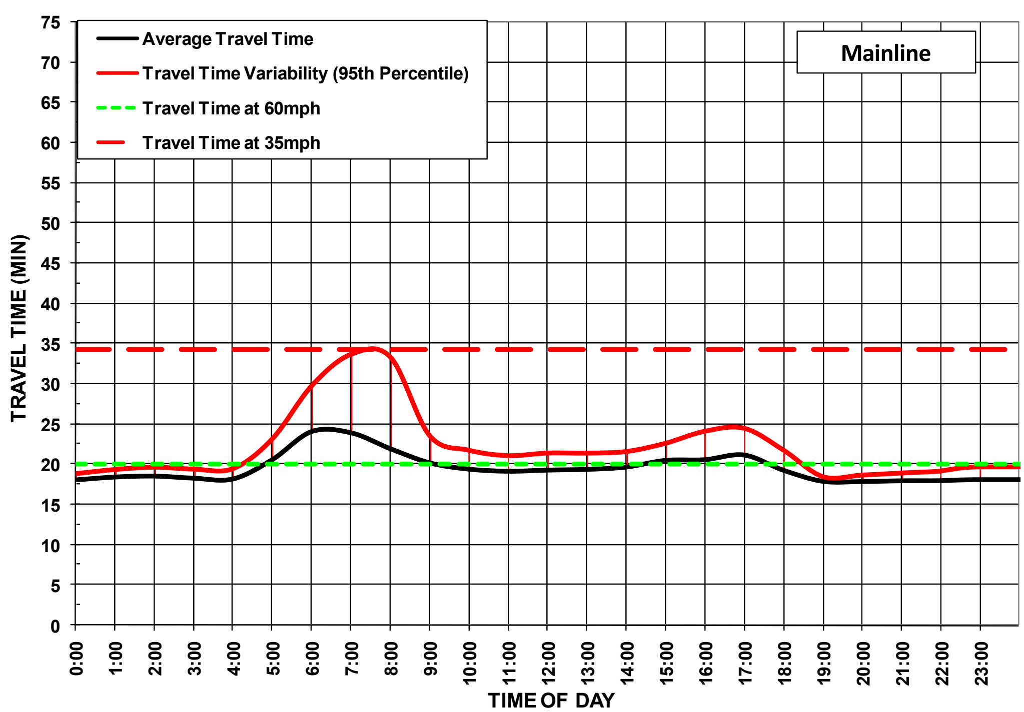
Source: Vehicle detector data

Exhibit 3B-28: Westbound Mainline Travel Time Variability (2007)



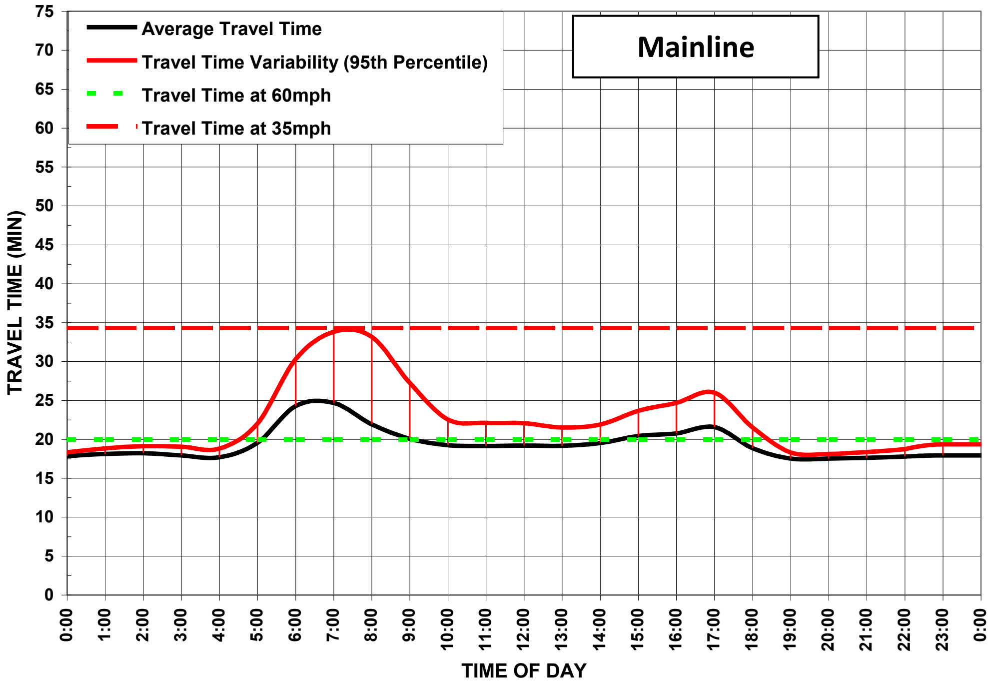
Source: Vehicle detector data

Exhibit 3B-29: Westbound Mainline Travel Time Variability (2008)



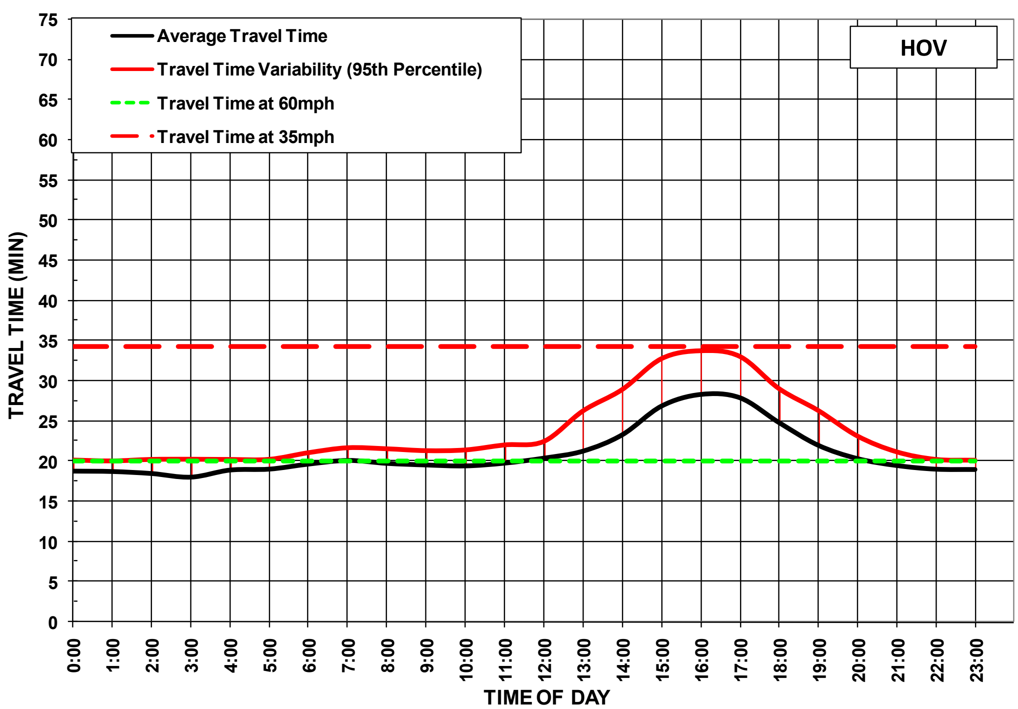
Source: Vehicle detector data

Exhibit 3B-30: Westbound Mainline Travel Time Variability (2009)



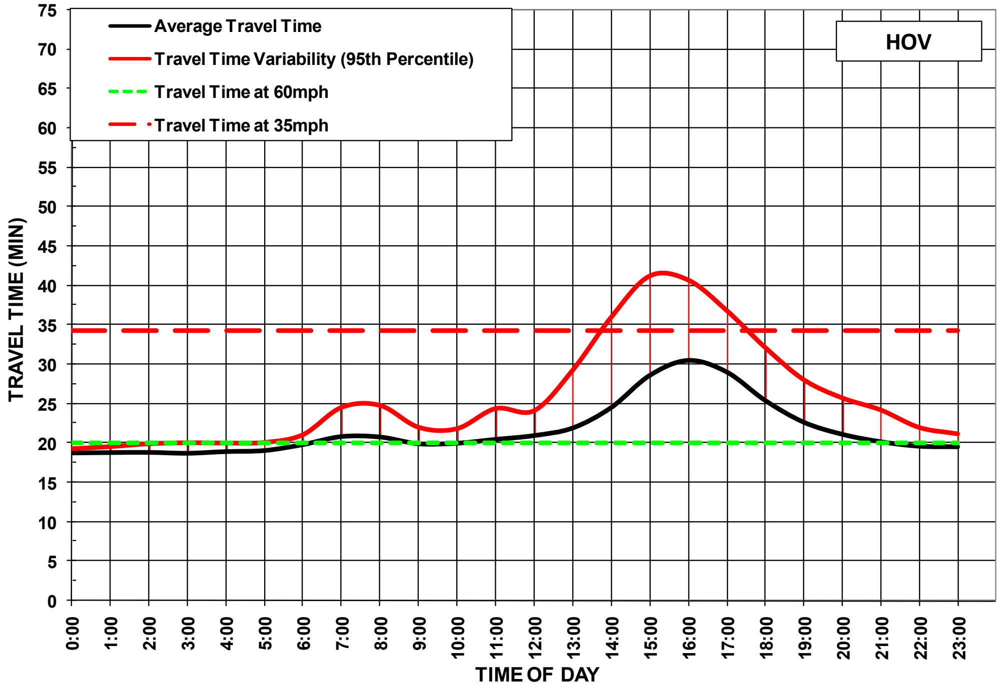
Source: Vehicle detector data

Exhibit 3B-31: Eastbound HOV Travel Time Variability (2005)



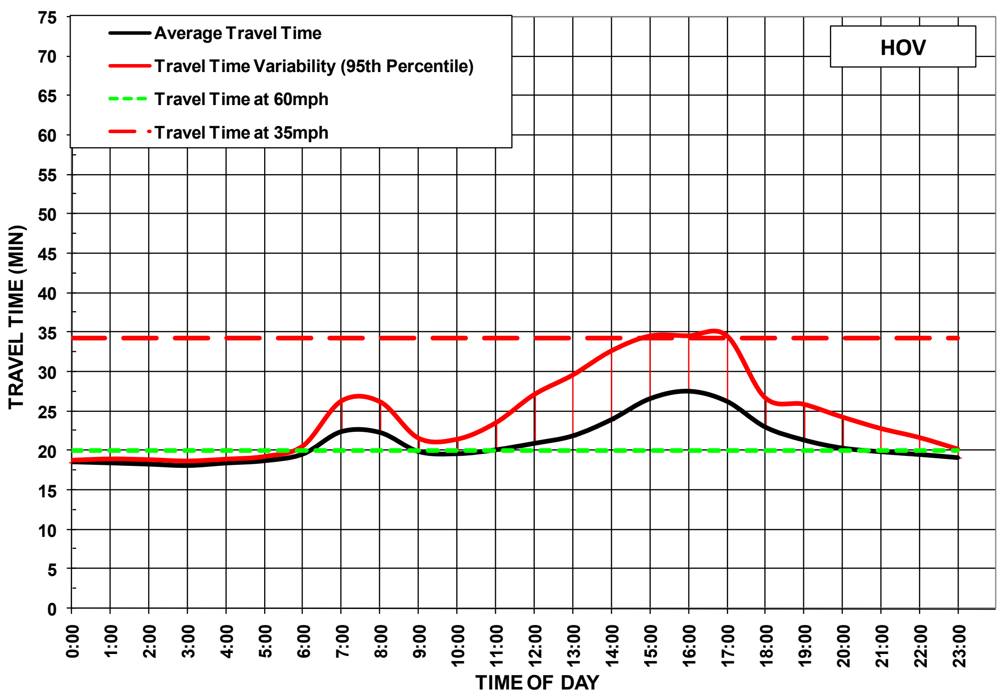
Source: Vehicle detector data

Exhibit 3B-32: Eastbound HOV Travel Time Variability (2006)



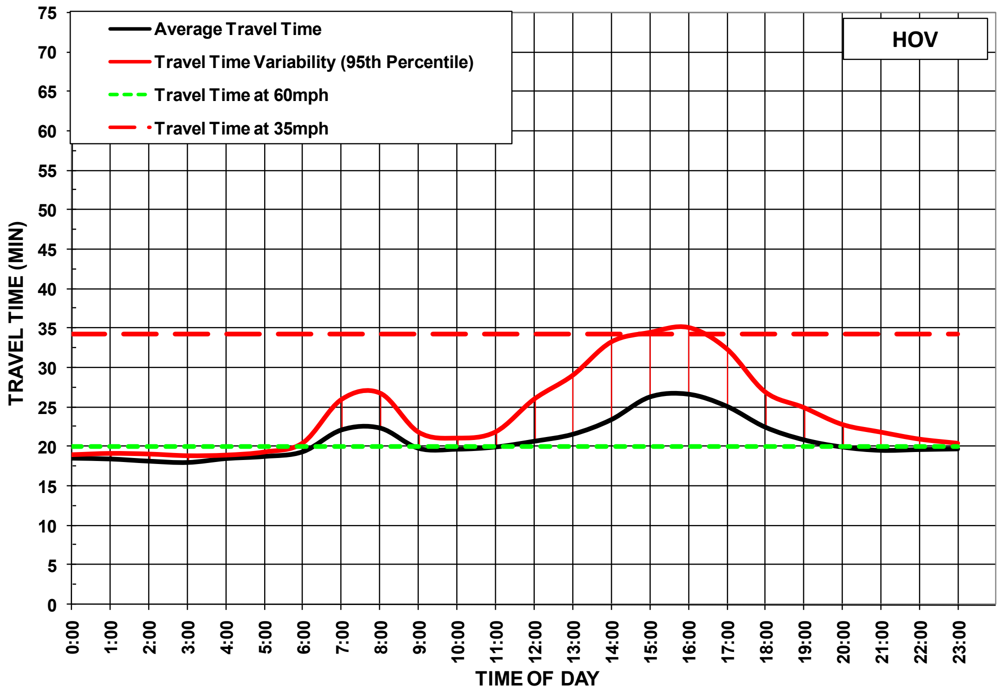
Source: Vehicle detector data

Exhibit 3B-33: Eastbound HOV Travel Time Variability (2007)



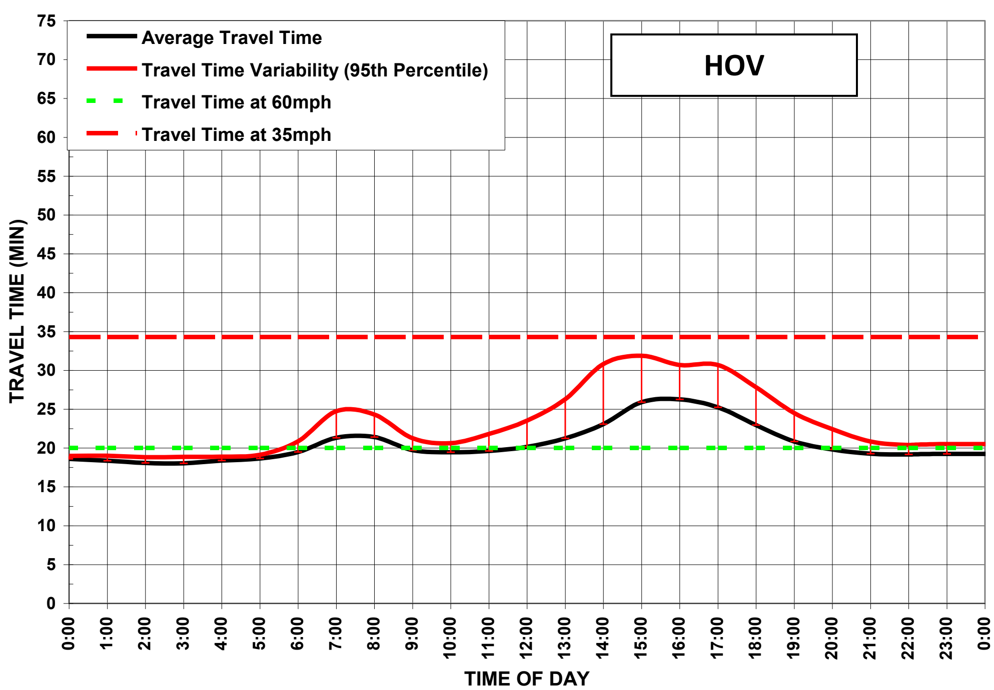
Source: Vehicle detector data

Exhibit 3B-34: Eastbound HOV Travel Time Variability (2008)



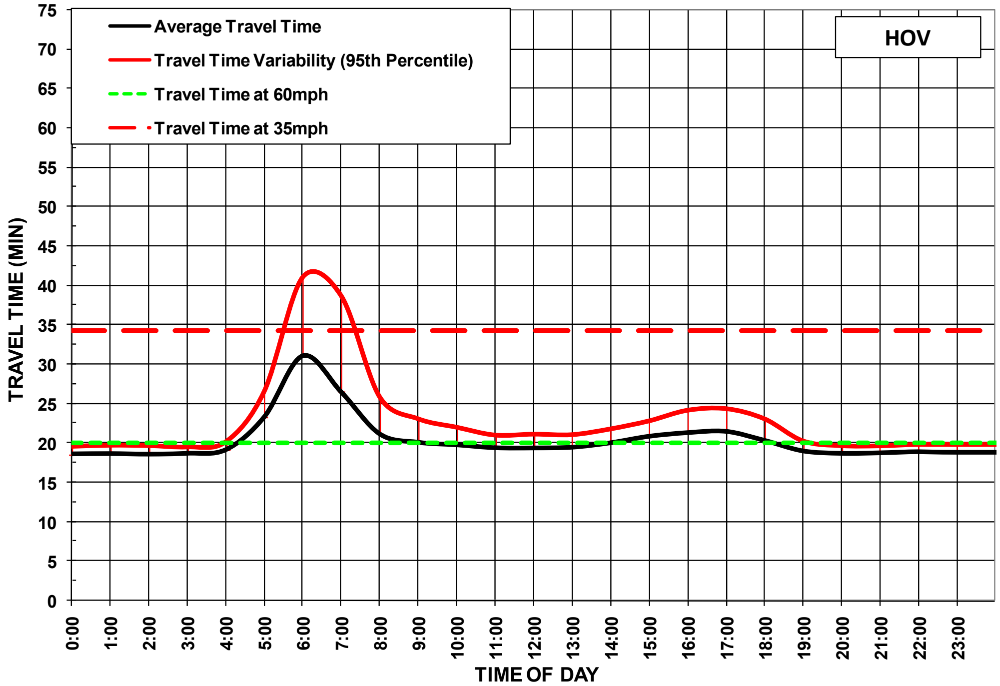
Source: Vehicle detector data

Exhibit 3B-35: Eastbound HOV Travel Time Variability (2009)



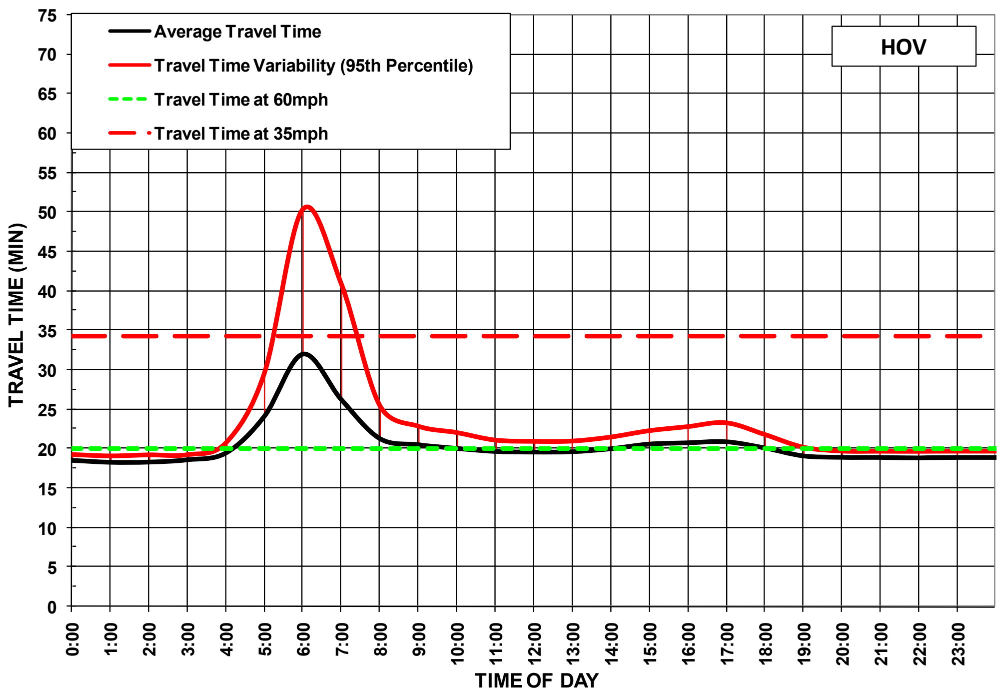
Source: Vehicle detector data

Exhibit 3B-36: Westbound HOV Travel Time Variability (2005)



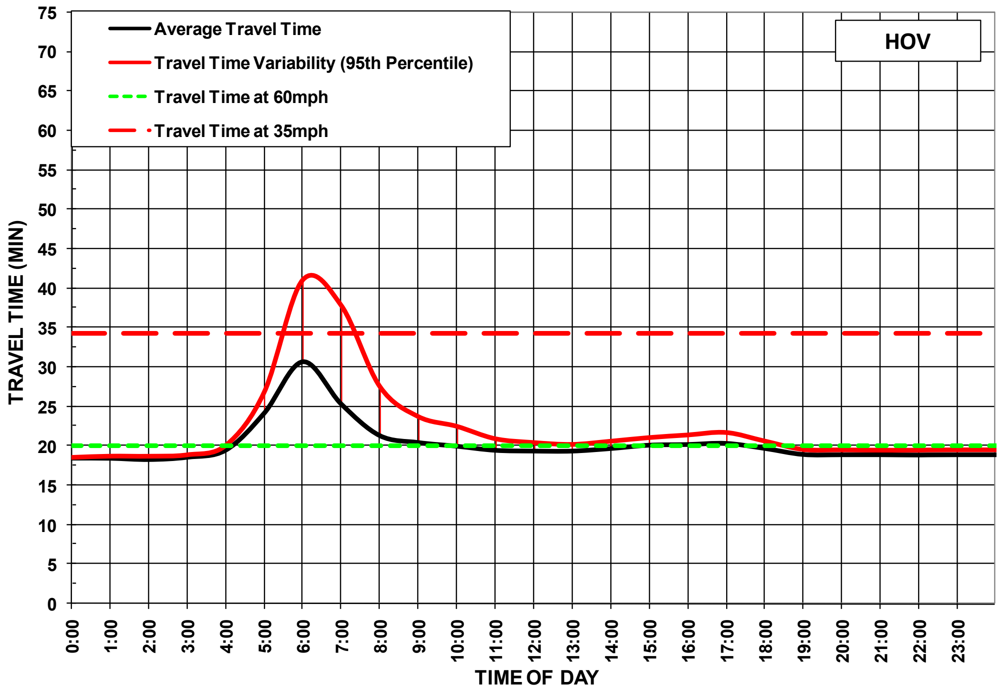
Source: Vehicle detector data

Exhibit 3B-37: Westbound HOV Travel Time Variability (2006)



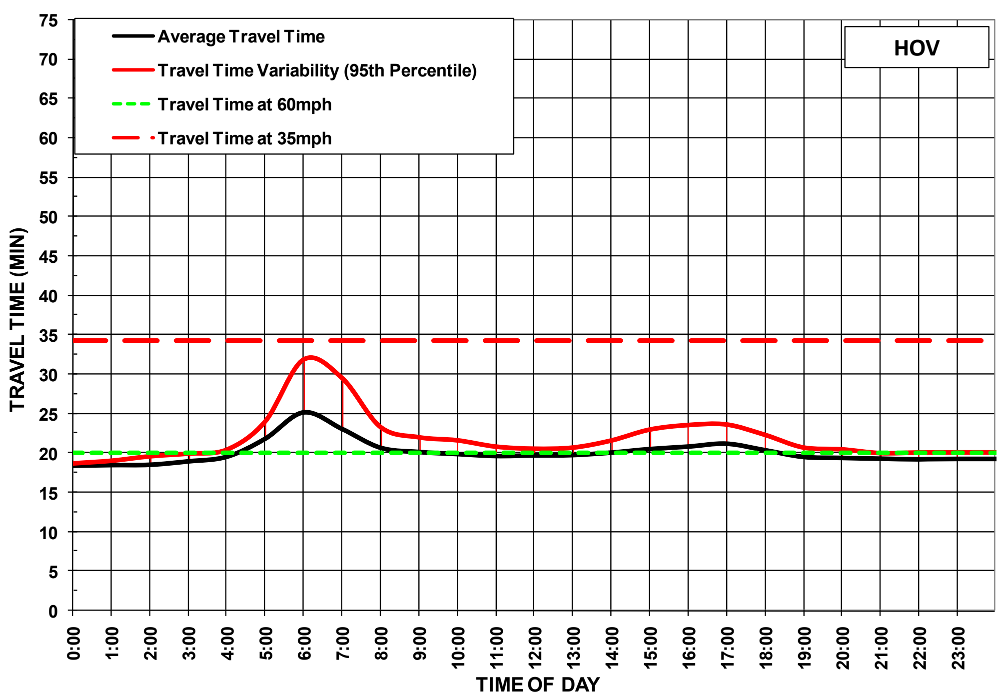
Source: Vehicle detector data

Exhibit 3B-38: Westbound HOV Travel Time Variability (2007)



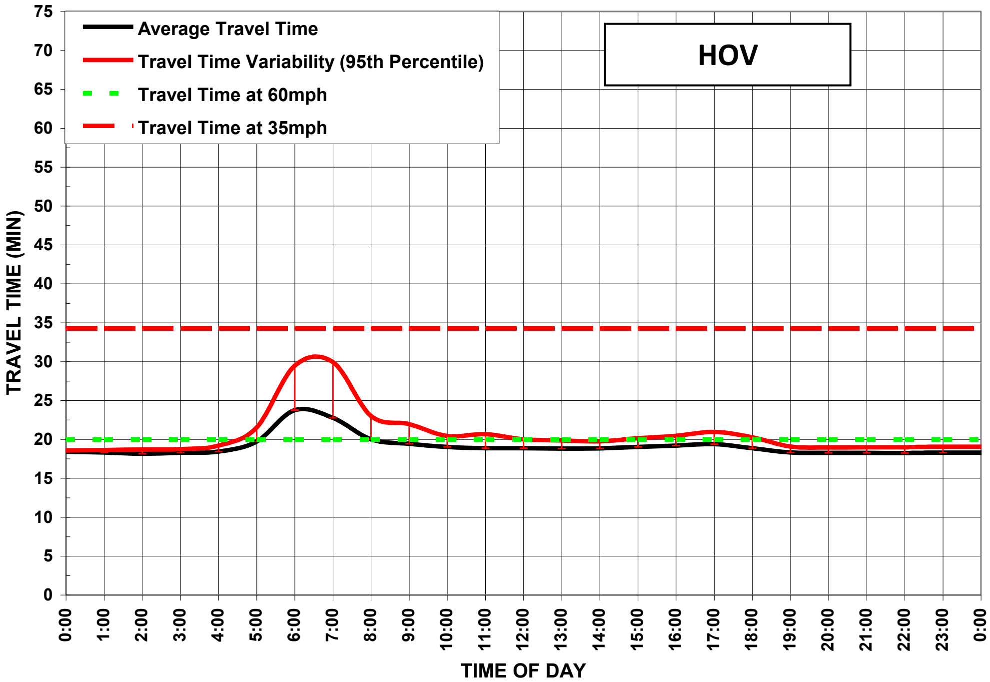
Source: Vehicle detector data

Exhibit 3B-39: Westbound HOV Travel Time Variability (2008)



Source: Vehicle detector data

Exhibit 3B-40: Westbound HOV Travel Time Variability (2009)



Source: Vehicle detector data

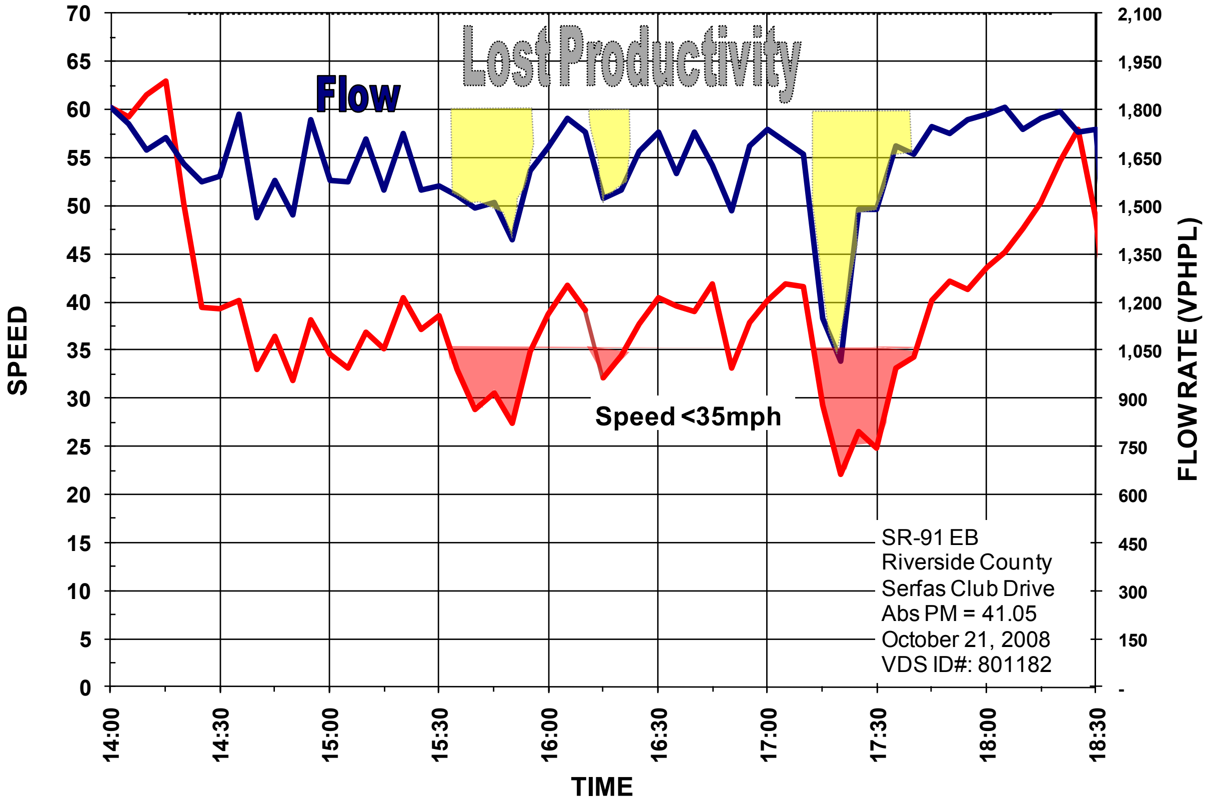
Productivity

Productivity is a measure of system efficiency that captures 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 number of people served divided by the level of service provided. For highways, it is the number of vehicles compared to the capacity of the roadways.

For the corridor analysis, productivity is defined as the percent utilization of the facility or mode under peak conditions. The highway productivity performance measure is calculated as actual volume divided by the capacity of the highway. Travel demand models generally do not project capacity loss for highways, but detailed micro-simulation tools can forecast productivity. For highways, productivity is particularly important because the lowest "production" from the transportation system occurs often when capacity is needed the most.

Exhibit 3B-41 provides an example of this loss in productivity for the SR-91 corridor. 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. There are a few ways to estimate productivity losses. Regardless of the approach, productivity calculations require good detection or significant field data collection at congested locations. One approach is to convert this lost productivity into "equivalent lost lane-miles." These lost lane-miles represent a theoretical level of additional capacity that would be needed to achieve maximum productivity. For example, losing six lane-miles implies that congestion has caused a loss in capacity roughly equivalent to one lane along a six-mile section of freeway.

Exhibit 3B-41: Lost Productivity Illustrated



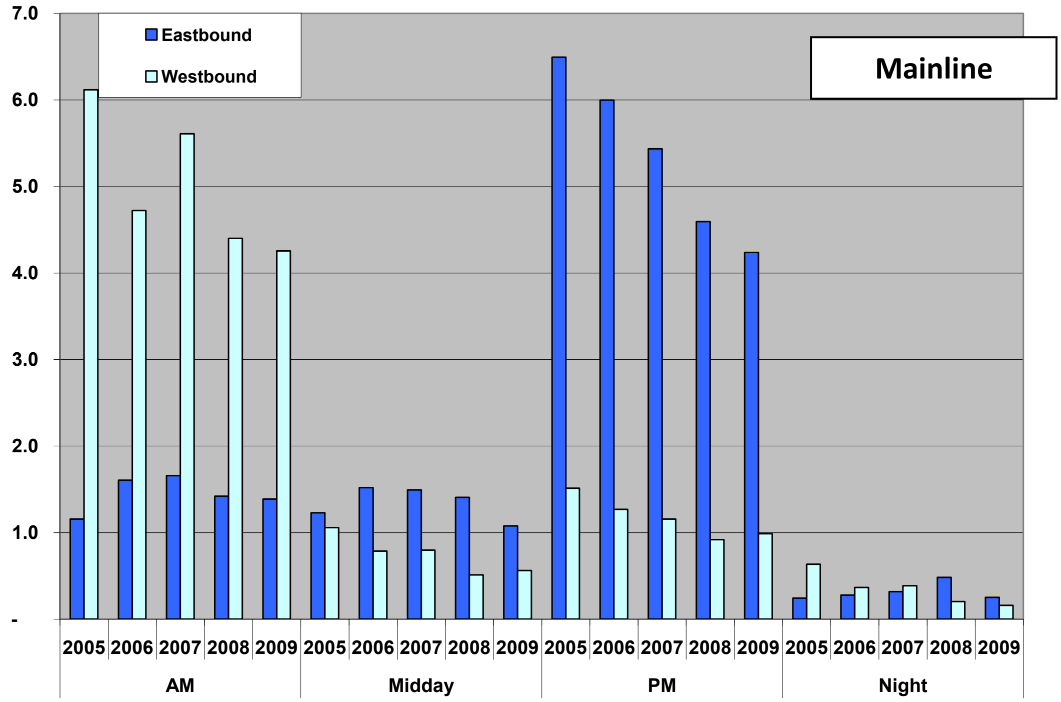
Equivalent lost lane-miles is computed as follows (for congested locations only):

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

Exhibits 3B-42 and 3B-43 summarize the productivity losses on the SR-91 Corridor mainline and HOV facilities during the 2005-2009 period. The trends in the productivity losses are comparable to the delay trends. The largest productivity losses occurred in the PM peak period in the eastbound direction, which is the time and direction that experienced the most congestion. Productivity during the PM peak in the eastbound direction improved continuously from 2005 to 2009 on the mainline and from 2007 to 2009 on the HOV lane. Productivity during the AM peak in the westbound direction also improved, but only from 2008 to 2009 on both the mainline and the HOV facilities.

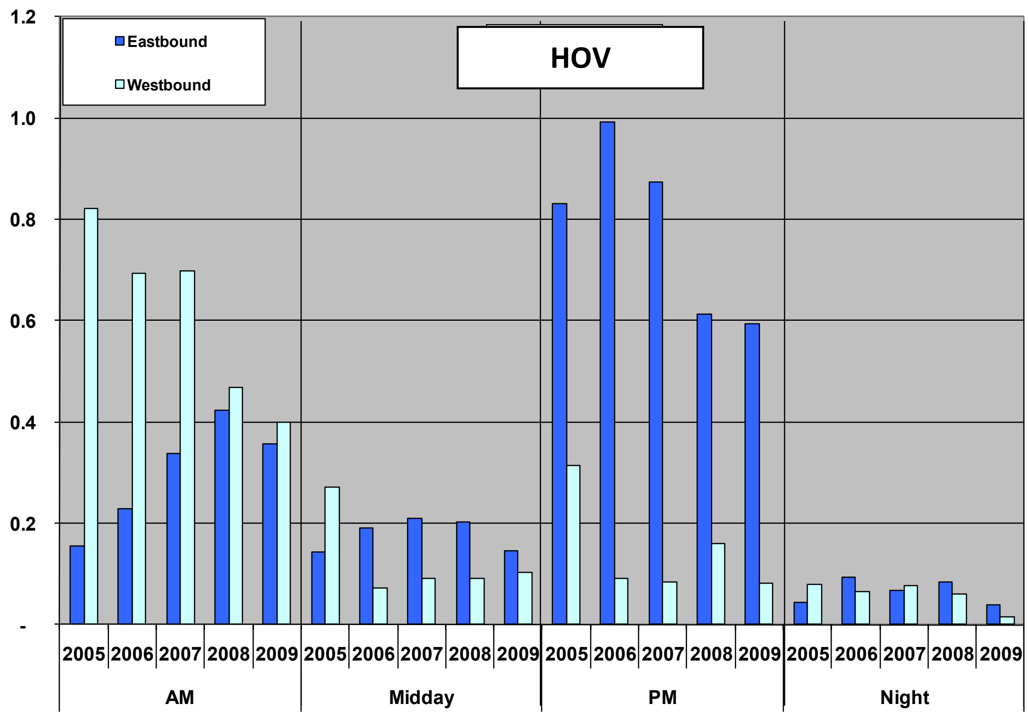
Strategies to combat such productivity losses are related primarily to operations. These strategies include: building new or extending auxiliary lanes, developing more aggressive ramp metering strategies without negatively influencing the arterial network, and improving incident clearance times.

Exhibit 3B-42: Average Lost Lane-Miles by Direction, Time Period, and Year (ML)



Source: Vehicle detector data

Exhibit 3B-43: Average Lost Lane-Miles by Direction, Time Period, and Year (HOV)



Source: Vehicle detector data

Safety

The adopted performance measures to assess safety are: the number of accidents and accident rates computed from the Caltrans Traffic Accident Surveillance and Analysis System (TASAS). TASAS is a traffic records system containing an accident database linked to a highway database. The highway database contains description 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 readily apparent patterns. This report is not intended to supplant more detailed safety investigations performed routinely by Caltrans staff.

Exhibit 3B-44 shows TASAS Table B accident rates for the three and a half-year period between January 1, 2006 and June 30, 2009. For each direction of travel, the data breaks up the corridor into two sections, from PM 0.0 to 7.5, and from PM 7.5 to 21.7. In the eastbound direction, the corridor experienced a total of 3,245 accidents, which includes both fatalities and injuries. The westbound corridor experienced fewer accidents than the eastbound with a total combined of 2,558. The rate of fatalities and injuries for this corridor is lower compared to other state highway facilities with similar operating characteristics, particularly in the westbound direction. The accident rate for westbound SR-91 (0.88) is lower than the rate on similar facilities (between 1.15 and 1.26)

Exhibit 3B-44: Total Number of Accidents by Type and Accident Rate (2006-2009)

	Number of Accidents on SR-91					Accident Rates					
						Actual Rates on SR-91			Average Rates on Similar Facilities		
	Tot	Fat	Inj	F+I	Multi Veh	Fat	F+I	Total	Fat	F+I	Total
EB (CA PM 0 -7.5)	1,433	5	398	403	1,288	0.004	0.33	1.16	0.011	0.36	1.15
EB (CA PM 7.5-21.7)	1,812	11	521	532	1,566	0.007	0.32	1.08	0.013	0.39	1.26
Total EB Direction	3,245	16	919	935	2,854	0.005	0.32	1.11	-	-	-
WB (CA PM 0 -7.5)	1,081	5	306	311	959	0.004	0.25	0.87	0.011	0.36	1.15
WB (CA PM 7.5-21.7)	1,477	6	453	459	1,235	0.004	0.27	0.88	0.013	0.39	1.26
Total WB Direction	2,558	11	759	770	2,194	0.004	0.26	0.88	-	-	-

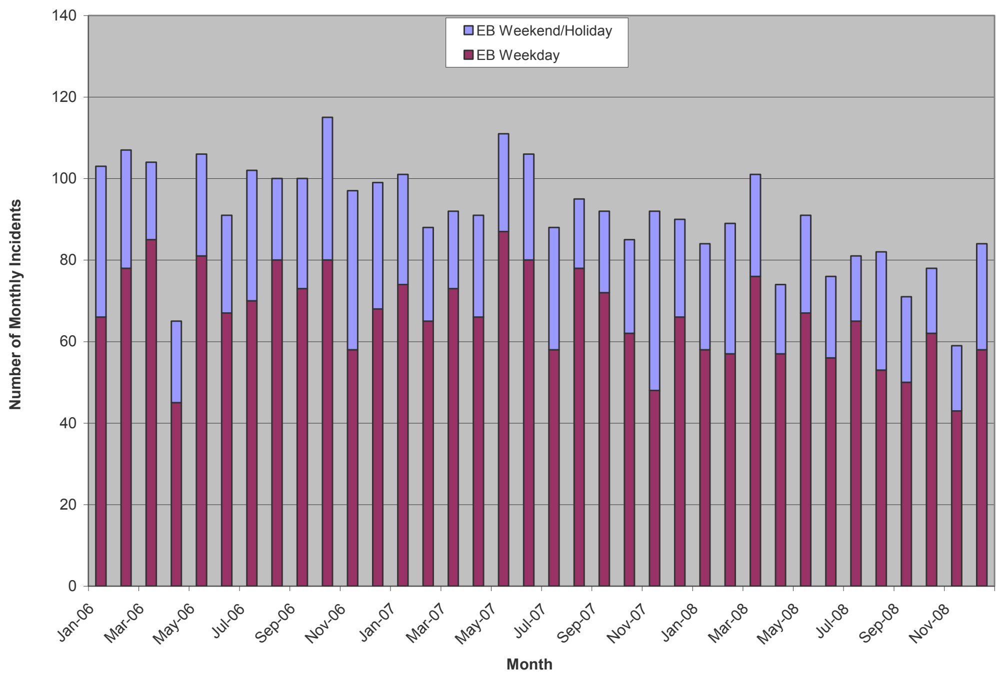
Source: Caltrans Table B

Exhibits 3B-45 and 3B-46 illustrate the accidents that occurred on the eastbound westbound directions of the SR-91 Corridor. Caltrans typically analyzes the latest three-year safety data. The latest available data from January 1, 2006 through December 31, 2008 were analyzed and summarized. Note that these are comprehensive and do not rely on automatic detection systems.

As depicted in the exhibits, both the eastbound and westbound directions experienced fewer collisions in 2007 and 2008 than in 2006. An average of 100 collisions occurred each month in the eastbound direction, as opposed to an average of 75 collisions that occurred each month in the westbound direction. In each direction, there is a downward trend in total number of accidents starting in 2006.

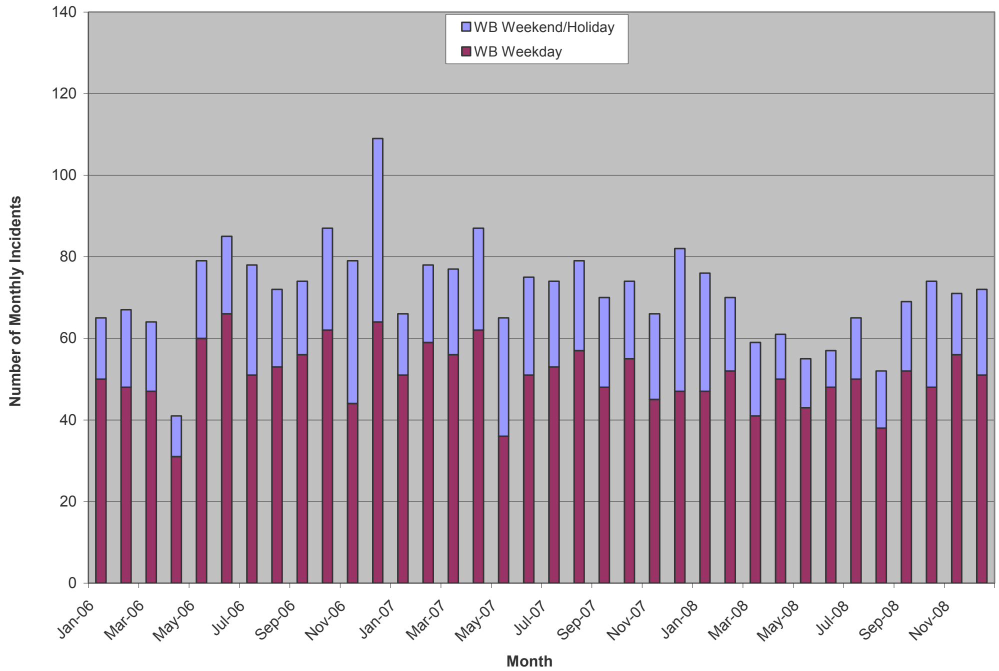
However, a significant point is that monthly eastbound accidents are higher on average than westbound accidents. This may be due to the higher congestion levels during the PM peak period (particularly in the eastbound direction).

Exhibit 3B-45: Eastbound Monthly Accidents (2006-2008)



Source: TASAS

Exhibit 3B-46: Westbound Monthly Accidents (2006-2008)



Source: TASAS

C. Bottlenecks and Causality

Bottlenecks, or locations of significant mobility constraints, were preliminarily identified as “potential” bottlenecks based on readily available, existing data sources, including the 2008 State Highway Congestion Monitoring Program (HICOMP) Annual Report, Caltrans District 8 2008 probe vehicle runs, and Caltrans vehicle detector station data. Actual bottlenecks were verified from extensive field observations.

This section summarizes the findings of that analysis. Exhibits 3C-1 and 3C-2 summarize the bottleneck locations identified in this analysis by direction. The exhibits also show “bottleneck areas.” These areas are defined for reporting performance later in this report. They represent the area from one bottleneck to the one upstream. Exhibits 3C-1 and 3C-2 include an extra row at the end to cover the remainder of the corridor after the last bottleneck. The actual queues formed at the bottlenecks may have a different length than the bottleneck area. This concept is described in detail later in the report and illustrated in Exhibit 3C-15.

Exhibits 3C-3 and 3C-4 are maps that identify the bottleneck locations by AM and PM peak periods.

Exhibit 3C-1: Eastbound SR-91 Identified Bottleneck Areas

Bottleneck Location	Bottleneck Area	Active Period		From		To		Distance (miles)
		AM	PM	Abs	CA	Abs	CA	
Serfas Club Dr On	ORA/RIV Co Line to Serfas Club Dr On		✓	37.2	0.0	41.1	R3.8	3.8
Maple St On	Serfas Club Dr On to Maple St On		✓	41.1	R3.8	41.6	4.2	0.5
Lincoln Ave On	Maple St On to Lincoln Ave On		✓	41.6	4.2	42.9	5.5	1.3
I-15 Connectors (East-North & East-South)	Lincoln Ave On to I-15		✓	42.9	5.5	44.4	7.0	1.5
I-15 Connectors (South-East & North-East)	I-15 *		✓	44.4	7.0	45.1	7.7	0.7
McKinley St On	I-15 to McKinley St On		✓	45.1	7.7	46.5	9.2	1.4
Magnolia Ave On	McKinley St On to Magnolia Ave On	✓	✓	46.5	9.2	48.5	11.2	2.0
Madison Off	Magnolia St On to Madison Off	✓		48.5	11.2	53.9	16.5	5.4
Arlington Ave On	Madison Off to Arlington Ave On	✓		53.9	16.5	55.4	18.0	1.5
Central Ave On	Arlington Ave On to Central Ave On	✓		55.4	18.0	55.9	18.6	0.5
Not a bottleneck location	Central Ave On to SR-60/I-215	N/A		55.9	18.6	59.0	21.7	3.1

* segment is not included in the bottleneck area analysis due to insufficient detection

Exhibit 3C-2: Westbound SR-91 Identified Bottleneck Areas

Bottleneck Location	Bottleneck Area	Active Period		From		To		Distance (miles)
		AM	PM	Abs	CA	Abs	CA	
Mission Inn Ave	SR-60/I-215 to Mission Inn Ave *		✓	59.0	21.7	58.3	20.9	0.7
14th St On	Mission Inn Ave to 14th St On		✓	58.3	20.9	57.3	19.8	1.0
Arlington Ave On	14th St On to Arlington Ave On		✓	57.3	19.8	55.1	17.6	2.2
Tyler St On	Arlington Ave On to Tyler St On		✓	55.1	17.6	50.3	12.9	4.7
Pierce St On	Tyler St On to Pierce St On	✓	✓	50.3	12.9	48.0	10.6	2.3
I-15 Connectors (South-West & North-West)	Pierce St On to I-15	✓		48.0	10.6	45.2	7.8	2.8
School St/Grand Blvd On	I-15 to School St/Grand Blvd On	✓		45.2	7.8	43.3	5.9	1.9
Lincoln Ave On	School St/Grand Blvd On to Lincoln Ave On	✓		43.3	5.9	42.7	5.3	0.6
Serfas Club Dr On	Lincoln Ave On to Serfas Club Dr On	✓		42.7	5.3	40.9	R3.5	1.8
Not a bottleneck location	Serfas Club Dr On to RIV/ORA Co Line	N/A		40.9	R3.5	37.2	R0.9	3.7

* segment is not included in the bottleneck area analysis due to the short distance in length or insufficient detection

Exhibit 3C-3: SR-91 AM Bottleneck Locations

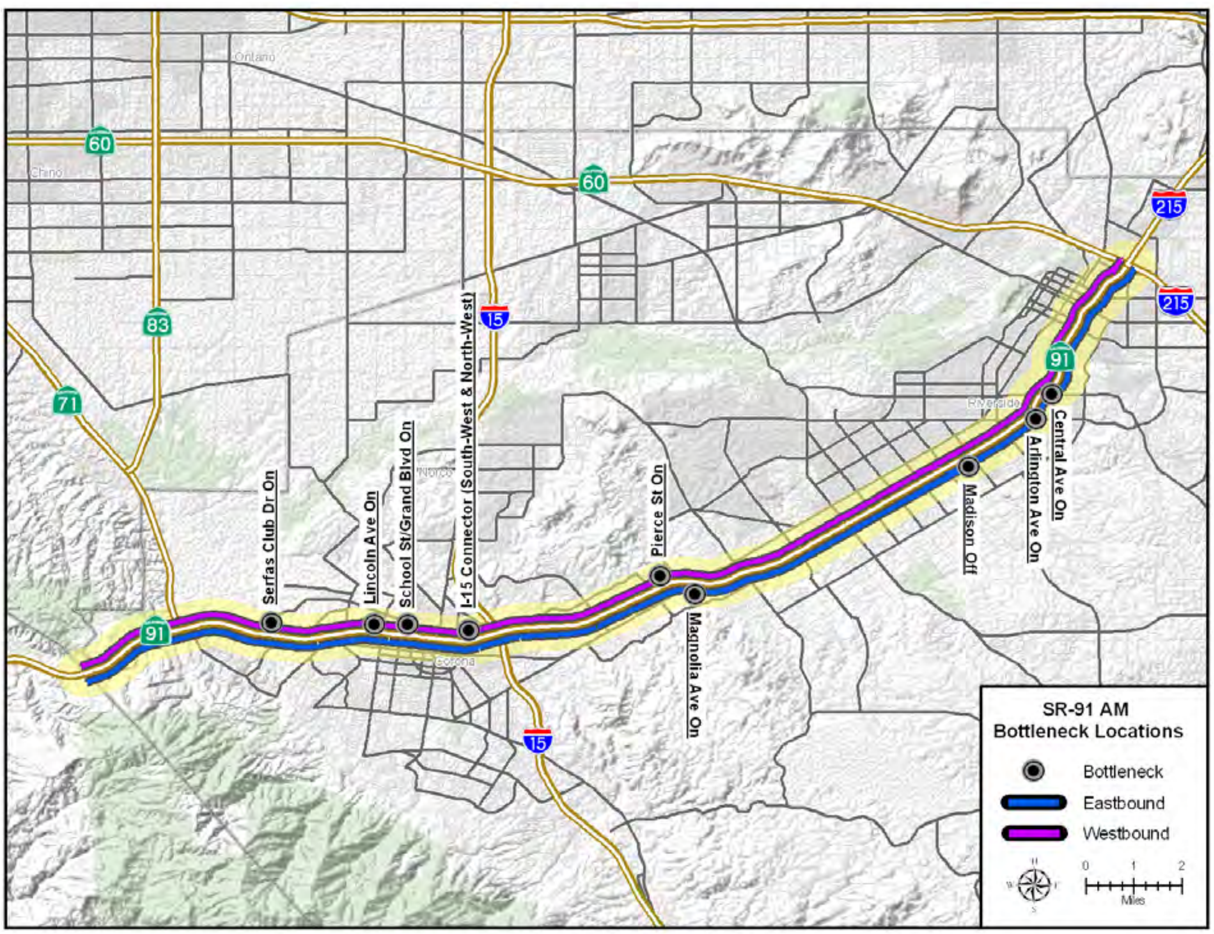
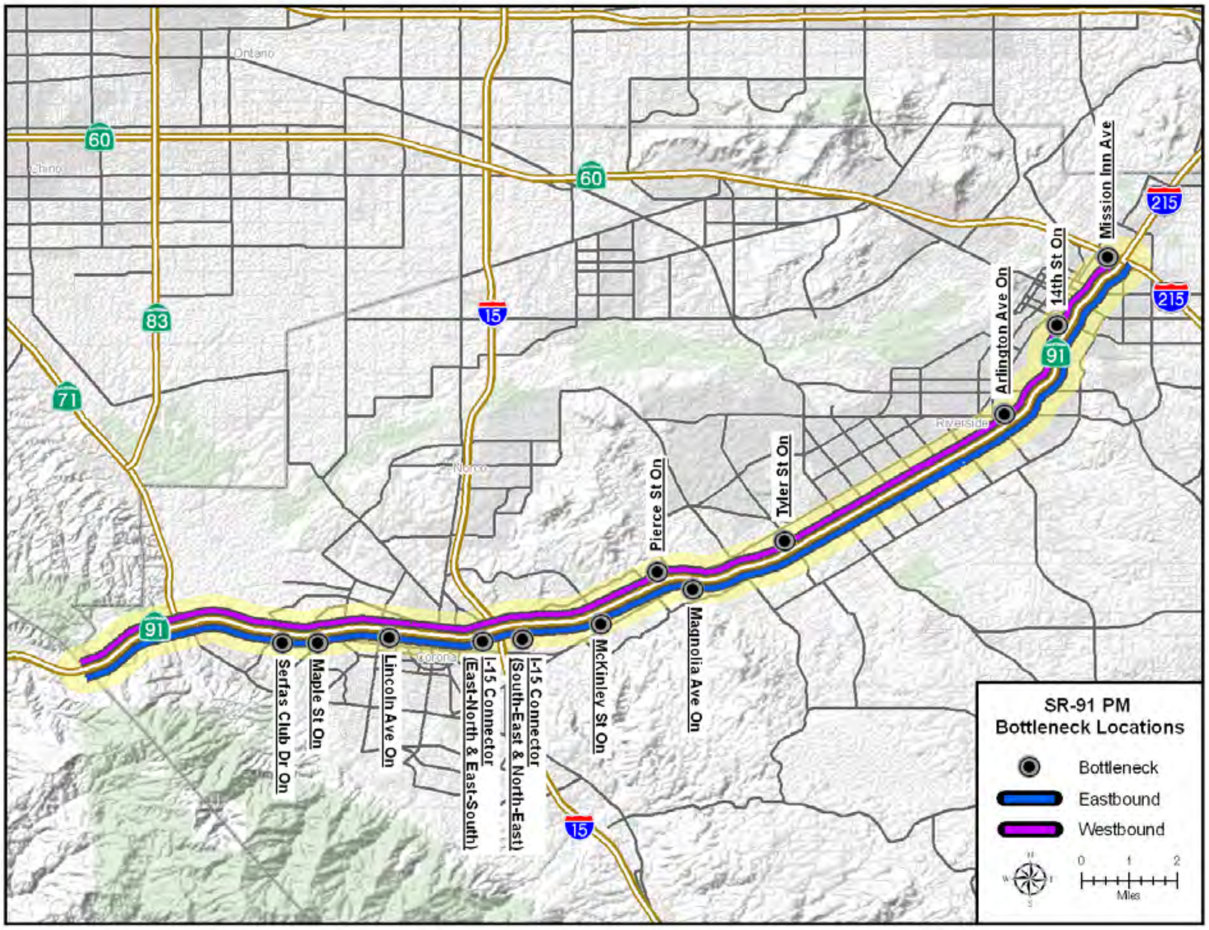


Exhibit 3C-4: SR-91 PM Bottleneck Locations



Eastbound Bottlenecks

Starting from the Orange/Riverside County Line and moving eastbound, the following bottlenecks were identified:

- Serfas Club Drive On-ramp
- Maple Street On-ramp
- Lincoln Avenue On-ramp
- I-15 Connector (East-North & East-South)
- I-15 Connector (South-East & North-East)
- McKinley Street On-ramp
- Magnolia Avenue On-ramp
- Madison Street Off-ramp
- Arlington Avenue On-ramp
- Central Avenue On-ramp.

Westbound Bottlenecks

Starting from SR-60/I-215 and moving westbound, the following bottlenecks were identified:

- Mission Inn Avenue
- Fourteenth Street On-ramp
- Arlington Avenue On-ramp
- Tyler Street On-ramp
- Pierce Street On-ramp
- I-15 Connector (South-West & North-West)
- School Street/Grand Boulevard On-ramp
- Lincoln Avenue On-ramp
- Serfas Club Drive On-ramp

Bottleneck Identification

As stated earlier, bottlenecks were initially identified (as "potential" bottlenecks) based on a variety of data sources. Data from the following sources were reviewed to identify potential bottlenecks:

- State Highway Congestion Monitoring Program (HICOMP) report
- Vehicle detector data
- Aerial photos

HICOMP

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

An initial identification of bottleneck locations was performed by reviewing the 2008 Caltrans HICOMP report, which was the most recent data available at the time of the data analysis. Congested queues form upstream from bottlenecks, which are located "at the front" of the congested segment. Exhibits 3C-5 and 3C-6 show the HICOMP congestion maps with circles overlaid to indicate potential bottleneck locations, or locations with mobility constraints. Bottleneck areas are identified with blue circles in the eastbound direction and red circles in the westbound direction.

For the AM peak period in 2008 (Exhibit 3C-5), one major potential bottleneck location was reported for the eastbound direction (at Fourteenth Street), and three locations were reported for the westbound direction (SR-71, Serfas Club Drive, and I-15).

Exhibit 3C-5: 2008 HICOMP AM Congestion Map with Potential Bottlenecks

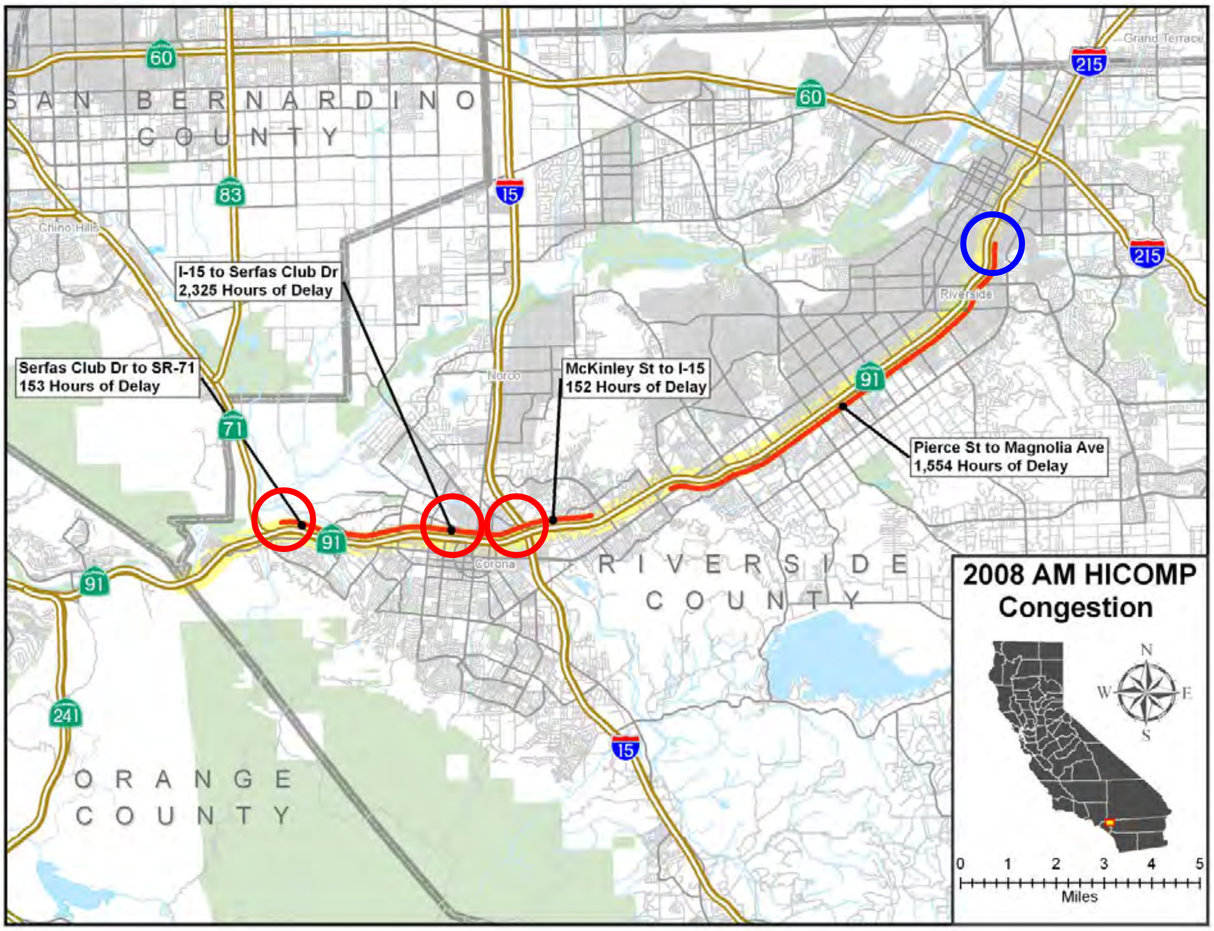
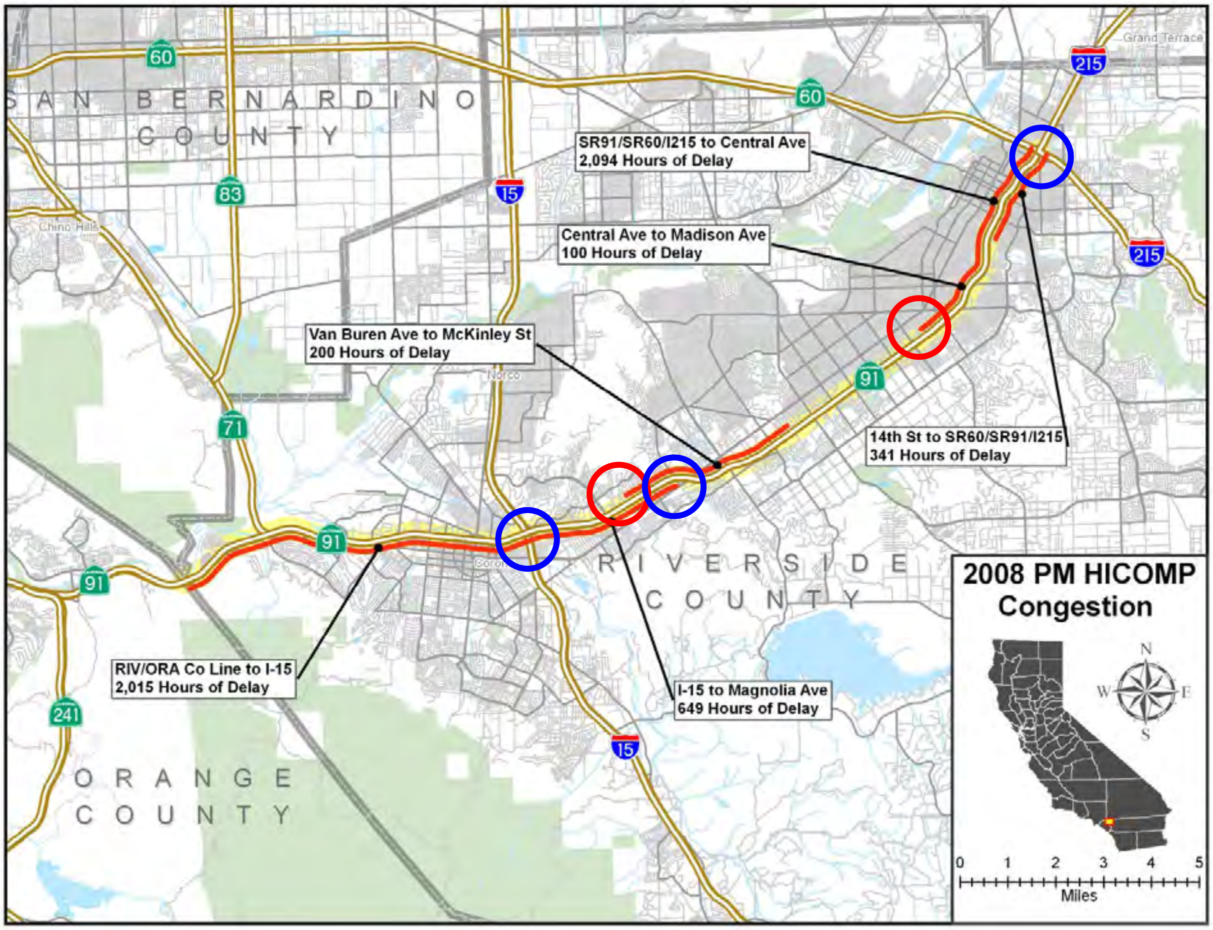


Exhibit 3C-6 shows PM peak period bottlenecks using data from the 2008 HICOMP Report. The PM peak period tends to be more congested than the AM peak period, which is shown in both HICOMP and sensor data.

Exhibit 3C-6: 2008 HICOMP PM Congestion Map with Potential Bottlenecks

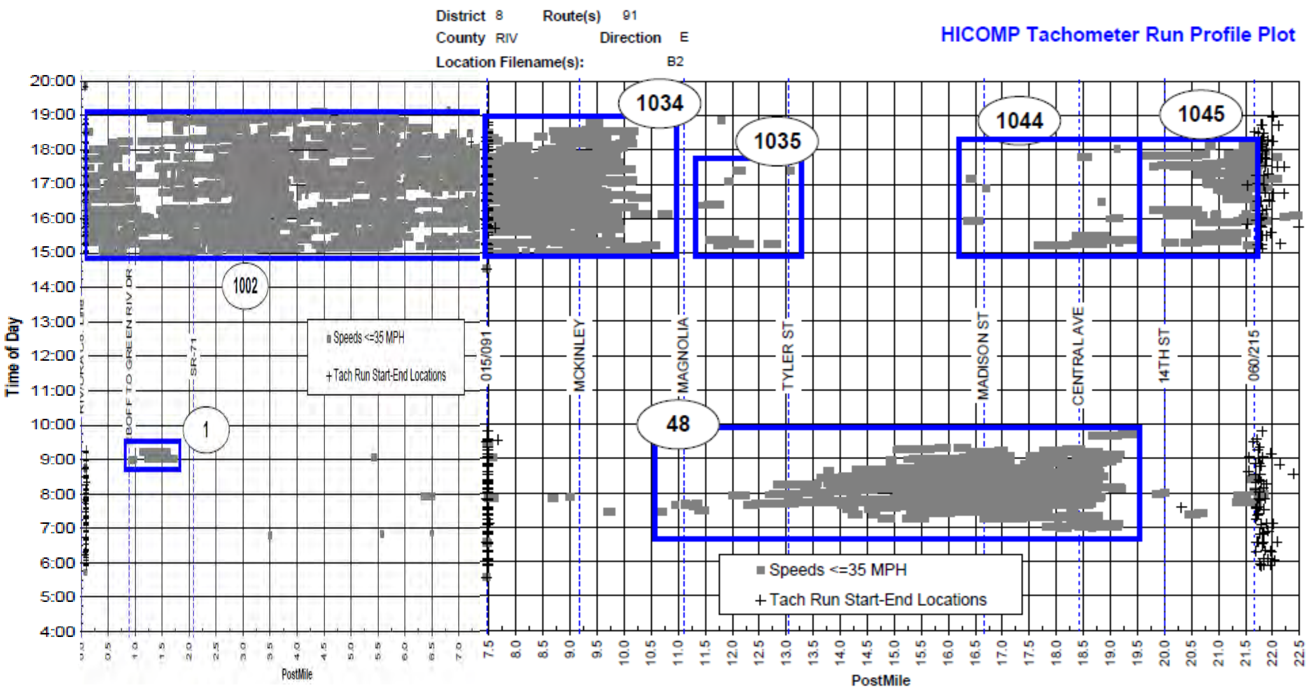


Probe Vehicle Runs

Probe vehicle data collected in 2008 were also used to conduct additional analyses to confirm the potential bottlenecks identified in the HICOMP data. Probe vehicle runs provide speed plots across the corridor for various departure times. Caltrans collects the data by driving a vehicle equipped with various electronic devices (e.g., tachograph and global positioning system) along the corridor at various departure times (usually at 10 to 20 minute intervals). The vehicles are driven in a middle lane to capture "typical" conditions during the peak periods. Actual speeds are recorded as the vehicle travels the corridor. Bottlenecks can be found downstream of a congested location where vehicles accelerate from congested speeds (e.g., below 35 mph) to a higher speed within a very short distance.

Probe vehicle data were collected for the SR-91 corridor on multiple mid-week days in both the spring (March and April) and fall (September and November) of 2008. Exhibit 3C-7 illustrates the eastbound and Exhibit 3C-8 illustrates the westbound probe vehicle runs presented in speed contour diagram from 4 AM to 8 PM. Note that not all of these bottleneck locations were confirmed by other sources or field visits.

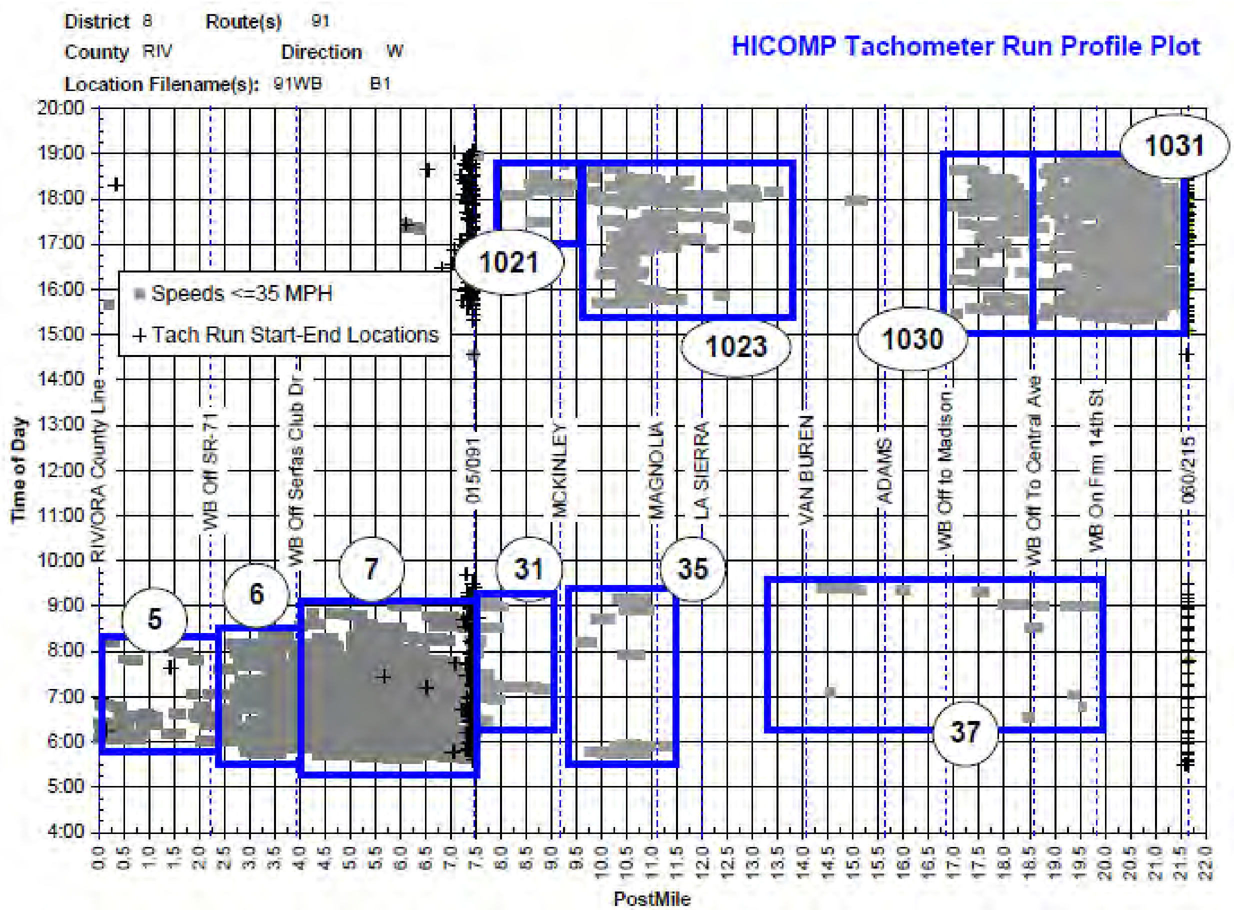
Exhibit 3C-7: Eastbound SR-91 Probe Vehicle Runs (2008)



As indicated, potential major <u>eastbound</u> bottlenecks were identified from probe vehicle runs at:

- I-15 (PM)
- Magnolia Avenue (PM)
- Tyler Street (PM)
- Fourteenth Street (AM and PM)
- I-215/SR-60 (AM and PM).

Exhibit 3C-8: Westbound SR-91 Probe Vehicle Runs (2008)



As indicated, potential major <u>westbound</u> bottlenecks were identified from probe vehicle runs at:

- Central Avenue (PM)
- Madison Street (PM)
- Pierce Avenue (AM and PM)
- I-15 (AM and PM)
- Serfas Club Drive (AM)
- SR-71 (AM)

Vehicle Detector Data

The third source used to identify potential bottlenecks was to review speed contour plots from 2008 vehicle detector data. Detector data were downloaded from the Caltrans Freeway Performance Measurement System (PeMS) to conduct this analysis.

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

Eastbound Vehicle Detector Data Analysis

Speed contour plots for sample days in October 2008 as well as 2008 quarterly weekday average were analyzed for the eastbound direction. Exhibits 3C-9 and 3C-10 present speed contour and speed profile plots for the SR-91 freeway corridor in the eastbound direction (traffic moving left to right on the plot). Along the vertical axis is the time period from 4 AM to 9 PM. Along the horizontal axis is the corridor segment from the Orange County Line to the SR-91/SR-60/I-215 interchange in the City of Riverside. The various colors represent the average speeds corresponding to the color speed chart shown below the diagram. As shown, the dark blue blotches represent congested areas where speeds are reduced. The ends of each dark blotches represent bottleneck areas, where speeds pickup after congestion, typically to 30 to 50 miles per hour. The horizontal length of each plot is the congested segment, queue lengths. The vertical length is the congested time period. The eastbound speed contour data analysis results indicated recurring bottleneck locations across multiple weekdays and quarterly averages.

In addition to multiple days, larger averages were also analyzed. Exhibit 3C-11 illustrates the weekday averages by each quarter of 2008. Again, the same bottleneck locations are identified.

As indicated in Exhibits 3C-9 through 3C-11, potential major eastbound bottlenecks were identified from the PeMS data plots at:

- Serfas Club On (PM)
- Maple On (PM)
- Lincoln On (PM)
- Main On/I-15 (AM)
- McKinley On (AM and PM)
- Arlington On (AM)
- Central On (AM)

Exhibit 3C-9: Eastbound SR-91 Speed Contour Plots (October 2008)

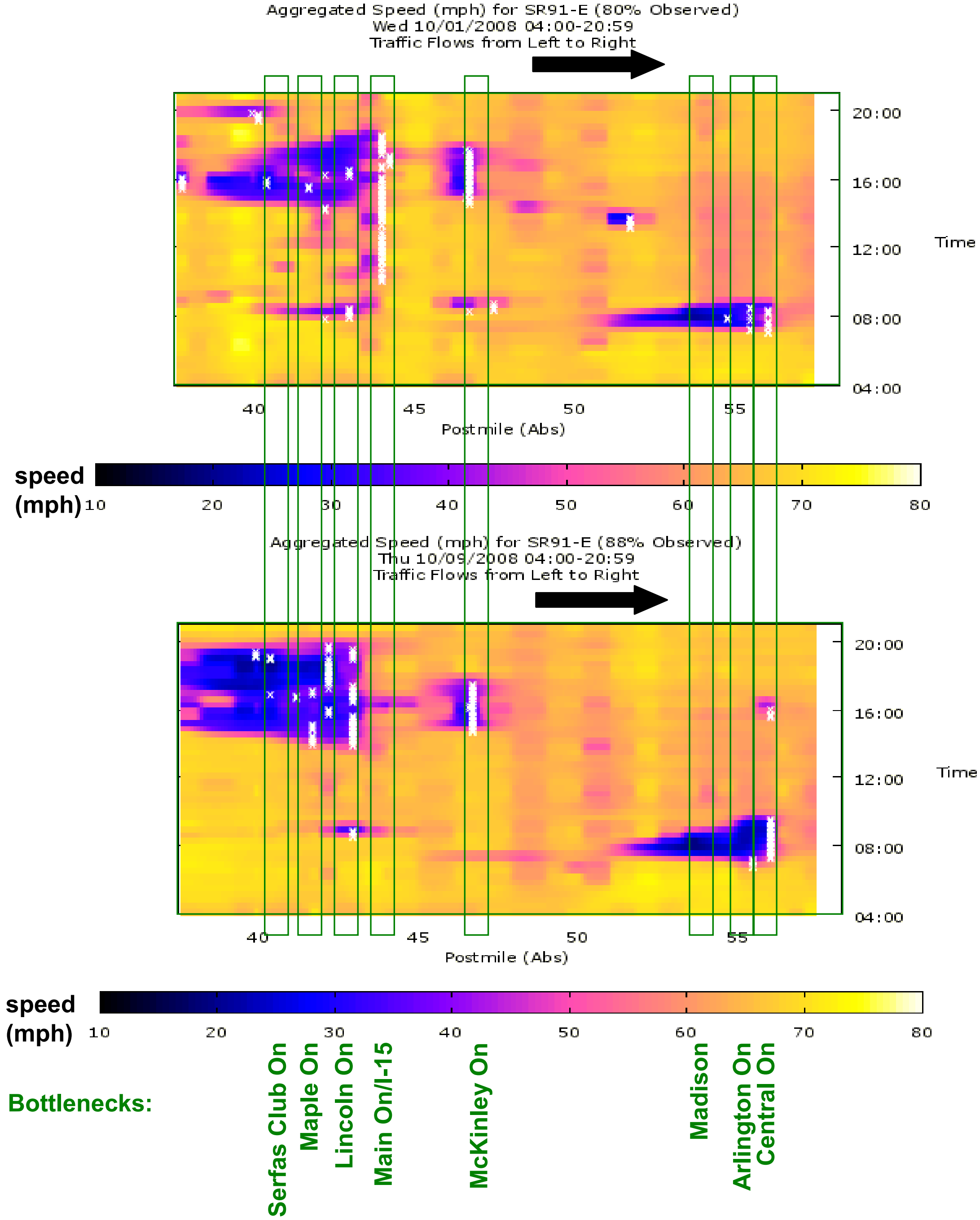


Exhibit 3C-10: Eastbound SR-91 Speed Profile Plots (October 9, 2008)

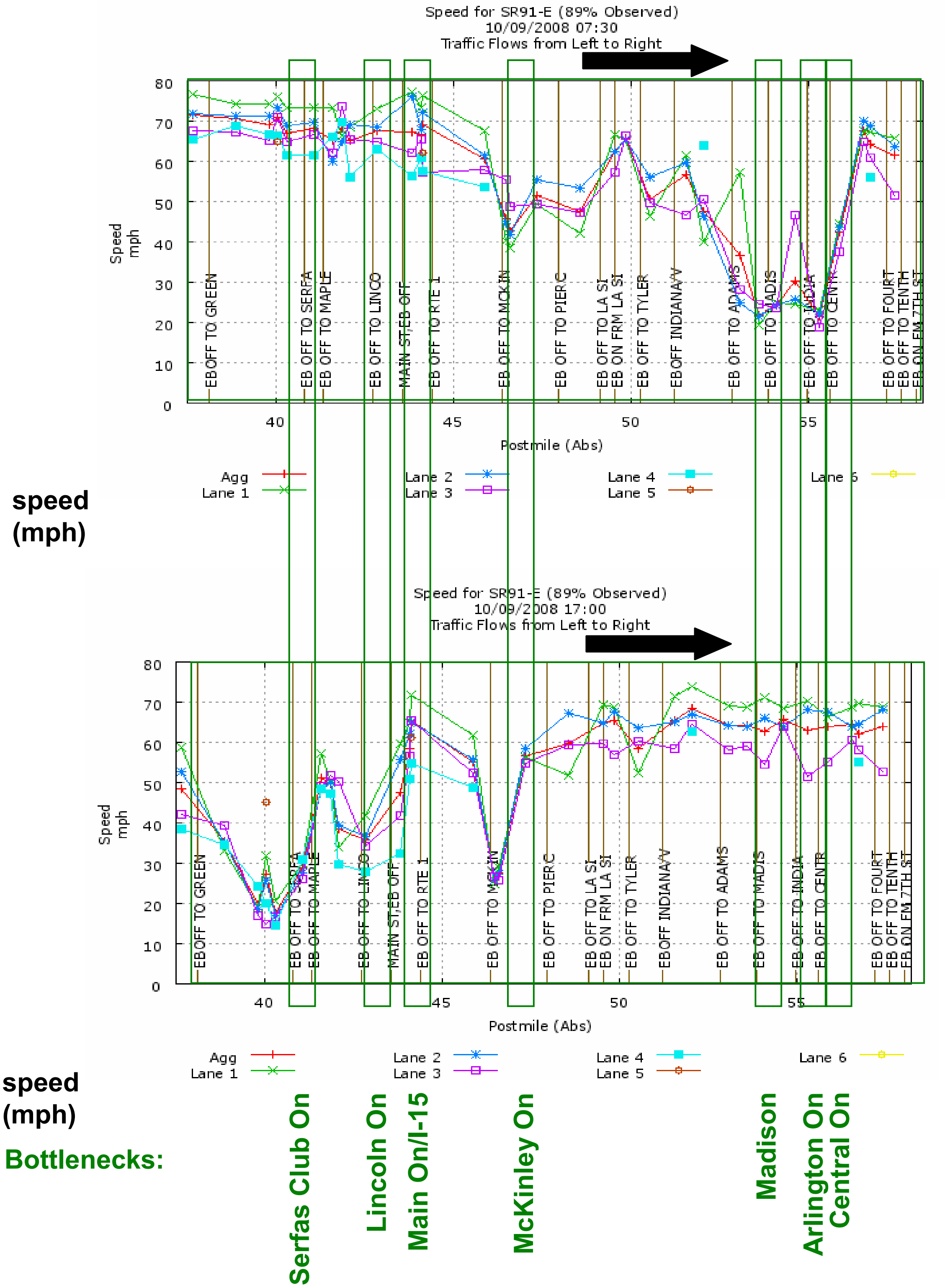
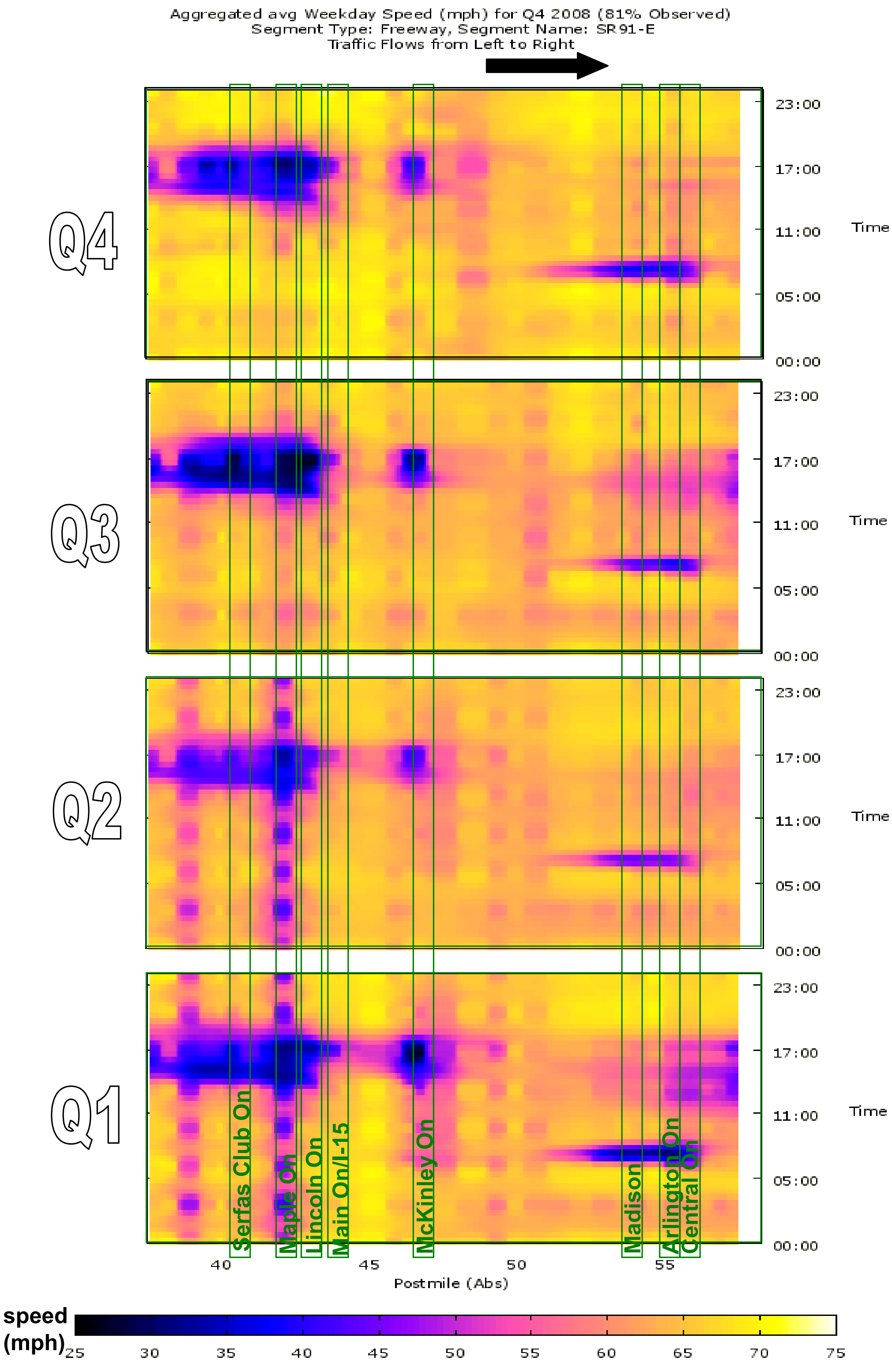


Exhibit 3C-11: Eastbound SR-91 Speed Contours (2008 Average by Quarter)



Westbound Vehicle Detector Data Analysis

Exhibit 3C-12 provides the speed contour plots for Wednesday, October 1, 2008 and Thursday, October 9, 2008 for westbound SR-91. These plots represent typical weekdays in order to highlight bottleneck locations and the resulting congestion. The vertical axis shows the time from 4 AM to 9 PM, while the horizontal axis shows the postmiles from the I-215 interchange to the Orange County Line. Exhibit 3C-13 shows the October 9, 2008 speed profile plots for two time slices in the westbound direction (8 AM and 5 PM).

Exhibit 3C-14 illustrates the weekday averages by each quarter of 2008. Again, the same bottleneck locations are identified, further validating the recurring pattern of the bottleneck locations.

As indicated from Exhibits 3C-12 through 3C-14, the following potential major westbound bottlenecks were identified from the PeMS data plots:

- Fourteenth On (PM)
- Arlington On (PM)
- Pierce On (AM and PM)
- I-15/School On/Lincoln (AM)
- Serfas Club On (AM).

Exhibit 3C-12: Westbound SR-91 Speed Contour Plots (October 2008)

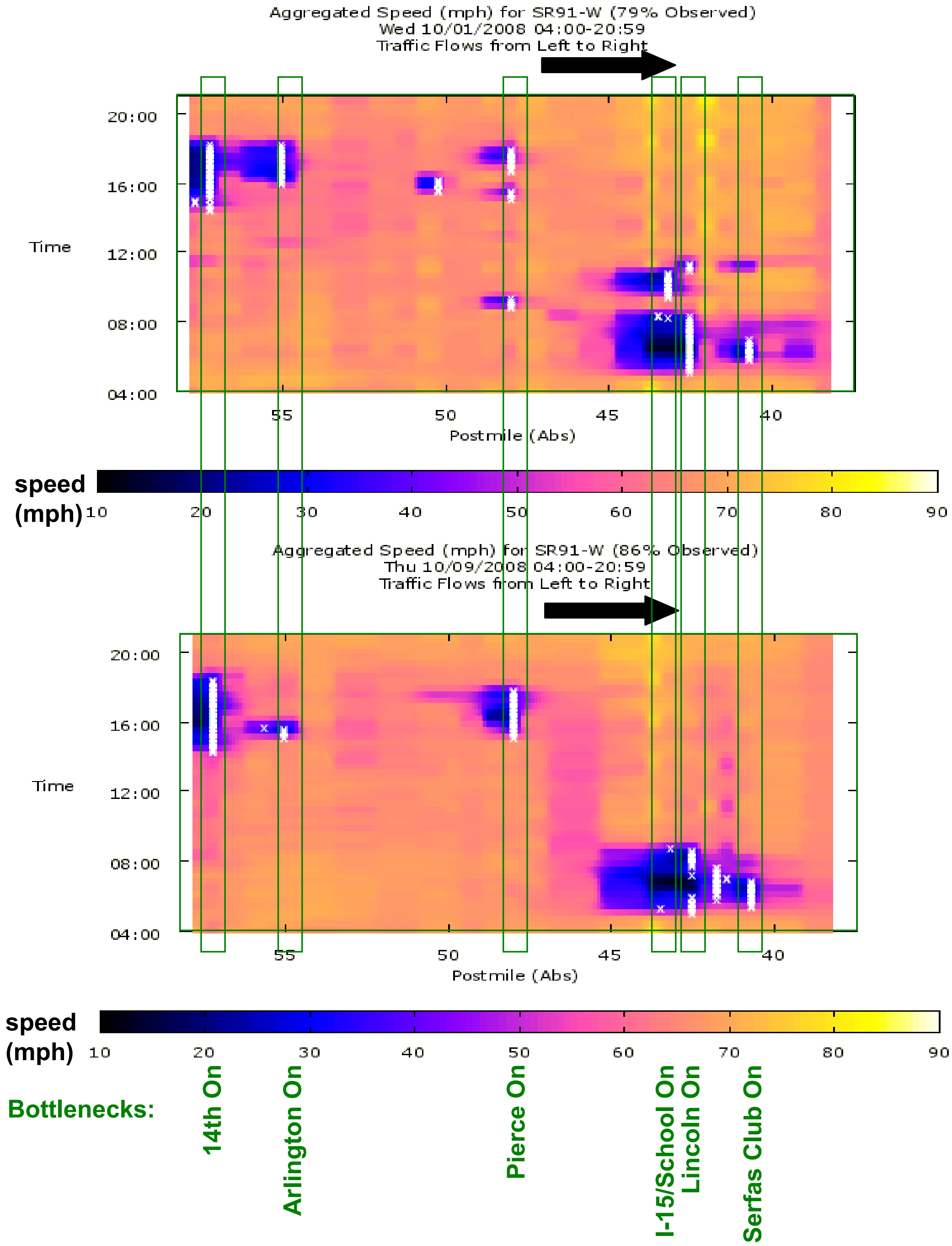


Exhibit 3C-13: Westbound SR-91 Speed Profile Plots (October 9, 2008)

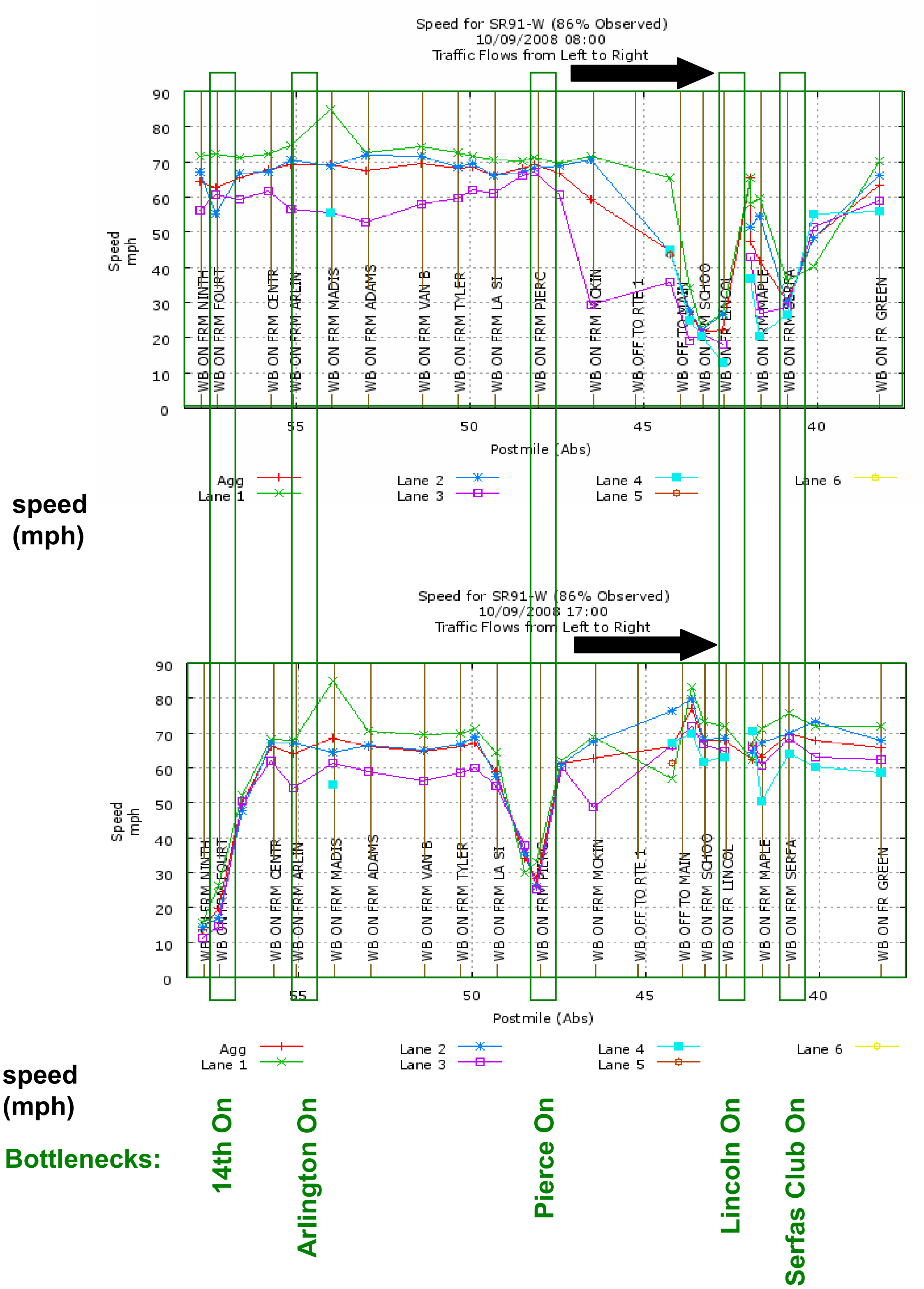
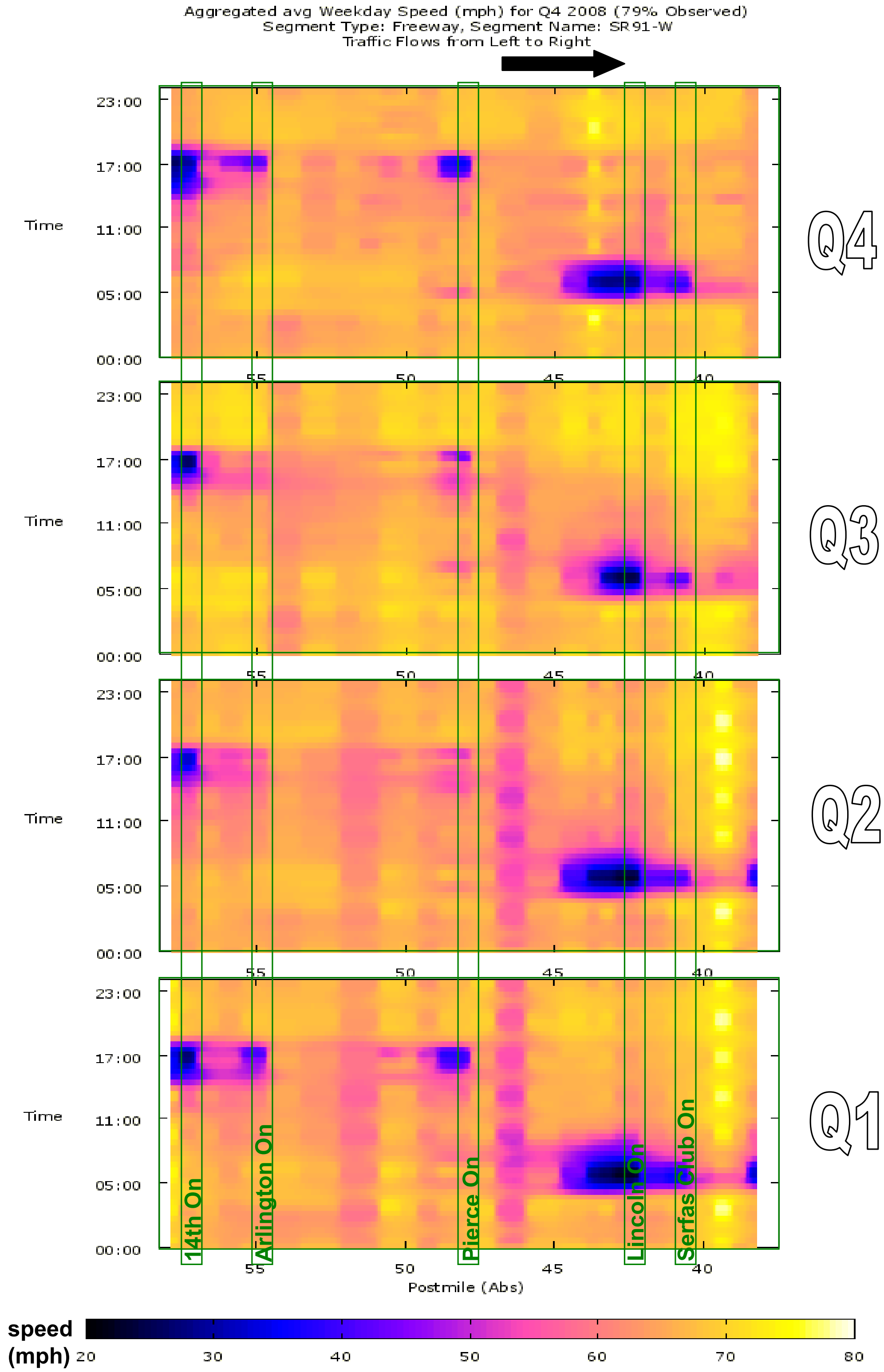


Exhibit 3C-14: Westbound SR-91 Speed Contours (2008 Average by Quarter)



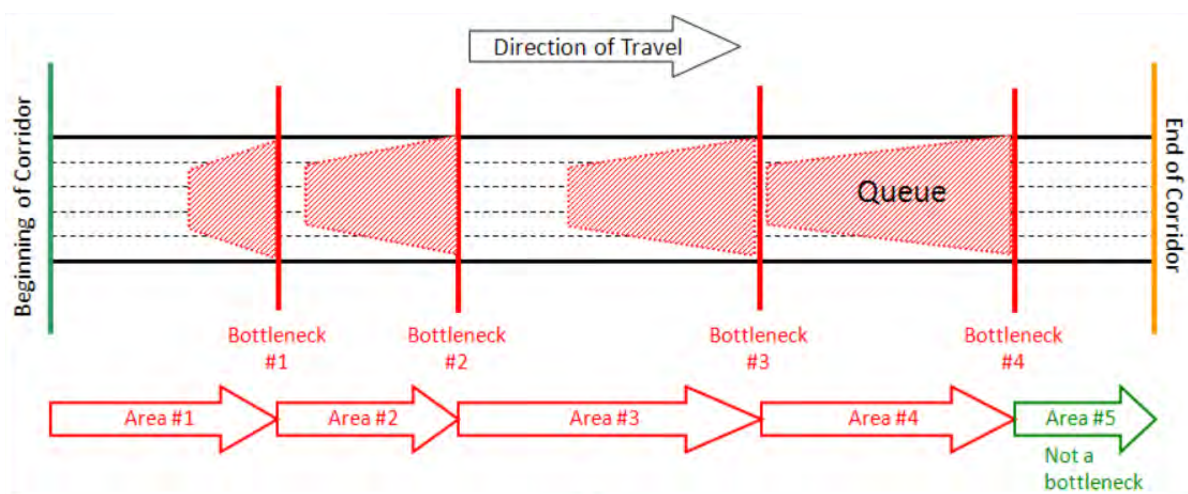
Bottleneck Area Performance

Once the bottlenecks were identified, the corridor was divided into "bottleneck areas." Bottleneck areas represent segments defined by one major bottleneck (or a number of smaller ones). By segmenting the corridors into these bottleneck areas, the performance statistics 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 the corridor performance can be gauged. The performance statistics that lend themselves to such segmentation include:

- Delay
- Productivity
- Safety.

The analysis of bottleneck areas is based on 2008 data and limited to the mainline lanes due to the limited detection available on the HOV lanes. Based on this approach, the study corridor comprises several bottleneck areas, which are different by direction. Exhibit 3C-15 illustrates the concept of bottleneck areas. They represent the area from one bottleneck to the one upstream. The actual queues formed at the bottlenecks may have different lengths than the bottleneck areas. The red vertical lines in the exhibit represent the bottleneck locations and the arrows represent the bottleneck areas.

Exhibit 3C-15: Dividing a Corridor into Bottleneck Areas

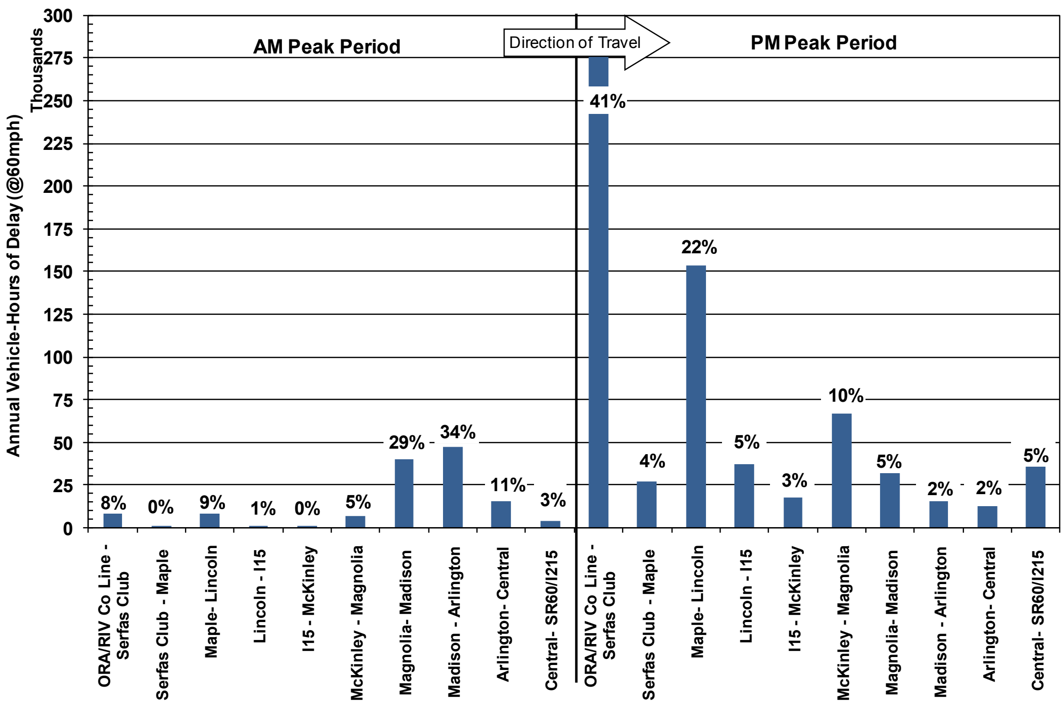


Mobility by Bottleneck Area

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

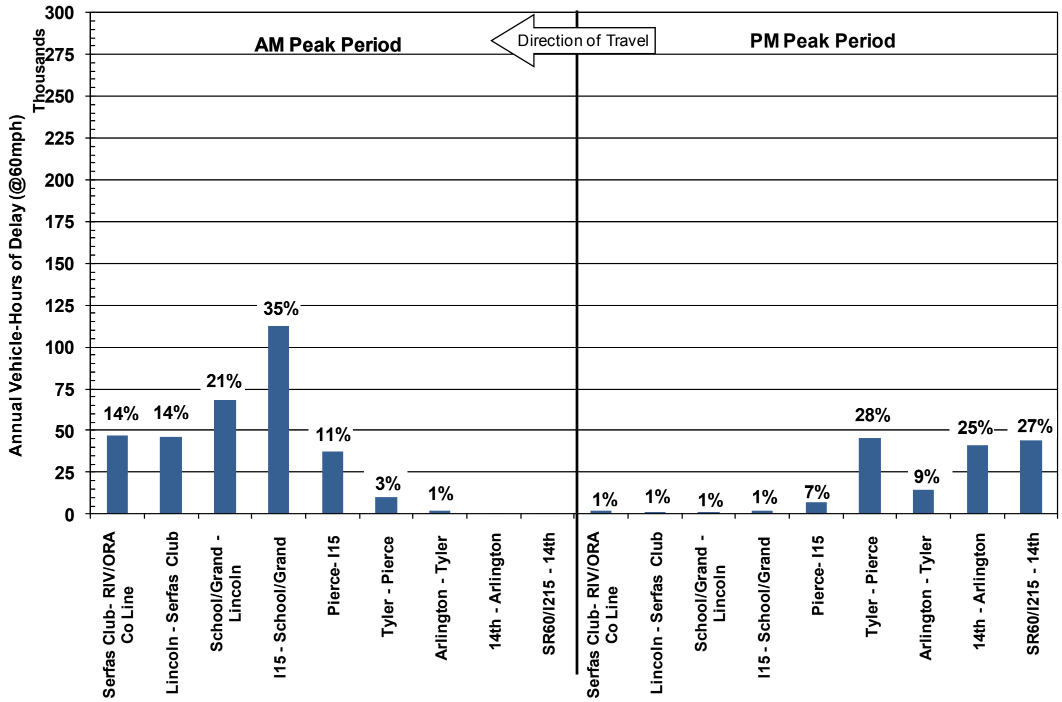
Exhibits 3C-16 and 3C-17 illustrate the vehicle-hours of delay experienced by each bottleneck area. These exhibits again illustrate the directional pattern of travel on SR-91. As depicted in Exhibit 3C-16, delay in the eastbound direction is concentrated in the PM peak with more than four times the delay than in the AM peak. The bottleneck area between the County Line and Serfas Club Drive experienced the greatest delay in the eastbound direction with roughly 280,000 annual vehicle-hours of delay, or 41 percent of the corridor's delay during the PM peak. As expected, Exhibit 3C-17 shows that delay in the westbound direction is concentrated in the AM peak. The westbound AM peak experienced more than twice the delay of the PM peak. During the AM peak, the bottleneck area between I-15 and School Street/Grand Boulevard experienced the greatest westbound delay with almost 113,000 annual vehicle-hours of delay (35 percent), followed by the bottleneck area from School/Grand to Lincoln (21 percent).

Exhibit 3C-16: Eastbound SR-91 Annual Vehicle-Hours of Delay (2008)



Source: Vehicle detector data

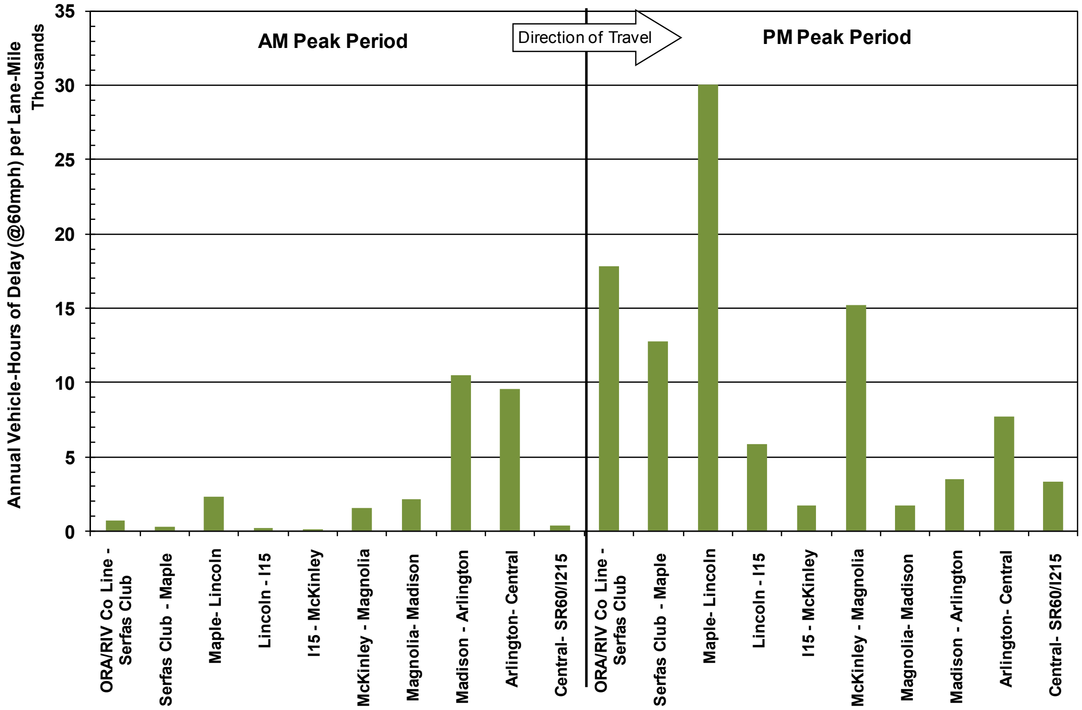
Exhibit 3C-17: Westbound SR-91 Annual Vehicle-Hours of Delay (2008)



Source: Vehicle detector data

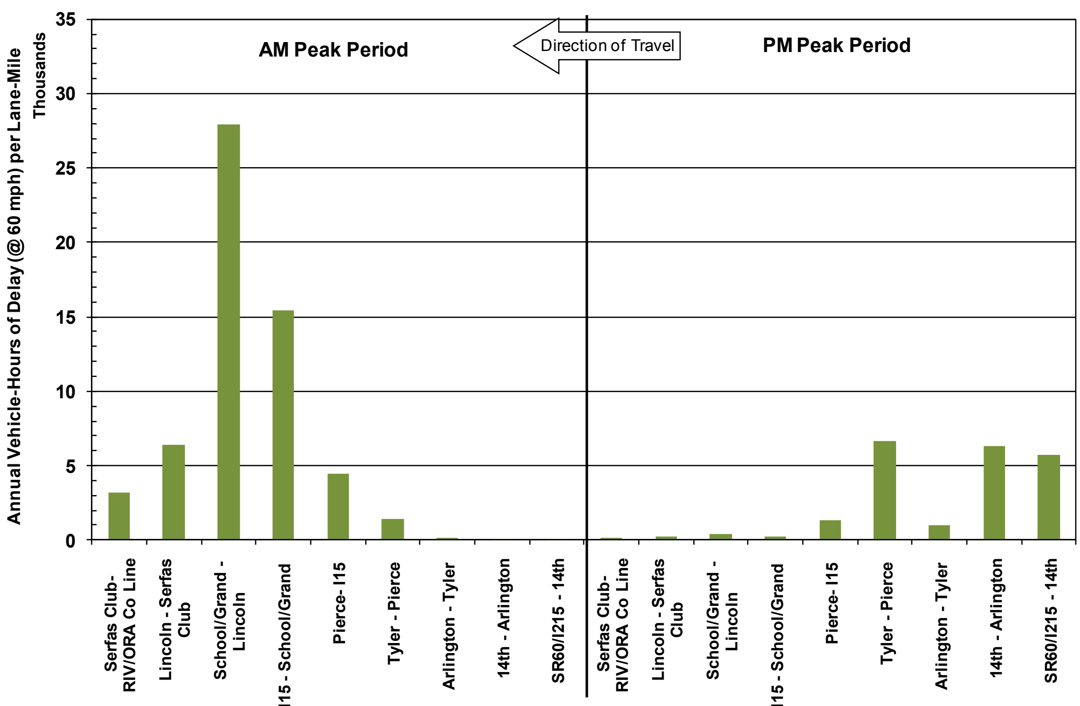
Exhibits 3C-18 and 3C-19 have been normalized to reflect delay per lane-mile. The delay calculated for each bottleneck area was divided by the total lane-miles for each bottleneck area to obtain delay per lane-mile. The results of these exhibits reveal different delay results than Exhibits 3C-16 and 3C-17. In the eastbound direction (Exhibit 3C-18), the bottleneck areas from Maple to Lincoln was the segment that experienced the highest delay per lane mile during the PM peak. This is different from the delay illustrated in Exhibit 3C-16, which shows that the highest delay occurred between the County Line and Serfas Club Drive. Similarly, during the AM peak in the westbound direction (Exhibit 3C-19), the bottleneck area from School/Grand to Lincoln experienced the highest delay per lane-mile, which differs from the delay illustrated in Exhibit 3C-17 that identified I-15 to School Street/Grand Boulevard as the segment with the highest delay.

Exhibit 3C-18: Eastbound SR-91 Delay per Lane-Mile (2008)



Source: Vehicle detector data

Exhibit 3C-19: Westbound SR-91 Delay per Lane-Mile (2008)



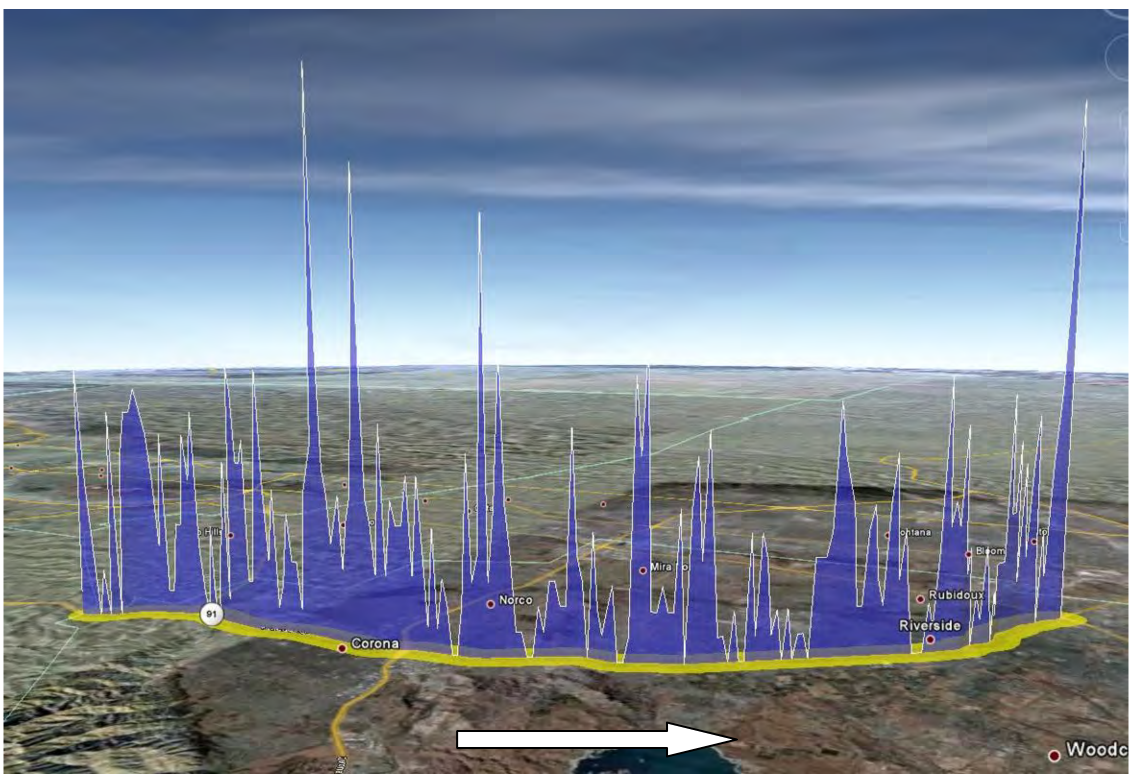
Source: Vehicle detector data

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.

Exhibit 3C-20 shows the location of all collisions plotted along the corridor in the eastbound direction. The spikes show the total number of collisions (fatality, injury, and property damage only) that occurred within 0.1-mile segments in 2008. The highest spike corresponds to roughly 23 collisions in a single 0.1-mile location. The size of the spikes is a function of how collisions are grouped.

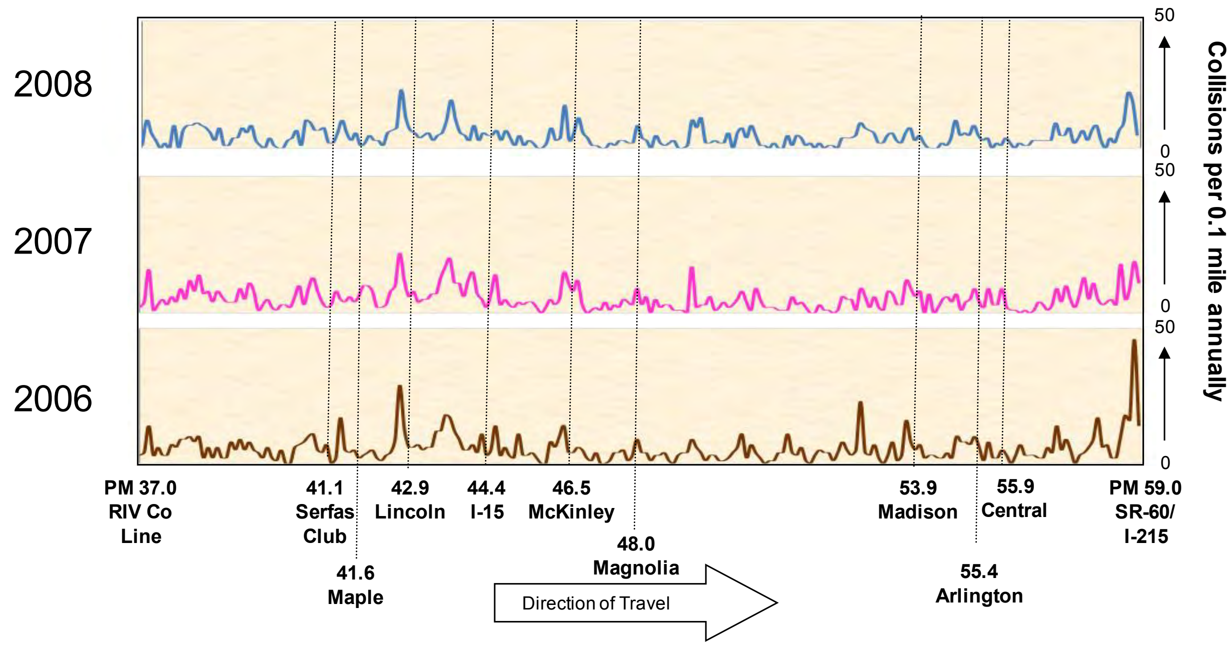
Exhibit 3C-20: Eastbound SR-91 Collision Locations (2008)



Source: TASAS

Exhibit 3C-21 illustrates the same data for the three-year period between 2006 and 2008. The vertical lines in the exhibit separate the corridor by bottleneck area. Spikes were noticeable around Lincoln Avenue (PM 42.9), at McKinley Street (46.5), around Adams Street (PM 52.8), and at the SR-60/I-215 interchange (PM 58.8). In addition to being high-collision locations, Lincoln Avenue and McKinley Street are bottleneck locations as well. The exhibit also shows that the pattern of collisions has stayed fairly consistent from one year to the next with a slight decline from 2006 to 2008.

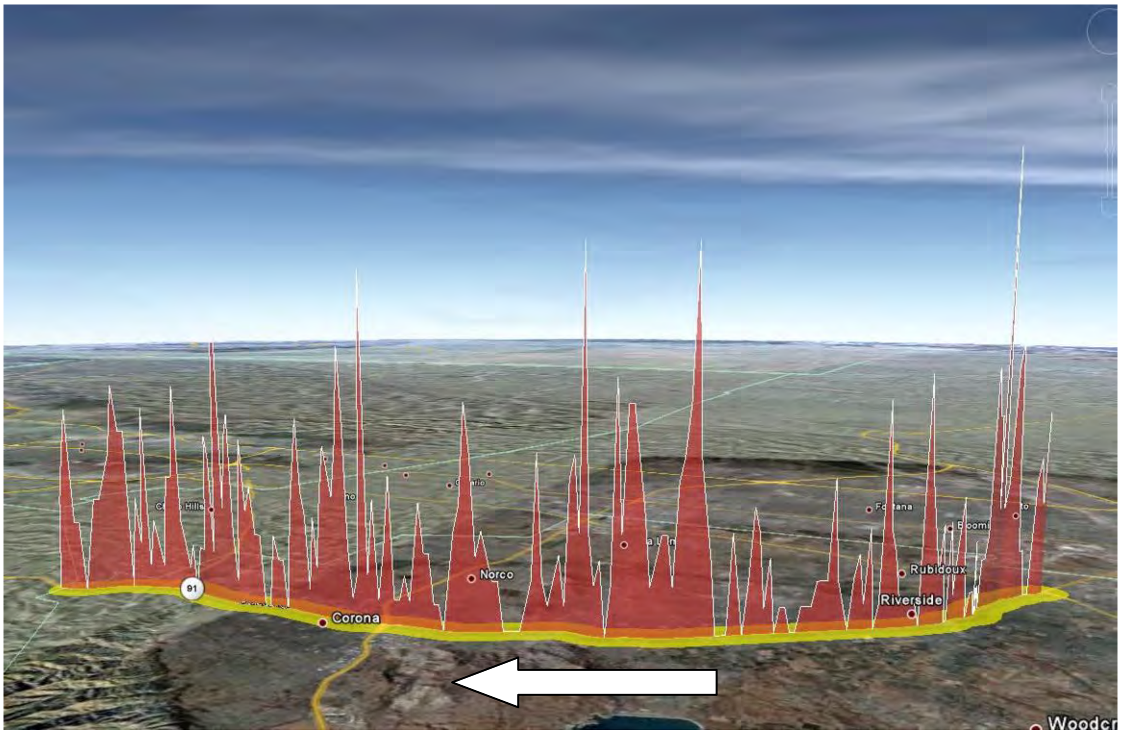
Exhibit 3C-21: Eastbound SR-91 Location of Collisions (2006-2008)



Source: TASAS

Exhibit 3C-22 shows the same 2008 collision data for the SR-91 in the westbound direction. The largest spike in this exhibit corresponds roughly to 19 collisions per 0.1 miles. The westbound direction did not experience as many accidents as the eastbound direction.

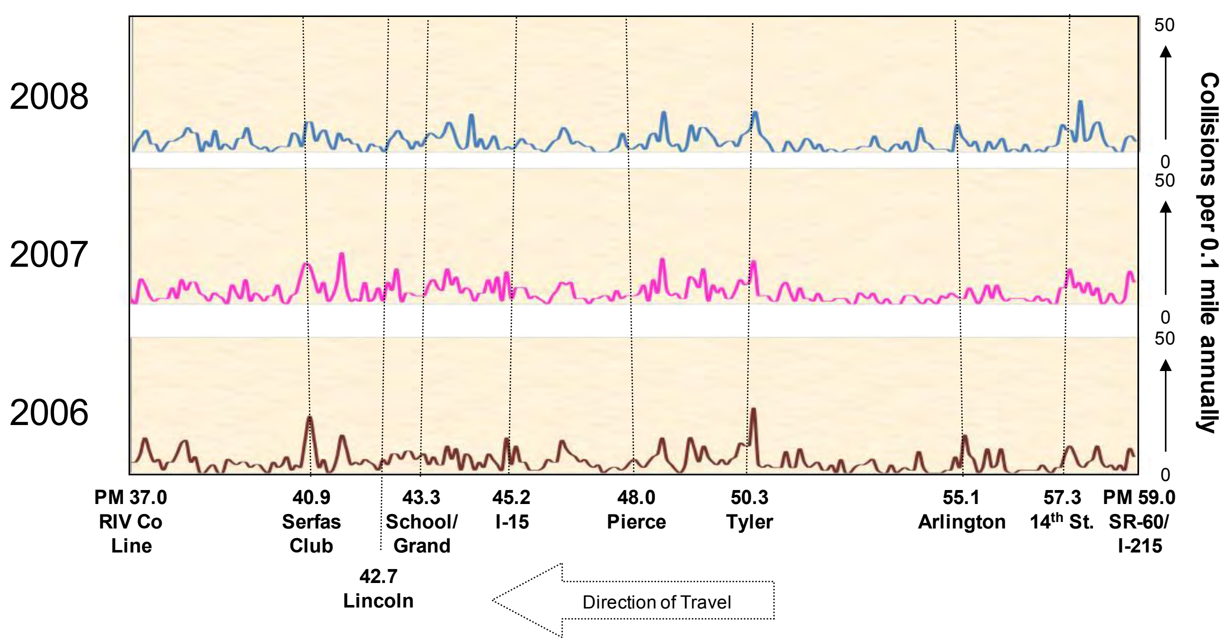
Exhibit 3C-22: Westbound SR-91 Collision Locations (2008)



Source: TASAS

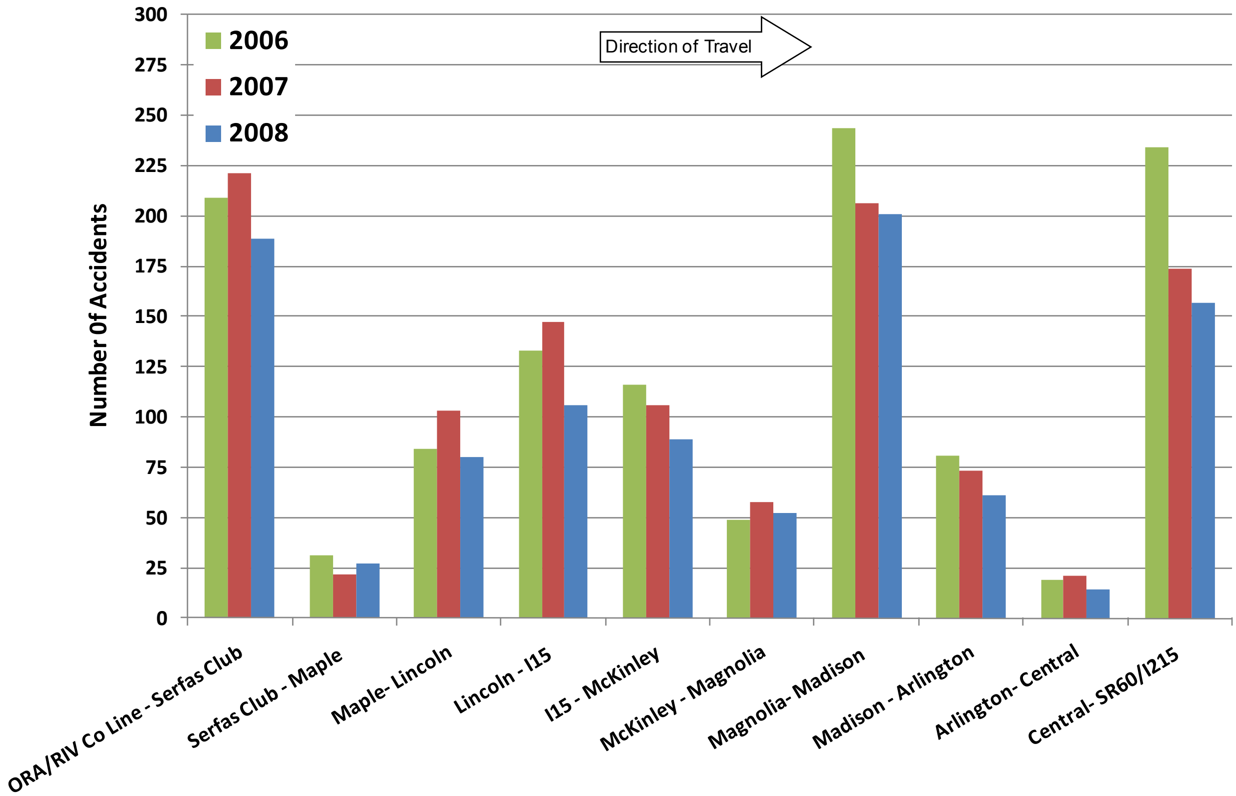
Exhibit 3C-23 shows the trend of collisions for the westbound direction from 2006 to 2008 period. The pattern of collisions has been fairly steady from one year to the next. The high accident locations depicted in Exhibit 3C-22 existed in the preceding years. Moving westbound, these locations are near Tyler Street (PM 50.3); at Serfas Club Drive (PM 40.9); and at the Riverside/Orange County line (PM 37.0). These high-collision locations are also bottleneck locations.

Exhibit 3C-23: Westbound SR-91 Collision Locations (2006-2008)



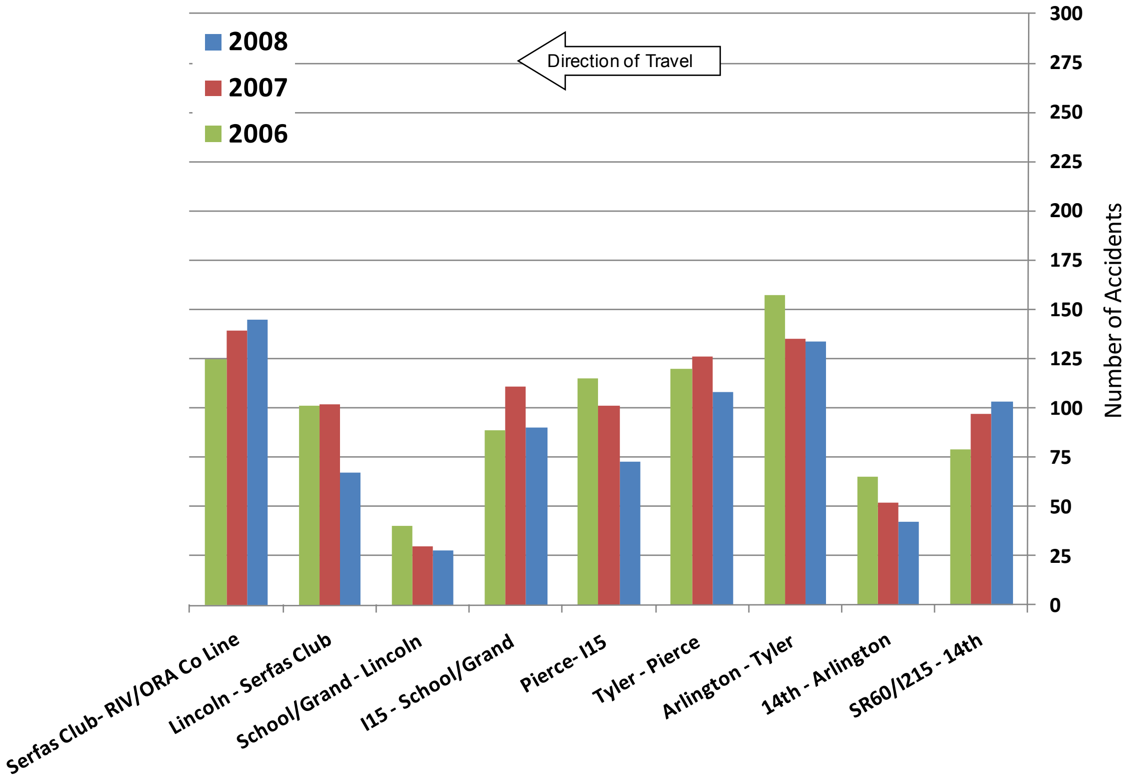
Source: TASAS

Exhibits 3C-24 and 3C-25 report the number of accidents annually from 2006 to 2008 by bottleneck area. The number of total accidents generally decreased from 2006 to 2007 and 2008 in both directions. In the eastbound direction, the areas from the County Line to Serfas Club Drive and from Magnolia to Madison experienced the most accidents in 2007 and 2008 with 190 and 200, respectively. In the westbound direction, the areas from Arlington to Tyler and from Serfas Club Drive to the County Line exhibited the most accidents with around 130 and 145, in 2007 and 2008, respectively.



Source: TASAS

)



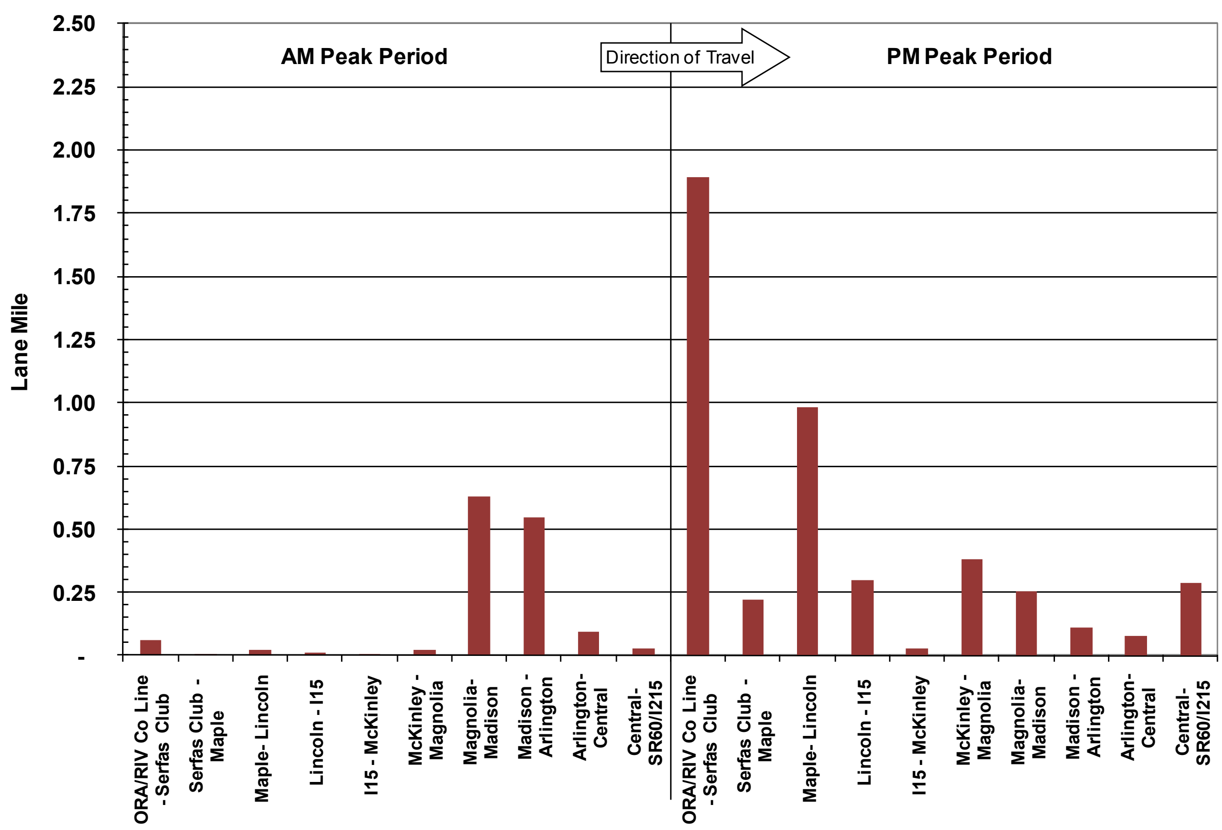
Source: TASAS

Productivity by Bottleneck Area

As previously discussed, 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 3C-26 and 3C-27 show the productivity losses for both directions of the corridor. In the eastbound direction, the bottleneck area between the County Line and Serfas Club Drive experienced the worst productivity of all the segments on the corridor with over 1.75 lost lane-miles in the PM peak. During the AM peak period, the eastbound direction experienced relatively high levels of productivity with most segments experiencing less than 0.75 lost lane-miles.

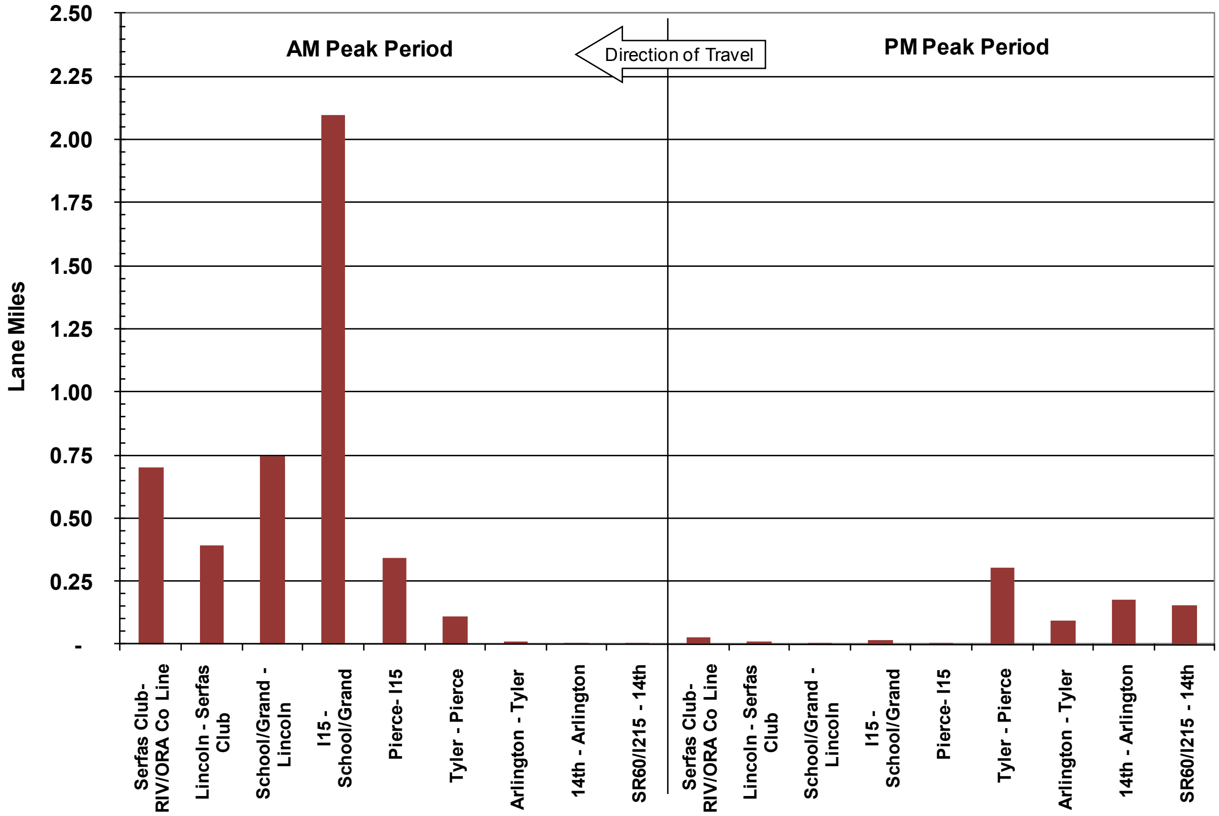
Exhibit 3C-26: Eastbound SR-91 Lost Lane-Miles (2008)



Source: Vehicle detector data

In the westbound direction, the bottleneck area between I-15 and School/Grand experienced the greatest productivity loss during the AM peak with over 2.0 lost lane-miles. Note that the segments of the corridor with the highest productivity losses are the same segments that experienced the highest levels of annual vehicle-hours of delay (refer to Exhibits 3C-16 and 3C-15).

Exhibit 3C-27: Westbound SR-91 Lost Lane-Miles (2008)



Source: Vehicle detector data

Bottleneck Causality

Bottlenecks are the location of corridor performance degradation and resulting congestion and lost productivity. It is important to verify the specific location and cause of each major bottleneck to determine appropriate solutions to traffic operational problems. By definition (HCM2000), a bottleneck is a road element in which traffic demand exceeds the capacity of the roadway facility. In other words, a location where traffic demand able to reach a section of roadway is greater than the section can handle, because there are too many vehicles or not enough road, or both (*Caltrans Freeway Operations Academy Manual*). In most cases, the cause of bottlenecks is related to a sudden reduction in capacity (such as roadway geometry, heavy merging and weaving, and driver distractions) or a surge in demand (from ramps or connectors) that the facility cannot accommodate.

For the SR-91 Corridor, field observations were conducted on multiple days (midweek) in November and December 2008, and January 2009, during the AM and PM peak period. Major bottleneck locations initially identified were verified and their causes identified.

Mainline Facility

<u>*Eastbound Bottlenecks and Causes*</u>

Major eastbound bottlenecks and congestion occur mostly during the PM peak period with several during the AM peak period. The following is a summary of the eastbound bottlenecks and the identified causes.

Serfas Club Drive Off/On

Exhibit 3C-28 is an aerial photograph of the SR-91 mainline at the Serfas Club Drive interchange. During the PM peak period, traffic congestion was observed at this location during field reviews. Queuing extended as far back as west of SR-71. However, the congestion can also be attributed to the lane drop at the SR-71 interchange. The merging and weaving, and the lane drop are likely to be the cause of this congestion at this location. A fifth lane, added from the SR-71 ends (or drops) at the Serfas Club Drive off-ramp. Vehicles are seen merging back onto the mainline just short of the off-ramp location. In addition, the mainline is at capacity, past the lane drop, such that the additional traffic from the Serfas Club Drive on-ramp cannot be accommodated, resulting in the bottleneck. Also, the cross weaving of this on-ramp traffic with the Maple Street off-ramp traffic contributes to the bottleneck. As indicated from the inset photograph, ramp metering operation was not observed during the peak period on any of the field site visits.

Exhibit 3C-28: Eastbound SR-91 at Serfas Club Drive On

<u>Maple Street On</u>

Exhibit 3C-29 is an aerial photograph of the SR-91 mainline at the Maple Street on-ramp. During the PM peak period, bottleneck and traffic congestion was observed at this location during field visits. Merging and weaving are likely to be the cause of this bottleneck. Ramp metering operation was not observed during the peak period on any of the field site visits.

Exhibit 3C-29: Eastbound SR-91 at Maple Street On

<u>Lincoln Avenue On</u>

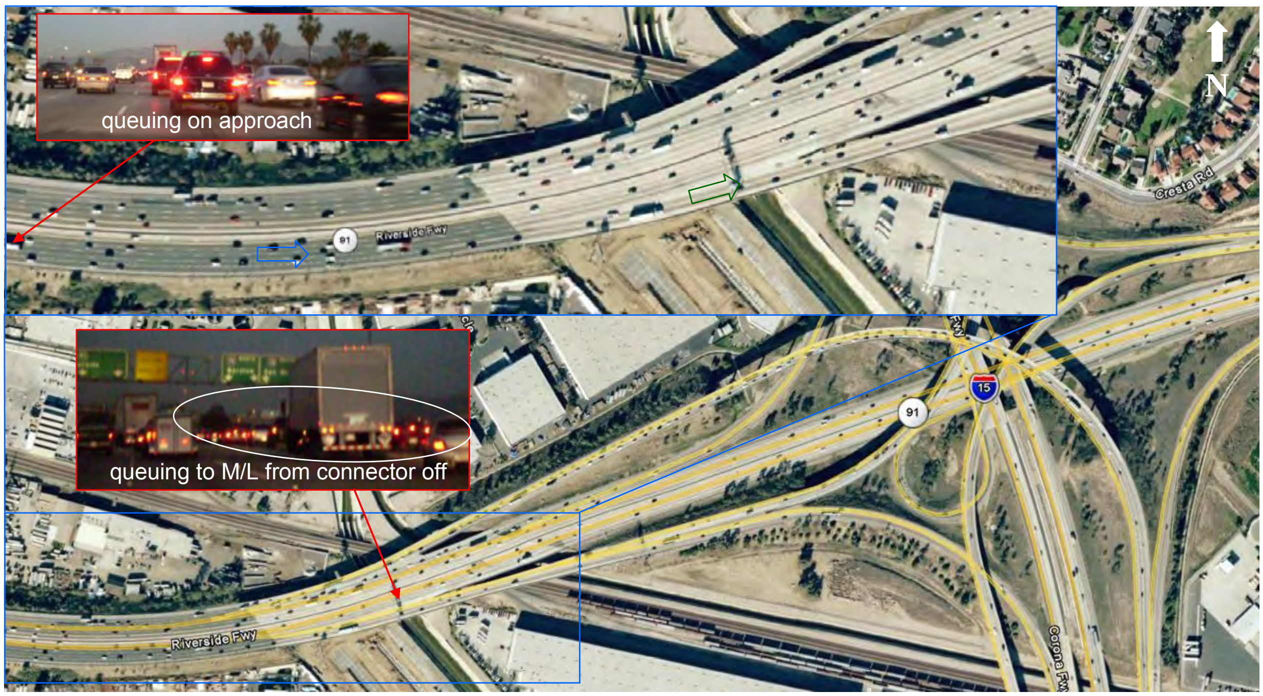
Exhibit 3C-30 is an aerial photograph of the SR-91 mainline at the Lincoln Avenue interchange. During the PM peak period, a bottleneck was observed at this location during the field reviews, as evident in the inset photographs. It is likely that the ramp merging is the cause of this bottleneck. Note that ramp metering was operational during all of the site visits as shown in one of the inset photographs. This is likely to have decreased the impact of the merging.

Exhibit 3C-30: Eastbound SR-91 at Lincoln Avenue On

I-15 Connectors (East-North & East-South)

Exhibit 3C-31 is an aerial photograph of the SR-91 connectors to I-15. As shown in the inset photographs, queuing from the I-15 connector traffic was observed backing onto the SR-91 mainline and causing congestion. This is due to the heavy demand for southbound I-15. Cross weaving from the heavy Main Street on-ramp traffic contributes to the condition.

Exhibit 3C-31: Eastbound SR-91 at the East-North & East-South I-15 Connectors



I-15 Connectors (South-East & North-East)

Exhibit 3C-32 is an aerial photograph of eastbound SR-91 at the I-15 Interchange. During the PM peak period, traffic congestion was observed during the field site visits. The congestion was primarily due to the lane drop that occurs at the South-East Connector, compounded by the uphill grade and the North-East Connector/auxiliary lane termination at the McKinley Street exit.

Exhibit 3C-32: Eastbound SR-91 at the South-East I-15 Connectors

<u>McKinley Street On</u>

Exhibit 3C-33 is an aerial photograph of the eastbound SR-91 at the McKinley Street on-ramps. As shown, merging from consecutive on-ramps is likely to be the cause of this bottleneck. The uphill grade contributes to this condition. Significant bottleneck and congestion were observed during the field site visits.

Exhibit 3C-33: Eastbound SR-91 at McKinley Street On

<u>Magnolia Avenue On</u>

Exhibit 3C-34 is an aerial photograph of eastbound SR-91 at the Magnolia Avenue on-ramp. During the PM peak period, minor traffic congestion was observed at this location during the field visits. On days when mainline demand is higher, the impact of this bottleneck to the mainline traffic condition is likely to be much more significant.

Exhibit 3C-34: Eastbound SR-91 at Magnolia Avenue On

<u>Madison Street Interchange</u>

Exhibit 3C-35 is an aerial photograph of eastbound SR-91 at the Madison Street Interchange. As shown in the inset photograph, significant traffic congestion and queuing is evident while approaching the interchange. This is due primarily to the lane drop, as shown in the exhibit. About half mile west of this location, the High Occupancy Vehicle (HOV) lane ends and continues on as the new mixed-flow number one lane and the outermost lane is dropped at this location, as shown in the inset photograph.

Traffic congestion and a bottleneck during the AM peak period were observed during the site visits. Further west at three lanes plus the HOV lane can accommodate this traffic. When the capacity is reduced to only three mixed-flow lanes, the demand exceeds the threshold level and breaks down, resulting in a bottleneck. East of the bottleneck location, volumes are normalized below the threshold level and speeds increase.

Exhibit 3C-35: Eastbound SR-91 at Madison Street Interchange

<u>Arlington Avenue On</u>

Exhibit 3C-36 is an aerial photograph of eastbound SR-91 at the Arlington Avenue on-ramp. During the AM peak period, traffic congestion and a bottleneck were observed during the site visits.

In addition, the roadway geometrics with the varying grade, horizontal curves, and short auxiliary lane, are likely to impact the capacity values. Significant congestion and queuing is shown in the inset photographs approaching the interchange and at the bottleneck location. East of the bottleneck location, increasing speeds are observed.

Exhibit 3C-36: Eastbound SR-91 at Arlington Avenue On

<u>Central Avenue On</u>

Exhibit 3C-37 is an aerial photograph of eastbound SR-91 at the Central Avenue on-ramp. During the AM peak period, traffic congestion was observed during the site visits. Heavy merging from the ramp was observed, likely to be the cause of the bottleneck. In addition, the roadway geometrics with the varying grade and roadway horizontal curve are also likely to impact the capacity values. Significant queuing was observed as evident in the inset photographs approaching the interchange and at the bottleneck location.

Exhibit 3C-37: Eastbound SR-91 at Central Avenue On

Westbound Bottlenecks and Causes

Major westbound bottlenecks and congestion occur mainly during the AM peak period, with several during the PM peak. The causes of these bottleneck locations are summarized below.

Mission Inn Avenue

The SR-91/SR-60/ I-215 Interchange reconstruction was completed and open to traffic in December 2008. With the new interchange and vertical grade correction, additional lanes from the northbound and southbound I-215 connectors to westbound SR-91 were added. These additional lanes terminate near the Mission Inn Avenue interchange from as many as five lanes down to three, creating a bottleneck. The total combined demand cannot be accommodated by the reduced lanes.

Fourteenth Street On

Exhibit 3C-38 is an aerial photograph of the westbound SR-91 mainline at the Fourteenth Street on-ramp. During the PM peak period, traffic congestion was observed during the site visits. Significant queuing was also observed, as evident in the inset photographs approaching the interchange and at the bottleneck location. Just past the bottleneck location, increasing speeds were observed.

Exhibit 3C-38: Westbound SR-91 at Fourteenth Street On

Arlington Avenue On

Exhibit 3C-39 is an aerial photograph of the westbound SR-91 mainline at the Arlington Avenue on-ramp. Although not a significant bottleneck in terms of congestion and delay it causes on a regular basis, congestion and queuing was observed at the on-ramp merge location during the PM peak period.

Exhibit 3C-39: Westbound SR-91 at Arlington Avenue On

<u>Pierce Street</u>

Exhibit 3C-40 is an aerial photograph of the westbound SR-91 mainline at Pierce Street and Magnolia Avenue. During the PM peak period, traffic congestion was observed during the site visits. With the roadway horizontal curvature and vertical profile, sight distance is affected. Compounded by heavy ramp merge at the crest, mainline flow breaks down, resulting in a bottleneck, as evident in the inset photograph. Beyond the bottleneck location, increasing speeds were observed. Roadway geometrics are likely to be the primary cause of the bottleneck at this location.

Exhibit 3C-40: Westbound SR-91 at Pierce Street On

I-15 Connectors

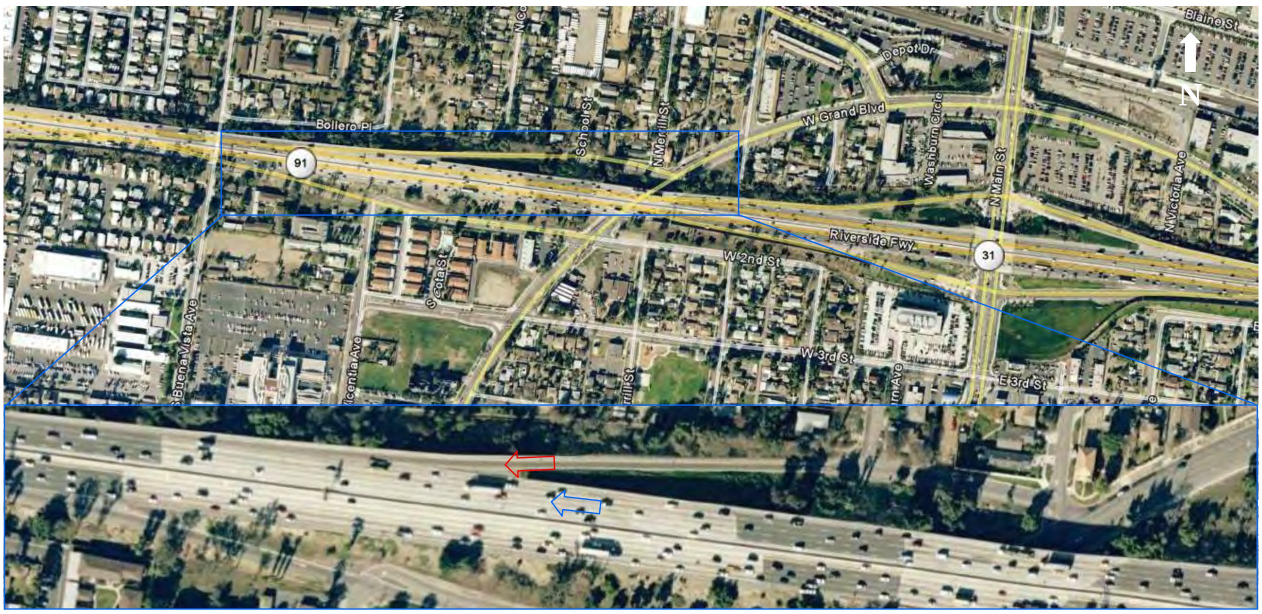
Exhibit 3C-41 is an aerial photograph of the westbound SR-91 mainline at the I-15 connectors. During the AM peak period, both I-15 connectors can add over 3,000 vph to the existing mainline traffic, sometimes overloading the facility. As indicated in the inset photograph, heavy volumes on the northbound I-15 to westbound SR-91 connector often queues back onto the I-15 mainline during the AM peak period. Also, this connector adds a fifth lane (auxiliary lane) to the mainline that ends at the Main Street exit, nearly half-mile in length. Heavy connector traffic volume was observed merging out of the auxiliary lane and into the fourth lane, near the end of the auxiliary lane. This is likely to be the primary cause of the bottleneck at this location. To compound the bottleneck condition is the weaving of the Main Street off-ramp traffic and the mainline uphill grade that slows down the traffic and increase its density.

Exhibit 3C-41: Westbound SR-91 at the I-15 Connectors

<u>School Street/Grand Blvd On</u>

Exhibit 3C-42 is an aerial photograph of westbound SR-91 at the School Street on-ramp. With the mainline at near capacity levels during the AM peak period, the merging from the School Street on-ramp is likely to be the cause of this bottleneck.

Exhibit 3C-42: Westbound SR-91 at School Street On



Lincoln Avenue On

Exhibit 3C-43 is an aerial photograph of the westbound SR-91 mainline at the Lincoln Avenue on-ramp. During the AM peak period, traffic congestion was observed at this location during site visits. The heavy ramp merging is likely to cause the mainline flow to break down, resulting in the bottleneck and traffic congestion, as evident in the inset photograph. Past the bottleneck location, increased speeds were observed.

Exhibit 3C-43: Westbound SR-91 at Lincoln Avenue On

<u>Serfas Club Drive On</u>

Exhibit 3C-44 is an aerial photograph of the westbound SR-91 mainline at the Serfas Club Drive on-ramp. During the AM peak period, the Serfas Club Drive on-ramp adds over 1,200 vph to the existing mainline traffic, increasing mainline traffic to over the threshold level and resulting in a bottleneck condition. Also, at this location, ramp metering operation was not observed during the peak period of the field site visits. Faster speeds were observed downstream of the bottleneck location.

Exhibit 3C-44: Westbound SR-91 at Serfas Club Drive On

HOV Facility

Bottleneck and causality analyses were also conducted for the SR-91 HOV lanes. Automatic detector data was the primary source for this HOV analysis. HOV lanes along the SR-91 Corridor operate on a full-time basis separated by a buffer with varying widths. It has a vehicle occupancy requirement of two plus (2+) in both directions.

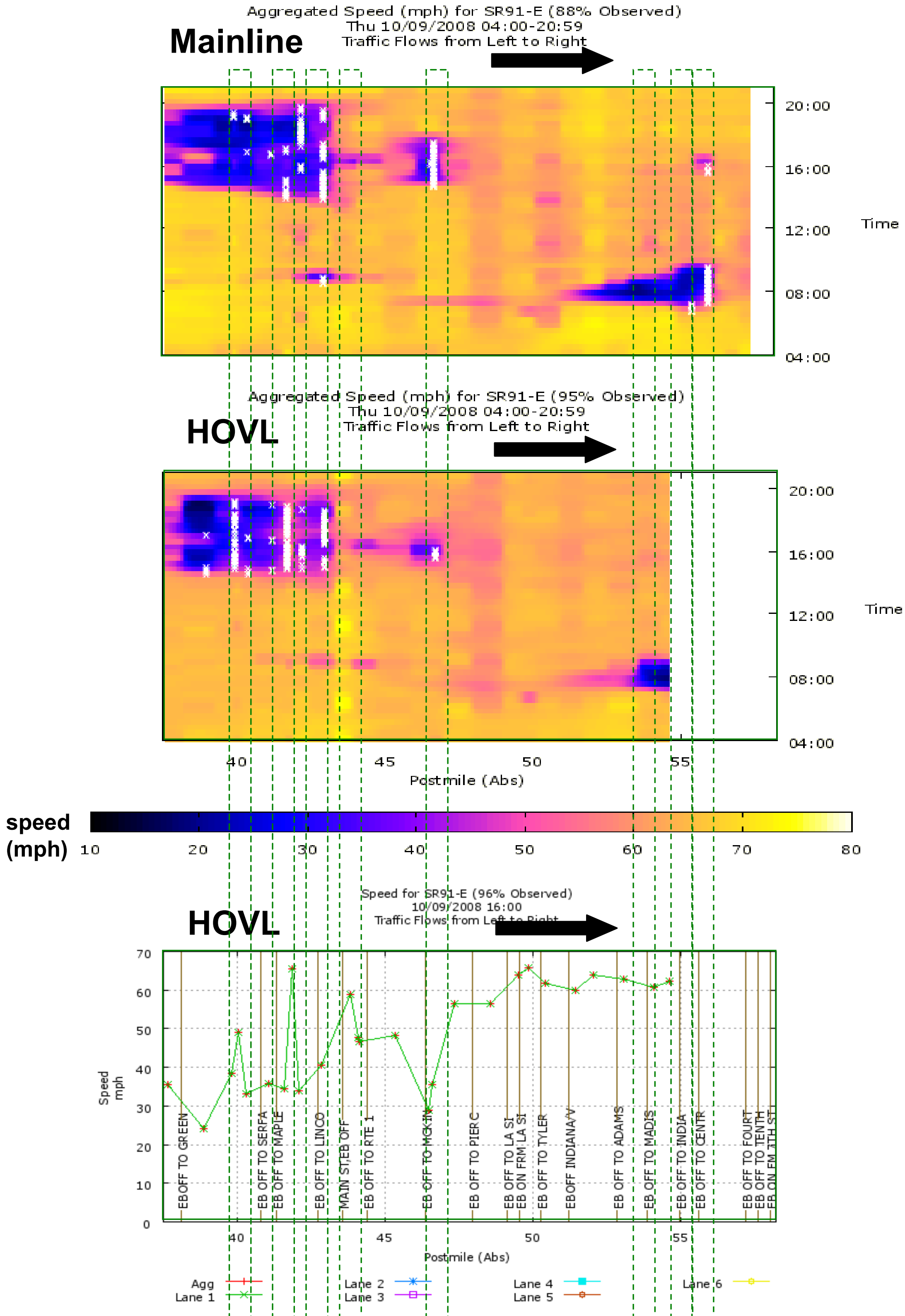
Eastbound HOV Bottlenecks and Causes

In the eastbound direction, five bottlenecks were identified at the following locations:

- Terminus of the Express Lane (Caltrans postmile R2.1)
    - This HOV bottleneck location is at the beginning of the HOV and just beyond the terminus of the HOT (Express) lane. This bottleneck is caused by single occupant vehicles (from the HOT lane) trying to exit before the HOV in the congested mainline traffic stream.
- Maple Street (Caltrans postmile 4.2)
    - These bottleneck locations are likely caused by the heavy demand on the HOV where peak volumes exceed 1,500 vph during the PM peak period. The facility cannot accommodate the volumes efficiently at these two locations. The heavy congestion on the mainline is also likely to impact the flow of the HOV lane.
- Lincoln Avenue (Caltrans postmile 5.4)
    - This bottleneck location is likely caused by the heavy demand on the HOV during the PM peak period and congestion and bottleneck on the mainline, which influences the flow on the HOV.
- Main Street ingress/egress (Caltrans postmile 6.5)
    - This bottleneck does not occur consistently or frequently but does occur on occasion, as evident from speed contour samples of multiple days. This bottleneck location is likely caused by the congestion and bottleneck on the mainline, which influences the flow on the HOV. Also traffic bound for I-15 exits the HOV into a congested mainline traffic stream and slows down the flow of the HOV.
- McKinley Street (Caltrans postmile 10.0)
    - This bottleneck location is due to the steep uphill grade affecting the flow where volume reaches 1,500 vph during the PM peak period.

Exhibit 3C-45 presents the speed contour diagram of the eastbound SR-91 mainline and HOV lane and PM peak (4PM) HOV lane speed profile diagram for weekday in October 2008. Multiple sample days and monthly averages in 2008 were reviewed. All indicated the same bottleneck locations.

Exhibit 3C-45: Eastbound SR-91 ML & HOV Speed Contour (October 2008)



Westbound HOV Bottlenecks and Causes

In the westbound direction, two bottlenecks were identified at the following locations:

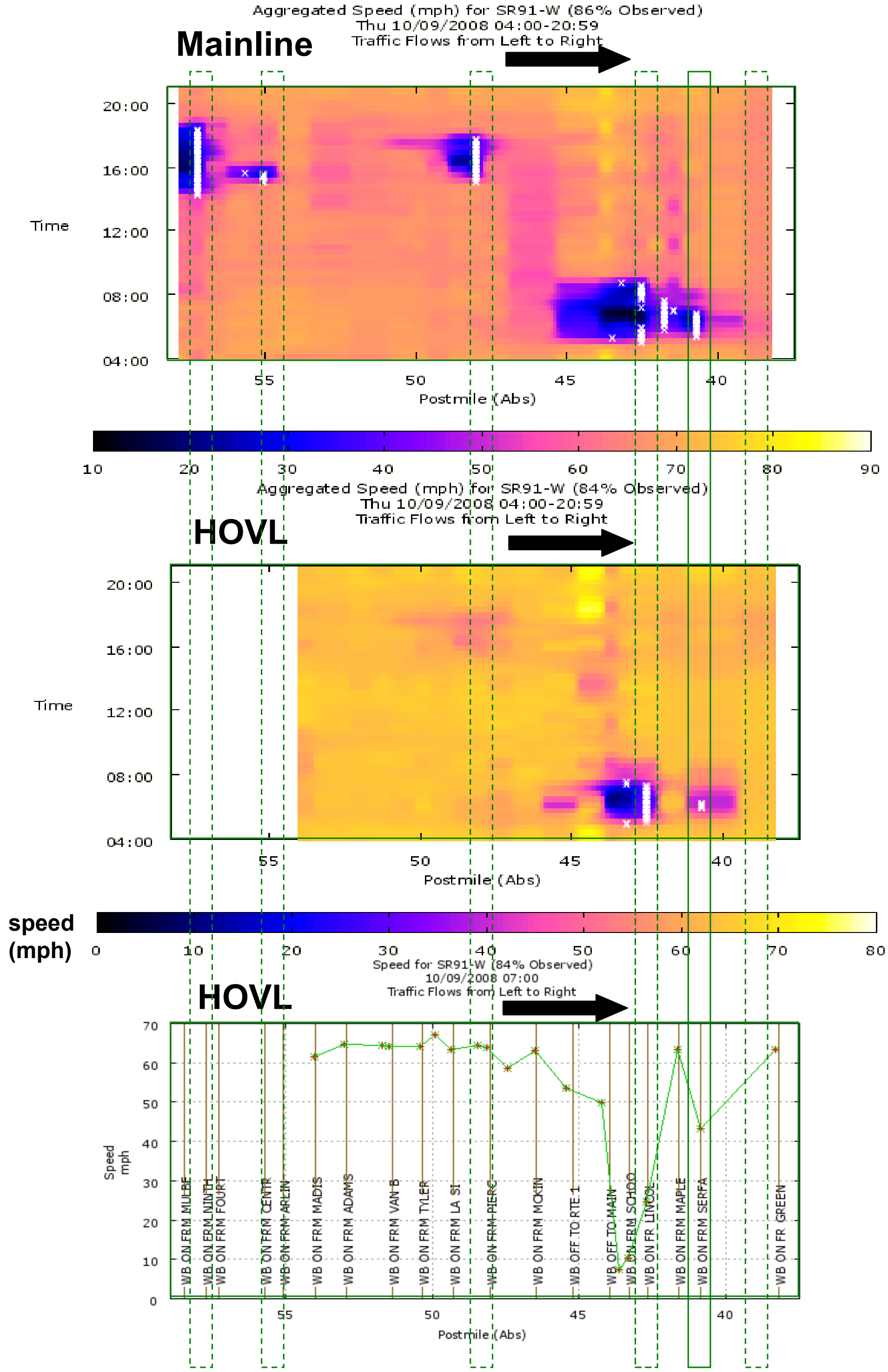
- Lincoln Avenue (Caltrans postmile 5.3)
- Serfas Club Drive (Caltrans postmile R3.5)

The Lincoln Avenue bottleneck is caused by the heavy demand on the HOV lane during the AM peak period. The congestion and bottleneck on the mainline traffic flow likely influences the HOV lane where the slow speeds on the mainline results in slower speeds on the HOV lane. The nearest ingress/egress locations are about quarter mile preceding Lincoln Avenue interchange and about half mile past Serfas Club Drive interchange. Based on field observations, it did not appear that Lincoln Avenue ingress/egress contributed to the bottleneck condition. The ingress/egress location was upstream of the bottleneck location.

The Serfas Club Drive bottleneck is a minor bottleneck with speeds rarely falling below 40 miles per hour based on detector speed data samples of multiple days. However, speeds slow to below 50 miles per hour consistently at this location. The nearest ingress/egress location is downstream of the bottleneck location, about half mile downstream of the interchange. The drop in speeds is likely caused by the congestion and much slower speeds of the adjacent mainline lanes.

Exhibit 3C-46 presents the speed contour diagram of the westbound SR-91 mainline and HOV lane and AM peak (7AM) HOV lane speed profile diagram for weekday in October 2008, indicating the locations of the congestion and bottlenecks. Multiple 2008 sample days and monthly averages were reviewed to determine the bottleneck locations.

Exhibit 3C-46: Westbound SR-91 ML & HOV Speed Contour (October 2008)



D. Pavement Condition

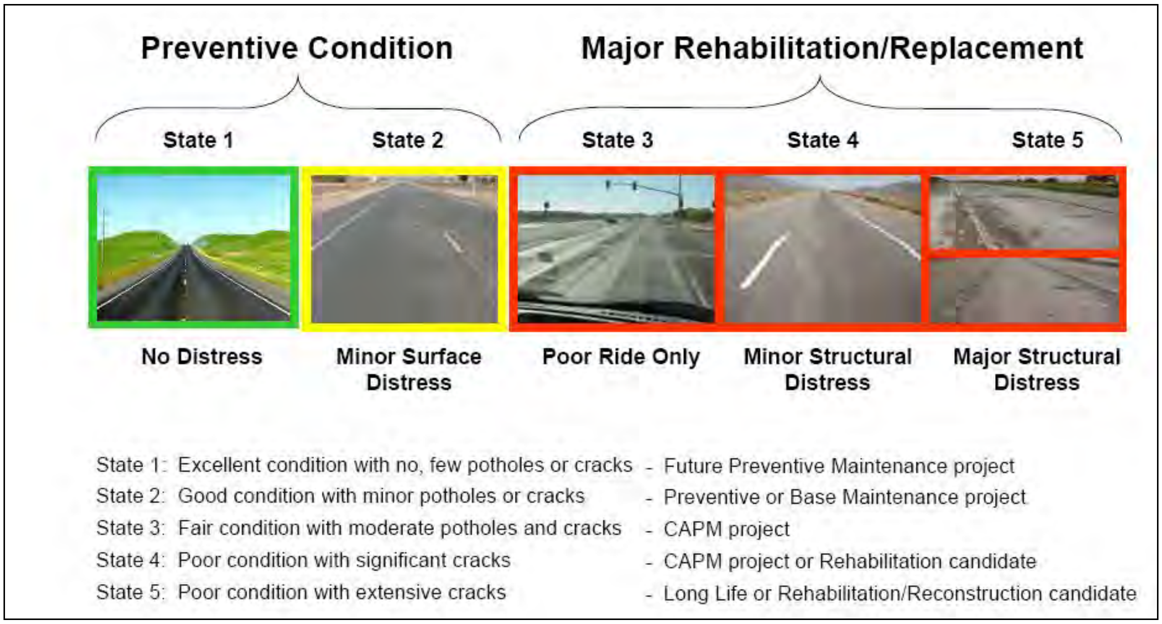
The condition of the roadway pavement (or ride quality) on the corridor can influence its traffic performance. Rough or poor pavement conditions can decrease the mobility, reliability, safety, and productivity of the corridor, whereas smooth pavement can have the opposite effect. Pavement preservation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

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 distressed lane miles for external reporting, this report uses the Caltrans data to present results for both measures.

Distressed lane-miles distinguishes among pavement segments that require only preventive maintenance at relatively low costs and segments that require major rehabilitation or replacement at significantly higher costs. All segments that require major rehabilitation or replacement are considered to be distressed. Segments with poor ride quality are also considered to be distressed. Exhibit 3D-1 provides an illustration of this distinction. The first two pavement conditions include roadway that provides adequate ride quality and is structurally adequate. The remaining three conditions are included in the calculation of distressed lane-miles.

Exhibit 3D-1: Pavement Condition States Illustrated



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

IRI distinguishes between smooth-riding and rough-riding pavement. The distinction is based on measuring the up and down movement of a vehicle over pavement. When such movement is measured 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 Condition

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

The 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 2007 PCS revealed that the majority of distressed pavement was on freeways and expressways (Class 1 roads). This is the result of approximately 56 percent of the State Highway System falling into this road class. As a percentage of total lane-miles for each class, collectors and local roads (Class 3 roads) had the highest amount of distress.

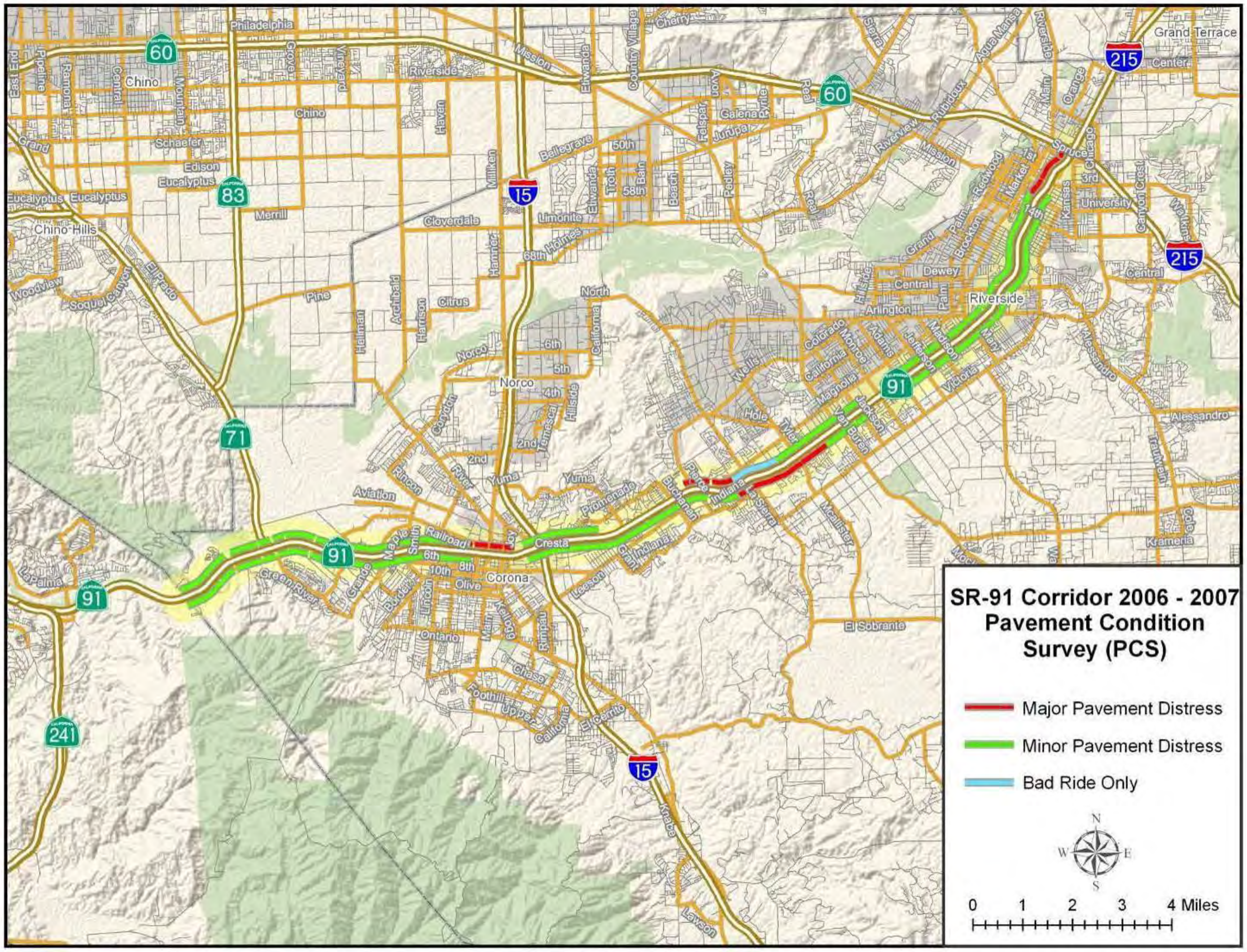
Exhibit 3D-2 shows the pavement distress recorded along the SR-91 Corridor for the 2007 PCS data. The three categories shown in this exhibit represent the three distressed conditions that require major rehabilitation or replacement and were presented earlier in Exhibit 3D-1.

The SR-91 Corridor exhibits average pavement condition for a freeway in the Inland Empire. The corridor has very little major pavement distress, which is common on highways outside the urban core area. However, the majority of the corridor does show signs of minor pavement distress.

Exhibit 3D-3 compares results from prior pavement condition surveys along the SR-91 Corridor. The total number of distressed lane-miles remained steady from 2003 to 2004. Since 2004, the number of distressed lane-miles has more than tripled. Most of the increase has been in minor pavement distress.

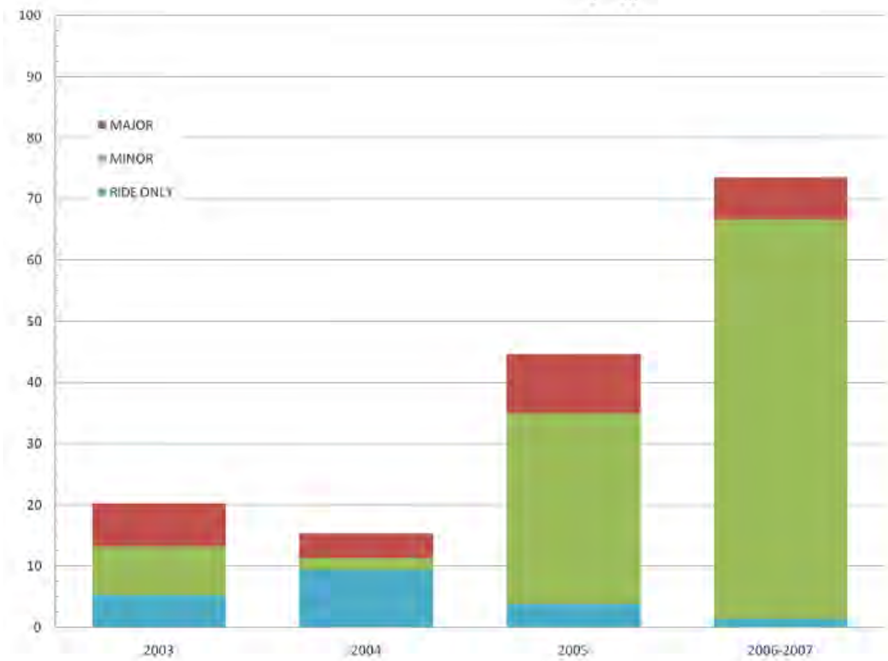
The change in the percent mix of distressed lane-miles is presented more clearly in Exhibit 3D-4. As the exhibit shows, both ride quality issues and major pavement distress have declined and been replace by minor pavement distress since 2004. While the distress on highways split fairly evenly among the three categories in 2003, minor pavement distress dominated distressed lane-miles in the 2007 PCS data. As shown in Exhibit 3D-4, nearly 90 percent of distressed lane-miles were due to minor pavement distress in the last survey.

Exhibit 3D-2: Distressed Lane-Miles on SR-91 Corridor (2006-2007)



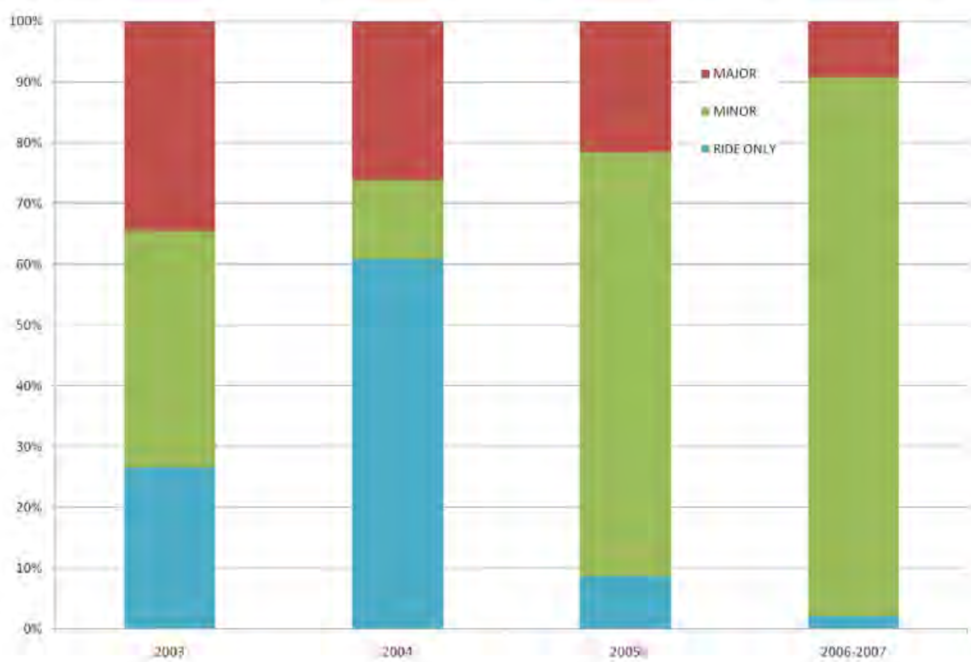
Source: SMG mapping of 2007 Pavement Condition Survey data

Exhibit 3D-3: SR-91 Distressed Lane-Miles Trends



Source: 2003 to 2007 Pavement Condition Survey data

Exhibit 3D-4: SR-91 Distressed Lane-Miles by Type



Source: 2003 to 2007 Pavement Condition Survey data

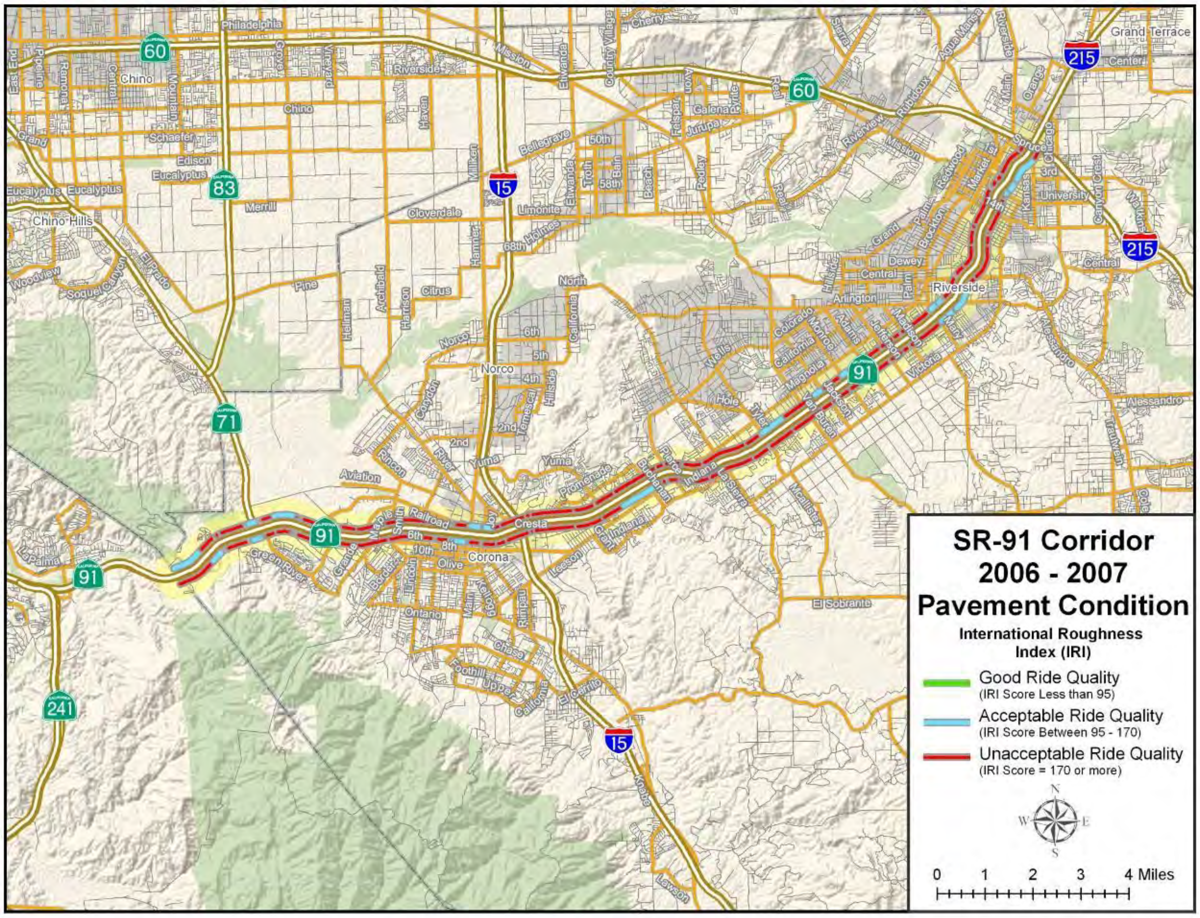
Exhibit 3D-5 shows IRI along the study corridor for the lane with the poorest pavement condition in each freeway segment. The worst pavement quality is shown since pavement investment decisions are made on this basis. As seen in the exhibit, nearly the entire corridor has at least one lane with ride quality issues (IRI greater than 170), but it is important to keep in mind that some lanes have better quality than others within the same roadway section.

In fact, the corridor exhibits relatively good ride quality when the conditions on all lanes are considered. The study corridor is comprised of roughly 182 lane-miles, of which:

- 26 lane-miles, or 14 percent, are considered to have good ride quality (IRI ≤ 95)
- 91 lane-miles, or 50 percent, are considered to have acceptable ride quality (95 < IRI ≤ 170)
- 66 lane-miles, or 36 percent, are considered to have unacceptable ride quality (IRI > 170).

Note: the lane-miles do not add due to rounding.

Exhibit 3D-5: SR-91 Road Roughness (2006-2007)

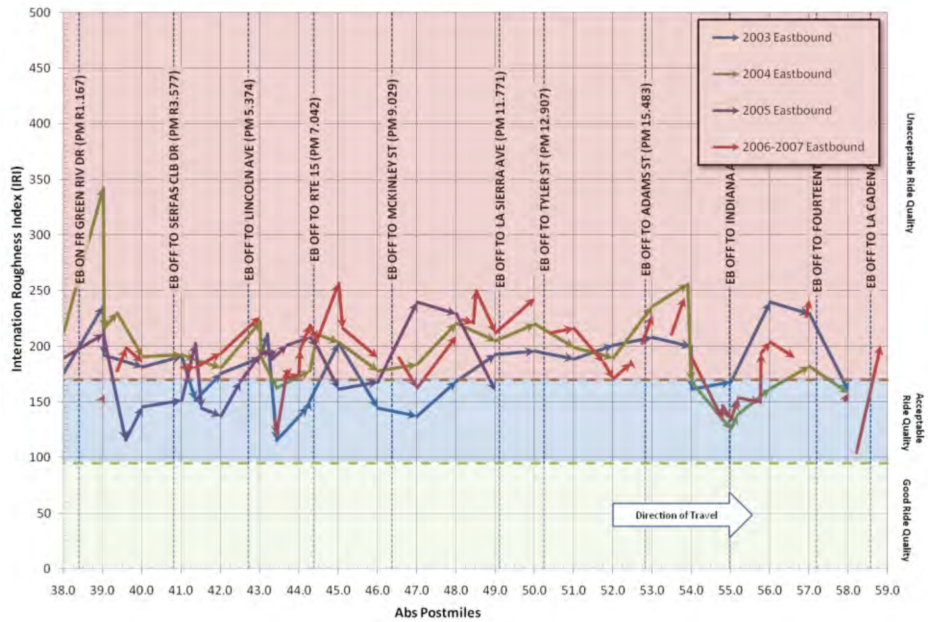


Source: SMG mapping of 2007 Pavement Condition Survey data

Exhibits 3D-6 and 3D-7 present ride conditions for the worst lane in each section on the SR-91 Corridor using IRI from the last four pavement surveys. The information is presented by postmile and direction. The exhibits include color-coded bands to indicate the three ride quality categories defined by Caltrans: good ride quality (green), acceptable ride quality (blue), and unacceptable ride quality (red). The exhibits exclude a number of sections that were not measured or had calibration issues (i.e., IRI = 0) during the 2007 PCS survey. This is shown as breaks in the 2006-2007 line.

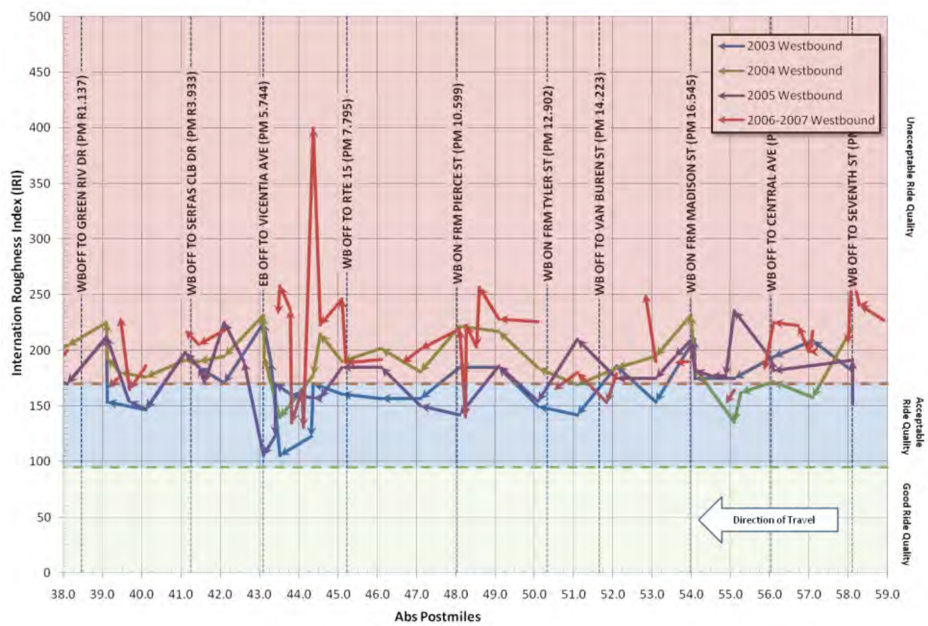
Over time, the surveys show fairly consistent patterns of good, acceptable, and unacceptable conditions. Ride quality has remained fairly constant over the last several surveys, despite the aging of the freeway.

Exhibit 3D-6: Eastbound SR-91 Road Roughness (2003-2007)



Source: 2003 to 2007 Pavement Condition Survey data

Exhibit 3D-7: Westbound SR-91 Road Roughness (2003-2007)



Source: 2003 to 2007 Pavement Condition Survey data

4. SCENARIO DEVELOPMENT AND EVALUATION

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

- Developing traffic models for 2008 base-year and 2020 horizon year
- Combining projects in a logical manner for modeling and testing
- Evaluating model outputs and summarizing results
- Conducting benefit-cost assessments of scenarios.

Traffic Model Development

A traffic model was developed for SR-91 using Vissim micro-simulation software. Micro-simulation models are among the few tools capable of providing a reasonable approximation of bottleneck formation and queue development. Although they require extensive calibration, simulation models help quantify the impacts of operational strategies that traditional travel demand models cannot.

Exhibit 4-1 shows the corridor roadway network included in the micro-simulation model. All freeway interchanges and on- and off-ramps are included. However, only arterial intersections adjacent to ramp intersections are included. Adding a more complete arterial network would have challenged the calibration process and delayed the overall project.

The base year model was calibrated against the 2008 conditions presented earlier. After the base year model met acceptance tests, a model with 2020 demands was interpolated from the Southern California Association of Government's (SCAG) 2030 travel demand model. Micro-simulation modeling captures the benefits of operational strategies, but can be calibrated to only short- and medium-term forecasts. Due to these modeling limitations, a 2020 Horizon Year was chosen to capture medium-term benefits.

In 2010, an eastbound lane addition from the Orange County line to SR-71 was completed as a CMIA project. The 2008 base year and 2020 horizon year models were modified to include this project. These "modified" base and horizon year models were then used to evaluate different scenarios (combinations of projects) to quantify the associated mobility benefits and to compare the project costs against their benefits.

Exhibit 4-1: SR-91 Micro-Simulation Model Network

Scenario Development Framework

A framework was developed to combine projects into scenarios for evaluation. The previously discussed projects and additional improvement strategies were grouped into these scenarios. It would be desirable to evaluate every possible combination of projects, but this would have entailed thousands of model runs. Instead, the projects were combined based on a number of factors, including:

- Projects that could be delivered in the short-term (before 2015) were tested using both the 2008 and 2020 models to capture the short-term (2008) and medium-term (2020) benefits. Total benefits were based generally on a 20-year useful life assumption.
- For horizon year 2020, a “do minimum” model was developed that does not include improvements scheduled for delivery before 2020 so that expected benefits from fully programmed improvements can also be evaluated. This is different from other studies that simply look for additional projects beyond those

programmed. These types of studies start with a "baseline" horizon year and include only projects completed before the horizon year.

It was assumed that projects developed before 2015 could reasonably be evaluated using the 2008 base year model. The 2020 forecast year for the SR-91 CSMP corridor was consistent with the origin-destination matrices in the SCAG regional travel demand model.

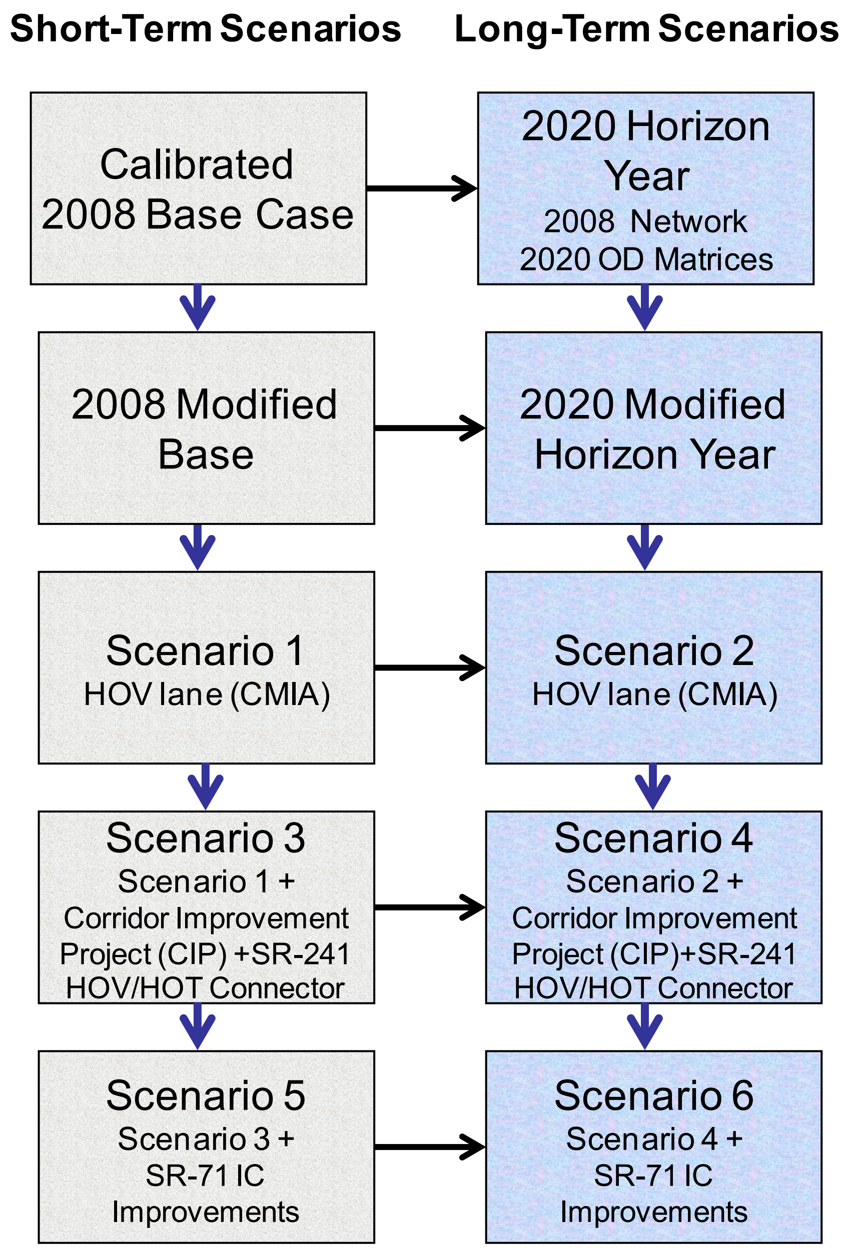
Project lists were obtained from the Regional Transportation Improvement Program (RTIP), the Regional Transportation Plan (RTP), and the State Highway Operation and Protection Program (SHOPP) and used to develop scenarios. Projects that do not directly affect mobility were eliminated. For instance, sound wall and landscaping improvements were eliminated because micro-simulation models cannot evaluate them. Appendix A provides project lists used in developing the micro-simulation scenarios.

Scenario testing performed for the SR-91 CSMP differs from traditional alternatives evaluations included in MIS 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 are compared. At the end, a locally preferred alternative is defined.

In contrast, the CSMP scenarios build on each other. A given scenario generally equates to a previous scenario plus one or more projects. This difference is important since corridor management studies are new and often confused with alternative studies.

Exhibit 4-2 summarizes the approach used and scenarios tested. It also provides a general description of the projects included in the 2008 and 2020 micro-simulation runs.

Exhibit 4-2: Micro-Simulation Modeling Approach



Exhibits 4-3 and 4-4 show the delay results for all the 2008 scenarios evaluated for the AM and PM peak periods, respectively. Exhibits 4-5 and 4-6 show similar results for scenarios evaluated using the 2020 horizon year model. The percentages shown in the exhibits indicate the difference in delay between the current scenario and the previous scenario (e.g., Percent Change = (Current Scenario – Previous Scenario)/Previous Scenario). Impacts of strategies differ based on a number of factors such as traffic flow conditions, ramp storage, bottleneck locations, and levels of congestion.

For each scenario, the proposed improvements were added to the model, multiple model runs were conducted, and composite results by facility type (i.e., mainline, HOV, ramps, and adjacent arterial intersections) and vehicle type (SOV, HOV, and trucks) as well as speed contour diagrams were produced. The results of each scenario were reviewed in detail to ensure they made sense before testing the next scenario of proposed improvements.

Exhibits 4-7 to 4-10 show the delay results by corridor segments (current bottleneck areas) and peak period for all 2008 scenarios. Exhibits 4-11 to 4-14 show similar results for all 2020 scenarios. A traffic report with all the model output details is available under separate cover.

Exhibit 4-3: AM Peak Micro-Simulation Delay Results by Scenario (2008)

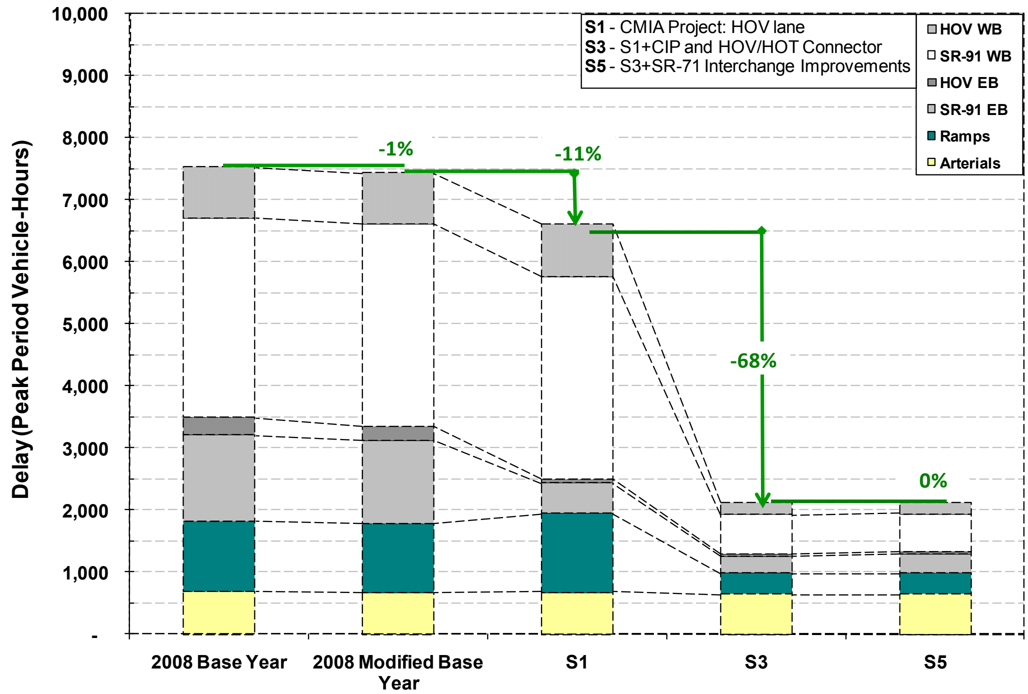


Exhibit 4-4: PM Peak Micro-Simulation Delay Results by Scenario (2008)

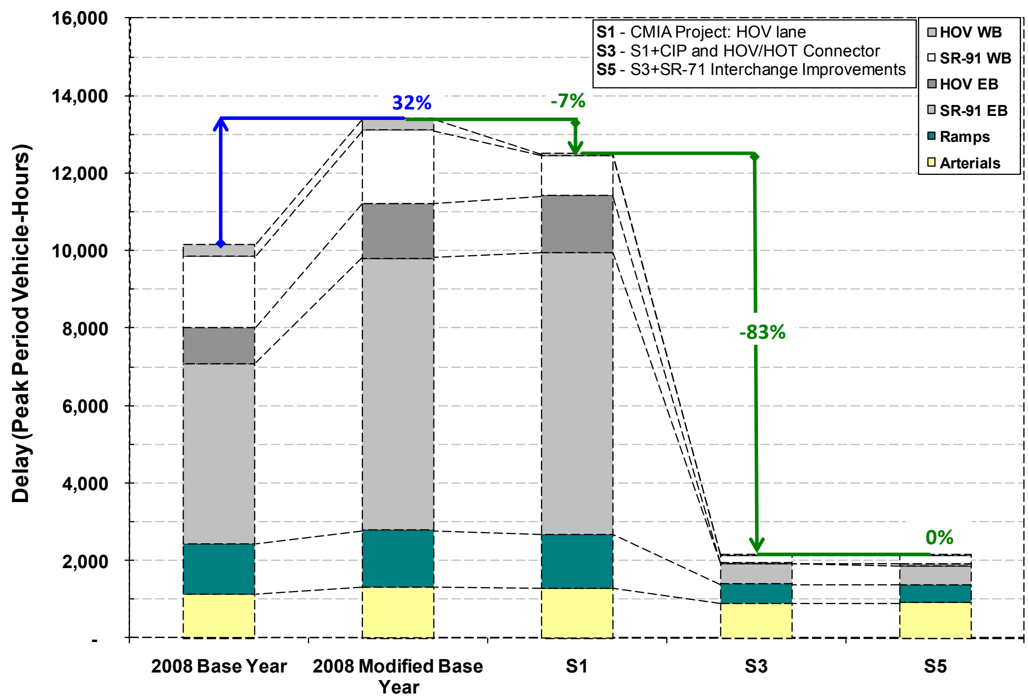


Exhibit 4-5: AM Peak Micro-Simulation Delay Results by Scenario (2020)

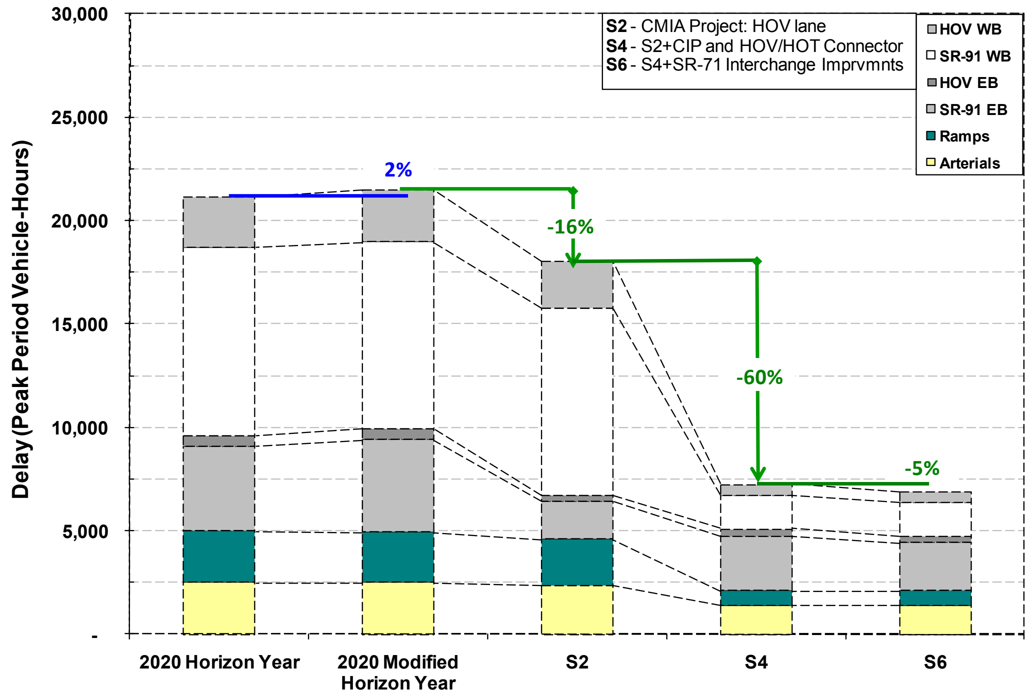


Exhibit 4-6: PM Peak Micro-Simulation Delay Results by Scenario (2020)

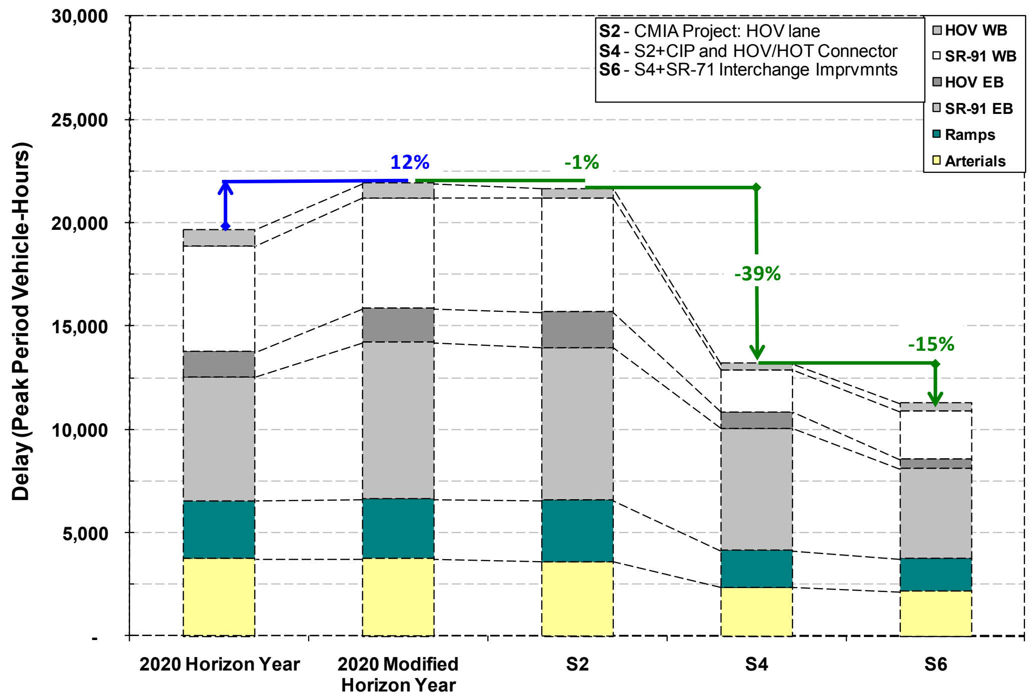


Exhibit 4-7: Eastbound AM Delay Results by Scenario and Bottleneck Area (2008)

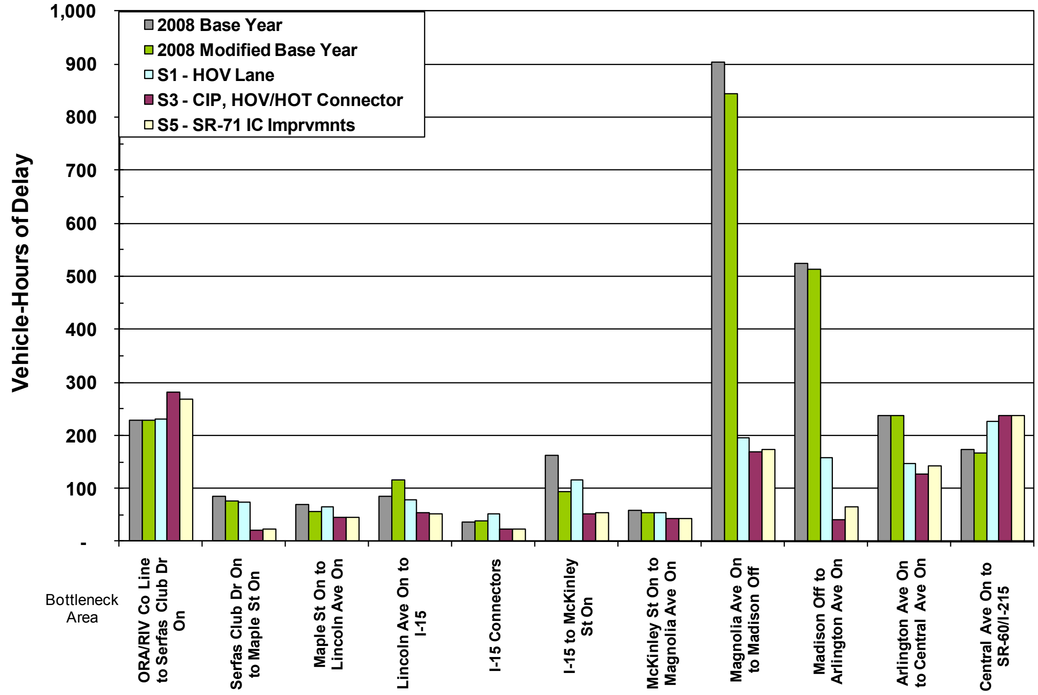


Exhibit 4-8: Eastbound PM Delay Results by Scenario and Bottleneck Area (2008)

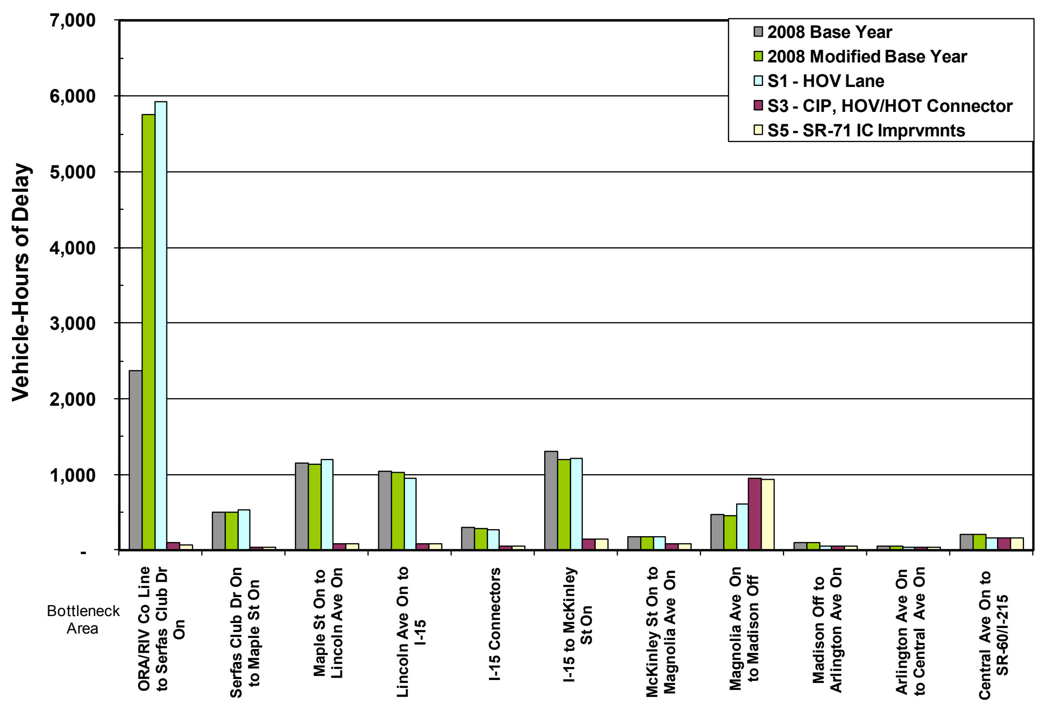


Exhibit 4-9: Westbound AM Delay Results by Scenario and Bottleneck Area (2008)

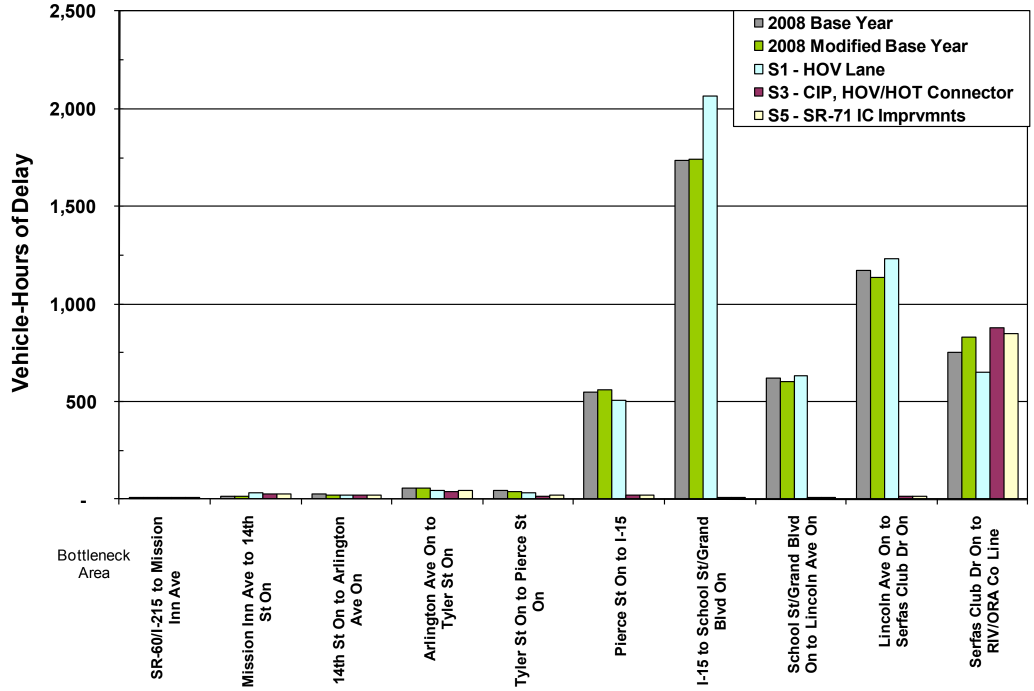


Exhibit 4-10: Westbound PM Delay Results by Scenario and Bottleneck Area (2008)

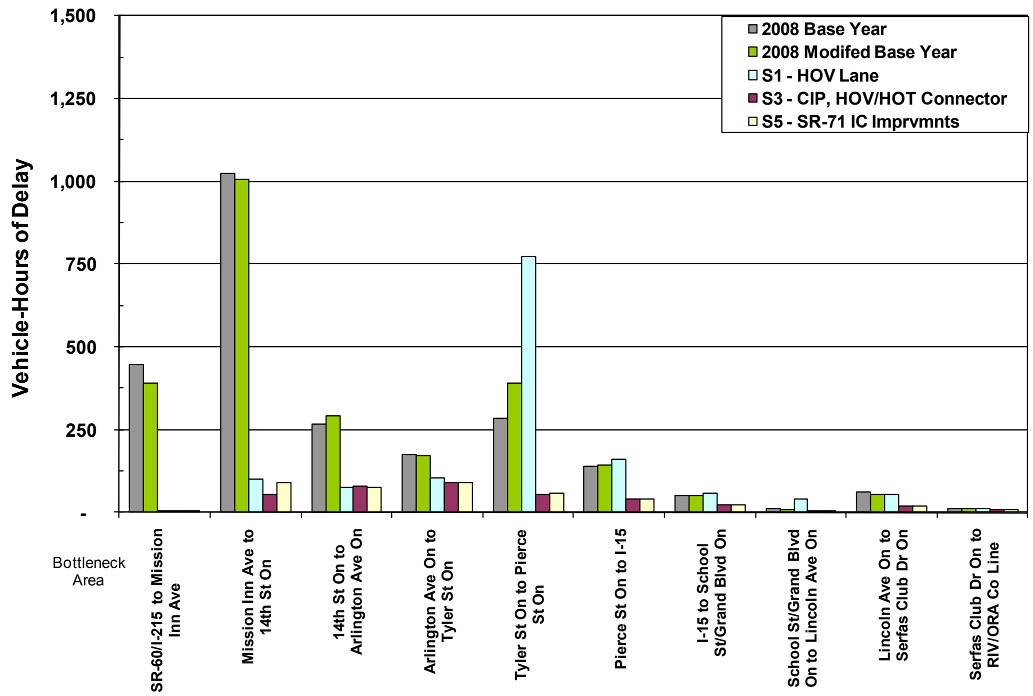


Exhibit 4-11: Eastbound AM Delay Results by Scenario and Bottleneck Area (2020)

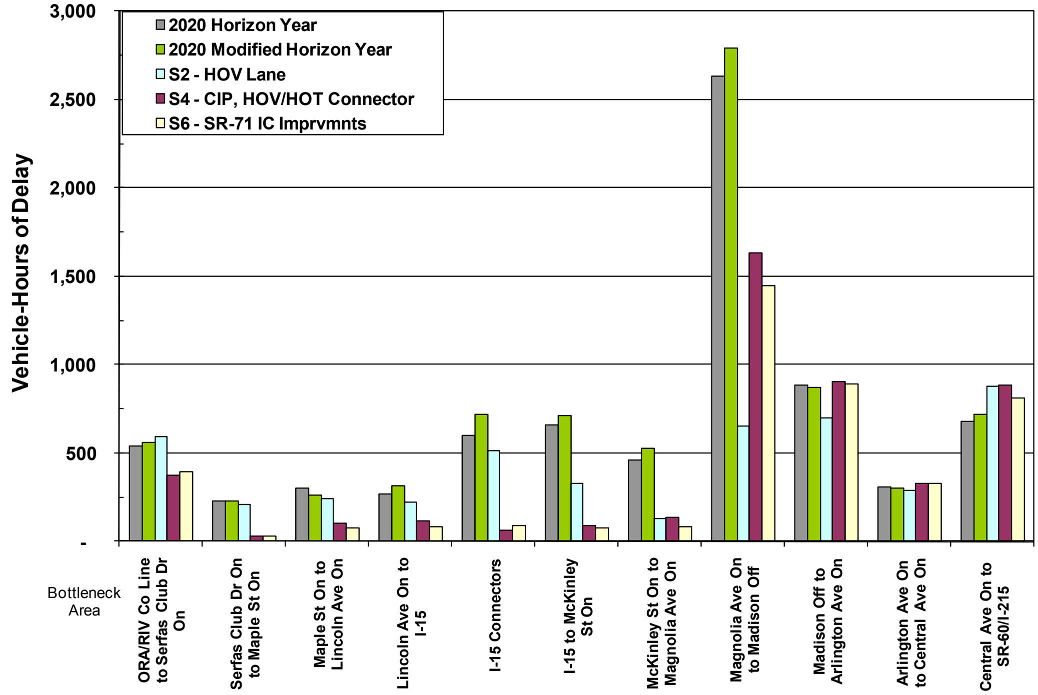


Exhibit 4-12: Eastbound PM Delay Results by Scenario and Bottleneck Area (2020)

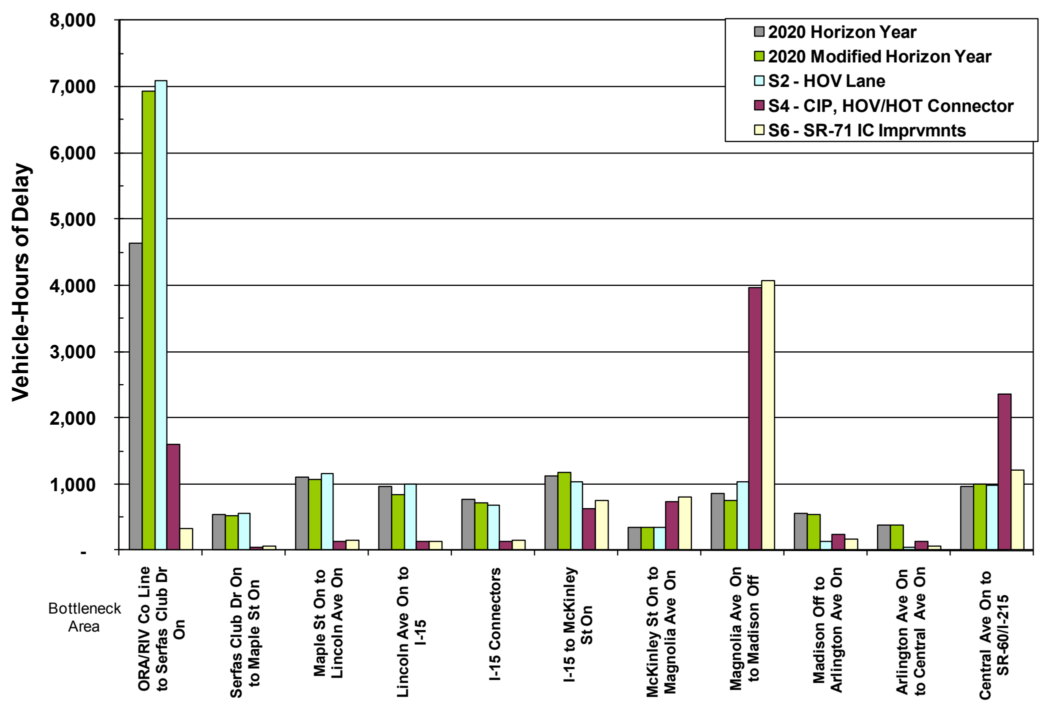


Exhibit 4-13: Westbound AM Delay Results by Scenario and Bottleneck Area (2020)

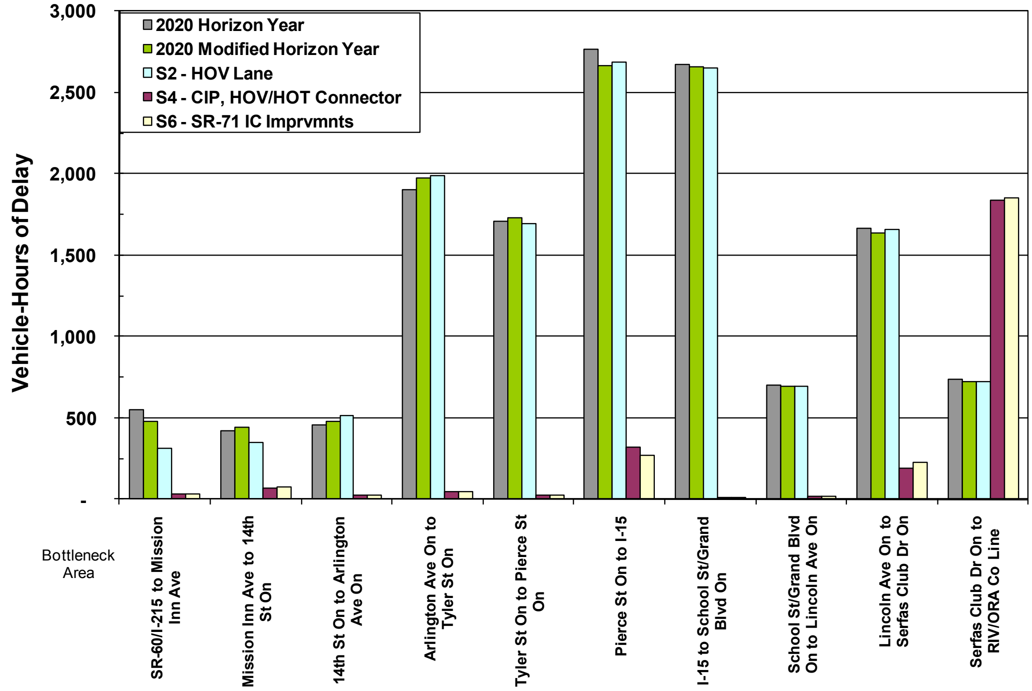
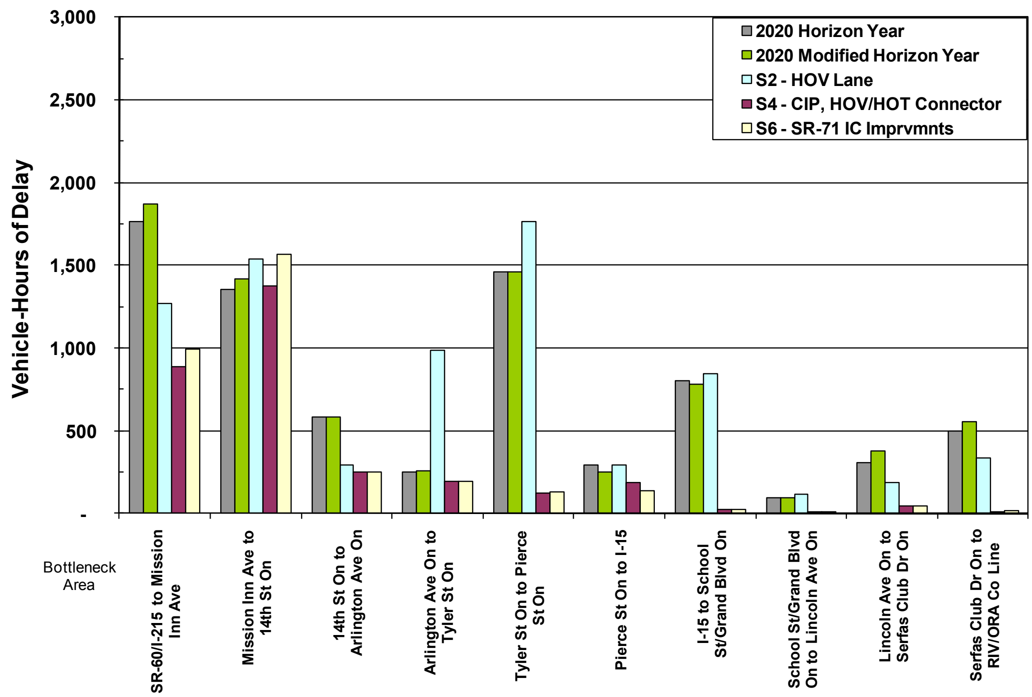


Exhibit 4-14: Westbound PM Delay Results by Scenario and Bottleneck Area (2020)



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

2008 Base Year and 2020 "Do Minimum" Horizon Year

Without any physical improvements, it is estimated that by 2020, total delay (mainline, HOV, ramps, and arterial intersections adjacent to ramps) will increase by 130 percent compared to 2008 (from a total of around 17,700 daily vehicle-hours of delay to nearly 40,800 daily vehicle-hours of delay). Demand may continue to increase beyond 2020 and require further study.

2008 Modified Base Year and 2020 Modified "Do Minimum" Horizon Year

The 2008 Base Year and 2020 "Do Minimum" Horizon Year models were modified to include an eastbound lane addition (a CMIA project) from the Orange County line to SR-71. This modification more accurately reflects current conditions, since the lane addition was completed in 2010. From the modified base to the modified horizon year model, delay increases by almost 110 percent from 20,900 vehicle-hours of delay in 2008 to over 43,400 daily vehicle-hours of delay. Most of the delay increase occurs in the eastbound direction during the PM peak period because the added lane ends, which creates merging issues at SR-71. These congestion problems are addressed in Scenarios 3 and 4.

Scenarios 1 and 2 (CMIA Project: HOV Lane)

Scenarios 1 and 2 include a CMIA project to construct an HOV lane in each direction from Adams Street to University Avenue in the City of Riverside and to restripe from University Avenue to the SR-60/I-15 interchange.

The 2008 model, Scenario 1, estimates that the HOV lane project will reduce delay on the corridor by 11 percent in the AM peak period and almost seven percent in the PM peak period. In total, this scenario produces a reduction of over 1,725 vehicle-hours of daily (AM and PM peak period) delay. In the eastbound direction, the majority of the delay reduction occurs during the AM peak period from Magnolia Avenue to Madison Street. In the westbound direction, delay increased from Tyler Street to Pierce Street during the PM peak period as a result of better throughput/capacity from upstream traffic.

The 2020 model, Scenario 2, estimates that the same project will reduce delay on the corridor by 16 percent in the AM peak period and over one percent in the PM peak period, for a total daily reduction of over 3,700 vehicle-hours of delay.

Scenarios 3 and 4 (CIP and SR-241 HOV/HOT Connector)

Scenarios 3 and 4 build on Scenarios 1 and 2 by testing two projects. The first project involves widening the SR-91 corridor by one general-purpose lane in each direction from east of the County line to the I-15 interchange as part of the SR-91 Corridor Improvement Project (CIP). This project Improvement also involves construction of collector-distributor roads, direct connectors at the I-15 interchange, and extension of the express lanes. The second project involves the construction of the SR-241 HOV/HOT connector.

The 2008 model estimates that Scenario 3 will result in delay reductions of 68 percent in the AM peak period and 83 percent in the PM peak period. The 2020 model estimates that Scenario 4 will result in large delay reductions of 60 percent in the AM peak period and 39 percent in the PM peak period.

In summary, the models estimate that these two projects will provide compelling benefits to the corridor. Delivery of these projects would reduce congestion on the corridor by over 14,800 vehicle-hours in the near term and by over 19,250 vehicle-hours by 2020.

Scenarios 5 and 6 (SR-71 Interchange Improvements)

Scenario 5 and 6 build on Scenarios 3 and 4 by adding improvements at the SR-71 interchange. This project will replace the eastbound SR-91 connector to the northbound SR-71 connector with a new two-lane direct fly-over connector. It will also modify the existing Green River Road interchange and construct a collector-distributor system from Green River Road to east of the SR-71 junction.

The 2008 model estimates that Scenario 5 delays will remain the same as Scenario 3 delays. The 2020 model estimates that Scenario 6 will result in delay reductions of almost five percent in the AM peak period and almost 15 percent in the PM peak period, for a total daily reduction of over 2,250 vehicle-hours.

The 2020 model shows that the residual congestion remaining to be addressed with future improvements is less than the total delay experienced during the 2008 Base Year conditions. In the eastbound direction, Magnolia Avenue to Madison Street still has over 5,500 vehicle-hours of delay remaining. In the westbound direction, Mission Inn Avenue to 14th Street has approximately 1,650 vehicle-hours of delay remaining.

Benefit-Cost Analysis

Following an in-depth review of the model results, a benefit-cost analysis was developed for each scenario. The benefit-cost results represent the incremental benefits over the incremental costs of a given scenario. Scenarios 1 and 2 are compared to the modified base and horizon year scenarios.

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

Project costs were obtained from various sources, including the RTIP and RTP. A benefit-cost ratio (B/C) greater than one means that a scenario's projects return benefits greater than they cost to construct or implement. It is important to consider the total benefits that a project brings.

Exhibit 4-15 illustrates typical benefit-cost ratios for different project types. Large capital expansion improvements generally produce low benefit-cost ratios because the costs are so high. Conversely, transportation management strategies such as ramp metering produce high benefit-cost ratios given their low costs. The benefit-cost analysis for the SR-91 Corridor is summarized in Exhibit 4-16.

Exhibit 4-15: Benefit-Cost Ratios for Typical Projects

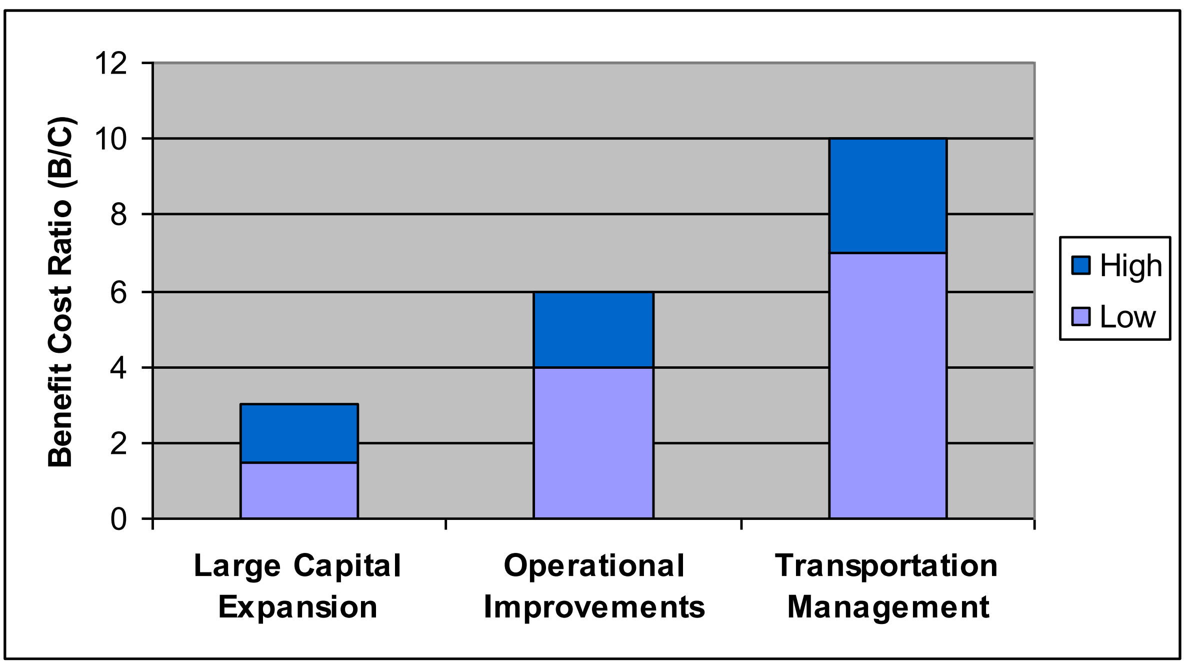


Exhibit 4-16: Scenario Benefit/Cost (B/C) Results

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

- Scenarios 1 and 2 (HOV lane) produce a low benefit-cost ratio of about 1.3 to 1. The benefit-cost for this expansion-type project is low, but within the typical range of benefits for this type of project.
- Scenarios 3 and 4 (CIP and SR-241 HOV/HOT connector) produce a benefit-cost ratio of roughly 1 to 1 (benefits slightly greater than costs). These two projects are also expansion projects, but they have high total project costs.
- Scenarios 5 and 6 (SR-71 interchange improvements) produce a relatively low benefit-cost ratio of 1.2 to 1.
- The benefit-cost ratio of all the scenarios combined is about 1.1 to 1. If all the projects are delivered at current cost estimates, the public will get slightly over one dollar of benefits for each dollar expended. In current dollars, costs add to around $1.74 billion whereas the benefits are estimated to be about $1.75 billion.
- The projects also alleviate greenhouse gas (GHG) emissions by almost 1.4 million tons over 20 years, averaging nearly 70,000 tons reduced per year. The emissions reductions are estimated in Cal-B/C using data from the California Air Resources Board (CARB) Emissions Factors (EMFAC) model.

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

5. CONCLUSIONS AND RECOMMENDATIONS

This section summarizes the conclusions and recommendations based on the analysis presented. Many of these conclusions are based on the micro-simulation model results using the best data available at the time of the analysis.

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

Based on the results, the following conclusions and recommendations are offered:

- The benefit-cost ratio for the CMIA HOV project (Scenarios 1 and 2) is low. However, with the cost of over $275 million, the model results indicate positive benefits are expected reaching almost $350 million over a 20-year lifecycle.
- Although the combined costs of the Scenarios 3 and 4 projects are over $1.74 billion. These two projects produce significant reductions in delay and still show benefits ($1.75 billion) slightly greater than costs (by about $10 million).
- Although many of the major bottleneck areas are already addressed by projects in Scenarios 1 to 4, the SR-71 interchange improvements produce a benefit of almost $150 million.

Exhibits 5-1 and 5-2 show speed contour maps for the SR-91 mainline in the 2020 “Do Minimum” Horizon Year with the growth in congestion before any improvements. Exhibits 5-3 and 5-4 show the speed contour maps produced by the model for the mainline at the conclusion of Scenario 6, the final scenarios tested. Other speed contour maps are in the traffic report. Exhibits 5-3 and 5-4 show the residual congestion and bottleneck locations. There is still some congestion remaining from Magnolia Avenue to Madison Street by year 2020 after all scenarios are implemented. Since the CSMP horizon year model is for 2020, further study or other methodology may be needed to assess the benefits of addressing demand beyond 2020.

Exhibit 5-1: Eastbound PM Peak Model Speed Contours Before Improvements (2020)

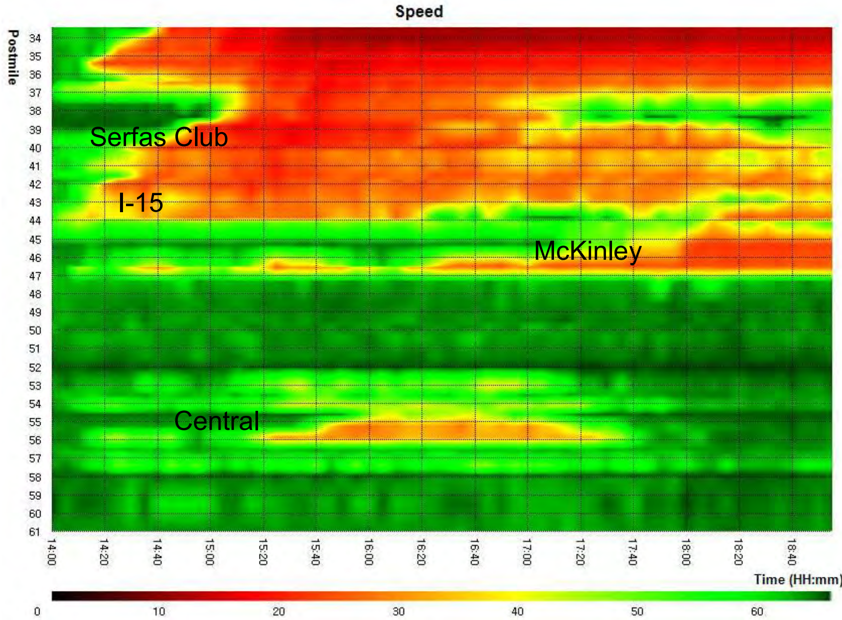


Exhibit 5-2: Westbound AM Peak Model Speed Contours Before Improvements (2020)

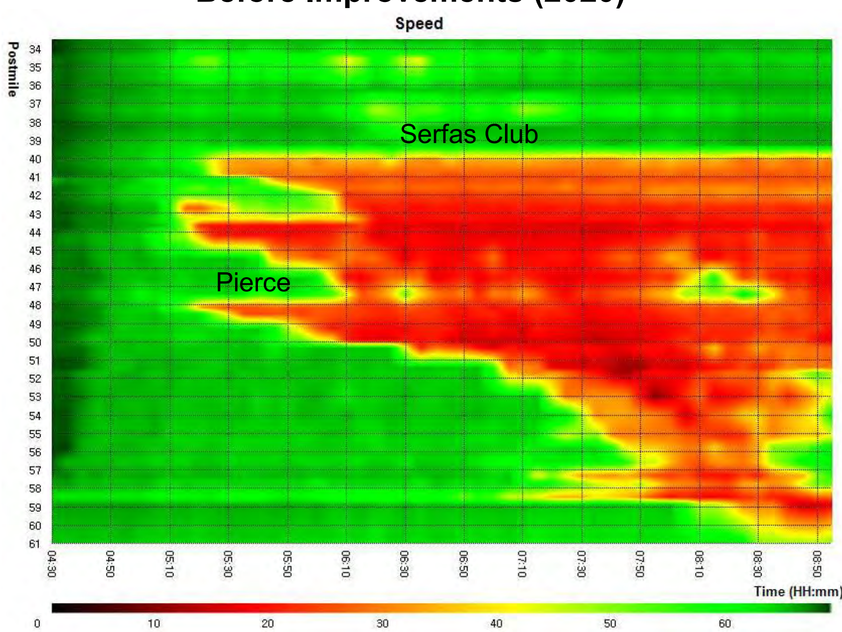


Exhibit 5-3: Eastbound PM Peak Model Speed Contours After Improvements (2020)

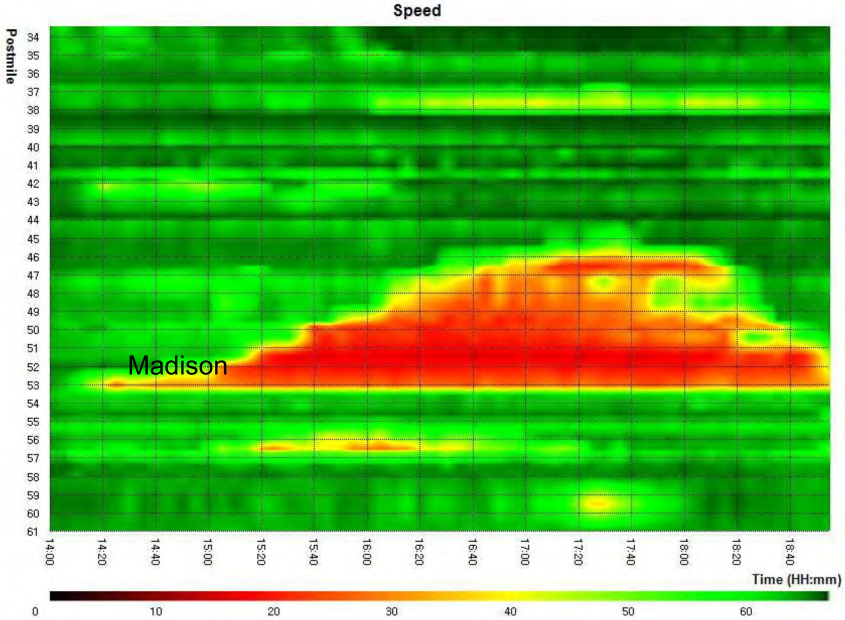
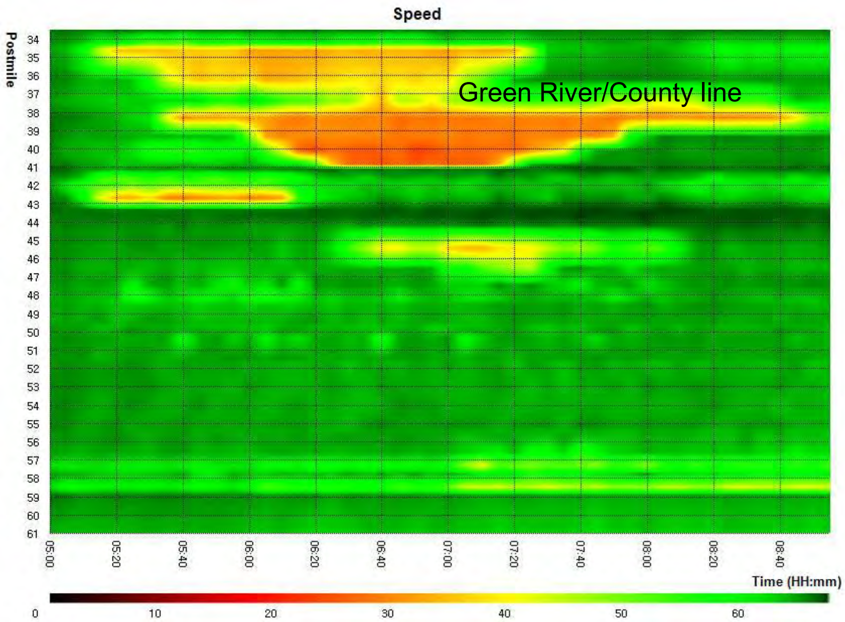


Exhibit 5-4: Westbound AM Peak Model Speed Contours After Improvements (2020)



This is the first-generation CSMP for the SR-91 corridor. It is important to emphasize that CSMPs should be updated, on a regular basis, if possible. This is particularly important since future traffic conditions and travel patterns can differ from current projections. After projects are delivered it is useful to compare the resulting performance, realized benefits, and the actual costs to the current estimates in order to improve future models as appropriate.

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

Appendix A: Project List for Micro-Simulation Scenarios

Scenario	Proj ID	Improvement	Lead Agency	Expected Complete Date	Source	Est Total Proj Cost (in 1,000s)
1 (2008-1) 2 (2020-1)	RIV010212 EA 44840	Construct two High Occupancy Vehicle (HOV) lanes on SR-91, one lane in each direction from Adams Street to University Avenue in the City of Riverside; re-stripe from University Avenue to the 60/91/215 Interchange; reconstruct/widen IC at Arlington Ave, Central Ave, 14th St, Madison St, and University Ave	RCTC	2013	06 & 08 RTIP CMIA	$ 275,777
3 (2008-2) 4 (2020-2)	RIV071250 EA 0F540	SR-91 Corridor Improvement Project (Initial CIP): Widen SR-91 by 1 GP lane in each direction east of County Line, CD roads and direct connectors at I-15/SR-91 Direct South Connector, Extension of Express Lanes to I-15 and system interchange improvements	RCTC	2016	2008 RTIP **Impl Plan (#4)** 03 CRAA	$ 1,300,517
	RCTC	SR-241/SR-91 HOV/HOT Connector	RCTC	2017	2008 RTIP **Impl Plan (#6)**	$ 440,000
5 (2008-3) 6 (2020-3)	RIV070308 EA 0F541	SR-71/SR-91 Interchange Improvements. Replace EB 91 to NB 71 connector with a new two-lane direct fly-over connector, and modifications to the existing Green River Road interchange. Construct a collector-distributor (CD) system from Green River Road to east of the SR-91/SR-71 junction.	RCTC	Unknown	06 & 08 RTIP **Impl Plan (#3)**	$ 123,500

Appendix B: Benefit-Cost Analysis Results

This appendix provides more detailed benefit-cost analysis (BCA) results than found in Section 5 of the SR-91 Corridor System Management Plan (CSMP) II Final Report. The BCA results for this CSMP were estimated by using the *California Life-Cycle Benefit/Cost Analysis Model (Cal-B/C) Version 4.0* developed for Caltrans by System Metrics Group (SMG).

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

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

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

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

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

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

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

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

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

The exhibits in this appendix are listed as follows:

- Exhibit B-1: Scenarios 1 and 2 Benefit-Cost Analysis Results
- Exhibit B-2: Scenarios 3 and 4 Benefit-Cost Analysis Results
- Exhibit B-3: Scenarios 5 and 6 Benefit-Cost Analysis Results
- Exhibit B-4: Cumulative Benefit-Cost Analysis Results

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

3

INVESTMENT ANALYSIS
SUMMARY RESULTS

Life-Cycle Costs (mil. $)	$275.8
Life-Cycle Benefits (mil. $)	$352.5
Net Present Value (mil. $)	$76.8
Benefit / Cost Ratio:	1.3
Rate of Return on Investment:	6.4%
Payback Period:	13 years

ITEMIZED BENEFITS (mil. $)	Average Annual	Total Over 20 Years
Travel Time Savings	$14.5	$290.1
Veh. Op. Cost Savings	$2.3	$46.6
Accident Cost Savings	$0.0	$0.0
Emission Cost Savings	$0.8	$15.9
TOTAL BENEFITS	$17.6	$352.5
Person-Hours of Time Saved	1,855,907	37,118,136
Additional CO_2 Emissions (tons)	-11,950	-239,006
Additional CO_2 Emissions (mil. $)	-$0.3	-$6.9

Incremental Costs (mil. $)	$275.8
Incremental Benefits (mil. $)	$352.5
Incremental Benefit / Cost Ratio:	1.3

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

3

INVESTMENT ANALYSIS
SUMMARY RESULTS

Life-Cycle Costs (mil. $)	$2,016.3
Life-Cycle Benefits (mil. $)	$2,103.1
Net Present Value (mil. $)	$86.8
Benefit / Cost Ratio:	1.0
Rate of Return on Investment:	4.4%
Payback Period:	14 years

ITEMIZED BENEFITS (mil. $)	Average Annual	Total Over 20 Years
Travel Time Savings	$86.2	$1,723.9
Veh. Op. Cost Savings	$13.8	$276.1
Accident Cost Savings	$0.0	$0.0
Emission Cost Savings	$5.2	$103.1
TOTAL BENEFITS	$105.2	$2,103.1
Person-Hours of Time Saved	10,830,525	216,610,497
Additional CO_2 Emissions (tons)	-66,912	-1,338,236
Additional CO_2 Emissions (mil. $)	-$2.0	-$39.7

Incremental Costs (mil. $)	$1,740.5
Incremental Benefits (mil. $)	$1,750.6
Incremental Benefit / Cost Ratio:	1.0

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

3

INVESTMENT ANALYSIS
SUMMARY RESULTS

Life-Cycle Costs (mil. $)	$2,139.8
Life-Cycle Benefits (mil. $)	$2,249.7
Net Present Value (mil. $)	$109.9
Benefit / Cost Ratio:	1.1
Rate of Return on Investment:	4.5%
Payback Period:	14 years

ITEMIZED BENEFITS (mil. $)	Average Annual	Total Over 20 Years
Travel Time Savings	$93.0	$1,860.9
Veh. Op. Cost Savings	$14.2	$283.6
Accident Cost Savings	$0.0	$0.0
Emission Cost Savings	$5.3	$105.3
TOTAL BENEFITS	$112.5	$2,249.7
Person-Hours of Time Saved	11,752,797	235,055,937
Additional CO_2 Emissions (tons)	-69,686	-1,393,715
Additional CO_2 Emissions (mil. $)	-$2.1	-$41.1

Incremental Costs (mil. $)	$123.5
Incremental Benefits (mil. $)	$146.6
Incremental Benefit / Cost Ratio:	1.2

Exhibit B-4: Cumulative Benefit-Cost Analysis Results

3

INVESTMENT ANALYSIS
SUMMARY RESULTS

Life-Cycle Costs (mil. $)	$2,139.8
Life-Cycle Benefits (mil. $)	$2,249.7
Net Present Value (mil. $)	$109.9
Benefit / Cost Ratio:	1.1
Rate of Return on Investment:	n/a
Payback Period:	n/a

ITEMIZED BENEFITS (mil. $)	Average Annual	Total Over 20 Years
Travel Time Savings	$93.0	$1,860.9
Veh. Op. Cost Savings	$14.2	$283.6
Accident Cost Savings	$0.0	$0.0
Emission Cost Savings	$5.3	$105.3
TOTAL BENEFITS	$112.5	$2,249.7
Person-Hours of Time Saved	11,752,797	235,055,937
Additional CO_2 Emissions (tons)	-69,686	-1,393,715
Additional CO_2 Emissions (mil. $)	-$2.1	-$41.1