Pilot Testing of SHRP 2 Reliability Data and Analytical Products: Southern California

DETAILS

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SHRP 2 Reliability Project L38A

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Accelerating solutions for highway safety, renewal, reliability, and capacity

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SHRP 2 Reliability Project L38A

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Contents

1 Executive Summary

16 **CHAPTER 1** Background
16 1.1 Introduction
17 1.2 Southern California Pilot Site
20 1.3 Organization of the Report

22 **CHAPTER 2** Research Approach

25 **CHAPTER 3** Selection and Description of Test Facilities
25 3.1 Selection of Facilities
27 3.2 Final Test Facilities

42 **CHAPTER 4** Data Compilation and Analysis of Existing Conditions
42 4.1 Introduction
42 4.2 Overview of the L02 Guide
43 4.3 Evaluation of the L02 Guide
44 4.4 Average Route Travel Times Based on Infrastructure Sensor Data
54 4.5 See What Factors Affect Reliability (AE1)
68 4.6 Assess the Contributions of the Factors (AE2)

70 **CHAPTER 5** C11 Reliability Analysis Tool
70 5.1 Overview of the C11 Reliability Analysis Tool
71 5.2 Limitations of the C11 Reliability Analysis Tool
76 5.3 Baseline Condition Estimation of the C11 Reliability Analysis Tool
80 5.4 Results of the I-5 Scenario Testing
91 5.5 Results of the I-210 Scenario Testing

100 **CHAPTER 6** L07 Analysis Tool
100 6.1 Overview of the L07 Analysis Tool
101 6.2 Limitations of the L07 Analysis Tool
110 6.3 Baseline Condition Estimation of the L07 Analysis Tool
113 6.4 Results of the I-5 Scenario Testing
120 6.5 Results of the I-210 Scenario Testing

132 **CHAPTER 7** L08: FREEVAL-RL
132 7.1 Overview of FREEVAL-RL

132 7.2 Limitations of FREEVAL-RL
138 7.3 Base Model Development
142 7.4 Model Calibration
148 7.5 Scenario Testing

174 CHAPTER 8 Benefit-Cost Findings
174 8.1 Use of the C11 Tool
176 8.2 Procedure for Estimating Reliability Benefits
180 8.3 Benefit-Cost Results
187 8.4 Implications for Decision Making

189 CHAPTER 9 Functionality Assessment and Research Outcome
190 9.1 Technical Feasibility of Products
194 9.2 Decision Maker Perceptions
196 9.3 Impacts on Decision Making

197 CHAPTER 10 Conclusions and Suggested Research
197 10.1 Conclusions
200 10.2 Suggested Research

201 REFERENCES

Executive Summary

Background

The second Strategic Highway Research Program (SHRP 2) has been investigating the critical subject of travel time reliability for several years. As part of this research, SHRP 2 supported multiple efforts to develop products to evaluate travel time reliability and to estimate the impact of projects on reliability. SHRP 2 reliability projects have developed several methods to help public agencies:

- Collect and analyze data on the variability of travel time
- Diagnose problems
- Propose actions or alternative mitigation strategies
- Test the impacts of solutions

One goal of this research has been to find ways to demonstrate how operational strategies improve travel time reliability, which is highly valued by both the person and goods movement transportation markets. Operational strategies are critical to improve mobility and travel time reliability on highways and can be implemented faster than larger system expansion projects, since they often do not require detailed environmental reviews, and they generally cost much less.

In current practice, travel demand and microsimulation models have not been able to adequately estimate the reliability benefits of operations projects. As a result, the SHRP 2 reliability products have the potential to fill a void in the ability of transportation professionals to analyze reliability and quantify the likely benefits of these strategies. Some activity-based models (ABM) with dynamic traffic assignment (DTA) tools under assessment (e.g., in the report, *SHRP 2 L04 Incorporating Reliability Performance Measures into Operations and Planning Modeling Tools*) may be able to meet this need in the future, but none are currently in widespread use.

SHRP 2 L38 Project

The SHRP 2 L38 project is intended to provide the necessary testing and feedback on existing SHRP 2 reliability tools. The request for proposal (RFP) for SHRP 2 L38 listed the following objectives:

1. Assist agencies in moving reliability into their business practices through testing of data integration and analytical tools developed by SHRP 2. Include a data collection/integration component, an analytical component, and a decision-making component.

2. Provide feedback to SHRP 2 on the applicability and usefulness (benefits and value) of the products tested. Suggest potential refinements [to the products tested].

Pilot testing under the L38 project occurred at four separate sites in Florida, Minnesota, Washington State, and Southern California. This report describes the approach and findings from the Southern California pilot site. Pilot testing at the other three sites was conducted by different study teams under separate contracts.

Southern California Pilot Site

The Southern California pilot site is one of the most congested regions in the United States. The Texas Transportation Institute *2012 Urban Mobility Report* ranks the Los Angeles-Long Beach-Santa Ana urban area second only to the Washington, D.C., metro area in terms of yearly delay per auto commuter (Texas Transportation Institute 2012). The pilot testing in Southern California was a team effort involving consultants, staff at the Southern California Association of Governments (SCAG), and input from the California Department of Transportation (Caltrans).

Both SCAG and Caltrans are already actively involved in analyzing travel time reliability. SCAG has a long history of performance-based transportation planning and recognizes the importance of operational strategies. In April 2012, the SCAG Regional Council unanimously adopted the current Regional Transportation Plan/Sustainable Communities Strategy (RTP/SCS), which includes a specific reliability goal (SCAG 2012). The RTP/SCS also provides a high-level evaluation of reliability impacts based on work done for Corridor System Management Plans (CSMPs) in Southern California.

Caltrans is committed to system management and has formally embraced what it terms the “Mobility Pyramid,” which focuses on the importance of operational strategies (Figure ES.1). As a champion of system management, Caltrans is interested in research that furthers its commitment to funding operational strategies, especially given its role in improving interregional mobility. Management in Caltrans District 12 (Orange County) would like an expansion of the work performed as part of the pilot studies to better identify the causes and impacts of congestion at a corridor level, so they can develop mitigation strategies to address reliability.

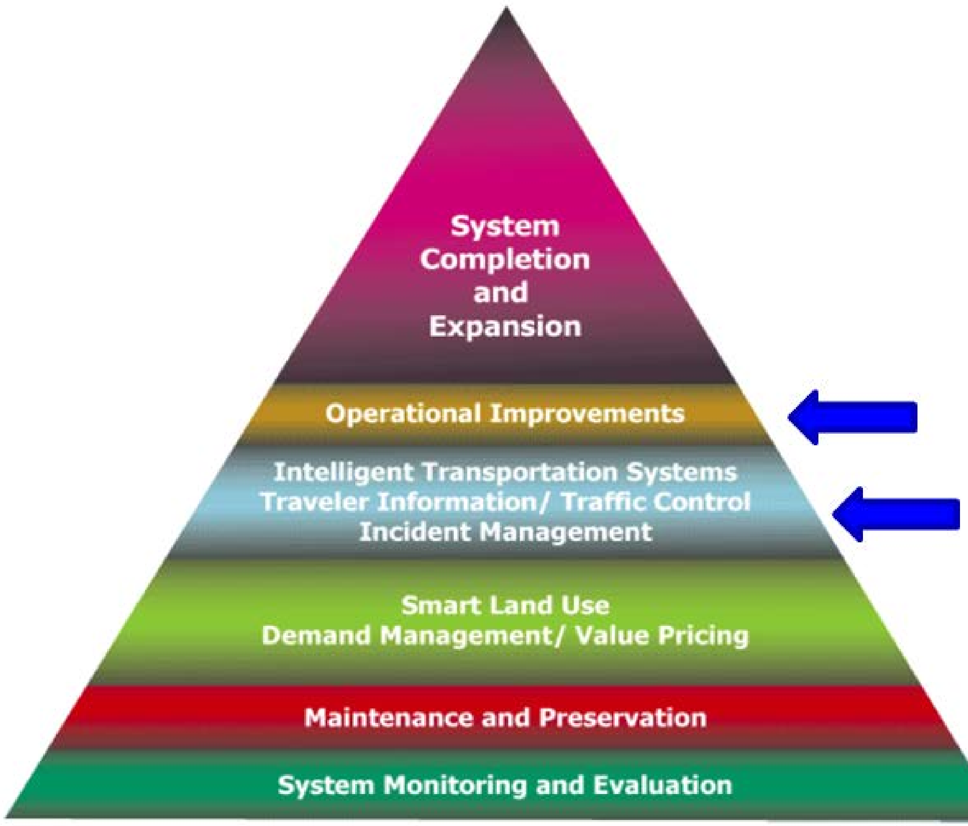


Figure ES.1. Caltrans Mobility Pyramid.

By engaging advanced users, the Southern California pilot site tested two aspects of the SHRP 2 products without the need to introduce the travel time reliability concept:

- Technical functionality: How easy are the products to use? How consistent are they with each other and to prior work?
- Practical use: Do they help Southern California select and prioritize projects? Do decision makers understand the reliability analyses and find the results credible?

The Southern California pilot site also benefitted from the extensive automated detection and performance measurement available in the Caltrans Performance Measurement System (PeMS). This is an Internet-based tool that allows the extraction of real-time and historical performance data collected through automated roadway sensors, such as loop detectors (Figure ES.2).

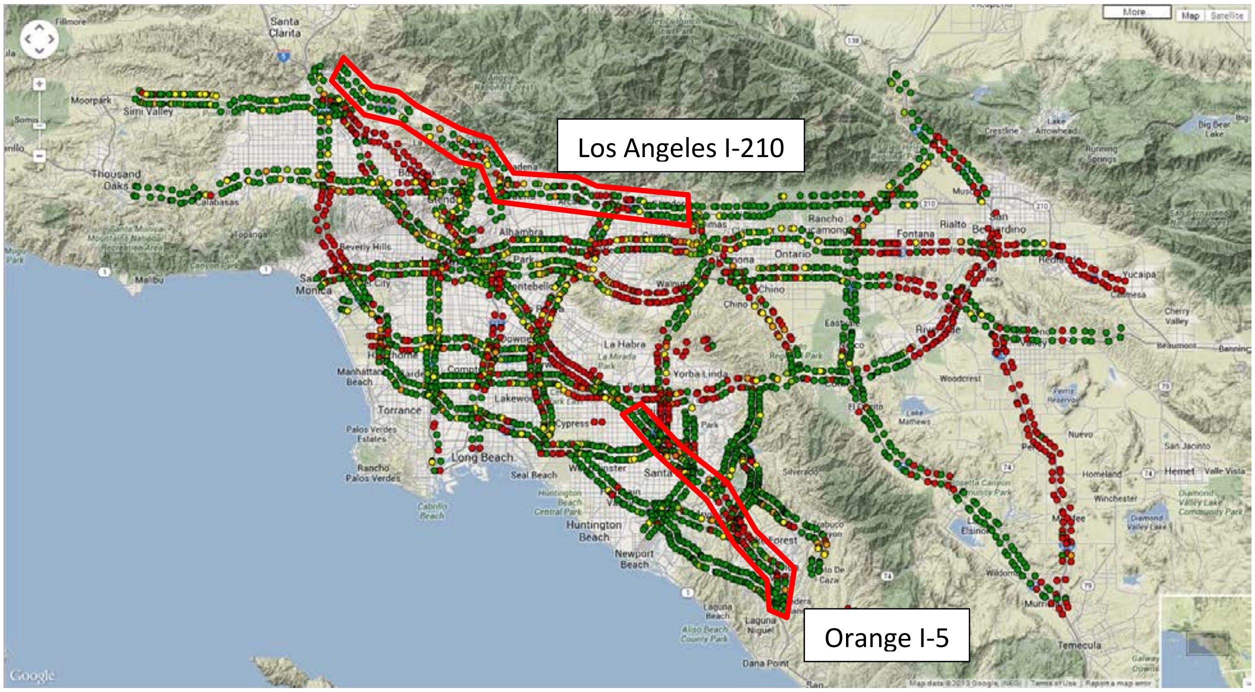


Figure ES.2. Sensor coverage in the Southern California pilot site.

Source: Caltrans Freeway Performance Measurement System (PeMS). pems.dot.ca.gov.

Research Approach

The Southern California pilot site conducted its SHRP 2 reliability product testing by leveraging existing CSMPs. These system management plans describe how each freeway corridor is currently performing, identify operational strategies and carefully chosen system expansion opportunities to improve performance, and quantify the likely benefits that result from these investments. In addition, each Southern California facility has a microsimulation model that can quantify the mobility benefits of various operational and system management strategies. Southern California has roughly a dozen corridors with completed CSMPs, which could be leveraged for further analysis and implementation of SHRP 2 products.

The Southern California pilot site updated the analysis of the CSMPs for two freeways to examine the impacts of including travel time reliability. The study team followed these general steps for the pilot testing:

- Review facilities with existing CSMPs and select two of the most promising facilities for reliability improvement;
- Compare reliability on the facilities and understand factors that affect reliability;
- Use SHRP 2 tools to develop more detailed, robust analyses of travel time reliability;
- Leverage available microsimulation models, travel demand models, and automatic sensor data;

- Test recently programmed or planned projects and potential operational strategies; and
- Present results to SCAG policy and technical committees and to Caltrans District 12 management.

These steps allowed the study team to test multiple reliability products from five separate SHRP 2 projects (Table ES.1).

Table ES.1. SHRP 2 Reliability Products Tested in the Southern California Pilot Site

Type of Product	L02	L05	L07	L08	C11
Methods for Describing Reliability and Contributing Factors	✓				
Suggested Alternative Strategies and Design Features		✓	✓		
Tools for Forecasting Reliability and Estimating Impacts			✓	✓	✓
Benefit Estimates for Benefit-Cost Analysis			✓		✓
Guidelines for Goal Setting		✓			

Test Facilities

With the consultation of SCAG and Caltrans, the study team selected two test facilities. The first is the I-5 in Orange County, a 45-mile, heavily congested interstate highway with four to six general-purpose lanes in each direction. There are also multiple barrier-separated high-occupancy vehicle and auxiliary lanes throughout the I-5 corridor. This complex geometry led to some difficulties in calibrating the SHRP 2 products, especially the FREEVAL-RL model from the L08 product.

The second facility is also heavily congested. The 16-mile, urban segment of I-210 in Los Angeles County has the worst reliability of any Southern California freeway evaluated through the CSMP process. It has four to five general-purpose lanes as well as barrier-separated high-occupancy vehicle and auxiliary lanes in each direction.

Analysis of Existing Conditions

The study team analyzed existing reliability conditions along the two freeways by following the approach described in the L02 guide. This allowed the team to test the value of collecting, storing, and using nonrecurring event data from various sources to help explain causal relationships. The L02 guide provided specific techniques for determining these causal factors and for assessing the relative contributions of these factors on the two pilot facilities.

One such technique is the use of cumulative distribution functions (CDFs) to visualize the impact of specific reliability factors on travel rates at different congestion levels. Figure ES.3 shows an example of a CDF curve for I-5. Different lines indicate "normal" conditions for uncongested and low-, moderate-, and high-congested regimes. Dotted lines show the same travel rates, but during special events. As can be seen in the figure, special events can dramatically increase travel rates on the facility such that, even under moderate congestion, the travel rates for special events can exceed those on the most heavily congested weekdays.

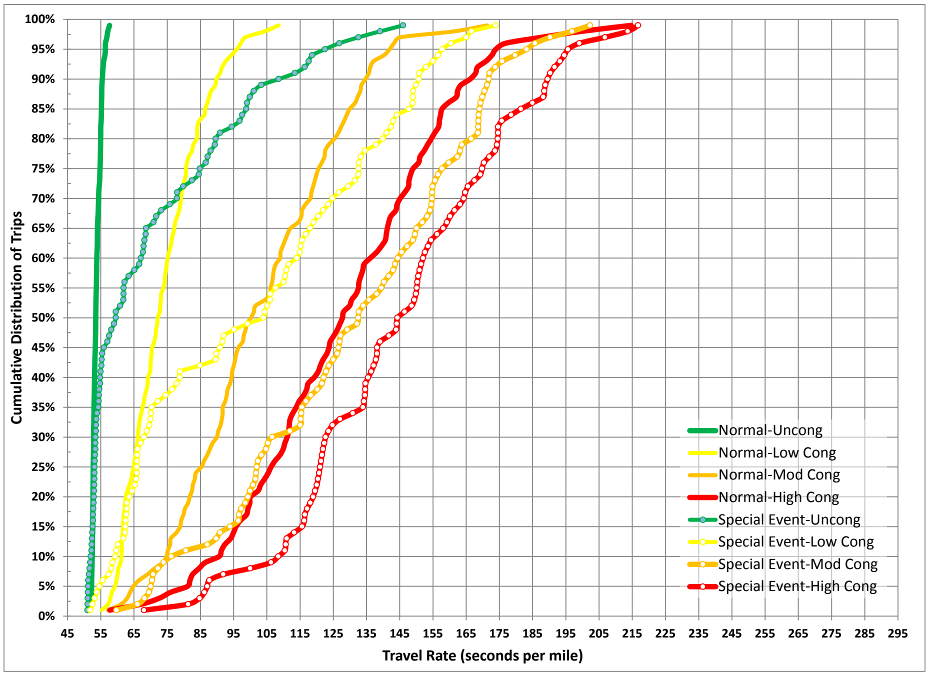


Figure ES.3. Cumulative distribution functions for I-5 special events.

Another useful technique presented in the guide summarizes the relative contributions of different nonrecurring events to reliability on the facility (Table ES.2). Decision makers particularly liked this table for its ability to summarize critical factors and suggested that they would be interested in seeing this tested on other facilities.

Table ES.2. Percentages for Semi-Variances (SVs) for Each Regime on the I-5 Facilities

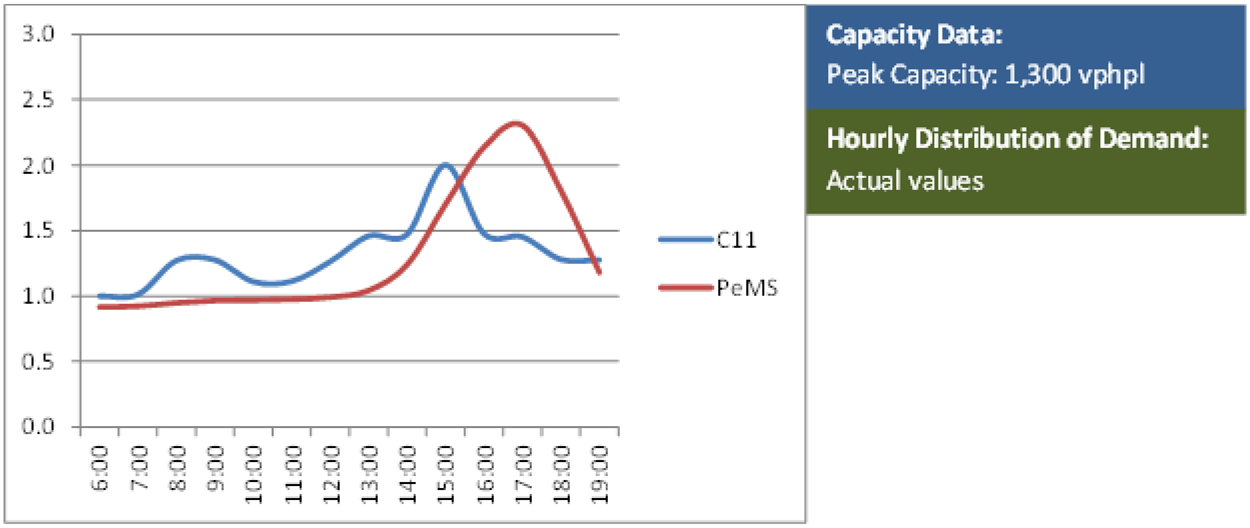
County	Route	Regime	Normal	Demand	Weather	Special Event	Incident	Regime Total SV	Facility Total
Orange	I-5	Uncong	2%	0%	2%	1%	1%	**6%**	**100%**
		Low Cong	9%	0%	5%	1%	3%	**18%**	
		Mod Cong	13%	0%	6%	4%	5%	**27%**	
		High Cong	28%	0%	12%	1%	8%	**49%**	
I-5 Totals			**52%**	**0%**	**24%**	**7%**	**17%**	**100%**	

SHRP 2 Analysis Tools

After examining the contributions of nonrecurring events to reliability on the facility, the study team tested analysis tools from three different projects:

- The Reliability Analysis Tool developed under **Project C11** is a sketch planning tool intended to help users incorporate reliability analysis into a standard benefit-cost framework by providing estimates of reliability impacts and monetizing those impacts using a reliability ratio and a value of travel time. The tool also provides a simple method for estimating the reliability impacts of projects.
- The **Project L07** Analysis Tool is designed to analyze the effects of highway geometric design treatments on nonrecurrent congestion using a reliability framework. The tool has built-in, custom algorithms for modeling 16 treatments using relatively simple input data on the treatment effects and cost parameters. The algorithms are based upon work done in previous research.
- **Project L08** developed the FREEVAL-RL tool. This tool is derived from the FREEVAL model, which implements the freeway modeling methodologies found in the 2010 *Highway Capacity Manual* (HCM). FREEVAL-RL is intended to test the reliability impacts of projects by dynamically modeling multiple operating scenarios along a facility using a Monte Carlo–type strategy. This tool is more complicated than the previous two tools.

The study team calibrated each tool for existing conditions for each facility and then tested multiple scenarios that were developed as part of the CSMP process. Figure ES.4 provides an example of model calibration along the I-210 site using the C11 tool. The study team found that the level of detail in FREEVAL-RL requires significantly more effort than the other SHRP 2 reliability tools. The calibration process is roughly comparable to that of a microsimulation model in terms of time and technical knowledge required.



Capacity Data:
Peak Capacity: 1,300 vphpl

Hourly Distribution of Demand:
Actual values

Figure ES.4. Calibration of C11 tool on the I-210 by comparing mean Travel Time Index (TTI).

Benefit-Cost Findings

After exploring the calibration and modeling capabilities of the three SHRP 2 analysis tools, the study team examined the impact of adding travel time reliability to benefit-cost analysis. The team found that the C11 tool was relatively easy to use and provided reasonable results, so this tool was used to estimate the reliability benefits of projects.

Figures ES.5 and ES.6 show how the CSMP benefit-cost analysis changed with the inclusion of travel time reliability benefits. The shaded portion of the bars indicates benefits due to improvements in travel time reliability, while the solid portion indicates the benefits in the original benefit-cost analysis found in the CSMP. While the ramp metering scenario resulted in a very high benefit-cost ratio, the C11 tool does not seem to show a large benefit from improving travel time reliability on the facility. However, operational improvement benefits are reflected in the total benefits calculated, which include travel time savings, vehicle operational cost savings, and emission cost savings. The addition of reliability benefits did not affect the rank order of projects on either facility in terms of total user benefits or benefit-cost ratios. Nevertheless, it may make a marginal project cost beneficial (benefit-cost ratio above one). Furthermore, travel time reliability can make a difference in the ranking of projects that have very similar benefits.

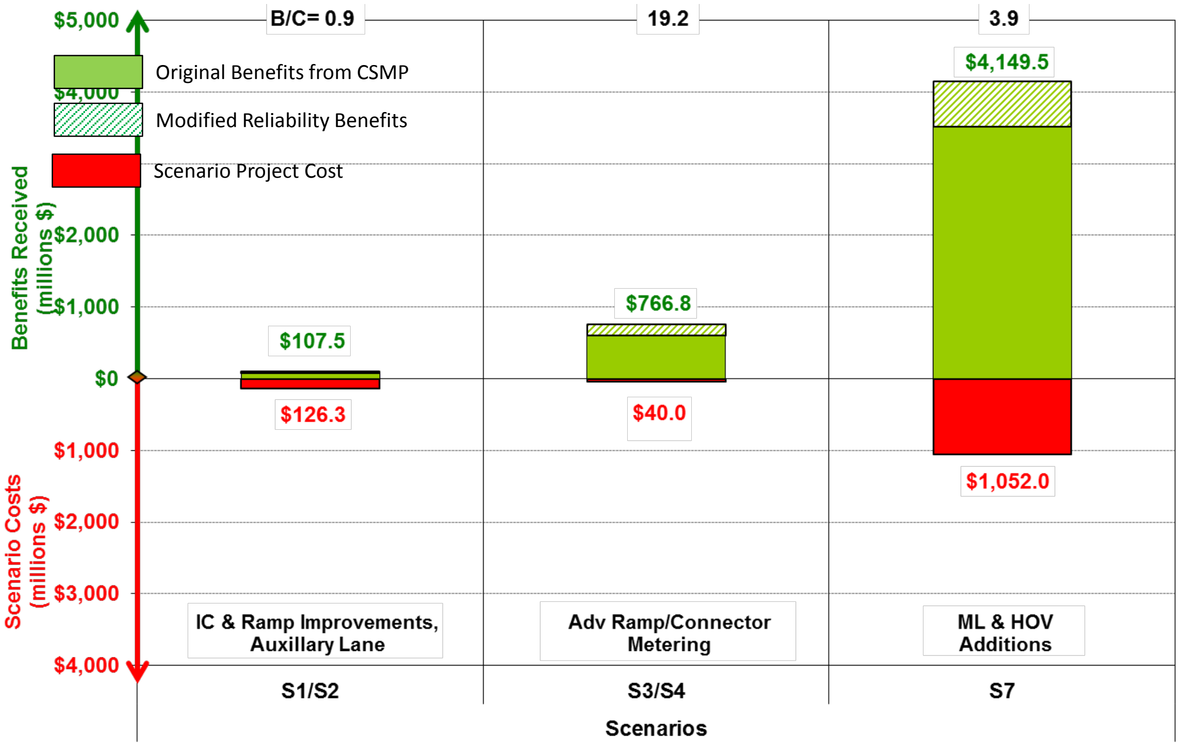


Figure ES.5. Benefit-cost results for I-5 facility with C11 reliability estimate modified.

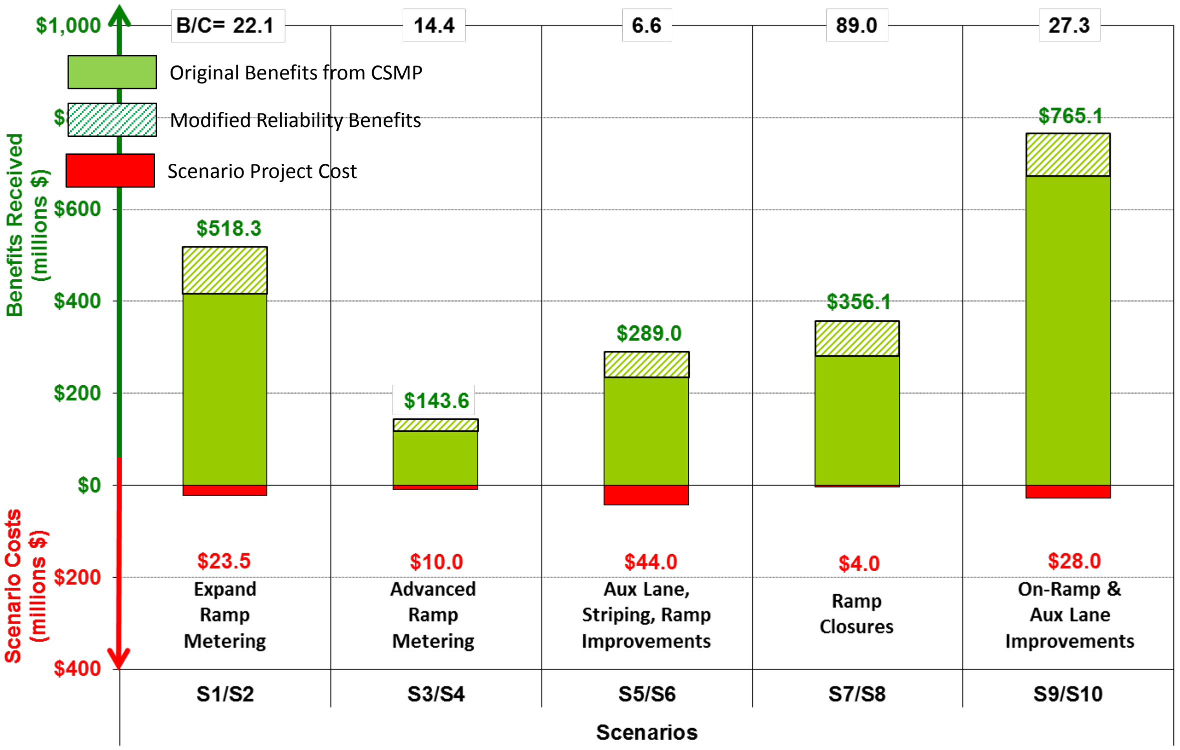


Figure ES.6. Benefit-cost results for I-210 facility with C11 reliability estimate modified.

Technical Feasibility of Products

The L02 guide provided a number of new analysis techniques and ways of looking at the causes of unreliability. The CDFs and the percent contribution tables help to show the relative contribution of reliability factors and visualize their impact on facility reliability. The study team found that the order in which factors are assigned affects the results of the analysis. The analysis should include categories for multiple factors (e.g., incidents and weather issues occurring simultaneously) and specifically consider factors such as work zones and lane closures. These reliability analysis techniques could be incorporated into future CSMPs, which was an interest expressed by regional stakeholders who reviewed the findings from this project.

The bulk of the testing, documented in Chapters 5 through 7 of this report, is devoted to calibrating the three reliability analysis tools (from L07, L08, and C11) and using these tools to test improvement strategies. The study team found that these tools could be calibrated to baseline conditions after appropriate calibration levers such as capacity, hourly demand, and adjustment factors were identified. None of the tools had built-in capabilities to model the types of operational projects most likely to be tested in California, including ramp metering, ramp improvements, auxiliary lanes, and freeway connectors. The SHRP 2 reliability tools should be updated to handle these types of improvements.

Since the tools were unable to model key operational strategies used in Southern California, the study team had to rely on microsimulation modeling to estimate the changes in capacity needed to test the strategies in the SHRP 2 tools. With these inputs, the tools' estimated reliability impacts were lower than expected, and these impacts were highly correlated with mobility (or recurring delay) results. In fact, reliability benefits fell in a narrow range between 29 percent and 36 percent of total benefits.

The study team found that there was a clear order in terms of ease of use among the SHRP 2 reliability tools (Figure ES.7). The C11 and L07 tools were much easier to use than the FREEVAL-RL tool. The study team had intended to split the analysis among SCAG and other team members, so that agency and consulting staff used all of the tools. The team quickly discovered that calibrating the FREEVAL-RL tool was complicated, so the calibration was assigned only to modelers on the pilot study team.

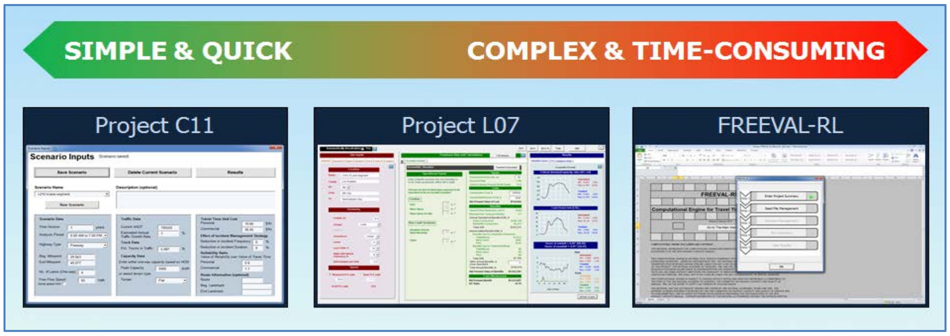


Figure ES.7. SHRP 2 reliability tools by ease of use.

The modelers were able to calibrate the three tools to baseline conditions on both the I-5 and I-210 freeways. The C11 tool could be calibrated by adjusting the capacity and changing the demand-by-hour distribution to match the facility distribution of volume by hour. The L07 tool could be calibrated using the same levers. The FREEVAL-RL tool was much harder to calibrate to baseline conditions, due to an inability to handle limited-access high-occupancy vehicle lanes and significant congestion along the facility that exceeded the maximum extent and duration supported in FREEVAL-RL.

None of the tools produced results that could be used directly in benefit-cost analysis, but each could be do so with minor adjustments:

- The C11 tool estimates benefits for the current year and a future year, but it does not estimate life-cycle benefits over a given time period. These can be approximated by interpolating and discounting the current and future year benefits outside the model.
- The L07 tool estimates life-cycle benefits by estimating benefits for the current year and assuming these benefits are constant over the life cycle. The tool needs to be modified to accommodate demand growth.
- The FREEVAL-RL tool does not estimate monetized user benefits using the reliability results. However, these could be calculated from the travel time reliability performance measures (i.e., standard deviation or 50th and 80th percentile TTI) and vehicle-miles traveled (VMT) data outputted by the model.

Decision Maker Perceptions

SCAG and Caltrans representatives agreed that considering reliability in the decision-making process would be an important step forward, particularly since project selection decisions in Southern California have been influenced by environmental and sustainability considerations in recent years.

Although measures of mobility and asset condition continue to influence decision making, other factors such as vehicle-miles traveled (VMT) per capita and greenhouse gas (GHG) emissions have been added to the list of factors considered. California state law (SB 375 and AB 32) now requires regional agencies to demonstrate that their regional transportation plans (RTPs) reduce GHGs per capita. Specific thresholds are defined by the California Air Resources Board, and regional agencies have to develop a sustainable community strategy that incorporates smart growth along with the RTP. Large expansion projects that encourage more driving are difficult to implement in this policy environment. Therefore, using reliability to make operational projects more visible to policy makers was encouraged by regional stakeholders.

In reviewing the findings from the SHRP 2 products, the reliability results were consistent with agency expectations. SCAG and Caltrans representatives reacted positively to the CDF graphs and percent contribution tables as ways to summarize factors contributing to reliability. Representatives from both agencies noted that the SHRP 2 products would be useful to include in the Southern California CSMPs and expressed an interest in extending and focusing SHRP 2 efforts on short- to medium-term operations-centric projects. These projects tend not to be controversial to environmental stakeholders; improving reliability will generally lead to improvements in GHG emissions.

This is in line with a goal of this SHRP 2 pilot testing to find ways to demonstrate how operational strategies improve travel time reliability, which is highly valued by both the person and goods movement transportation markets:

- Travelers get frustrated when their trip travel times vary significantly. They either have to routinely plan for longer travel times or frequently arrive at their destinations later than planned.
- Truck drivers often do not have choices. They have to arrive at a certain time, so they must plan for a margin of unexpected delays, which reduces their productivity and increases costs.

Caltrans representatives recognized the value of incorporating reliability in decision making and thought reliability could be useful as one measure among many for choosing operations projects. Reliability also may help to promote managed lane projects, which are a major focus of planning efforts in Southern California.

SHRP 2 Tool Modifications

Calibrating the SHRP 2 tools to baseline conditions is a critical first step before any reliability analysis can occur. The reliability tools show promise for analyzing travel time reliability on highway facilities, but they need modifications to their user interfaces and calculation analytics before they are ready for implementation by transportation agencies.

The Southern California pilot site provided the SHRP 2 Reliability program with a list of quick fixes that are critical for moving the tools toward implementation. The detailed findings in this report support those quick fixes. Below are a few common threads of modifications needed across the tools:

- There needs to be *guidance for how to calibrate* each tool to baseline conditions. This guidance should cover how to identify study areas and analysis periods as well as which levers allow the tool to be calibrated.
- These *calibration levers must be easily accessible* to the user. The Southern California study team identified several variables, such as capacity, capacity adjustment factors, and demand by hour of day that can be used to calibrate models. In some tools, these calibration levers are hidden from the user or not presented directly on the input pages. They need to be made more easily accessible.

- The tools need *modifications to support scenario analysis*. These modifications should include the ability to designate specific time periods and highway segments for analysis. Practitioners need the ability to tailor reliability analyses to support existing studies and analysis. In addition, tool users need to be able to adjust time periods and highway segments and then rerun analyses without having to set up the models from scratch.
- A related need is the *ability to import and save data*. The reliability tools tested in the Southern California pilot site needed varying amounts of data, but generally required the user to enter information through pull-down menus or manual entry. For the tools that require large amounts of information (e.g., FREEVAL-RL), the ability to copy and paste data or import data from external spreadsheet files would significantly aid the calibration and scenario processes.
- The tools also need *analytics to support specific types of operational improvements*. For Southern California, the most common operational projects to test include ramp metering strategies, auxiliary lanes, freeway connectors, and ramp modifications. The other three pilot sites may identify additional project types. The SHRP 2 reliability tools should be able to analyze the projects that users are most likely to want to test.
- The tools need to be able to *model reliability for highly congested facilities*. Practitioners most likely will want to test reliability on these facilities, yet the extent and duration of congestion in Southern California exceeded the ability of some SHRP 2 tools to model congestion.
- The tools need to *support life-cycle benefit analysis*. Benefit-cost analysis needs the sum of user benefits over an expected life cycle. The current tools either estimate benefits for specific years or assume that the current benefits remain constant over the life cycle. The tools should be modified so that agencies can simply take the sum of the reliability benefits and add them to standard benefit-cost analysis.

Reliability Performance Measures

Common reliability performance measures should be used across the planning process. The SHRP 2 reliability research has resulted in different measures and tools, but inconsistency can result if they are applied to a practical planning problem. Figure ES.8 summarizes a simple planning process and the inconsistency in measures when the SHRP 2 tools are applied.

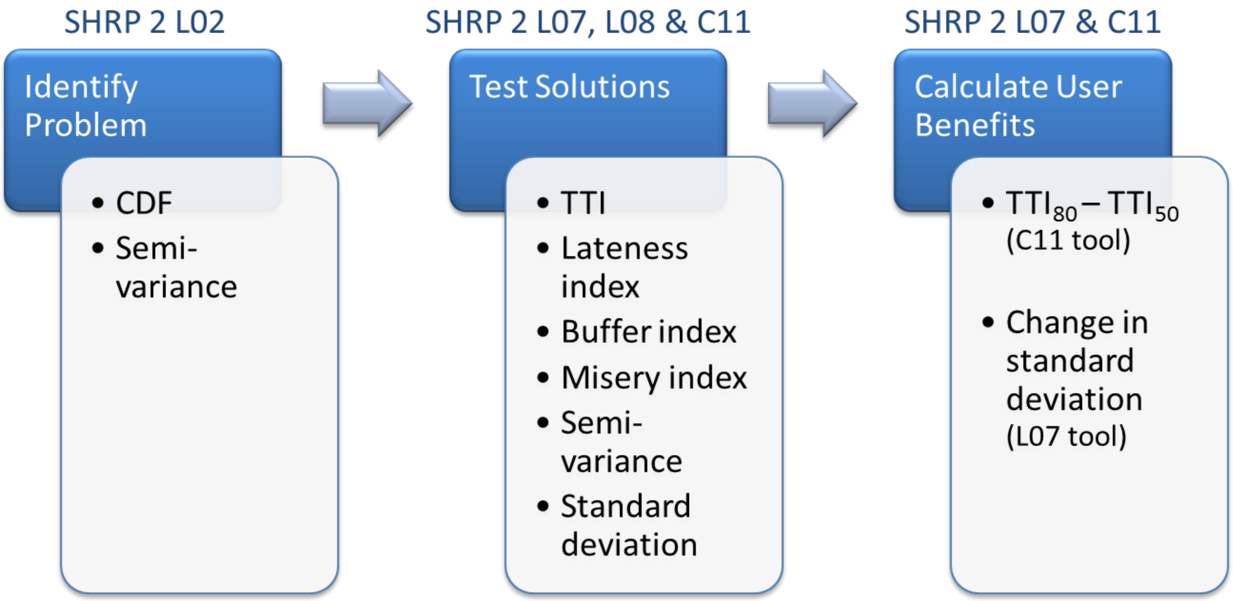


Figure ES.8. Inconsistency in performance measures for planning process.

The L02 project provides a number of methods for analyzing travel time reliability and suggests that users present results in terms of CDF or semi-variance. Other SHRP 2 projects (e.g., L07, L08, and C11) provide tools for testing the reliability impacts of projects. While these tools summarize the reliability impacts in a variety of performance measures, the measures differ from the ones used to identify the travel time reliability problem in L02.

L07 and C11 provide methods for estimating the value of the travel time reliability benefits, but they differ in the performance measures used to estimate the value of the benefits. FREEVAL-RL will need to adopt one of these two methods if it is to calculate the value of reliability benefits. When the SHRP 2 projects are examined together, they could benefit from standardization in the measures used to identify reliability problems, test solutions, and calculate user benefits.

Suggested Research

The stakeholders involved in the Southern California pilot site responded positively to the results produced by the product testing. It was suggested that the tools used could be applied across multiple freeways in the region to be able to identify causal factors of congestion as well as compare among different facilities.

SHRP 2 implementation should involve further testing of the SHRP 2 products at the pilot sites and additional locations following revision of the tools in order to address the quick fixes suggested by the four current pilot sites. The Southern California pilot site found that the C11 tool produced reliability benefits in a narrow range between 29 percent and 36 percent of total benefits (from 30 percent to 32 percent for the I-5 facility and from 29 percent to 36 percent for the I-210 facility). Since this finding is based on a limited number of observations, more testing is suggested to see if this finding holds true across different pilot sites and for different types of projects.

Additional freeways could also test the various calibration methods proposed by the four pilot sites. Most of these calibration methods are a function of changing capacity. Further research could test whether similar capacity adjustments are warranted at other sites.

The current SHRP 2 tools are unable to test many of the common operational strategies used in Southern California. The SHRP 2 program could collect a list of operational strategies from the four pilot sites and conduct research on the impacts of these types of projects on travel time reliability, following the approach adopted for L07.

CHAPTER 1

Background

1.1 Introduction

The second Strategic Highway Research Program (SHRP 2) has been researching the critical subject of travel time reliability for several years. As part of this research, SHRP 2 supported multiple efforts to develop tools for evaluating travel time reliability and estimating the impact of projects on reliability. In particular, the SHRP 2 reliability projects developed several methods to help public agencies:

- Collect and analyze data on the variability of travel time,
- Diagnose problems,
- Propose actions or alternative mitigation strategies, and
- Test the impacts of solutions.

A goal of this research was to find ways to demonstrate how operational strategies improve travel time reliability, which is highly valued by both the person and goods movement transportation markets:

- Travelers get frustrated when their trip travel times vary significantly. They either have to routinely plan for longer travel times or frequently arrive at their destinations later than planned.
- Truck drivers often do not have choices. They have to arrive at a certain time, so they must plan for a margin of unexpected delays, which reduces their productivity and increases costs.

Operational strategies are critical to improving both mobility and travel time reliability on highways. These strategies generally can be implemented faster than larger system expansion projects, often do not require detailed environmental reviews, and generally cost much less. However, decision makers often defer operational investments, in part because of the limitations of existing tools. Examples of operational strategies used to mitigate traffic congestion and improve reliability include:

- Ramp metering,
- Auxiliary lanes,
- Improved incident management, and
- Improved traveler information.

Traditional tools, including travel demand and microsimulation modeling, have to date not been able to adequately estimate the reliability benefits of projects. As a result, the SHRP 2 reliability products have the potential to fill a void in the ability to analyze reliability impacts and quantify likely benefits of operational strategies. The SHRP 2 products need to be tested on real facilities using complex data sets and within complex political processes.

The SHRP 2 L38 project is intended to provide the necessary testing and feedback on existing SHRP 2 reliability tools. The RFP for SHRP 2 L38 provided the following objectives:

1. Assist agencies in moving reliability into their business practices through testing of data integration and analytical tools developed by SHRP 2. Include a data collection/integration component, an analytical component, and a decision-making component.
2. Provide feedback to SHRP 2 on the applicability and usefulness (benefits and value) of the products tested. Suggest potential refinements [to the products tested].

Pilot testing under the SHRP 2 L38 project occurred at four separate sites in Florida, Minnesota, Washington State, and Southern California. This report describes the approach and findings from the Southern California pilot site. Pilot testing at the other three sites was conducted simultaneously by different study teams under separate contracts. However, the study teams for the four pilot sites interacted multiple times and were able to share ideas on product testing.

1.2 Southern California Pilot Site

The Southern California pilot site is one of the most congested regions in the United States. The Texas Transportation Institute *2012 Urban Mobility Report* ranks the Los Angeles-Long Beach-Santa Ana urban area second to the Washington, D.C. metro area in terms of yearly delay per auto commuter. The Los Angeles area ranks first in terms of having the worst travel time index (i.e., the ratio of travel time in the peak period to the travel time at free-flow conditions) and ranks either first or second worst in several travel time reliability measures (Texas Transportation Institute 2012). Clearly, this is a region where reliability improvements are needed.

The Southern California pilot site conducted a practical, yet critical evaluation of the SHRP 2 products and concepts developed to date with an emphasis on analyzing operational strategies that can mitigate the region's travel time reliability issues. The study team performed its testing in conjunction with the Southern California Association of Governments (SCAG) and the California Department of Transportation (Caltrans).

SCAG is the largest metropolitan planning organization (MPO) in the United States. It represents six counties, 191 cities, and more than 18 million residents. The agency has a long history of performance-based transportation planning and recognizes the importance of operational strategies. SCAG played a very active role in the SHRP 2 L38 evaluation by helping to select facilities for testing, conducting hands-on testing of the SHRP 2 reliability tools, reviewing work products, providing feedback on the tools, and soliciting input from the larger stakeholder group within the region.

In April 2012, the SCAG Regional Council, which is comprised of over 90 locally elected officials, unanimously adopted the 2012–2035 Regional Transportation Plan/Sustainable Communities Strategy (RTP/SCS). Figure 1.1 shows the goals adopted by the Regional Council and included in the 2012 RTP/SCS.

As shown in the figure, ensuring travel reliability is one of the regional goals. The RTP/SCS goes a step further and includes a specific reliability goal with a 10-percent improvement benchmark (SCAG 2012). SCAG would greatly benefit from methods that help to quantify future reliability improvements, especially since its Regional Council has directed staff to work on further quantification of performance measures.

RTP Goals
Align the plan investments and policies with improving regional economic development and competitiveness
Maximize mobility and accessibility for all people and goods in the region
Ensure travel safety and reliability for all people and goods in the region
Preserve and ensure a sustainable regional transportation system
Maximize the productivity of our transportation system
Protect the environment and health for our residents by improving air quality and encouraging active transportation (non-motorized transportation)
Actively encourage and create incentives for energy efficiency, where possible
Encourage land use and growth patterns that facilitate transit and non-motorized transportation
Maximize the security of the regional transportation system through improved system monitoring, rapid recovery planning, and coordination with other security agencies

Figure 1.1. SCAG 2012 RTP/SCS goals.

Source: SCAG, 2012-2035 Regional Transportation Plan and Sustainable Community Strategy

In addition, the 2012 RTP/SCS also provided a high-level regionwide estimate for potential improvements in reliability for three different hours during the day. These improvements were expected as a result of the operational investments, particularly through improved incident management. The estimates presented in the SCAG RTP/SCS were based on the Corridor System Management Plan (CSMP) efforts in the SCAG region.

As part of the SHRP 2 L38 evaluation, SCAG helped the study team navigate the complex organizational relationships and decentralized decision making found in Southern California. Many funding decisions are made at the local or regional level due to the presence of self-help counties. These are counties in which voters have voluntarily agreed to tax themselves to pay for transportation improvements. For example, Los Angeles County has enacted a combination of permanent and temporary measures that dedicate a combined total 1.5 percent sales tax to transportation. As a result, SCAG took a lead role in coordinating public agency participation for this SHRP 2 L38 effort.

The stakeholder group included elected officials, county transportation commissions (CTCs) and Caltrans district offices as well as some of the larger local operators, such as the Los Angeles County Metropolitan Transportation Authority (LA Metro). SCAG assisted in convening transportation stakeholder group meetings as necessary, relying on its existing policy and technical committee structure as forums for additional dialog with the stakeholders and decision makers. SCAG included a written update on the SHRP 2 L38 project in its consent calendar for the Transportation Committee. SCAG also held a meeting with its technical working group on December 18, 2013.

Caltrans is committed to system management. The agency has formally adopted what it terms the Mobility Pyramid, which focuses on the importance of operational strategies. As a champion of system management, Caltrans is interested in research that furthers its commitment to funding operational strategies, especially given its role in improving interregional mobility. Although Caltrans played a less direct role than SCAG in the SHRP 2 pilot testing, Caltrans provided feedback on facility selection, the SHRP 2 reliability products, and the results of the reliability evaluations through its district offices. For example, the study team met with Caltrans District 12 in Orange County on January 28, 2014, to review the study findings and gain additional stakeholder perceptions from senior level management at the district.

Caltrans District 12 is very familiar with the concept and use of reliability measures since each of the freeways in Orange County has had a reliability evaluation performed as part of the CSMP efforts in that district. For each CSMP, the buffer index was calculated for non-holiday weekdays for both mainline and high-occupancy vehicle (HOV) lanes. During the January 28 meeting, Caltrans district management was interested in learning more on how reliability assessments, particularly through the work done on L02, could be applied in the district and communicated this to the Orange County Transportation Authority (OCTA), which controls most of the funding within the district.

By engaging these “advanced users,” the Southern California pilot site tested two aspects of the SHRP 2 products without the need to introduce the travel time reliability concept:

- Technical functionality: How easy are the products to use? How consistent are they with each other and prior work?

- Practical use: Do they help Southern California select and prioritize projects? Do decision makers understand the reliability analyses and find the results credible?

In addition, SHRP 2 testing in Southern California benefitted from extensive automated detection and performance measurement through the Caltrans Performance Measurement System (PeMS). This is an Internet-based system that allows the extraction of real-time and historical performance data collected through automated sensors, such as loop detectors. Users can access PeMS with any computer using an Internet connection and standard web browser. The system includes a diagnostics function that attempts to identify data issues, and PeMS automatically estimates travel time reliability performance measures. Figure 1.2 shows an example of the extensive detection coverage available through PeMS. The green circles indicate detectors providing good data, while the red circles indicate sensors with bad data on the day the map was generated. The facilities analyzed as part of the Southern California pilot site are outlined on the map as well.

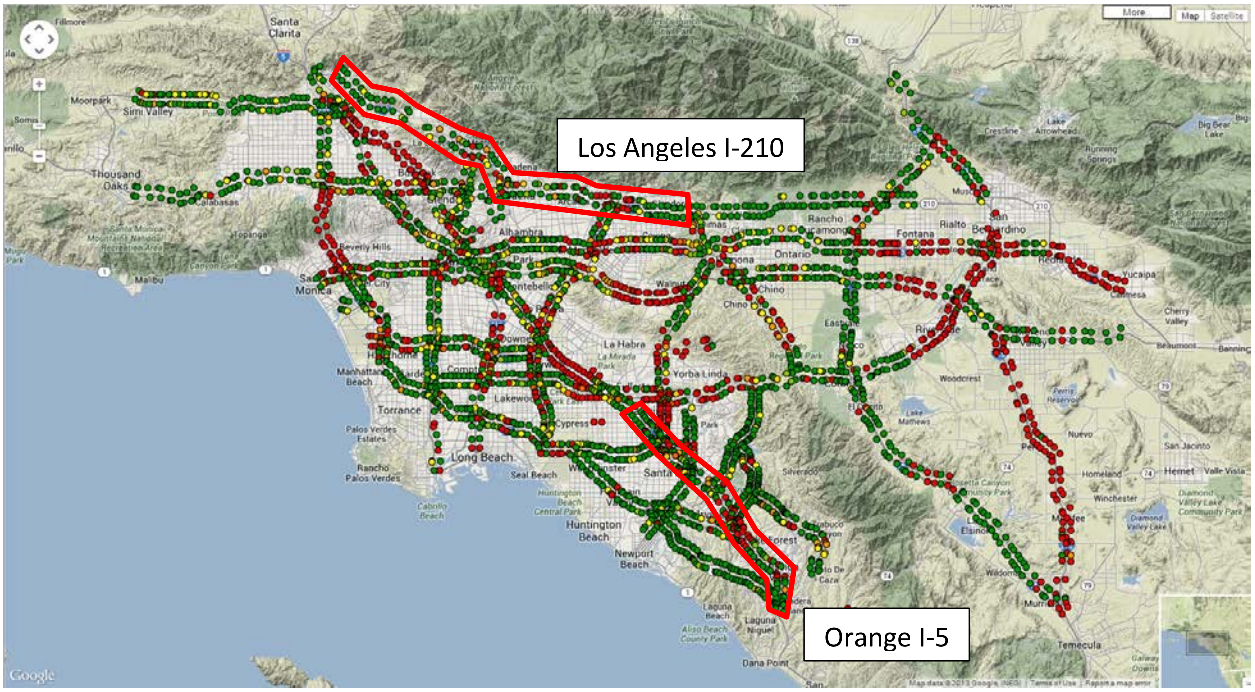


Figure 1.2. Sensor coverage in the Southern California pilot site.

Source: Caltrans Freeway Performance Measurement System (PeMS). pems.dot.ca.gov.

1.3 Organization of the Report

The rest of this report provides detailed findings from the Southern California pilot site. The next two chapters describe the overall research approach taken for the Southern California pilot site and the selection of two facilities for testing (I-210 in Los Angeles County and I-5 in Orange County). Chapter 4 discusses the compilation of data for the reliability analysis and the application of the L02 guide to understand what factors affect reliability along the test facilities as well as the contributions of these factors to unreliability. This is followed by three chapters dedicated to each of the reliability analysis tools included in the pilot testing:

- C11 Reliability Analysis Tool (for incorporating reliability in benefit-cost analysis)
- L07 Analysis Tool (for analyzing the effects of highway geometric design treatments)
- FREEVAL-RL (for implementing proposed changes to the Highway Capacity Manual to incorporate reliability analysis).

These chapters describe the calibration of the tools to the test facilities as well as their application to facility improvements previously identified by SCAG, Caltrans, and other stakeholders. Based upon these findings, the study team conducted a detailed benefit-cost analysis using the C11 tool and results available from microsimulation analyses. The benefit-cost findings are presented in their own chapter.

After these findings, the study team summarizes observations from the analysis tools and outreach from stakeholders to conduct a functionality assessment of the products and outcomes. The functionality assessment considers the technical feasibility of products, decision maker perceptions, and potential impacts on decision making. A final chapter provides conclusions from the pilot testing along with a summary of suggested modifications to the SHRP 2 reliability tools and suggested research.

CHAPTER 2
Research Approach

The Southern California pilot site conducted its SHRP 2 reliability product testing by leveraging existing CSMPs prepared for facilities in Southern California. Both SCAG and Caltrans have invested significant resources in the development of these CSMPs. The plans are intended to describe how a facility is currently performing, identify operational strategies and select system expansion opportunities that can improve performance, and quantify the likely benefits that result from these investments.

CSMPs were initially developed for facilities that received funding from the California Corridor Mobility Improvement Account (CMIA), which was created by the passage of State Proposition 1B in November 2006. To a great extent, CSMPs were produced to complement existing expansion plans with value-added operational strategies, though Caltrans intends to prepare CSMPs for all major travel facilities in California and to update them periodically.

Southern California has roughly a dozen facilities with completed CSMPs. Each plan includes a comprehensive performance assessment with data from PeMS and other sources to document mobility, safety, productivity, preservation, and travel time reliability. In addition, Caltrans has invested millions in developing microsimulation models for each Southern California CSMP that can quantify the mobility benefits of various operational and system management strategies on each facility.

Each CSMP also includes benefit-cost analysis to demonstrate the cost effectiveness of proposed strategies. Currently, the benefit-cost analysis includes user benefits in terms of travel time savings, vehicle operating cost savings, and emission reductions. Although the comprehensive performance assessment describes travel time reliability, the benefit-cost analysis does not include reliability benefits because microsimulation modeling is unable to capture the reliability impacts of improvement strategies.

The Southern California pilot site built on the tools and analysis available from the development of CSMPs. In addition to the comprehensive performance assessments and microsimulation models, the study team had travel demand models that identify origins and destinations along the facilities. As a result, the team had the pieces needed to conduct a deeper analysis of reliability causality, compare facilities, select the most appropriate facilities, and use the models already developed to forecast demand for the SHRP 2 tools.

The study team tested several of the SHRP 2 products using the two CSMP facilities. The team selected features considered to be the most applicable to facility management planning in California and to have the greatest likelihood to help with developing California CSMPs, expanding benefit-cost analysis capabilities, and setting goals for the SCAG RTP/SCS. If the tools prove to be capable of supporting enhanced travel time reliability analysis, they may also help Caltrans set goals for the State Highway Operations and Protection Program (SHOPP) and develop operational playbooks for freeway facilities.

Table 2.1 summarizes the SHRP 2 reliability tools that the Southern California pilot site initially planned to include in its testing. The study team focused on the L02 methods for describing travel time reliability and contributing factors as well as the analysis tools for forecasting reliability and estimating impacts from L07, L08, and C11. The next several chapters discuss results from testing these tools.

Table 2.1. SHRP 2 reliability products tested in the Southern California pilot site

Type of Product	L02	L05	L07	L08	C11
Methods for Describing Reliability and Contributing Factors	✓				
Suggested Alternative Strategies and Design Features		✓	✓		
Tools for Forecasting Reliability and Estimating Impacts			✓	✓	✓
Benefit Estimates for Benefit-Cost Analysis			✓		✓
Guidelines for Goal Setting		✓			

The team reviewed the L05 guide (Cambridge Systematics 2013) and found that it would not help the team in suggesting alternative strategies and design features. However, SCAG believes that the guide will be helpful in articulating the issue of system reliability, developing a framework for incorporating reliability into its planning and decision-making processes, and communicating the results to the stakeholders, members of the public, and decision makers as part of its next RTP. The guide may be helpful for local partner agencies, such as county transportation commissions and Caltrans, to utilize in local planning processes.

This local focus for incorporating reliability into the decision-making process is based on how decisions for transportation investments are made in California. Self-help counties that have passed one or more voter measures to collect sales taxes dedicated to transportation control most of the funding. Even decisions for 75 percent of the funds administered by the state, such as federal and state gas taxes, are made by regional agencies. For example, the Los Angeles County Metropolitan Transportation Authority (Metro) controls more than $2 billion of annual transportation funds, significantly more than Caltrans controls.

In addition to reviewing L05, SCAG played a critical role in the SHRP 2 product testing for other products. SCAG helped to select facilities for the Southern California pilot site. SCAG reviewed work products and provided feedback as a potential user of tools. Additionally, SCAG coordinated and facilitated input from the larger stakeholder group using its existing policy and technical committee structure. This included input from Caltrans district offices, county transportation commissions, and elected officials.

The study team split responsibilities for tool testing among team members. SCAG and its consulting partners were each responsible for testing on a facility. In this way, the study team was able to get hands-on feedback from a public agency perspective. To facilitate the testing of FREEVAL-RL and to ensure comparability of the SHRP 2 reliability testing, the study team used the modelers who were involved in microsimulation modeling on the CSMP facilities. In the end, the Southern California pilot site hopes to have better CSMPs and quantification of reliability for benefit-cost analysis and goal setting.

Overall, the study team followed these general steps for the pilot testing:

- Review facilities with existing CSMPs and select two of the most promising facilities for reliability improvement;
- Compare reliability on the facilities and understand factors that affect reliability;
- Use SHRP 2 tools to develop more detailed, robust analyses of travel time reliability;
- Leverage available microsimulation models, travel demand models, detection, and automatic sensor data;
- Test recently programmed or planned projects and potential operational strategies; and
- Present results to SCAG policy and technical committees.

The next chapter reviews the Southern California CSMP facilities and describes the two facilities selected for pilot testing. Subsequent chapters provide results and reviews for each tool.

CHAPTER 3
Selection and Description of Test Facilities

3.1 Selection of Facilities

The study team started its pilot testing by identifying and discussing potential test facilities that already had completed CSMPs. As shown in Figure 3.1, there are roughly a dozen facilities in Southern California with CSMPs completed or underway. While not covering the entire freeway system in Southern California, these facilities cover many of the most congested routes in the SCAG region. After some discussion with SCAG and Caltrans staff, these were narrowed to nine potential test facilities in Los Angeles and Orange counties.

Figure 3.1. Facilities with CSMPs in Southern California.

The study team then researched the quality of the data available in PeMS and other sources reporting travel time reliability along the CSMP facilities. Table 3.1 provides a summary of the team’s analysis of the potential pilot facilities. The table delineates the facility limits in terms of Caltrans postmiles and provides an indication of detection quality on the mainline freeway and adjacent high-occupancy vehicle lanes, if applicable. As shown in the table, most facilities have extensive detection with average detection spacing of less than one half mile.

Table 3.1. Analysis of Potential Pilot Facilities

Caltrans District	County	Facility	From/To Location	From Abs p.m.	To Abs p.m.	Mainline Detection				High-Occupancy Vehicle Detection				Usefulness for "Unreliability" of Travel Time	Analysis Summary
						Total Facility Distance (miles)	Number of Detectors by Direction (N or E/S or W)	Average Detector Spacing (miles/detector)	Data Quality Assessment	High-Occupancy Vehicle Distance (miles)	Number of Detectors by Direction (N or E/S or W)	Average Detector Spacing (miles/detector)	Data Quality Assessment		
7	Los Angeles	I-5 North	I-10 to I-210	132.7	160.7	28.0	41/50	0.7/0.5	○	6.0	6/3	0.8/1.2	●	◉	Long average spacing compared to other Facilities, poor data quality for both ML and high-occupancy vehicle.
7	Los Angeles	I-5 South	Orange County Line to I-710	116.6	130.5	13.9	33/34	0.4/0.4	◉					●	Excellent spacing, but average data quality. No high-occupancy vehicle facility. Highly "unreliable" facility.
7	Los Angeles	I-110	I-405 to Adams St	8.5	20.5	12.0	24/24	0.5/0.5	●	21.4	8/12	1.0/0.7	◉	◉	Good spacing and reasonable data quality for both ML and high-occupancy vehicle.
7	Los Angeles	I-210	SR-134 to SR-57	24.6	44.9	20.3	40/43	0.5/0.5	●	20.3	39/42	0.5/0.5	●	●	Good spacing and reasonable data quality for both ML and high-occupancy vehicle. Highly "unreliable" facility.
7	Los Angeles	I-405 North	I-10 to I-5	53.7	72.1	18.4	25/32	0.7/0.6	○	8.3	12/24	0.7/0.6	○	◉	Long average spacing compared to other Facilities, poor data quality for both ML and high-occupancy vehicle.
7	Los Angeles	I-405 South	I-110 to I-10	36.4	53.7	17.3	38/39	0.4/0.4	●	16.3	37/40	0.4/0.4	◉	●	Excellent spacing and good data quality. Highly "unreliable" facility.
12	Orange	I-5	San Diego County Line to Los Angeles County Line	72.3	116.6	44.4	106/103	0.4/0.4	●	36.0	93/90	0.4/0.4	◉	○	Excellent spacing and very good data quality. Relatively "reliable" facility.
12	Orange	SR-22	SR-55 to I-405	1.5	14.3	12.8	40/40	0.3/0.3	●	10.3	35/32	0.3/0.3	●	○	Excellent spacing and excellent data quality. Relatively "reliable" facility.
12	Orange	SR-57	I-5/SR-22 to Los Angeles County Line	0.0	11.9	11.9	28/27	0.4/0.4	◉	11.2	31/27	0.4/0.4	◉	●	Good spacing, and reasonable data quality.
12	Orange	SR-91	Riverside County Line to I-5	18.0	37.2	19.2	37/35	0.5/0.5	◉	18.4	30/30	0.6/0.6	◉	○	Good spacing and reasonable data quality. Relatively "reliable" facility.
12	Orange	I-405	I-5 to I-605	0.0	23.6	23.6	58/55	0.4/0.4	●	23.2	54/58	0.4/0.4	◉	◉	Excellent spacing, and very good data quality.

Key:

●	**High rank**
◉	**Medium rank**
○	**Low rank**

PeMS has a built-in diagnostic feature that identifies the percentage of sensor data that is "good." Good data are those that have been successfully transmitted from sensors in the field into the PeMS system and that meet other diagnostic criteria (e.g., speeds not excessive and reported flows within acceptable traffic engineering ranges). The circles in Table 3.1 indicate the relative availability of data, with green circles corresponding to facilities that have roughly 70 percent or more good data available, while red circles represent facilities with less than 50 percent of data available. Blue circles lie between these two thresholds.

The next-to-last column in Table 3.1 provides an indication of current travel time reliability along the facility. The study team wanted to select facilities with at least a reasonable level of unreliability, or there would be no reliability problems for investments to solve or reliability benefits for the SHRP 2 analysis tools to measure. This assessment was compiled by looking at 2012 weekday travel time reliability along the facility. Travel time reliability was measured using the travel time index (TTI) as calculated in PeMS as well as calculated externally in a database using a "walk the time-space matrix" method. This method and the team's calculations are described in Section 4.4

The analysis shown in Table 3.1 allowed the study team to narrow the potential test facilities from nine facilities to four based on a review of detection quality, reliability levels, and potential facility solutions. The team initially chose Interstate 210 (I-210) in Los Angeles County and State Route 57 (SR-57) in Orange County. I-405 was selected as an alternate pilot site in either county. The team wanted to select a facility from each county to provide a wider range of travel conditions and stakeholders.

Further consultation with Caltrans allowed the study team to select two final facilities for the pilot testing: I-210 in Los Angeles County and I-5 in Orange County. The I-210 facility has the worst reliability among the facilities considered. It also has a mixture of urban and suburban development. The I-5 facility replaced the SR-57 facility as the facility selected in Orange County. Although SR-57 had a nice combination of data quality and poor reliability, the majority of improvements along the facility were already programmed, so analysis of the facility would not help future funding decisions. The I-5 facility offers right-of-way for potential expansion projects as well as relative flexibility in funding future projects. The team also considered including I-10 and I-110 in Los Angeles County, but these facilities were rejected due to the potential conflict with ongoing express lane demonstrations.

3.2 Final Test Facilities

The next two sections provide background information from the CSMPs for the two facilities selected as the focus for the SHRP 2 reliability pilot testing.

I-5 Facility in Orange County

The first facility selected is the I-5 facility in Orange County. As shown in Figure 3.2, I-5 is a 45-mile facility with four to six general-purpose (or mainline) lanes in each direction. There are also one to two high-occupancy vehicle lanes in each direction. As is the standard configuration in Southern California, these high-occupancy vehicle lanes are barrier-separated, so access is limited to designated locations along the freeway. As described in Chapter 7, this led to significant difficulty in calibrating a FREEVAL-RL model for the facility.

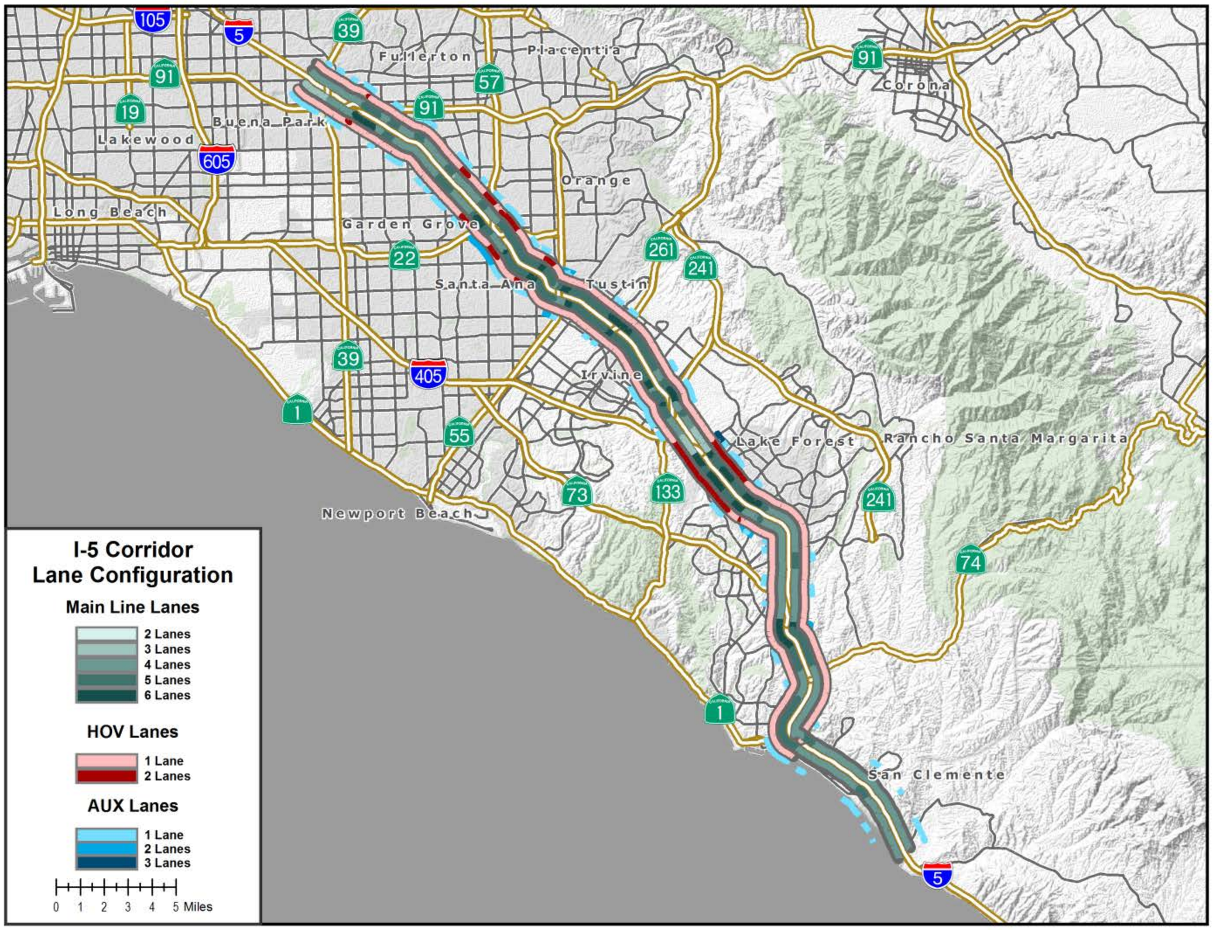


Figure 3.2. Map of I-5 facility in Orange County.

There are auxiliary lanes throughout the I-5 facility to improve merging to and from closely spaced ramps and connectors. Some short segments have up to three auxiliary lanes in a single direction. The I-5 facility has a very complex geometry that proved to be difficult to model in the SHRP 2 tools.

Figures 3.3 and 3.4 provide speed contour plots from the I-5 CSMP (Caltrans 2012). As shown in the figures, congestion is heaviest in the northbound direction during the p.m. peak period followed by congestion in the a.m. peak period for the southbound direction. During the most congested part of the day, congestion can extend 12 to 15 miles with queuing from downstream bottlenecks overtaking upstream bottleneck locations. Congestion during an individual peak can last 4 to 6 hours with some portion of the facility congested nearly the entire day.

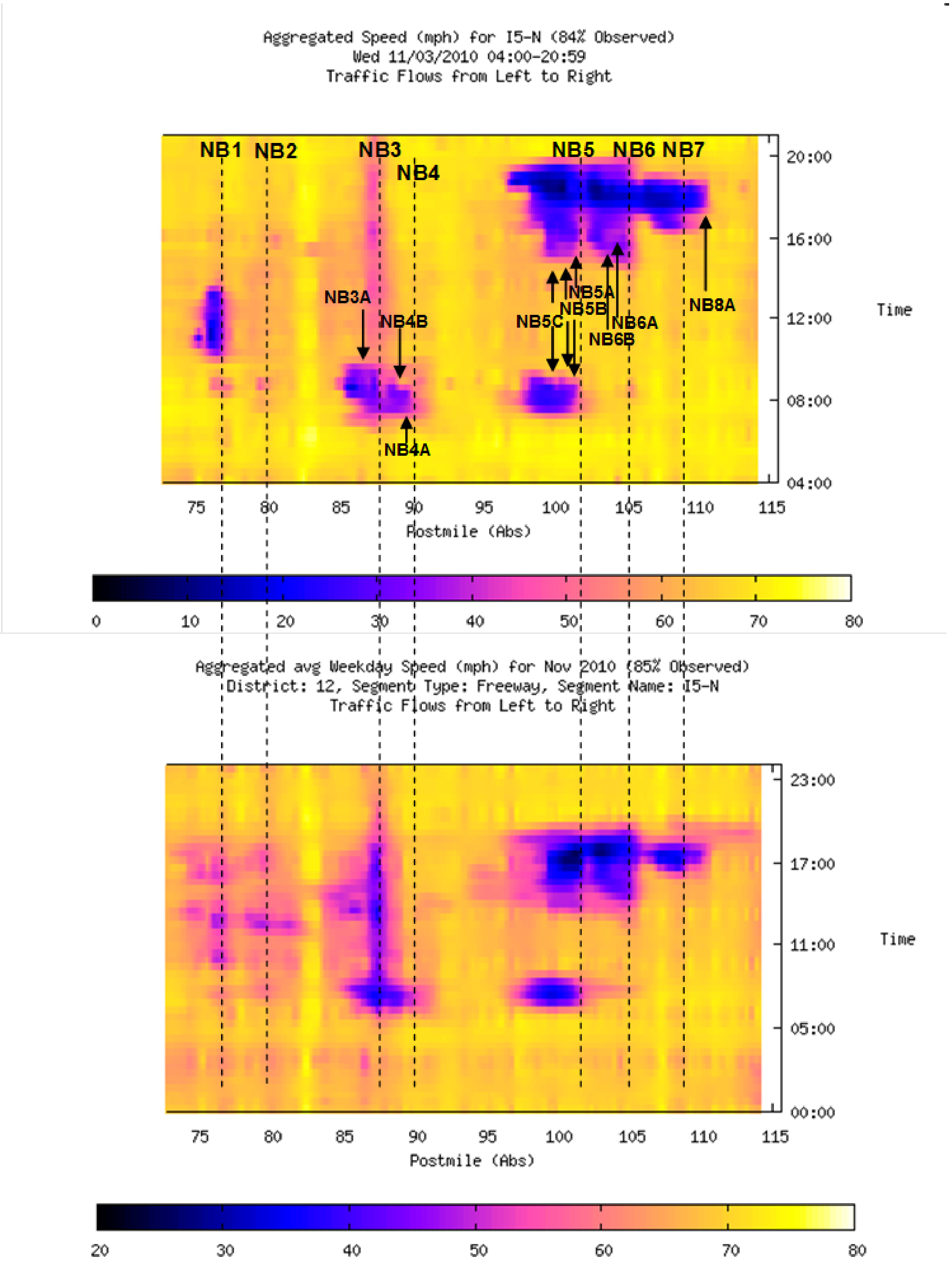


Figure 3.3. Speed contour plots for northbound I-5 in November 2010.

Source: Caltrans, I-5 CSMP.

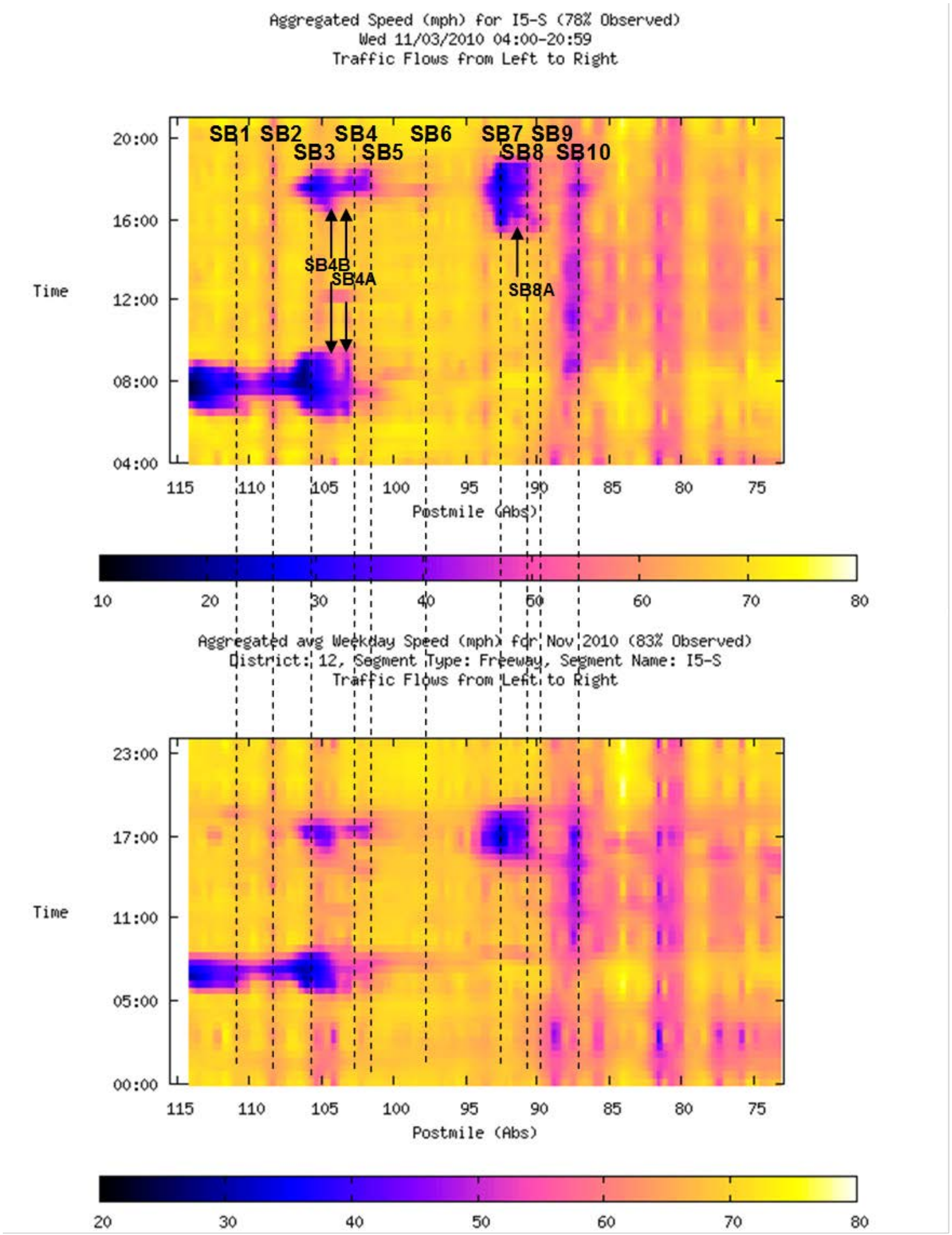


Figure 3.4. Speed contour plots for southbound I-5 in November 2010.

Source: Caltrans, I-5 CSMP.

This complex pattern of queuing and congestion is due to 19 major and minor bottlenecks along the facility, which are shown in Figure 3.5. In some cases, the bottlenecks are hidden, so they appear only under certain travel conditions. The I-5 CSMP contains an extensive discussion of each bottleneck and the causes of its formation.

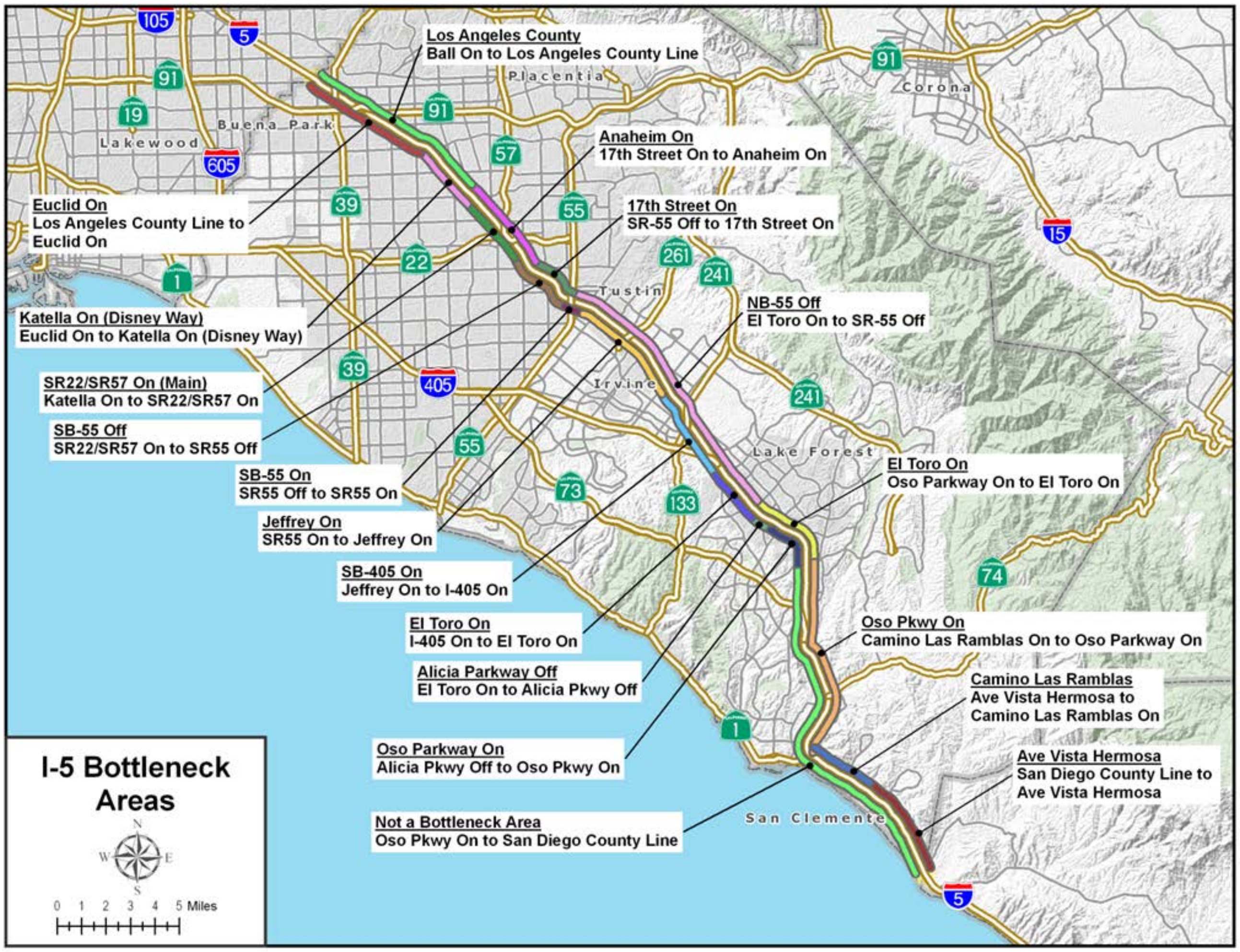


Figure 3.5. Map of bottleneck areas on I-5 facility in Orange County.
Source: Caltrans, I-5 CSMP.

Figures 3.6 and 3.7 show the travel time variation that occurs on the I-5 facility by time of day. The northbound direction has the highest average travel time during the 5:00 p.m. hour (60 minutes on average) as well as the highest travel time variability (approximately 78 minutes). There is also significant unreliability during the a.m. and midday periods in the northbound direction. The northbound and southbound directions do not mirror one another. The southbound direction has a.m. and p.m. peaking, but with average travel time and variability. The I-5 CSMP identifies a number of potential improvements to address the facility bottlenecks (Caltrans 2012).

These strategies were tested in the CSMP using microsimulation modeling to understand the effect on mobility, but reliability impacts were not modeled.

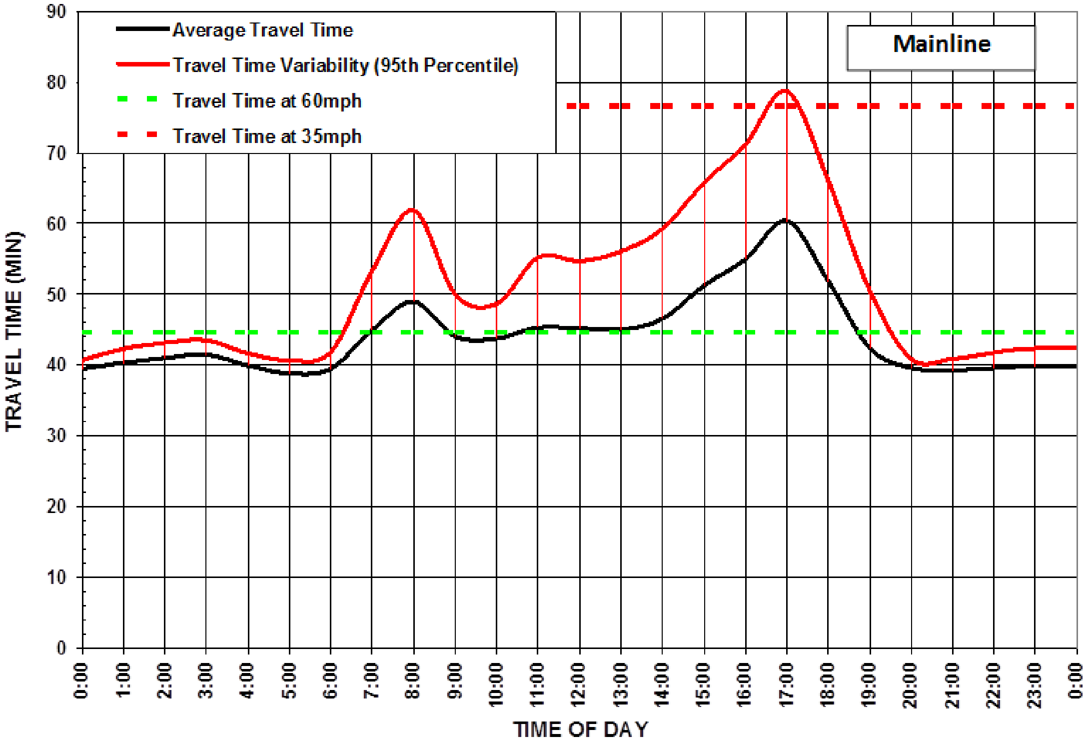


Figure 3.6. Travel time variation on northbound I-5 in 2010.

Source: Caltrans, I-5 CSMP.

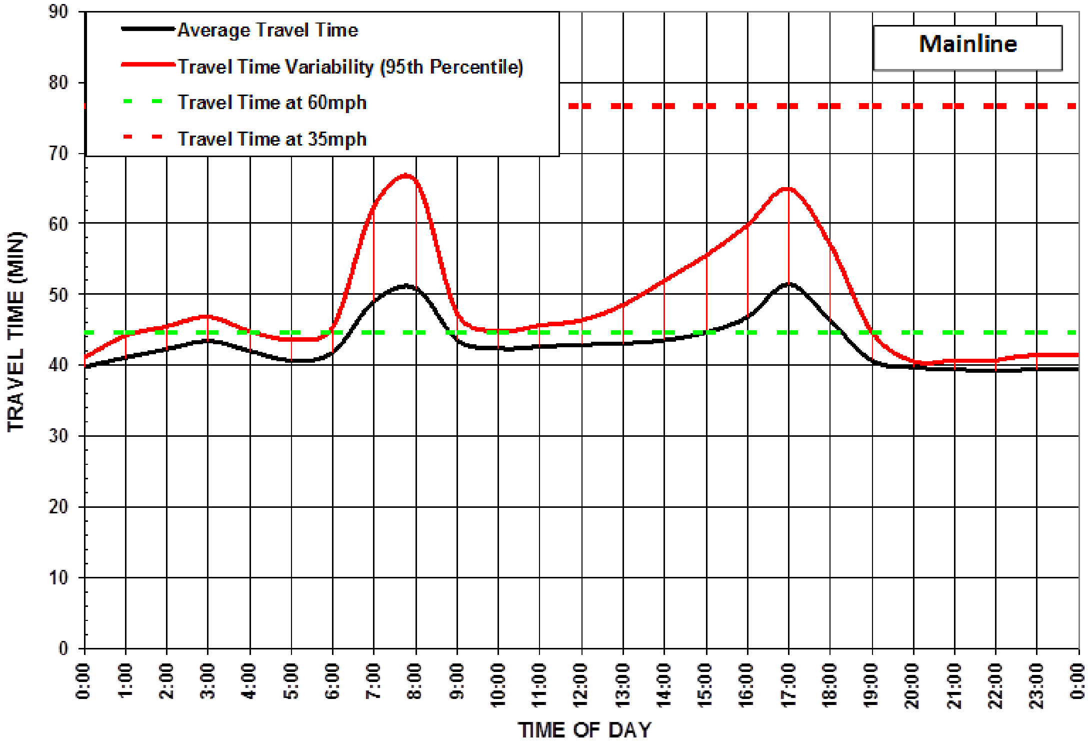


Figure 3.7. Travel time variation on southbound I-5 in 2010.

Source: Caltrans, I-5 CSMP.

Figure 3.8 summarizes the scenarios tested in the microsimulation modeling for the I-5 CSMP. Each scenario represents a bundle of improvements that builds on the improvements made in the previous scenario. For example, Scenarios 1 and 2 include a number of interchange, ramp, and auxiliary lane improvements to improve baseline conditions. Scenarios 3 and 4 build on these investments by adding adaptive metering strategies.

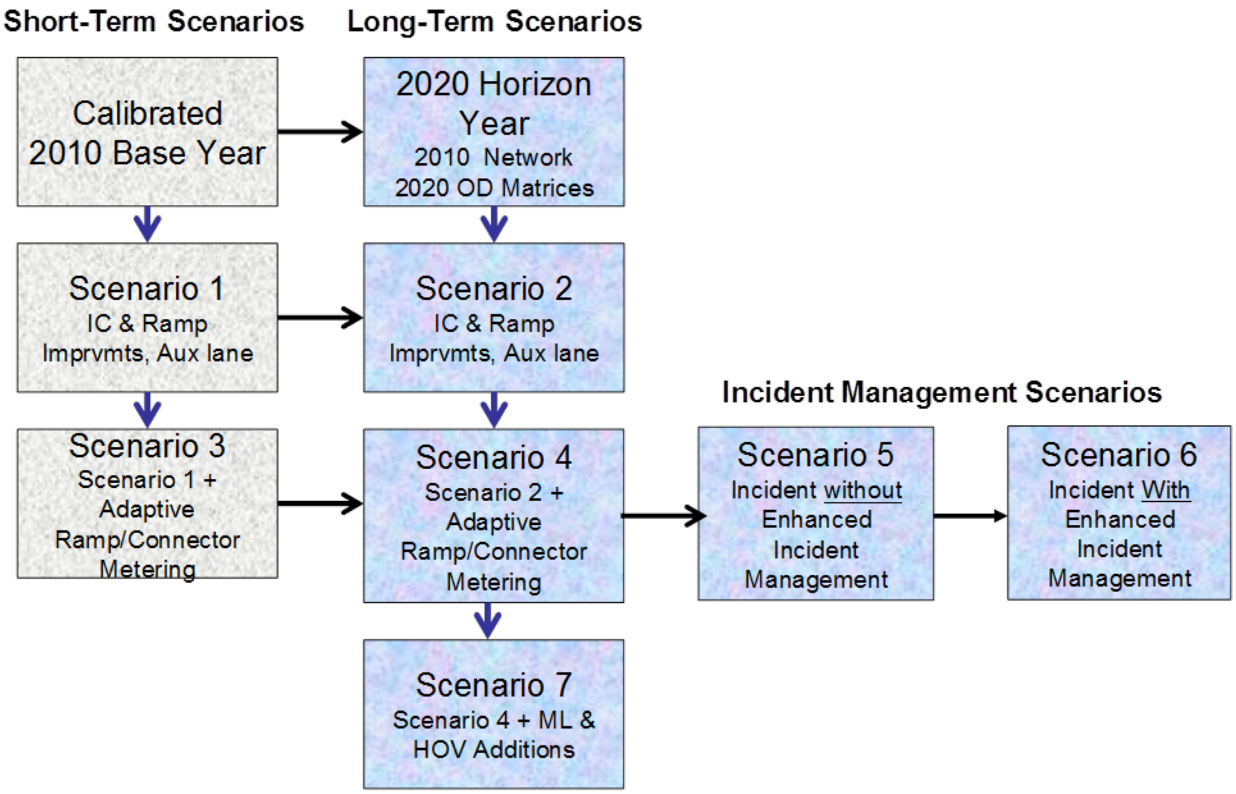


Figure 3.8. Scenarios tested in CSMP for I-5 facility.

Source: Caltrans, I-5 CSMP.

In the microsimulation modeling, the scenarios were analyzed for short-term impacts on a 2010 base year and the longer-term impacts on a 2020 horizon year. Scenario 7 was modeled for the horizon year only because the combination of mainline and high-occupancy vehicle additions could not be constructed in the short term. In addition, the CSMP modeling included testing of an enhanced incident management strategy. The SHRP 2 pilot testing examined the reliability impacts of these scenarios.

I-210 Facility in Los Angeles County

The second facility selected for pilot testing is a 16-mile congested urban segment of I-210 in Los Angeles County. Figure 3.9 shows the entire 45-mile facility covered by the I-210 CSMP. However, the CSMP notes that PeMS detection is available for only the 20 miles in the congested urban area east of I-110 (SCAG and Caltrans 2010). The travel conditions described in the CSMP and in this section are for those 20 miles. The study team decided to focus on the testing of the SHRP 2 reliability products on a slightly smaller 16-mile segment that extends from I-110 to just east of I-605.

As shown in Figure 3.9, the 20-mile congested urban area has four to five general-purpose lanes as well as barrier-separated high-occupancy vehicle and auxiliary lanes in each direction. The study team divided its reliability testing into the five-lane section from I-110 to SR-19 (Rosemead Boulevard) and the four-lane section from SR-19 to South Azusa Avenue.

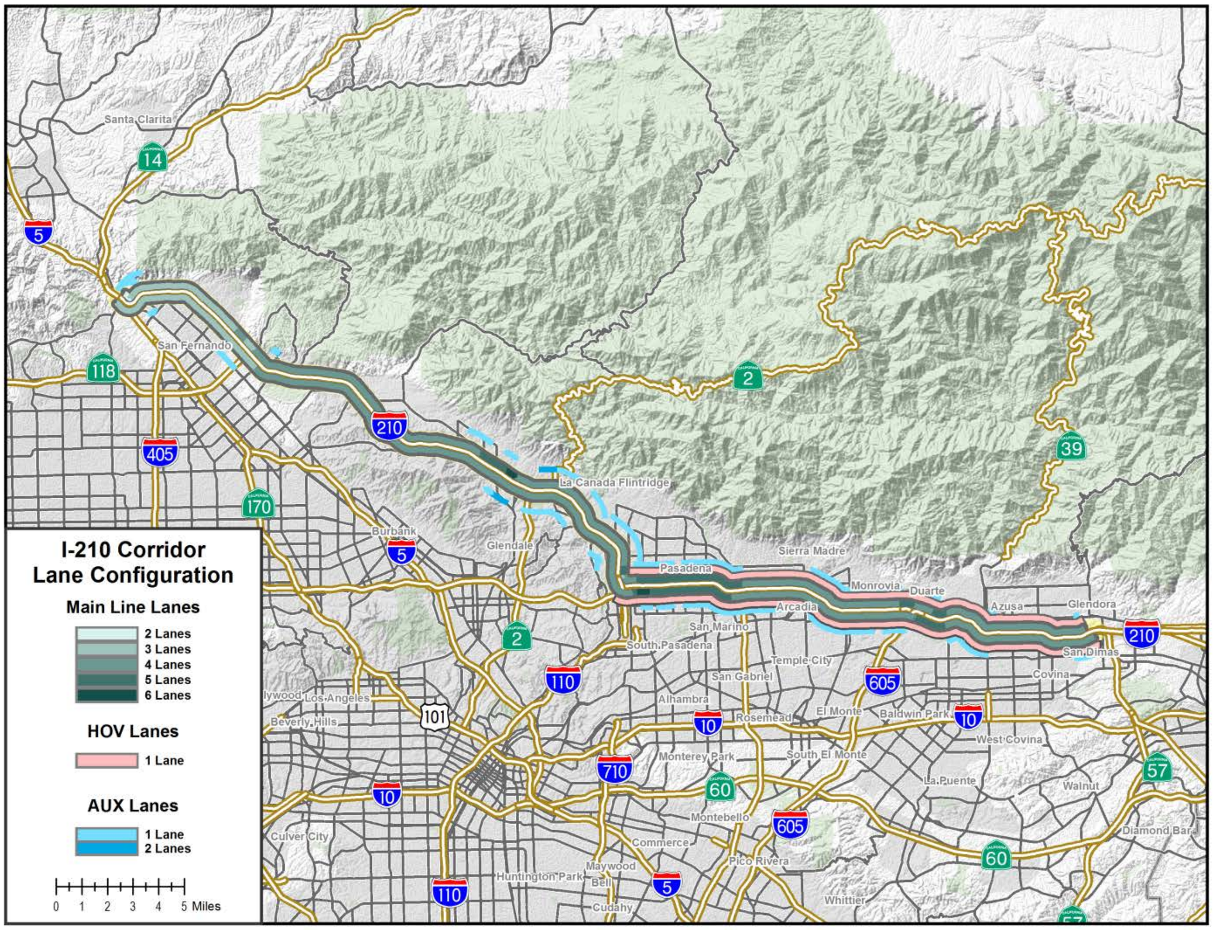


Figure 3.9. Map of I-210 facility in Los Angeles County.

Source: SCAG and Caltrans, I-210 CSMP.

Figures 3.10 and 3.11 show speed contour plots for the 20-mile congested urban area from the I-210 CSMP (SCAG and Caltrans 2010). As shown in the figures, the longest peak period is roughly six hours for both directions of the freeway. In the eastbound direction, traffic is heaviest during the p.m. peak period. In the westbound direction, traffic is heaviest during the a.m. peak period, with some congestion occurring during the p.m. peak period. Congestion is highly directional along the facility due to the location of major job centers in the western portion of the facility and residential communities in the eastern portion of the facility. The study team focused its tool testing on the eastbound direction to capture travelers returning home from work.

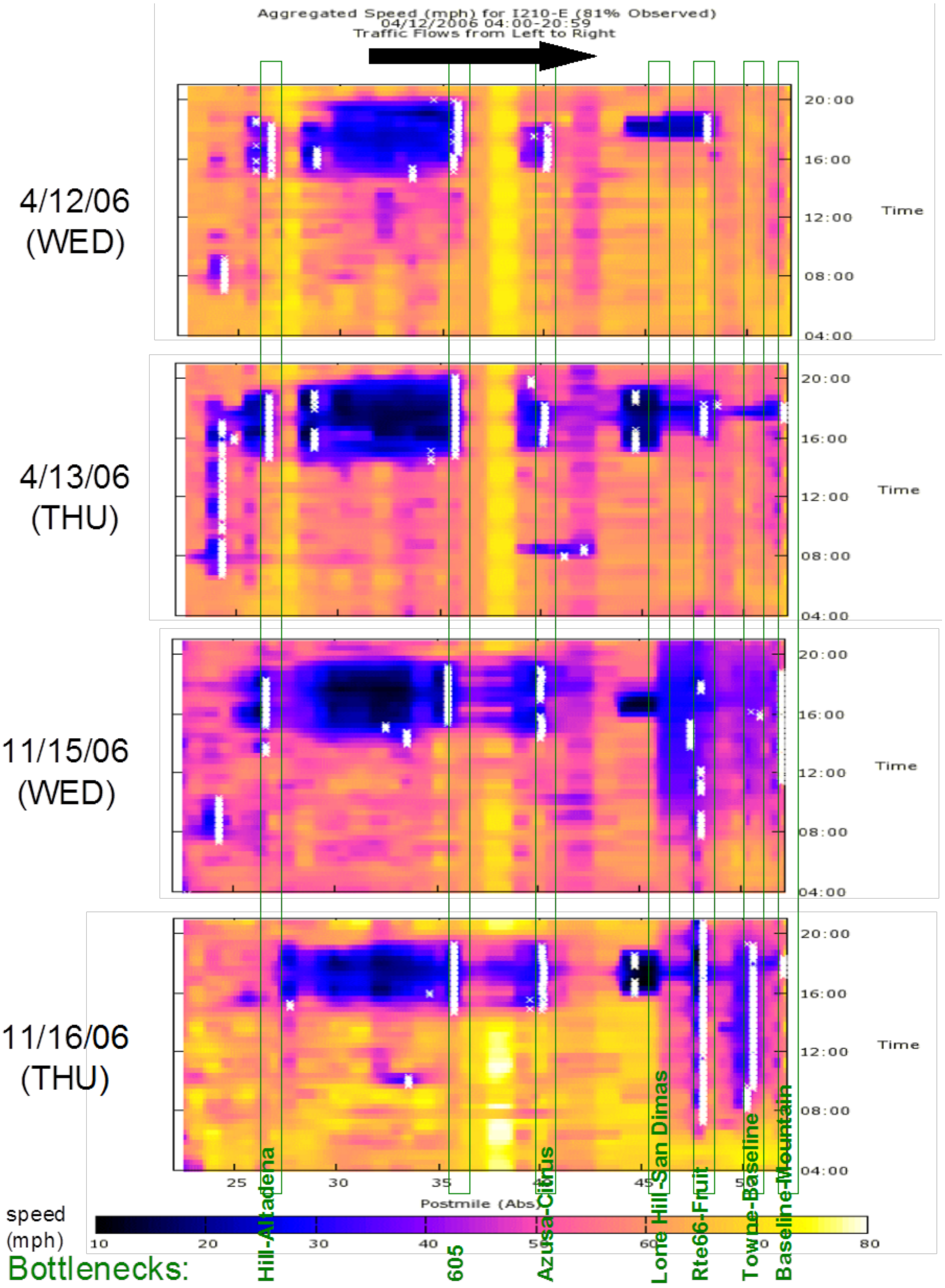


Figure 3.10. Speed contour plots for eastbound I-210 in April and November 2006.

Source: SCAG and Caltrans, I-210 CSMP.

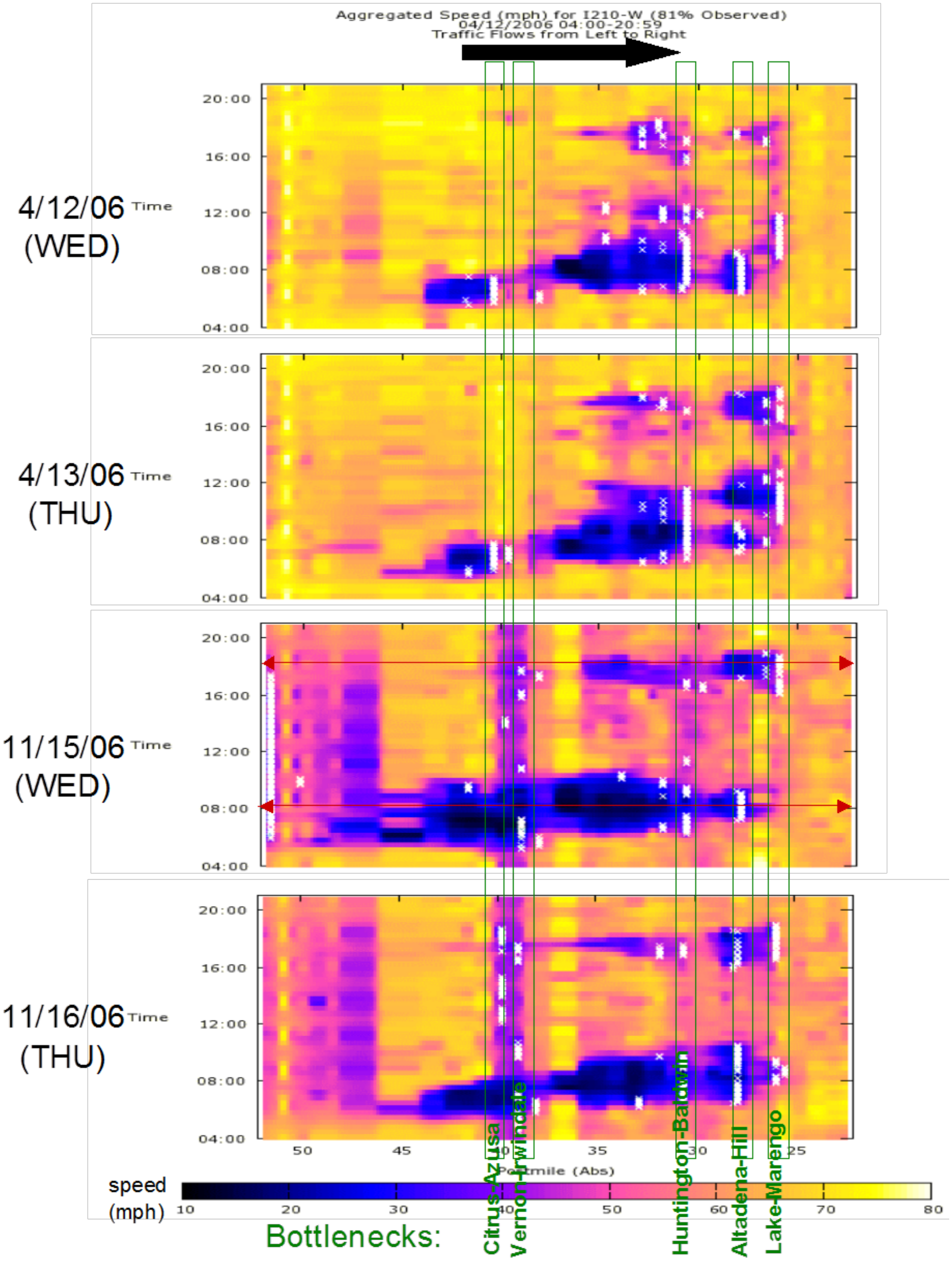


Figure 3.11. Speed contour plots for westbound I-210 in April and November 2006.

Source: SCAG and Caltrans, I-210 CSMP.

The I-210 CSMP identified 17 bottlenecks within the 20-mile urban congested area (SCAG and Caltrans 2010). Figure 3.12 shows the location of bottleneck areas during the p.m. peak period. The a.m. bottlenecks are a subset of these locations. The I-210 CSMP provides a description of the bottlenecks and a detailed causality analysis.

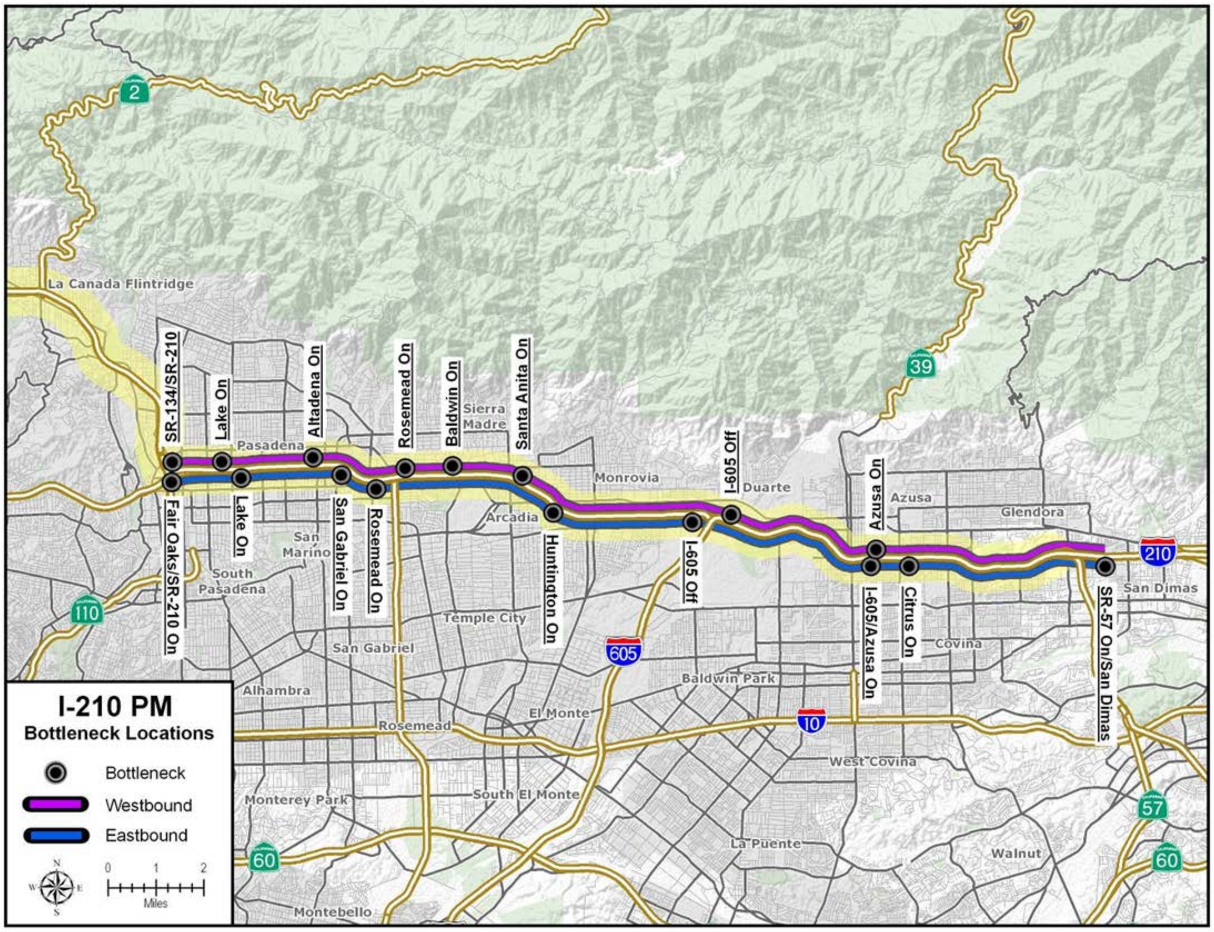


Figure 3.12. Map of p.m. bottleneck areas on the I-210 facility in Los Angeles County.
Source: SCAG and Caltrans, I-210 CSMP.

Figures 3.13 and 3.14 show the travel time variation that occurs along the I-210 facility within the congested urban area. The figures reflect the highly directional traffic flows that occur on the facility. Congestion and unreliable travel occurs during the morning as travelers commute to work in the westbound direction and during the afternoon as people return home in eastbound direction.

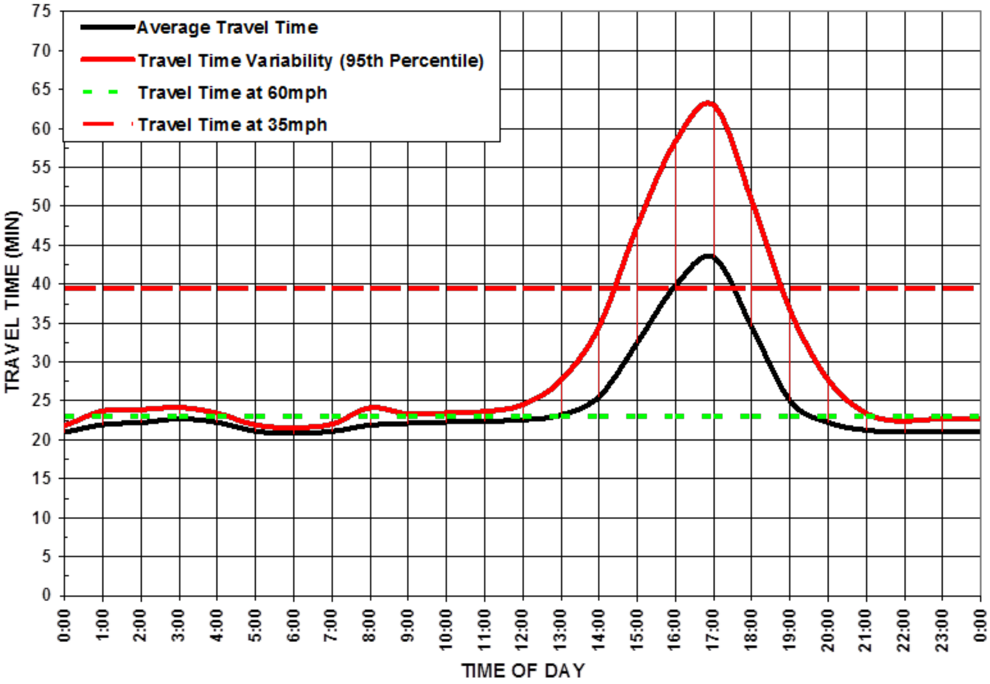


Figure 3.13. Travel time variation on eastbound I-210 in 2009.

Source: SCAG and Caltrans, I-210 CSMP.

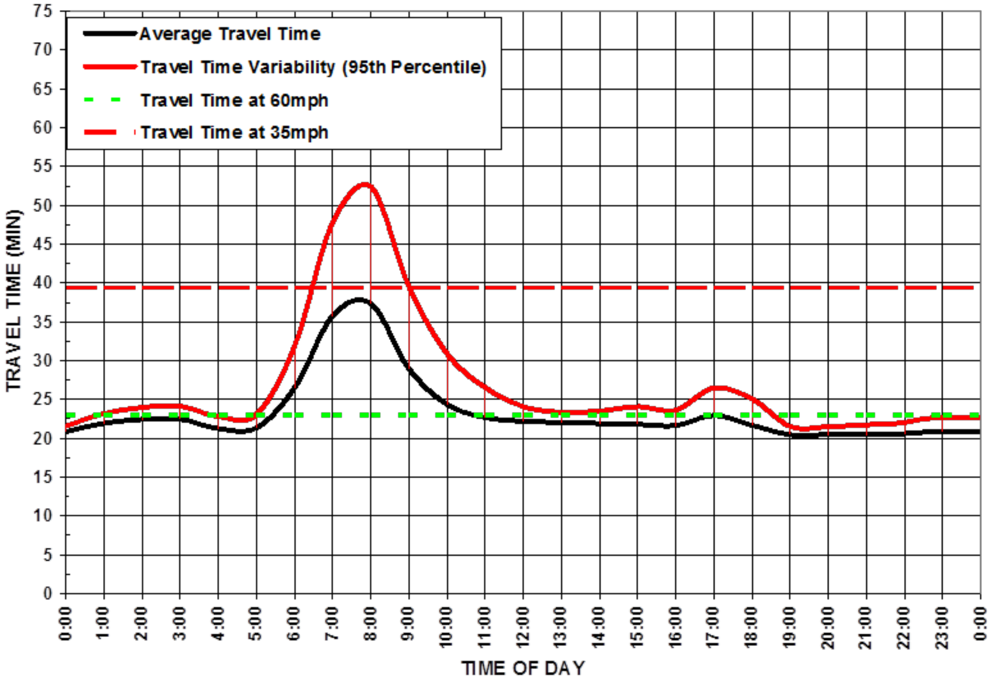


Figure 3.14. Travel time variation on westbound I-210 in 2009.

Source: SCAG and Caltrans, I-210 CSMP.

Figure 3.15 shows the many strategies tested in the microsimulation modeling for the I-210 CSMP. As with the I-5 facility, the strategies were tested for base and horizon years. Unlike the I-5 facility, a 2006 base year was used for the I-210 CSMP due to data availability. The study team decided to use a 2010 base year for consistency with the I-5 facility. The next chapter describes the data compilation for the two facilities in more detail.

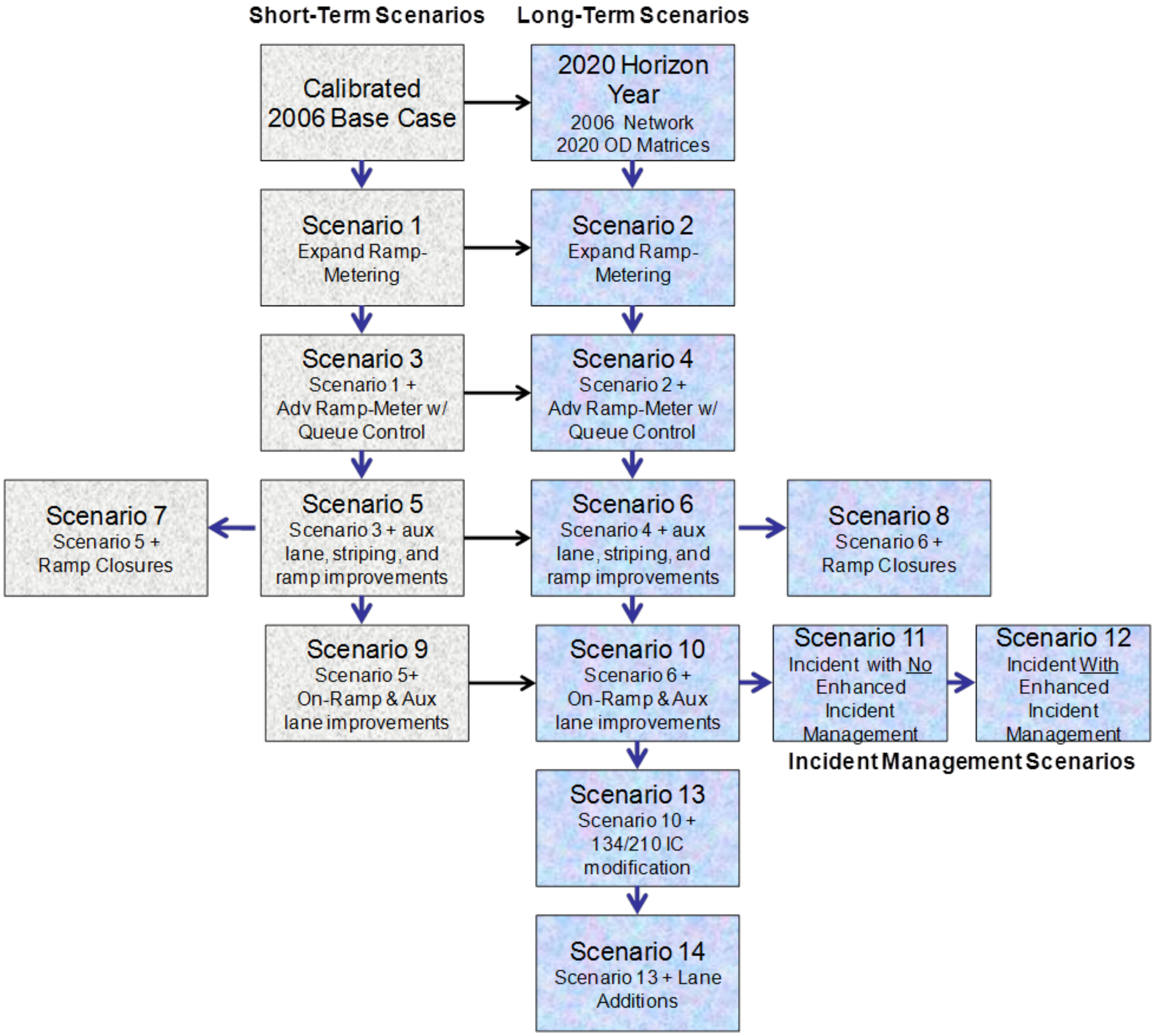


Figure 3.15. Scenarios tested in CSMP for I-210 facility.

Source: SCAG and Caltrans, I-210 CSMP.

CHAPTER 4

Data Compilation and Analysis of Existing Conditions

4.1 Introduction

As part of the evaluation of the tools described in subsequent chapters, the study team conducted a data compilation and analysis of existing conditions. The team followed the approach described in the *SHRP 2 Reliability Project L02 Guide to Establishing Monitoring Programs for Travel Time Reliability* (the guide) to determine the factors affecting reliability on the two study facilities and to assess the relative contributions of these factors (ITRE et al. 2012). This analysis allowed the team to test the value of collecting, storing, and using nonrecurring event data from various sources to help explain causal relationships.

Specifically, the study team used the following sections from the guide:

- Average Route Travel Times Based on Infrastructure Sensor Data
- See What Factors Affect Reliability (AE1)
- Assess the Contributions of the Factors (AE2)

The study team's activities to date for each of these sections are discussed below.

4.2 Overview of the L02 Guide

An earlier draft of the L02 guide (ITRE et al. 2012) describes how to develop and use a Travel Time Reliability Monitoring System (TTRMS). A TTRMS is designed to assist public agencies to monitor the performance of the transportation network and better understand the factors that influence variations in travel times on the network. By having a better grasp of how system reliability will change, given various events that occur, such as incidents, weather, special events, work zone closures, and surges in demand, public agencies can respond more effectively to mitigate the impacts of the event and provide the public with better traveler information. For example, a TTRMS may be able to provide a range of expected travel times to drivers given that a sporting event is taking place at a particular time of day.

The guide has five chapters that describe the process of measuring, characterizing, identifying, and understanding the impacts of events that affect travel time reliability. In addition there are four appendices that provide detailed information as follows:

- *Appendix A: Monitoring System Architecture* presents examples of detailed data structures for the organization of various data sources and provides supporting detail for Chapter 2 (Data Collection and Management) of the guide.
- *Appendix B: Methodological Details* presents detailed discussions of the analytical methods that can be used to calculate travel time reliability measures from a variety of

input sources. This document provides supporting detail for Chapter 3 (Computational Methods).

- *Appendix C: Case Studies* presents six detailed case studies that exercise various aspects of the guide, including system architecture, analysis of recurrent and nonrecurrent sources of congestion, and the application of a variety of use cases.
- *Appendix D: Use Case Demonstrations* illustrates the application of a variety of use cases for a travel time reliability monitoring system. This document provides supporting detail for Chapter 4 (Applications).

4.3 Evaluation of the L02 Guide

General Assessment of the Guide

Below, the study team provides a general assessment of the guide and makes recommendations based on its application of the guide to the Southern California pilot site. Following this section, the remaining three sections of this chapter address how the study team followed the three focus areas of the guide (i.e., calculating average route travel times, AE1 Use Case, and AE2 Use Case). Those sections provide a more detailed assessment of issues encountered while using the guide.

Technical Language

With the inclusion of supplements and appendices, the L02 guide has 635 pages of very technical information. While this level of detail may be necessary for the development of a robust TTRMS, the study team found that it makes the guide difficult to understand by the practitioners to which it is directed. Discussions of “disutility functions,” “probability density functions,” and “semi-variance” among other economic or statistical terms are difficult for practitioners to understand.

Some terminology used throughout the guide is not consistent with standard practice in transportation planning. For example, the term “nominal loading” in the guide represents the congestion level, but is more commonly known to practitioners as the “peak period.” “Multimodal” in the guide is a statistical term that the guide defines as “one point at which the probability density function reaches a maximum” (e.g., when weather and incidents both occur during the same time period). Transportation practitioners, however, refer to “multimodal” as representing different modes of travel, such as single occupant automobile, public transit, or walking. Although the guide does make this distinction and uses the term “regime” instead of multimodality, the term “multimodal” is still used throughout the guide to describe the statistical meaning.

The language in the manual could be streamlined to appeal to day-to-day managers and operators of the transportation system.

Technical Detail

Linked to the recommendation above concerning the use of statistical language used in the guide, the study team recommends splitting the guide into two manuals: a detailed guidebook for technically-oriented professionals tasked with implementing a TTRMS and a high-level guidebook for practitioners.

The second, high-level guidebook could provide an overview of travel time reliability and how a TTRMS can be applied to public agency practitioners charged with operating the transportation system. For example, the guide can focus on use cases related to planning and programming processes and then explain the techniques needed for these use cases. Currently, the guide describes technical approaches and then presents use cases as examples of how they could be applied rather than focusing on the use cases and introducing technical approaches, as needed, to support these use cases.

The L02 guide provides some interpretations of results in the use cases, but they appear to be in different locations. A more general guidebook could provide a discussion of how to interpret the cumulative distribution functions (CDFs). For example, what does it mean when the various plots are widely spaced on the chart and what do the slopes of the lines tell us about the impact of the regime being examined? This type of information is in the guide, but buried within the discussions of the different use cases. A general discussion of the CDFs should be provided at a level of detail sufficient for a manager or operator to readily understand.

Practical Considerations

The L02 guide does not consistently address practical issues that may arise during an analysis. For example, how should a user handle the addition of a detector mid-year, and how should incidents be labeled on rainy days? An automated and comprehensive TTRMS may be able to handle such issues with the appropriate coding in the application, but this creates computational difficulties, particularly on massive datasets that are common to real-time automated traffic data collection systems, such as the Caltrans Performance Measurement System (PeMS). The sections below discuss in more detail how the study team addressed some of the practical issues that arose in performing the data analysis for the two Southern California test facilities.

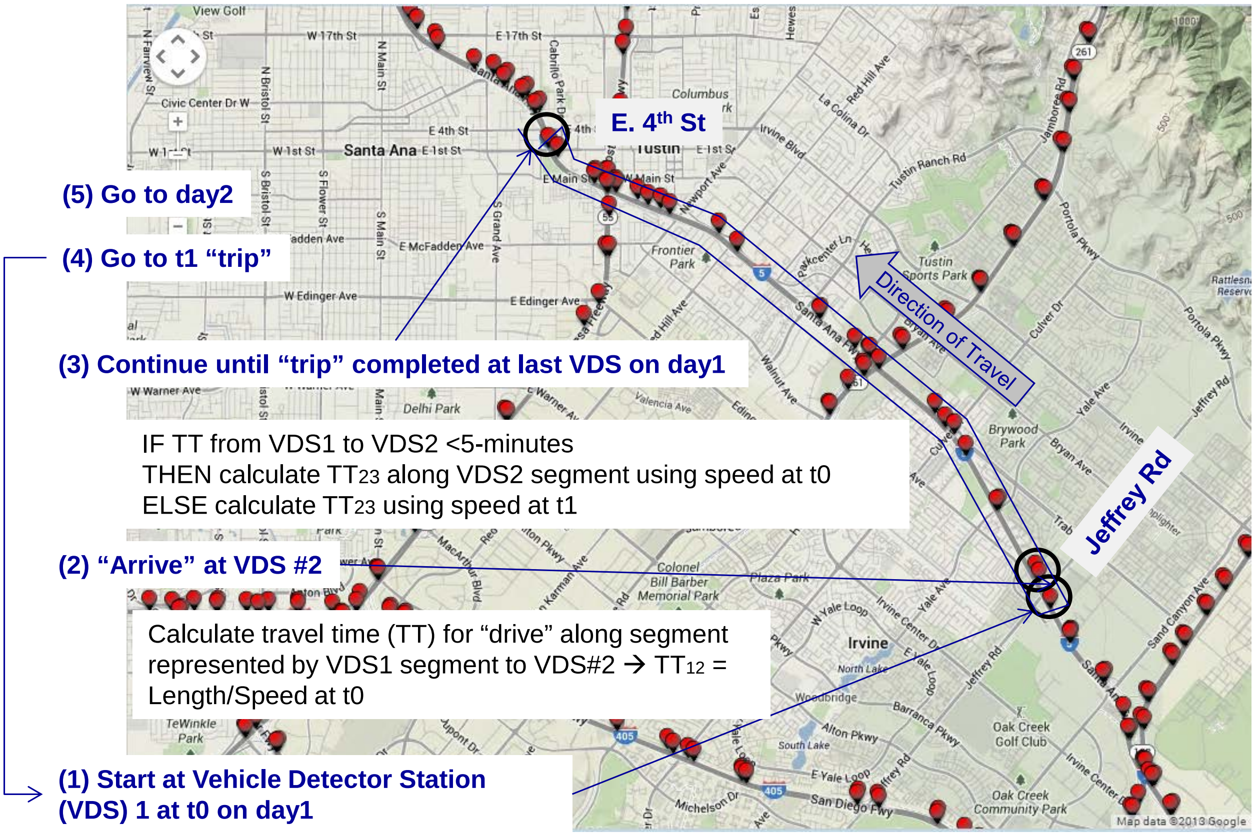
4.4 Average Route Travel Times Based on Infrastructure Sensor Data

Fixed-point vehicle detector sensors embedded in, or adjacent to, the roadway provide invaluable data (e.g., speed estimates and vehicle counts) for assessing traffic conditions. However, as described in the guide, translating sensor speed data into facility-level average travel time estimates is not a trivial matter. A comprehensive TTRMS cannot simply aggregate the travel times across individual sensors, but rather must “walk the time-space matrix” to develop a travel time estimate that a typical driver might expect when using the facility. Travel time information can be applied to a wide range of useful applications for transportation system administrators, planners, and users, such as commuters and freight operators.

In a hypothetical example of walking the matrix, a car traveling over a severely congested 5-mile facility at an average speed of 30 mph and passing over a sensor at the beginning of the facility at 8:00 a.m. will not reach the last sensor until just before 8:10 a.m. If sensors are spaced every half mile on average (considered the ideal spacing in the Caltrans *Transportation Management System Detection Plan*), there will be approximately 10 sensors on the facility. Since the data in this system are provided at 5-minute granularity, there would be two time periods in this example. As a result, the TTRMS will have to use either one of the two time intervals to calculate speeds and travel times.

The car is likely to pass over the first five sensors on the facility between 8:00 a.m. and 8:05 a.m. (assuming a day when congested speeds along the facility do not vary widely among the individual sensors), while passing over the remaining five sensors between 8:05 a.m. and 8:10 a.m. To get the best estimate of travel time under this hypothetical scenario, one would need to use sensor data from the 8:00 to 8:04:59 time period to calculate the travel times over each of the first five sensors, and use the data from the 8:05 to 8:09:59 time period for the last five sensors. The calculations in the TTRMS are simple to perform, but a TTRMS must have the intelligence to know which time frame to use for a given sensor and departure time along the facility. To automate these detailed calculations, the study team developed a database to calculate travel times using PeMS data, but outside the web-based system.

Figure 4.1 is a schema representing the 6.6-mile Orange County northbound I-5 facility. On this facility, starting from the southern end near Jeffrey Road in Irvine and ending in the north near East 4th Street in Santa Ana, the study team identified 19 sensor locations (called vehicle detector stations or VDS in PeMS) to be used in the analysis. The team identified the initial VDS for the analysis segment, and the next downstream VDS in the remaining string of 19 detector stations.



(5) Go to day2

(4) Go to t1 "trip"

(3) Continue until "trip" completed at last VDS on day1

IF TT from VDS1 to VDS2 <5-minutes
THEN calculate TT_{23} along VDS2 segment using speed at t0
ELSE calculate TT_{23} using speed at t1

(2) "Arrive" at VDS #2

Calculate travel time (TT) for "drive" along segment represented by VDS1 segment to VDS#2 → TT_{12} = Length/Speed at t0

(1) Start at Vehicle Detector Station (VDS) 1 at t0 on day1

Figure 4.1. Walking the time-space matrix on I-5 facility.

Source: Caltrans Freeway Performance Measurement System (PeMS). pems.dot.ca.gov.

In this schema, the database calculated the travel time along the segment represented by the first VDS using the speed reported by PeMS and the length of the VDS segment (typically measured as half of the distance from the previous VDS to half of the distance to the next VDS in the string). This is shown as (1) at the bottom of Figure 4.1.

The database stored the resulting travel time. If the travel time was less than 5 minutes, then the database would link the next VDS to the same date and time and calculate the travel time at that next VDS. If the travel time along VDS1 was 5 minutes or longer, then the new start time at VDS2 would be the end time on segment VDS1. The new time would be rounded down to the whole 5-minute interval and joined to VDS2 to rerun the query for the next segment's calculation.

This process continued until the end of the facility was reached for the initial start time. At every interval in the process, the travel times were aggregated and stored, so by the last VDS on the facility the total accumulated time is the travel time for the initial departure time. The database also stored vehicle-miles traveled (VMT), and vehicle-hours traveled (VHT) using the flows found in PeMS. This information was used to calculate harmonic mean speeds and travel rates for the facility. The study team also used VMT data to estimate demand surges in Use Cases AE1 and AE2 described in later sections.

The database then continued to time interval number 2 and began the calculations anew. This process continued to the end of the day and calculations were performed for each weekday in the year.

One issue that confronts planners and engineers using PeMS or any other data source is that perfect detection does not exist. In California, improving detector coverage and data quality has become a focus area for Caltrans. Caltrans has been adding detection throughout the system, so at any given time during the year a given facility may have one or more added detector stations. As can be expected, detectors occasionally break or go offline for extended periods. While increasing detector coverage is clearly better for calculating travel times, this creates an added dimension to a TTRMS in that the system must have information on when new detectors are added.

For both facilities in the Southern California pilot site, the study team examined data for 2010, since this was the base year for the facility CSMPs (Caltrans 2012, SCAG and Caltrans 2010). On both freeways, data quality was exceptional throughout 2010 with the percentage of observed data (assumed to be good) rarely falling below 75 percent for any given sensor. Figure 4.2 shows the average “good” data trends for both facilities for each month of 2010.

The guide does not address the question of data quality, which is a consideration when performing freeway assessments using PeMS in California. There are few correct answers for how to deal with imputed (i.e., estimated) data which can range from throwing out the bad data entirely to supplementing the data with other sources. PeMS users at Caltrans and local agencies are trained to examine the quality of the data when performing analyses. The PeMS system has a diagnostics function that attempts to identify data issues. If data are not received from a detector, the PeMS data record is flagged. PeMS also flags data when that data are received, but fail diagnostic thresholds (e.g., flows exceed accepted engineering lane capacities).

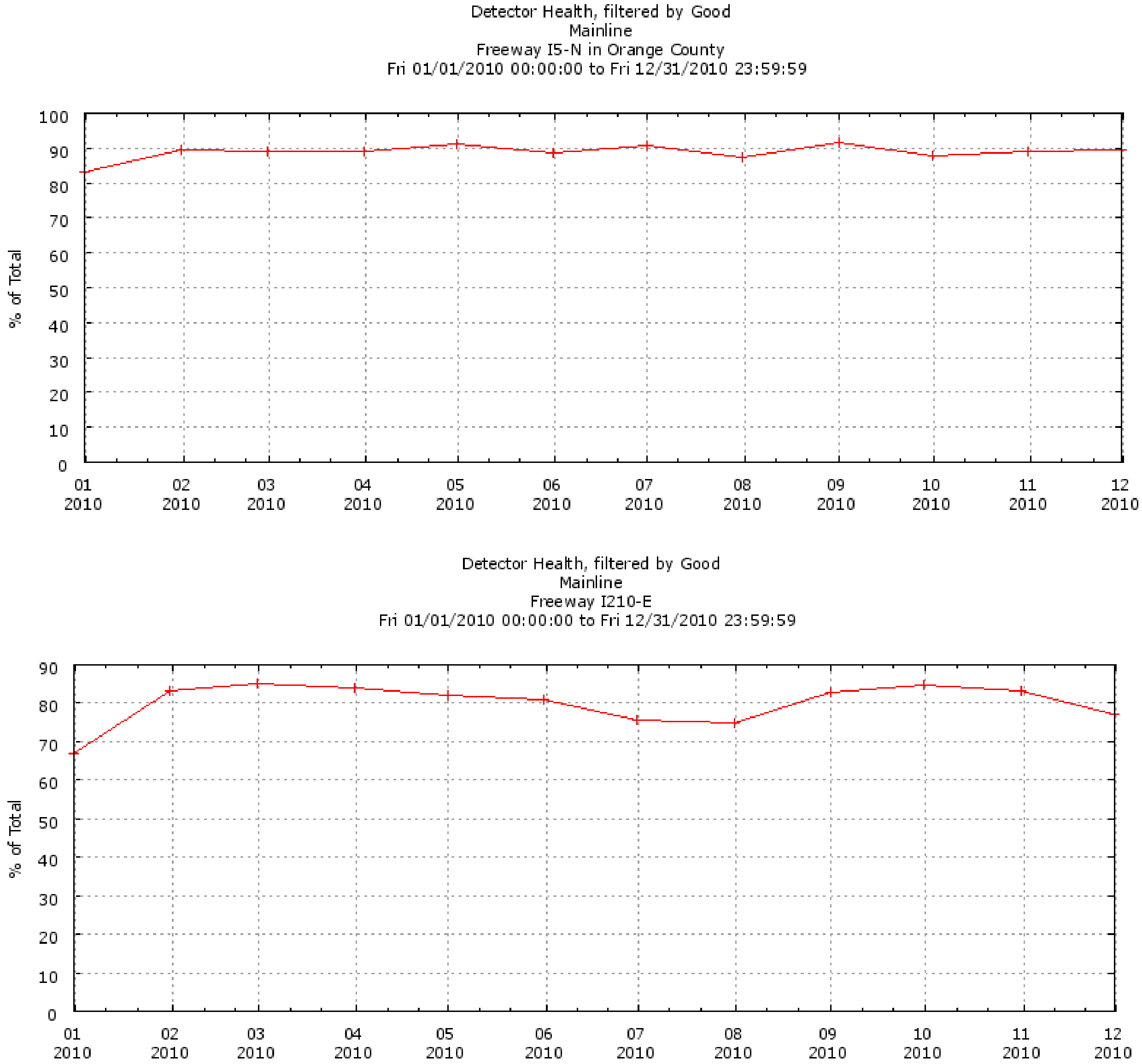


Figure 4.2. Data quality on I-5 and I-210 facilities.

Source: Caltrans Freeway Performance Measurement System (PeMS). pems.dot.ca.gov.

For the Southern California pilot site, the study team was fortunate that the two freeways had consistent detection throughout the year. However, the guidance does not address how to deal with sensors when a detector is added or removed during the analysis time frame. Figure 4.3 illustrates this situation using a portion of northbound I-5 in Orange County. On April 27, 2010, a new VDS was added to the facility. In the example in Figure 4.3, travel times are calculated based on the length “L” of the detector (TT = Speed/Length). If a detector is added (or removed) mid-year, then the length between adjacent detectors will change, thus changing the travel time calculation. In this example, the new detector created a new length “L3” from “L23” shown in the graphic.

A TTRMS system can be programmed to account for changes in detection, but for one-time efforts such as this pilot study a decision has to be made how to approach this issue. One approach is to identify the lengths for each sensor throughout the study period and set up procedures to produce the travel time results. This could be a time-consuming process depending on how many changes in detection occur during the study period.

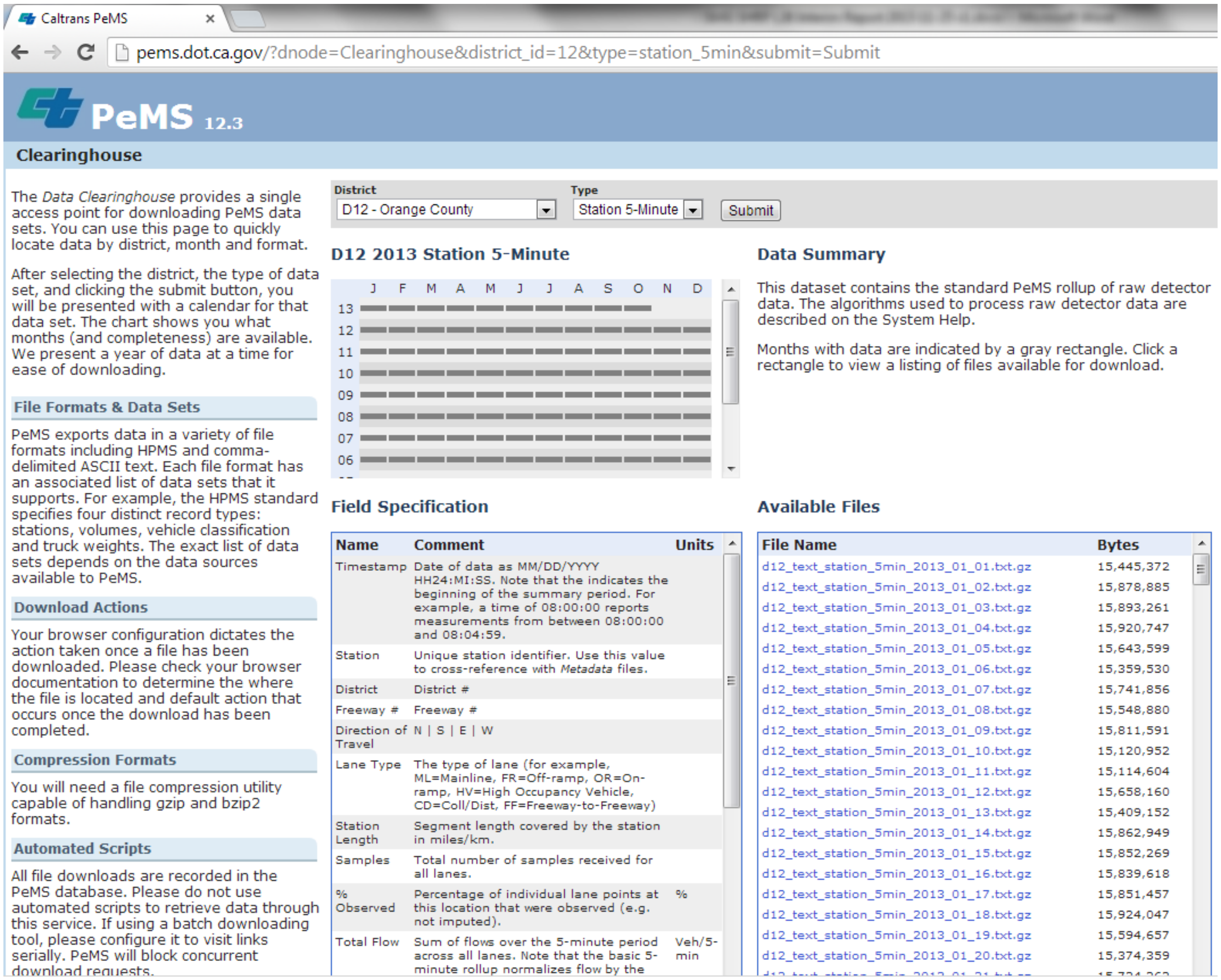
Figure 4.3. Example of detector station added mid-year on I-5.

Source: Caltrans Freeway Performance Measurement System (PeMS). pems.dot.ca.gov.

Another approach, one that the study team applied to this analysis, is to examine the impact on the facility travel time estimate if the new sensor is removed. On the pilot site facilities, the new VDS were in locations experiencing speeds consistent with the speeds from the upstream and downstream VDS. This implies that the new VDS locations operate under similar conditions as the upstream and downstream locations. Furthermore, in the example in Figure 4.3, the new VDS operated near free-flow speed. This means that removing the new location from all analysis would have little impact on the outputs.

Based on the previous discussion, the study team conducted several steps to produce the travel time estimates using a commercially available, Microsoft Access database. The Orange County I-5 facility is used as an example, but the approach was applied to both facilities. The data for calculating the travel times were obtained from the 5-minute PeMS data clearinghouse and imported into a Microsoft Access database (a screenshot of the PeMS clearinghouse is shown in Figure 4.4).

As background, PeMS is an Internet-based traffic and transit data and visualization tool for transportation professionals, first used in 1999. PeMS allows for the extraction of real-time and historical performance data in multiple formats and presentation styles to help managers, engineers, planners, and researchers understand transportation performance, identify problems, and formulate solutions. Users can access PeMS with any computer using an Internet connection and standard web browser (i.e., Microsoft Internet Explorer, Mozilla Firefox, or Google Chrome). However, users must have a PeMS user account, and users frequently take PeMS training classes.



Clearinghouse

The *Data Clearinghouse* provides a single access point for downloading PeMS data sets. You can use this page to quickly locate data by district, month and format.

After selecting the district, the type of data set, and clicking the submit button, you will be presented with a calendar for that data set. The chart shows you what months (and completeness) are available. We present a year of data at a time for ease of downloading.

File Formats & Data Sets

PeMS exports data in a variety of file formats including HPMS and comma-delimited ASCII text. Each file format has an associated list of data sets that it supports. For example, the HPMS standard specifies four distinct record types: stations, volumes, vehicle classification and truck weights. The exact list of data sets depends on the data sources available to PeMS.

Download Actions

Your browser configuration dictates the action taken once a file has been downloaded. Please check your browser documentation to determine the where the file is located and default action that occurs once the download has been completed.

Compression Formats

You will need a file compression utility capable of handling gzip and bzip2 formats.

Automated Scripts

All file downloads are recorded in the PeMS database. Please do not use automated scripts to retrieve data through this service. If using a batch downloading tool, please configure it to visit links serially. PeMS will block concurrent download requests.

District: D12 - Orange County
Type: Station 5-Minute

D12 2013 Station 5-Minute

Data Summary

This dataset contains the standard PeMS rollup of raw detector data. The algorithms used to process raw detector data are described on the System Help.

Months with data are indicated by a gray rectangle. Click a rectangle to view a listing of files available for download.

Field Specification

Name	Comment	Units
Timestamp	Date of data as MM/DD/YYYY HH24:MI:SS. Note that the indicates the beginning of the summary period. For example, a time of 08:00:00 reports measurements from between 08:00:00 and 08:04:59.	
Station	Unique station identifier. Use this value to cross-reference with *Metadata* files.	
District	District #	
Freeway #	Freeway #	
Direction of Travel	N | S | E | W	
Lane Type	The type of lane (for example, ML=Mainline, FR=Off-ramp, OR=On-ramp, HV=High Occupancy Vehicle, CD=Coll/Dist, FF=Freeway-to-Freeway)	
Station Length	Segment length covered by the station in miles/km.	
Samples	Total number of samples received for all lanes.	
% Observed	Percentage of individual lane points at this location that were observed (e.g. not imputed).	%
Total Flow	Sum of flows over the 5-minute period across all lanes. Note that the basic 5-minute rollup normalizes flow by the	Veh/5-min

Available Files

File Name	Bytes
d12_text_station_5min_2013_01_01.txt.gz	15,445,372
d12_text_station_5min_2013_01_02.txt.gz	15,878,885
d12_text_station_5min_2013_01_03.txt.gz	15,893,261
d12_text_station_5min_2013_01_04.txt.gz	15,920,747
d12_text_station_5min_2013_01_05.txt.gz	15,643,599
d12_text_station_5min_2013_01_06.txt.gz	15,359,530
d12_text_station_5min_2013_01_07.txt.gz	15,741,856
d12_text_station_5min_2013_01_08.txt.gz	15,548,880
d12_text_station_5min_2013_01_09.txt.gz	15,811,591
d12_text_station_5min_2013_01_10.txt.gz	15,120,952
d12_text_station_5min_2013_01_11.txt.gz	15,114,604
d12_text_station_5min_2013_01_12.txt.gz	15,658,160
d12_text_station_5min_2013_01_13.txt.gz	15,409,152
d12_text_station_5min_2013_01_14.txt.gz	15,862,949
d12_text_station_5min_2013_01_15.txt.gz	15,852,269
d12_text_station_5min_2013_01_16.txt.gz	15,839,618
d12_text_station_5min_2013_01_17.txt.gz	15,851,457
d12_text_station_5min_2013_01_18.txt.gz	15,924,047
d12_text_station_5min_2013_01_19.txt.gz	15,594,657
d12_text_station_5min_2013_01_20.txt.gz	15,374,359

Figure 4.4. PeMS clearinghouse.

Source: Caltrans Freeway Performance Measurement System (PeMS). pems.dot.ca.gov.

A PeMS 5-minute data file represents a single day in one Caltrans district. This file can be quite large. As shown in Figure 4.4, a single midweek day in Caltrans District 12 (Orange County) can range between 15.4 and 15.9 megabytes (MB), which translates into anywhere between 3.75 and 4.0 gigabytes (GB) of annual weekday data if the entire district were imported into a single database. Microsoft Access has a file size limitation of 3.0 GB, which means that the study team had to greatly reduce the dataset to represent only the route and direction of interest.

For this reason, the team developed automated procedures to download the data from PeMS, import it into the Access database, and reduce the data needed to only the fields necessary for carrying out subsequent analysis. These procedures allowed the team to limit the access file size to between 1.6 and 2.0 GB depending on the length of the facilities. Each Access database represented a one-directional freeway for an entire year in the respective county.

The field specifications shown in Table 4.1 are from PeMS and summarize the information provided in the 5-minute data. The relevant field used for estimating the average travel time is the “Avg Speed” field, which is the harmonic mean speed across all lanes represented by the VDS. Other fields needed for the analysis are the “Timestamp” (to get time and date), “Station” (to link to the configuration file), “Station Length” (to calculate travel time), “% Observed” (to assess data quality), “Total Flow” (to calculate VMT and VHT), and “Avg Speed.” The individual lane information was discarded to save space.

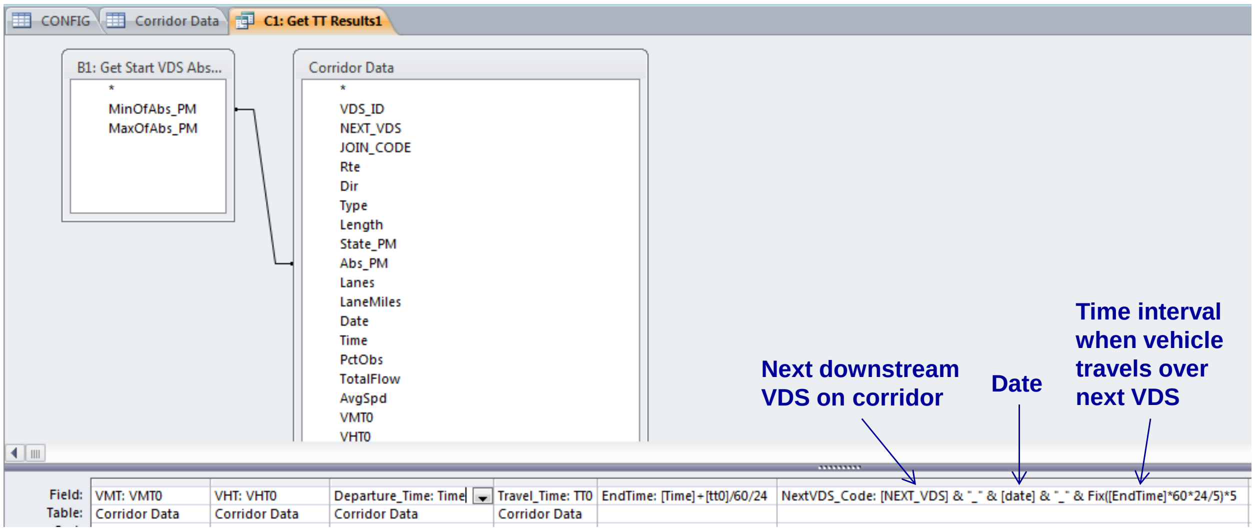
Table 4.1. PeMS 5-Minute Data Field Specifications

Name	Comment
Timestamp	Date of data as MM/DD/YYYY HH24:MI:SS. Note that the timestamp indicates the beginning of the summary period. For example, a time of 08:00:00 reports measurements from between 08:00:00 and 08:04:59.
Station	Unique station identifier. Use this value to cross-reference with *Metadata* files.
District	District #
Freeway #	Freeway #
Direction of Travel	N | S | E | W
Lane Type	The type of lane (for example, ML=Mainline, FR=Off-ramp, OR=On-ramp, HV=High-Occupancy Vehicle, CD=Coll/Dist, FF=Freeway-to-Freeway).
Station Length	Segment length covered by the station in miles/km.
Samples	Total number of samples received for all lanes.
% Observed	Percentage of individual lane points at this location that were observed (e.g. not imputed).
Total Flow	Sum of flows over the five-minute period across all lanes. Note that the basic five-minute rollup normalizes flow by the number of good samples received from the controller.
Avg Occupancy	Average occupancy across all lanes over the five-minute period expressed as a decimal number between 0 and 1.
Avg Speed	Flow-weighted average speed over the five-minute period across all lanes. If flow is 0, mathematical average of five-minute station speeds.
Lane N Samples	Number of good samples received for lane N. N ranges from 1 to the number of lanes at the location.
Lane N Flow	Total flow for lane N over the five-minute period normalized by the number of good samples.
Lane N Avg Occ	Average occupancy for lane N expressed as a decimal number between 0 and 1. N ranges from 1 to the number of lanes at the location.
Lane N Avg Speed	Flow-weighted average of lane N speeds. If flow is 0, mathematical average of five-minute lane speeds. N ranges from 1 to the number of lanes.
Lane N Observed	1 indicates observed data, 0 indicates imputed.

Source: Caltrans Freeway Performance Measurement System (PeMS). pems.dot.ca.gov.

The metadata files provided by PeMS contain the specifications for each VDS, identifying each by district, county, route, direction, postmile, and VDS type (e.g., mainline, high-occupancy vehicle, on-ramp). These configuration or “config” files were used to identify the postmiles on the two study facilities. The config files were modified prior to being imported into the database to identify the VDS downstream of the current VDS, which was necessary to walk the time-space matrix. Knowing the next VDS on the facility along with the date and time allowed the study team to develop Microsoft Access macros to run calculations iteratively for each five-minute interval of the day, one VDS station at a time.

The database assumes that a new vehicle trip starts at the beginning of each 5-minute interval. The travel time was calculated and stored in a table. A code was created that concatenated the next VDS downstream on the facility (coded in the config table in the previous step), the date, and the next time interval to use to obtain the speed for calculating the travel time at the next VDS on the facility. The next time interval was calculated as the cumulated travel time rounded down to the nearest 5-minute interval. An example from the Orange County I-5 pilot study facility Microsoft Access database is shown in Figure 4.5.



Field:	VMT: VMT0	VHT: VHT0	Departure_Time: Time	Travel_Time: TT0	EndTime: [Time]+[tt0]/60/24	NextVDS_Code: [NEXT_VDS] & "_" & [date] & "_" & Fix([EndTime]*60*24/5)*5
Table:	Corridor Data	Corridor Data	Corridor Data	Corridor Data		

Figure 4.5. Study facility Access database.

Setting up Access queries in this manner allowed the study team to develop macros and quickly create vehicle trip departure travel times for each 5-minute interval for each weekday of the year. All annual weekdays and all departure times were run simultaneously. The database macro ran the query for each VDS, calculating the travel time (and the travel rate, which is the inverse of travel time) for the segment and added that travel time and rate to the cumulative travel time, which are stored in an updated table. This process continued until the last VDS on the facility was evaluated for the day (e.g., January 1, 2010). The macro took 2 to 5 minutes to run for each facility. This flexibility allowed the study team to run multiple sections for each facility as needed.

The end result was an output table exported to a Microsoft Excel spreadsheet for further manipulation and analysis. The spreadsheet allowed the study team the flexibility to test various approaches to integrating incident, weather, and special event data into the tool described in the following sections on the use cases. A TTRMS could have all the analytical procedures incorporated into its functionality, but for pilot testing a spreadsheet-based approach was sufficient.

4.5 See What Factors Affect Reliability (AE1)

The guide presents several examples of applications that a TTRMS could address using outputs from the TTRMS. The guide calls these examples “Use Cases.” The study team examined two related use cases:

- AE1 – Described in this section, Use Case AE1 is geared toward agency administrators and planners who can potentially use the case study approach to identify the causes of unreliability on the highway system.
- AE2 – Summarized in the following section, Use Case AE2 can help administrators identify the contributions of each factor (ITRE et al. 2012).

Use Case AE1 examines how incidents, weather, work zones, special events, traffic control devices, and fluctuations in demand can contribute to unreliability. The study team followed the six steps outlined in the guide to see how well the guidance performed in developing the results:

1. Select the system of interest (e.g., a region or set of facilities).
2. Select the time frame for the analysis: the date range as well as the days of the week and times of day.
3. Assemble travel time (travel rate) observations for the system for the time frame of interest.
4. Label each observation in terms of the regime that was operative at the time the observation was made, that is, each combination of nominal congestion and nonrecurring event (including none).
5. Prepare TR-CDFs for each regime identified.
6. Analyze the contributions of the various factors so that the differences in impacts can be assessed.

The first two steps, selecting the system of interest and the time frame for analysis, were described in Chapter 3 of this report. The two facilities analyzed are Orange County I-5 from Jeffrey Road in Irvine to East 4th Street in Santa Ana as shown in Figure 4.6, and Los Angeles County I-210 facility from East Colorado Boulevard in Sierra Madre to Citrus Avenue in Azusa as shown in Figure 4.7. The time frame for analysis was all non-holiday weekdays in 2010. Travel rates were estimated from midnight to midnight for each of these days. The travel rate observations were developed using the database described in the previous section.

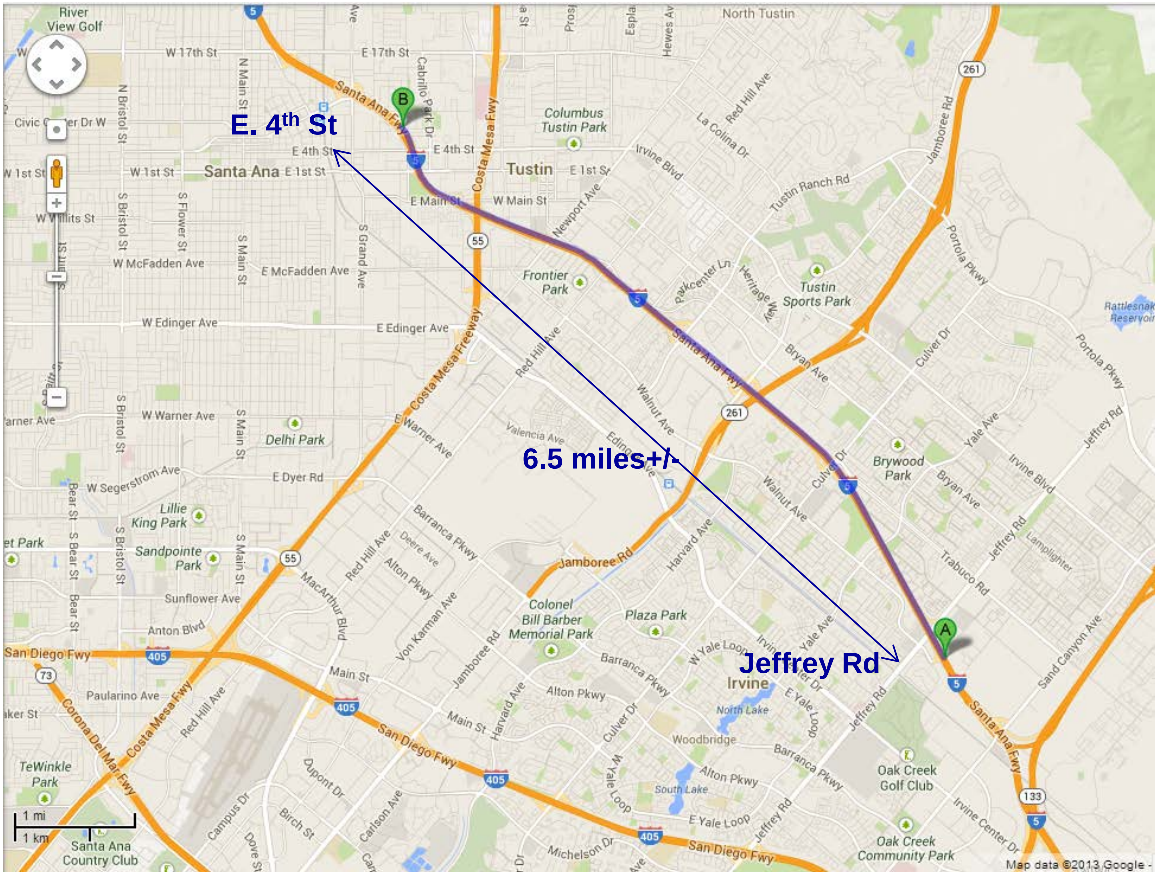


Figure 4.6. Orange County I-5 system of interest.

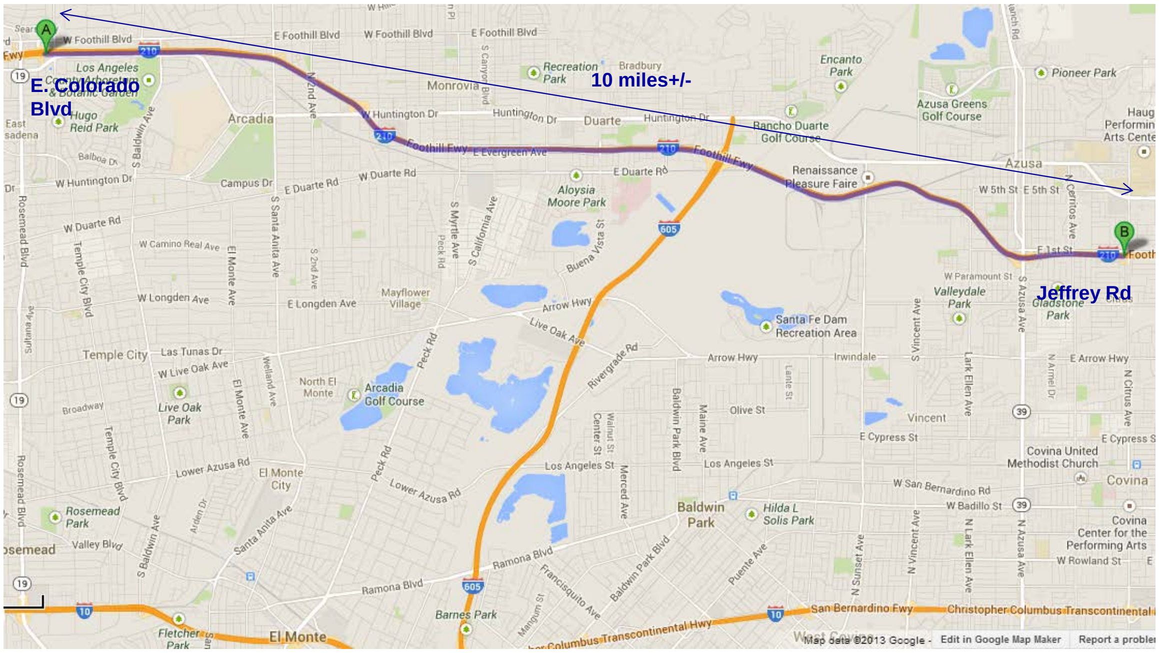


Figure 4.7. Los Angeles County I-210 system of interest.

Labeling Observations

Labeling the observations describes the process detailed in the guide to develop nonrecurrent events, that is, descriptions of the conditions prevailing during each individual trip taken on the facility. Nonrecurrent events were joined to a system-loading variable. This combination was called a regime. System loading refers to the demand conditions that might be expected during a time period, which most commonly occurs during the morning or afternoon peak commute periods. Using the Orange I-5 facility as an example, Figure 4.8 illustrates unreliable trips compared to trips taken during recurrent conditions on the facility.

The x-axis represents the time of day in 5-minute increments. The y-axis represents the travel rate on the facility. Each data point is a single trip from 2010 that started in a given 5-minute interval during the year (i.e., 24 hours x 12 5-minute intervals per hour x 250 days = 72,000 trips). The plot illustrates the commonly recognized a.m. and p.m. peak periods with the absolute a.m. peak occurring typically between 8:10 a.m. and 8:30 a.m. and the absolute p.m. peak occurring at 5:30 p.m. Trips that may be considered to take place under “recurring” congested conditions are outlined in yellow. Those trips that the study team labeled as being nonrecurring are outlined in red.

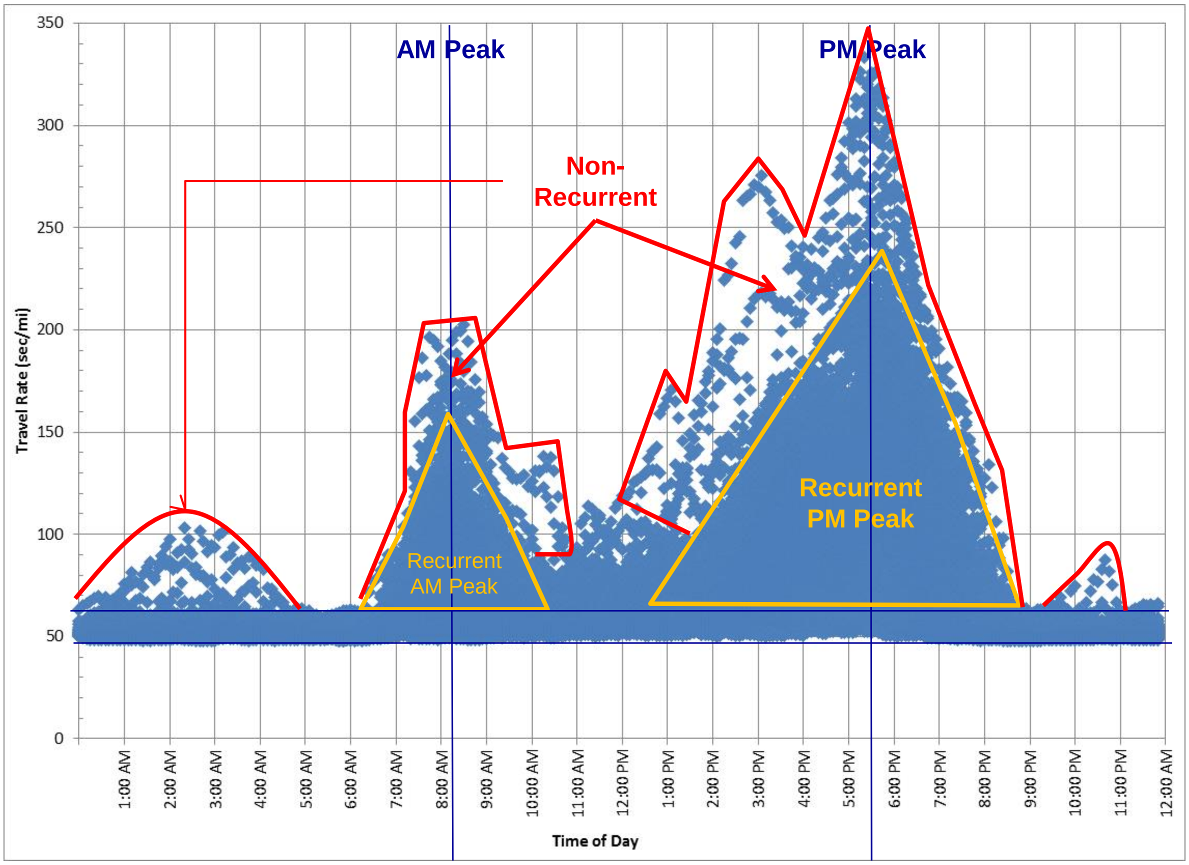


Figure 4.8. Recurrent and nonrecurrent congestion on I-5 facility.

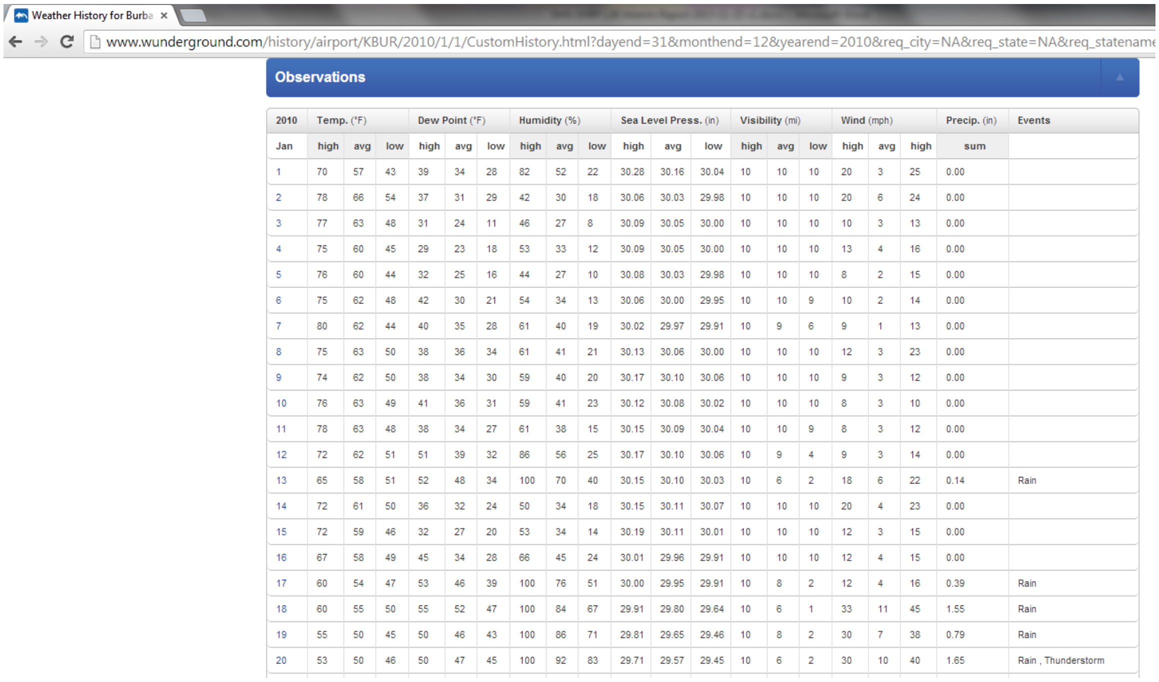
The guide describes four major causes of unreliability:

- Weather
- Incidents and accidents
- Special events, such as road closures and sporting events
- Demand surges

The study team found labeling the observations to be a time-consuming exercise; it required extensive manual manipulation and matching. The guide provided some technical approaches to assist with identifying nonrecurring conditions, but did not provide guidance on how to prioritize each of these conditions. For example, if an accident occurred during a weather event should the condition be classified as a weather cause of unreliability or an accident cause? It might be reasonable to create a combination category, which was done for the Sacramento/Lake Tahoe case study described in the guide, but the study team did not create a combination category for this use case.

Weather Data

The study team downloaded daily historical weather data from the Weather Underground website. For the Orange County I-5 facility, the study team used the Santa Ana weather location, since it is centrally located on the facility. For the Los Angeles County I-210 facility, the study team used Burbank weather, because it was available for 2010, as shown in Figure 4.9. Downloading the data was very easy and took only a minute or two to obtain data for both facilities.



Observations

2010	Temp. (°F)			Dew Point (°F)			Humidity (%)			Sea Level Press. (in)			Visibility (mi)			Wind (mph)			Precip. (in)	Events
Jan	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	low	high	avg	high	sum	
1	70	57	43	39	34	28	82	52	22	30.28	30.16	30.04	10	10	10	20	3	25	0.00	
2	78	66	54	37	31	29	42	30	18	30.06	30.03	29.98	10	10	10	20	6	24	0.00	
3	77	63	48	31	24	11	46	27	8	30.09	30.05	30.00	10	10	10	10	3	13	0.00	
4	75	60	45	29	23	18	53	33	12	30.09	30.05	30.00	10	10	10	13	4	16	0.00	
5	76	60	44	32	25	16	44	27	10	30.08	30.03	29.98	10	10	10	8	2	15	0.00	
6	75	62	48	42	30	21	54	34	13	30.06	30.00	29.95	10	10	9	10	2	14	0.00	
7	80	62	44	40	35	28	61	40	19	30.02	29.97	29.91	10	9	6	9	1	13	0.00	
8	75	63	50	38	36	34	61	41	21	30.13	30.06	30.00	10	10	10	12	3	23	0.00	
9	74	62	50	38	34	30	59	40	20	30.17	30.10	30.06	10	10	10	9	3	12	0.00	
10	76	63	49	41	36	31	59	41	23	30.12	30.08	30.02	10	10	10	8	3	10	0.00	
11	78	63	48	38	34	27	61	38	15	30.15	30.09	30.04	10	10	9	8	3	12	0.00	
12	72	62	51	51	39	32	86	56	25	30.17	30.10	30.06	10	9	4	9	3	14	0.00	
13	65	58	51	52	48	34	100	70	40	30.15	30.10	30.03	10	6	2	18	6	22	0.14	Rain
14	72	61	50	36	32	24	50	34	18	30.15	30.11	30.07	10	10	10	20	4	23	0.00	
15	72	59	46	32	27	20	53	34	14	30.19	30.11	30.01	10	10	10	12	3	15	0.00	
16	67	58	49	45	34	28	66	45	24	30.01	29.96	29.91	10	10	10	12	4	15	0.00	
17	60	54	47	53	46	39	100	76	51	30.00	29.95	29.91	10	8	2	12	4	16	0.39	Rain
18	60	55	50	55	52	47	100	84	67	29.91	29.80	29.64	10	6	1	33	11	45	1.55	Rain
19	55	50	45	50	46	43	100	86	71	29.81	29.65	29.46	10	8	2	30	7	38	0.79	Rain
20	53	50	46	50	47	45	100	92	83	29.71	29.57	29.45	10	6	2	30	10	40	1.65	Rain , Thunderstorm

Figure 4.9. Weather Underground daily data.

Source: www.weatherunderground.com.

This data was supplemented with the Caltrans Traffic Accident Surveillance and Analysis System (TASAS) database (described in the accident data section below) because the TASAS database identifies the prevailing conditions on the roadway when an accident occurred. The study team also considered supplementing these data with National Oceanic and Atmospheric Administration (NOAA) 15-minute data to obtain a better level of data granularity for the analysis. However, one aspect of Southern California weather is that it is relatively consistent during the day, compared to other regions.

For each 5-minute interval in the dataset, the study team identified the record as either having a 1 for a weather impact or a 0 for no weather impact. The weather impact was determined if the interval was described as “wet” in the TASAS dataset or as having recorded precipitation in the Weather Underground dataset.

Traffic Incident and Accident Data

The primary source for accident data in the dataset was the TASAS data described earlier. TASAS was developed by Caltrans to compile and summarize California Highway Patrol (CHP) state highway related collision reports. TASAS data can be downloaded from PeMS and provides the location of the accident (i.e., route, direction, postmile, and lane number), the severity (i.e., property damage only, injury, and fatality), as well as the lighting and weather conditions at the time of the accident. TASAS does not provide the duration of the accident, which was estimated in all cases based partly on data from the California Highway Patrol (CHP) dispatch logs.

The CHP dispatch logs, as well as the dispatch communications with the CHP officers in the field, are also found in PeMS. These data attempt to classify the type of incident and can be used to estimate the duration of incidents since each incident is "opened" and "closed" when CHP arrives at and leaves the scene of the incident. The dispatch data are very difficult to work with and are not always linked to the actual duration of an incident. For example, there are cases that the study team identified when an ambulance was dispatched and the event closed only a few minutes apart. It is unlikely that the ambulance arrived at the scene, provided medical assistance, and evacuated the scene, all within a few minutes.

Special Event Data

The study team used three primary data sources for special event data. For the analysis, the team included planned lane closures as special events. These data came from the Caltrans PeMS Lane Closure System (LCS). The LCS is a lane closure request and tracking system used by District Traffic Managers and contractors to request, review and approve lane closures on the freeway system. The dataset provided the location and date of the closure as well as the actual closing and opening times.

The secondary sources of data were from the published schedules of events near the facilities. Major special event trip generators were not identified for the Los Angeles I-210 facility, and no special event facilities lie adjacent to the I-5 in Orange County. However, on State Route 57 in Anaheim, just north of I-5, are the venues for the Anaheim Angels professional baseball team and the Anaheim Ducks professional hockey team. Both Angel Stadium and the Honda Center host an array of other events, such as concerts for which 2010 schedules could not be readily obtained. The Angels and Ducks schedules (including preseason and playoff games) were downloaded and used to label "Special Event" condition.

For the third data source, the study team analyzed VDS flow data at the interchanges adjacent to Angel Stadium and the Honda Center to identify times when flows were heavier than usual and to identify when other events occurred at these venues. The flows were compared against known event times (e.g., night baseball games) to validate findings from other nights. This approach allowed the study team to identify a fairly detailed set of special event times that might impact the I-5 facility. This facilitated the flagging of special events for each 5-minute interval with a 1 for special event or a 0 for no special event.

Demand Surges

The study team identified a "High Demand" category using the approach outlined in the guide by looking at the VMT traveling during each 5-minute interval. If demand exceeded two standard deviations above the mean for a given 5-minute interval, it was given a "Demand" designation (a 1 or a 0 as done with the previous approaches).

Identifying Regimes

Once all the causes were identified, a final category for expected system loading was developed using the semi-variance approach outlined in the “See What Factors Affect Unreliability (AE1)” use case provided in the guide. Figure 4.10 shows an example of the semi-variance results for the Los Angeles I-210 facility. Table 4-2 shows the system-loading results between 2:00 p.m. and 4:00 p.m. used to create Figure 4.10.

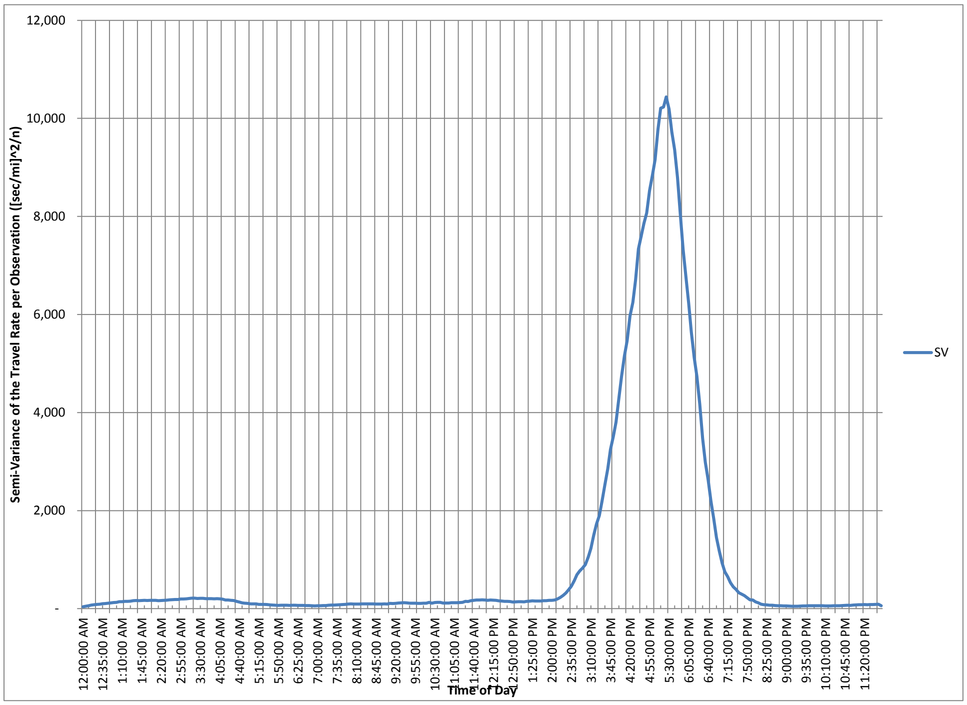


Figure 4.10. Semi-variance for I-210 facility.

Table 4.2. System Loading on the I-210 Facility

Time	Semi-Variance (SV)	Travel Rate (TR)	Average Speed	Regime Calculated
2:00:00 p.m.	171	60.4	60.0	Uncong
2:05:00 p.m.	178	60.6	59.8	Uncong
2:10:00 p.m.	196	61.2	59.3	Uncong
2:15:00 p.m.	228	62.0	58.6	Uncong
2:20:00 p.m.	270	63.2	57.6	Uncong
2:25:00 p.m.	319	64.5	56.5	Uncong
2:30:00 p.m.	387	66.1	55.3	Uncong
2:35:00 p.m.	458	67.8	53.9	LowCong
2:40:00 p.m.	569	70.4	51.9	LowCong
2:45:00 p.m.	693	72.9	50.2	LowCong
2:50:00 p.m.	771	74.3	49.2	LowCong
2:55:00 p.m.	826	75.5	48.4	LowCong
3:00:00 p.m.	899	76.7	47.7	LowCong
3:05:00 p.m.	1,051	79.2	46.2	LowCong
3:10:00 p.m.	1,228	81.9	44.7	ModCong
3:15:00 p.m.	1,505	85.6	42.8	ModCong
3:20:00 p.m.	1,724	88.3	41.4	ModCong
3:25:00 p.m.	1,898	90.4	40.5	ModCong
3:30:00 p.m.	2,191	93.6	39.1	ModCong
3:35:00 p.m.	2,529	96.9	37.9	ModCong
3:40:00 p.m.	2,852	99.9	36.8	ModCong
3:45:00 p.m.	3,246	103.3	35.6	ModCong
3:50:00 p.m.	3,510	105.7	34.8	HighCong
3:55:00 p.m.	3,803	108.0	34.1	HighCong
4:00:00 p.m.	4,290	111.7	33.0	HighCong

Applying the Use Case, the study team first calculated the semi-variance for each 5-minute interval over the year using the formula from Chapter 3 in the guide:

$$\sigma_r^2 = \frac{1}{n}\sum_{i=1}^{n}(x_i - r)^2 \quad and \quad \sigma_r = \sqrt{\sigma_r^2} \quad \exists\, x_i \geq r,$$

where

σ_r is the semi-variance,

n is the number of 5-minute intervals per year for the run start time (e.g., all the 3:55 p.m. time periods in 2010),

x_i is the observed travel rate (1/speed), and

r is the minimum travel rate observed over the entire year.

The length of the segment under analysis can impact the travel rate calculation, which can impact all the analysis performed using the L02 methods. There are no clear rules of thumb on how long a segment should be. However, choosing a segment that is too long will tend to smooth out travel times and travel rates across days, which will flatten out the semi-variance. Picking too short a segment may result in high semi-variances, which may not adequately reflect the traveler's overall trip experience on the facility.

Once all the unreliability conditions and system loadings were identified, the study team labeled the regime for each 5-minute interval. An example for the I-5 facility in Orange County is shown in Table 4.3. In this table, each condition (e.g., high demand, weather, special event, and incident) is coded with a 1 or a 0 to identify the condition (noted in the "Regime1" column). The ultimate regime (i.e., Regime1 and the Congestion Level) was labeled in the final column.

The study team followed a hierarchy in labeling the regimes. Weather was considered to be a prevailing cause of congestion, followed by incidents, special events, and high demand. Since a single time interval can experience multiple reliability factors, a different order of prevailing causes would change the factor analysis. The guide does not offer advice on an appropriate order or method for assigning intervals to categories. The study team tested several variations, including simplifying and expanding categories. Clearly, this is a step that is open to wide interpretation and requires extensive trial and error.

Table 4.3. Regime identification on I-5 facility.

Time 2	Timestamp	Time Period	Free Flow	Low Demand	High Demand	Weather	Special Event	Incident Score	Incident	Unk	SV Calc	Congestion Level	Regime1	Regime
5	1/4/10 0:00	Eve/ Early AM	1	0	0	0		0	0	0	5.8	Uncong	Normal	Normal-Uncong
5	1/4/10 0:05	Eve/ Early AM	1	0	0	0		0	0	0	6.6	Uncong	Normal	Normal-Uncong
10	1/4/10 0:10	Eve/ Early AM	1	0	0	0		0	0	0	6.2	Uncong	Normal	Normal-Uncong
15	1/4/10 0:15	Eve/ Early AM	1	0	0	0		0	0	0	8.4	Uncong	Normal	Normal-Uncong
20	1/4/10 0:20	Eve/ Early AM	1	0	0	0		0	0	0	8.5	Uncong	Normal	Normal-Uncong
25	1/4/10 0:25	Eve/ Early AM	1	0	0	0		0	0	0	7.2	Uncong	Normal	Normal-Uncong
30	1/4/10 0:30	Eve/ Early AM	1	0	0	0		0	0	0	8.9	Uncong	Normal	Normal-Uncong
35	1/4/10 0:35	Eve/ Early AM	1	0	0	0		0	0	0	17.4	Uncong	Normal	Normal-Uncong
40	1/4/10 0:40	Eve/ Early AM	1	0	0	0		0	0	0	14.7	Uncong	Normal	Normal-Uncong
45	1/4/10 0:45	Eve/ Early AM	1	0	0	0		0	0	0	13.9	Uncong	Normal	Normal-Uncong
50	1/4/10 0:50	Eve/ Early AM	1	0	0	0		0	0	0	14.8	Uncong	Normal	Normal-Uncong
55	1/4/10 0:55	Eve/ Early AM	1	0	0	0		0	0	0	18.4	Uncong	Normal	Normal-Uncong

Developing Travel Rate Cumulative Distribution Functions (TR-CDFs)

The fifth step in the process is to develop probability distributions and create cumulative distribution functions for the travel rates. This was done by creating a Microsoft Excel pivot table and binning the travel rates in percentiles to arrive at the TR-CDFs for each facility. Figure 4.11 shows the I-5 results and Figure 4.12 shows the I-210 results.

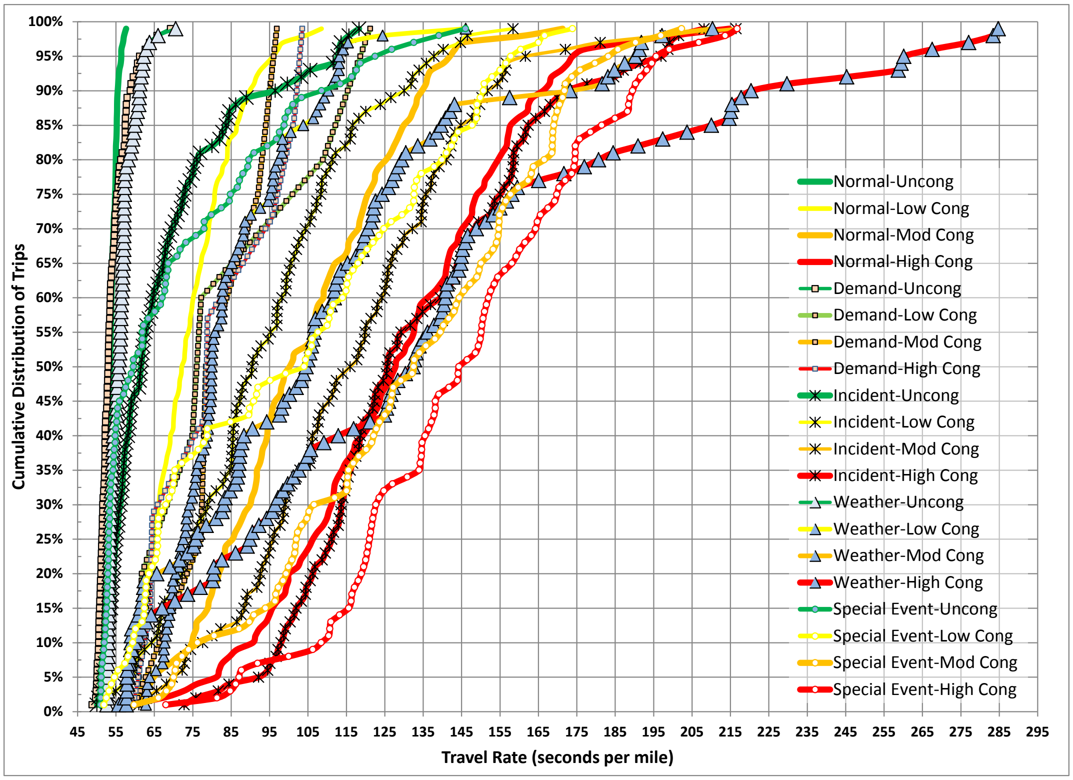


Figure 4.11. Travel rate cumulative distribution functions (TR-CDFs) for I-5.

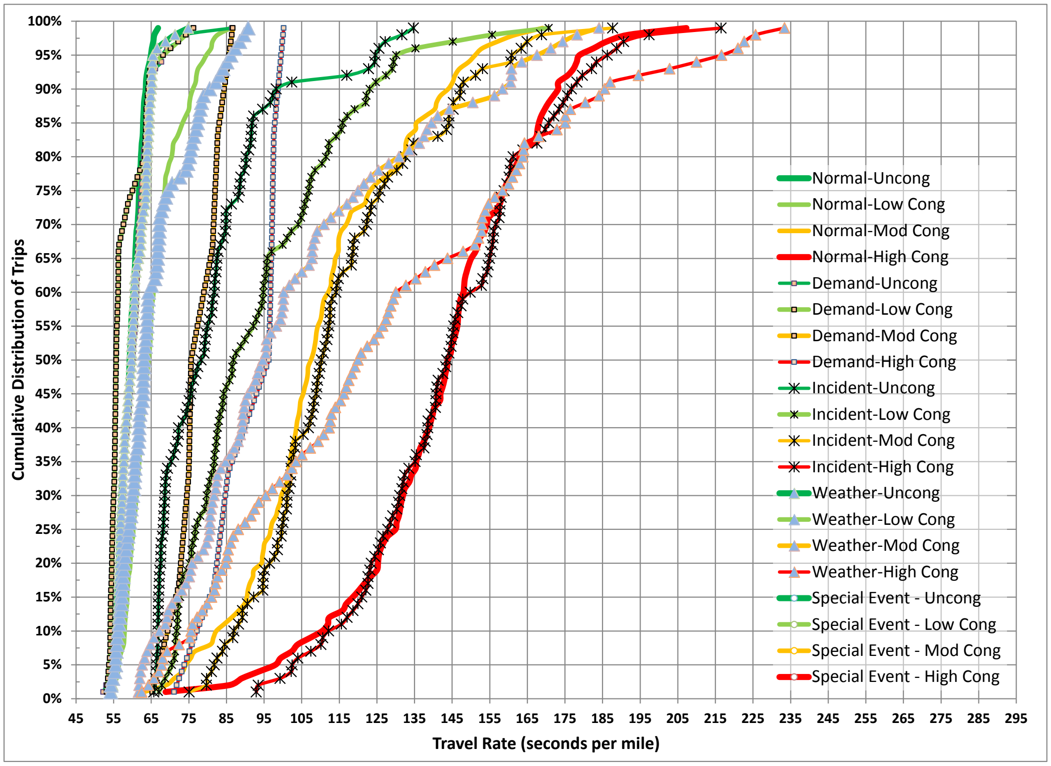


Figure 4.12. Travel rate cumulative distribution functions (TR-CDFs) for I-210.

As can be expected, intervals with high system loading (i.e., peak commute periods) have the highest congestion on both facilities (shown by the red lines). Weather also has a significant impact on both facilities. Days with bad weather (shown with the triangle symbol) exhibit particularly long tails to the right of the graph and show very long travel rates on some days. Of note is the impact of special events on the Orange County I-5 facility.

Occasionally, lines will cross other lines. This occurs primarily when there are relatively few observations available to create smooth transitions from one data point to the next. For example, there were only 47 rainy day observations in the year 2010 from which to develop the cumulative distribution for weather.

Using the I-5 facility as an example, even on days with low congestion, shown by the green lines, special events have a larger impact than days with moderate congestion and normal demand (shown by the orange lines with no symbol). Figure 4.13 shows the I-5 CDFs for normal (i.e., recurring) congested periods. Figure 4.14 shows the I-5 CDFs with the special event lines added.

Figure 4.13 shows the curves under normal conditions for uncongested and low-, moderate-, and high-congested regimes for I-5 in Orange County. Under uncongested conditions (e.g., in the middle of the night), there is little difference between the slowest trip at 57 seconds per mile (or 63 mph) and the fastest trip at 47 seconds per mile (or 76 mph). The green line representing this condition is nearly vertical, with a median trip at the 50th percentile, taking just under 55 seconds per mile. In contrast, under the most severely congested conditions (the red line), travel rates slow considerably. The median travel rate has more than doubled to 128 seconds per mile (28 mph). Approximately 5 percent of the trips under extremely congested conditions can take more than 175 seconds per mile (less than 20 mph).

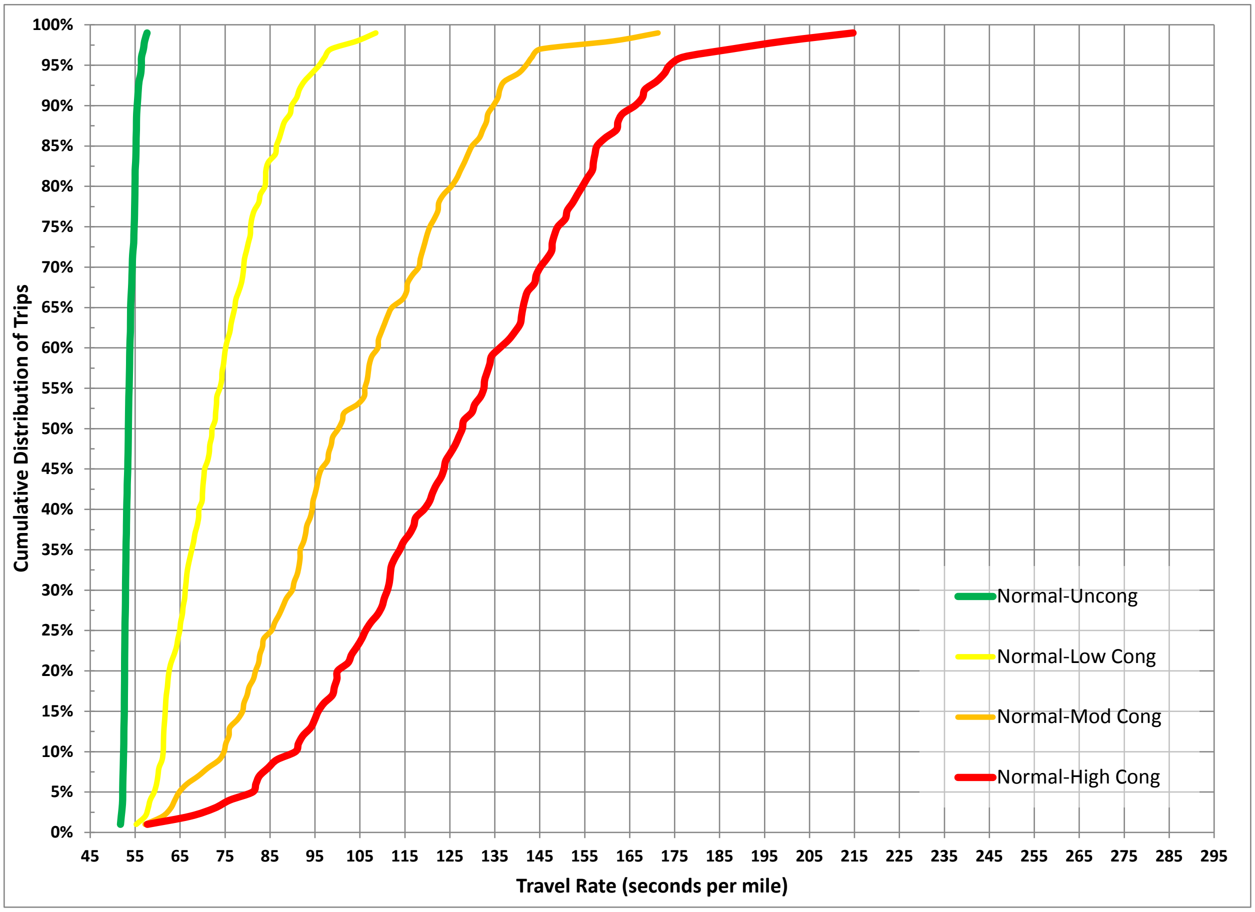


Figure 4.13. Travel rate cumulative distribution functions (TR-CDFs) for I-5 normal congestion.

Figure 4.14 shows the special event curves along with the normal curves shown in Figure 4.13. Special events can dramatically increase travel rates on the facility. Even under uncongested time periods (the green curve with the circle symbol), a special event can increase the median travel rate from about 53 seconds per mile to 60 seconds (an increase of 13 percent). The 85th percentile travel rate increases even more dramatically, from 55 seconds per mile (about 65 mph) to 99 seconds (36 mph), an increase of more than 80 percent. Figure 4.14 also shows that even under moderate congestion, the travel rates for special events can exceed the rate under recurrent congestion during the most heavily traveled weekday.

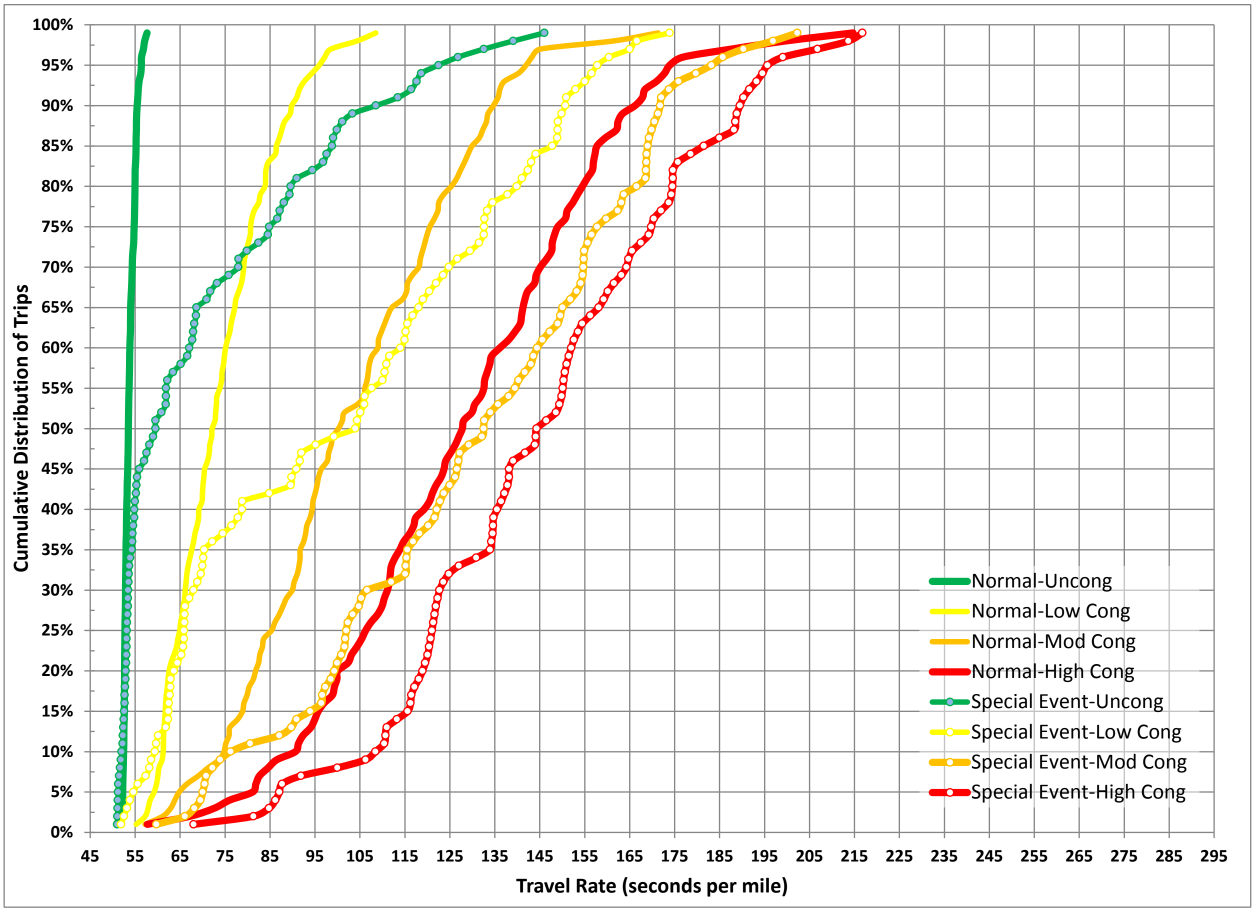


Figure 4.14. Travel rate cumulative distribution functions (TR-CDFs) for I-5 special events.

Figure 4.15 shows the curves under normal conditions for uncongested and low-, moderate-, and high-congested regimes for I-210 in Los Angeles County. I-210 shows a slightly wider range of variation in travel rate than does I-5. The slowest trip takes 67 seconds per mile (53 mph) and the fastest trip is at 55 seconds per mile (65 mph). This is slower than for the I-5, but unlike the I-5, the low congested regime for the I-210 is not much slower than the uncongested regime. The median trip under low congestion takes 59 seconds per mile for the uncongested regime, but only about 8 percent longer (64 seconds per mile) under the low congested regime. The most severely congested conditions on the I-210 (the red line) have travel rates slowing considerably, with the median travel rate increasing more than 144 percent to 144 seconds per mile (25 mph). Approximately 5 percent of the trips under extremely congested conditions can take more than 178 seconds per mile (20 mph), which is similar to the extreme tail for the I-5 in Orange County.

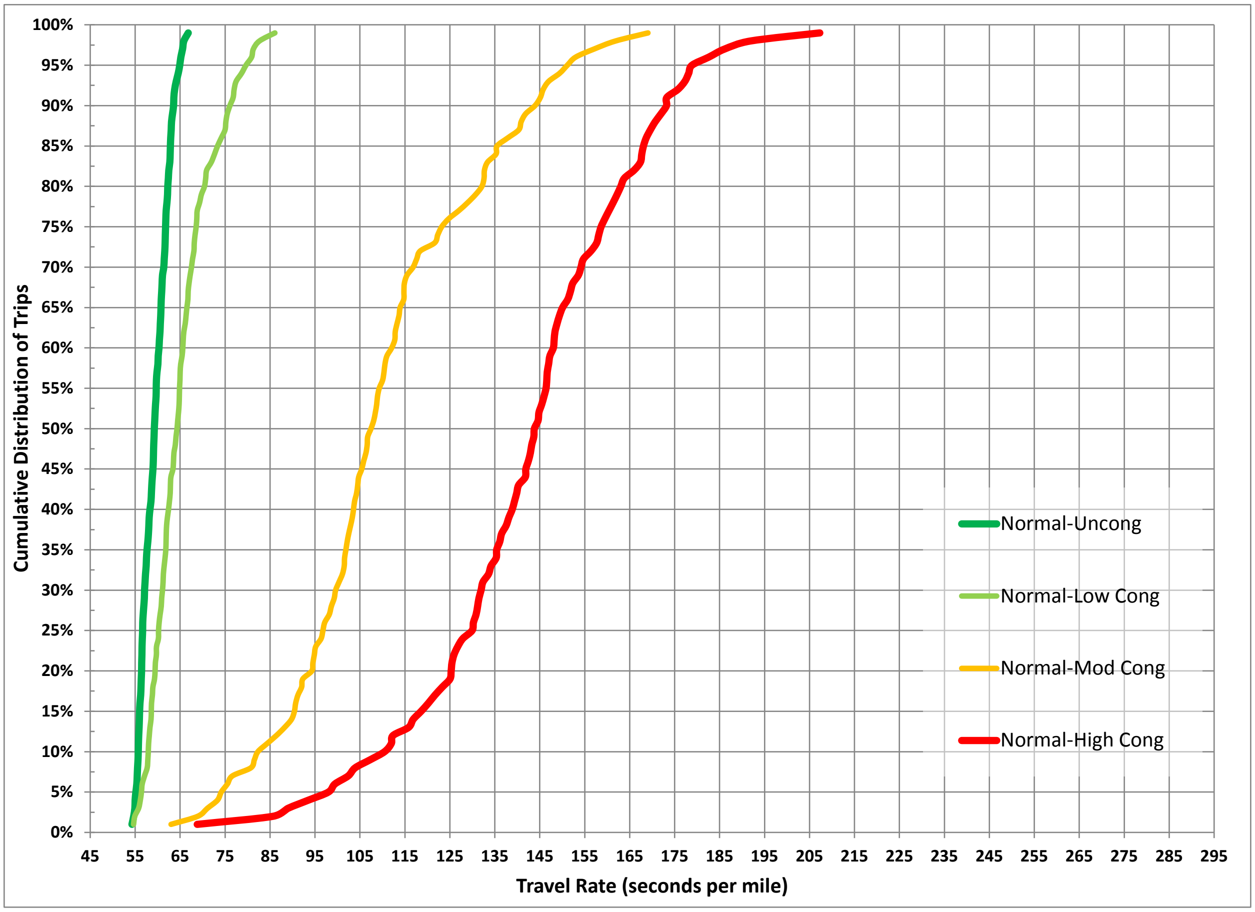


Figure 4.15. Travel rate cumulative distribution functions (TR-CDFs) for I-210 normal congestion.

Figure 4.16 shows the weather curves along with the normal curves that were shown in Figure 4.15. Under uncongested and low congested times (e.g., late at night) rain does not have much impact on travel rates. In peak periods (high congestion), rain appears to reduce travel rates. This may be due to the fact that there were only 46 rainy days during 2010 in Southern California and statistically the sample is too small—though likely significant—to arrive at a completely conclusive answer. Rain may cause people not to take trips that they would otherwise take, which would reduce congestion on the facility. At the extreme end of the high congestion weather curve, however, results are what would be expected. Around the 75th percentile of trips, weather begins to have a worsening effect on travel rates. Around 5 percent of peak period trips in rainy conditions can take longer than 217 seconds per mile or travel slower than 16 mph.

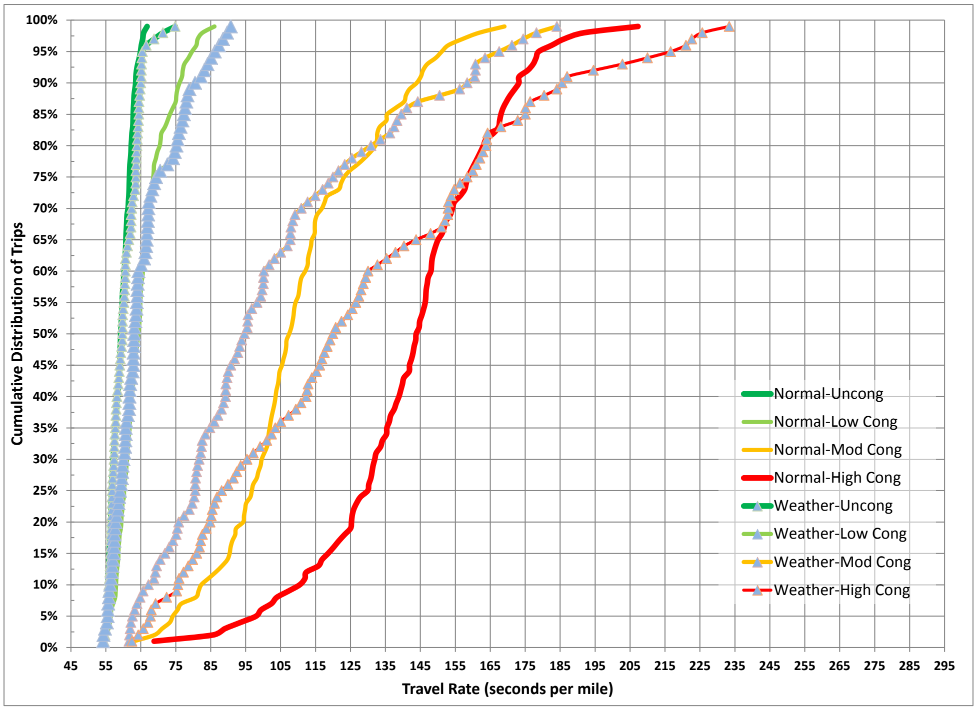


Figure 4.16. Travel rate cumulative distribution functions (TR-CDFs) for I-210 weather.

4.6 Assess the Contributions of the Factors (AE2)

Assessing the contributions of the factors involved all of the steps for AE1 as well as the added step of developing a rank order on the facilities based on the relative impacts. This required summing the total semi-variances (SV) for each nonrecurring event category by congestion type for both facilities. Table 4.4 shows the results of this calculation.

Table 4.4. Semi-Variances for Each Regime on the I-5 and I-210 Facilities

Co	Rte	Regime	Normal		Demand		Weather		Special Event		Incident		Regime Total SV	Facility Total
			SV	n	SV	n	SV	n	SV	n	SV	n		
Los Angeles	I-210	Uncong	177	36,624	182	3,526	223	9,184	n/a		1,428	794	**10,293,632**	**97,249,460**
		Low Cong	601	8,319	147	26	689	1,978			2,610	470	**7,595,685**	
		Mod Cong	4,692	3,560	711	25	4,387	1,012			5,146	925	**25,919,625**	
		High Cong	9,744	3,454	1,585	48	8,437	1,012			11,082	1,008	**53,440,518**	
Orange	I-5	Uncong	60	37,758	94	706	199	8,600	750	1,475	667	1,661	**6,255,508**	**97,787,935**
		Low Cong	1,115	7,647	2,305	8	2,495	1,849	4,145	342	2,752	947	**17,186,411**	
		Mod Cong	3,847	3,286	1,183	6	5,723	946	7,808	439	5,996	845	**26,555,908**	
		High Cong	7,780	3,546	1,465	11	12,091	946	9,958	121	8,401	898	**47,790,108**	

From the Facility Total column at the far right of the table, one can see that both facilities appear to have similar levels of unreliability as measured by semi-variance. As can be expected, the higher the congestion level, the more unreliable the facility becomes, with the Los Angeles I-210 facility being slight more unreliable.

Table 4.5 shows the percent contribution of each regime. Similar to what was observed in the L02 guide, the highest unreliability on the facilities comes under highly congested time periods with normal demands (35 percent for the I-210 facility and 28 percent for the I-5 facility). On the I-210 facility, incidents and weather provide approximately the same contribution to unreliability (at 19 and 17 percent respectively). I-5 presents a slightly different story with weather exhibiting a slightly higher impact on nonrecurrent congestion at 24 percent and incidents contributing only 17 percent.

Table 4.5. Percentages for Semi-Variances for Each Regime the I-5 and I-210 Facilities

County	Route	Regime	Normal	Demand	Weather	Special Event	Incident	Regime Total SV	Facility Total
Los Angeles	I-210	Uncong	7%	1%	2%		1%	**11%**	**100%**
		Low Cong	5%	0%	1%		1%	**8%**	
		Mod Cong	17%	0%	5%		5%	**27%**	
		High Cong	35%	0%	9%		11%	**55%**	
I-210 Totals			**64%**	**1%**	**17%**	**0%**	**19%**	**100%**	
Orange	I-5	Uncong	2%	0%	2%	1%	1%	**6%**	**100%**
		Low Cong	9%	0%	5%	1%	3%	**18%**	
		Mod Cong	13%	0%	6%	4%	5%	**27%**	
		High Cong	28%	0%	12%	1%	8%	**49%**	
I-5 Totals			**52%**	**0%**	**24%**	**7%**	**17%**	**100%**	

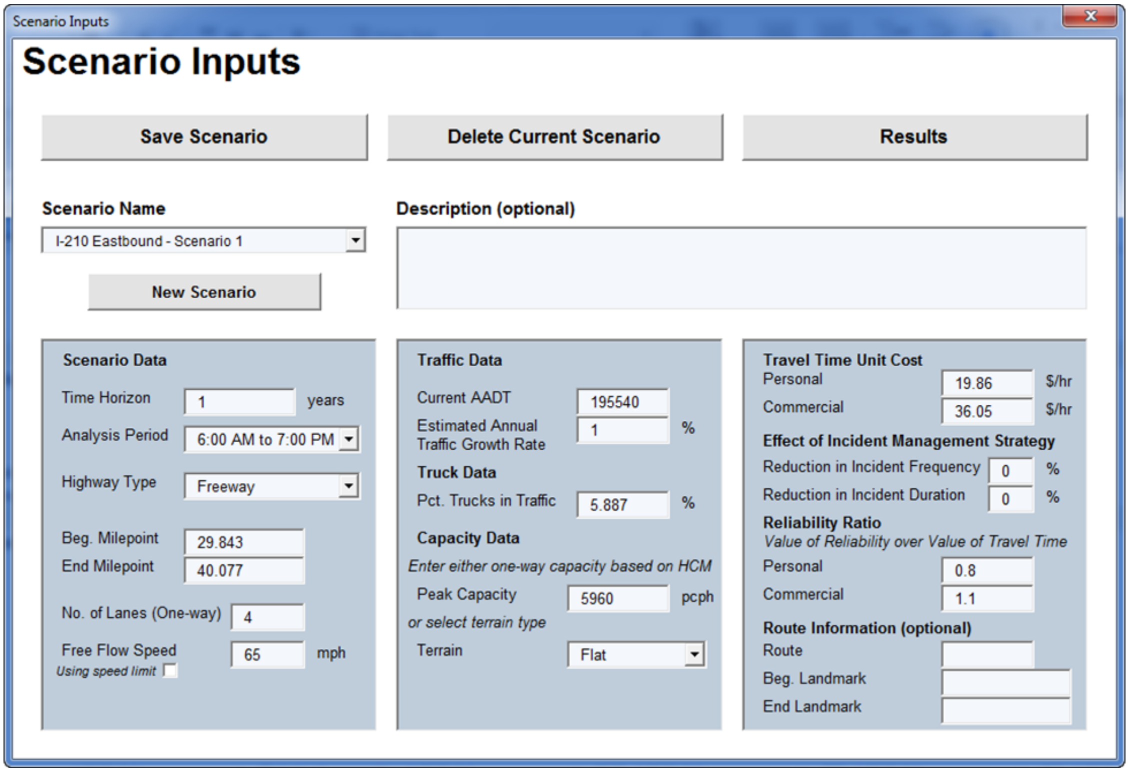
CHAPTER 5

C11 Reliability Analysis Tool

5.1 Overview of the C11 Reliability Analysis Tool

The Reliability Analysis Tool developed under **Project C11** is a sketch planning tool for facilities. The C11 tool is intended to help users incorporate reliability analysis into a standard benefit-cost analysis framework by providing estimates of reliability impacts and monetizing those impacts using a reliability ratio and value of travel time. Although the original purpose of the tool is to support benefit-cost analysis, it also provides a simple sketch method for estimating the reliability impacts of projects.

The Reliability Analysis Tool was developed in a Microsoft Excel workbook and estimates travel time index (TTI), delay, and congestion costs using a simple user interface. Figures 5.1 and 5.2 provide examples of the user interface and result summary screen. The tool requires input data that are relatively easy to collect and enter, and the output data are easy to find. The study team found the tool relatively easy to use and believes that the C11 tool serves its purpose as a quick sketch planning tool. However, users need to be familiar with model calibration principles in order to have the tool match ground-truth conditions as well as traffic engineering principles to effectively apply the tool to the analysis of potential mitigation strategies.



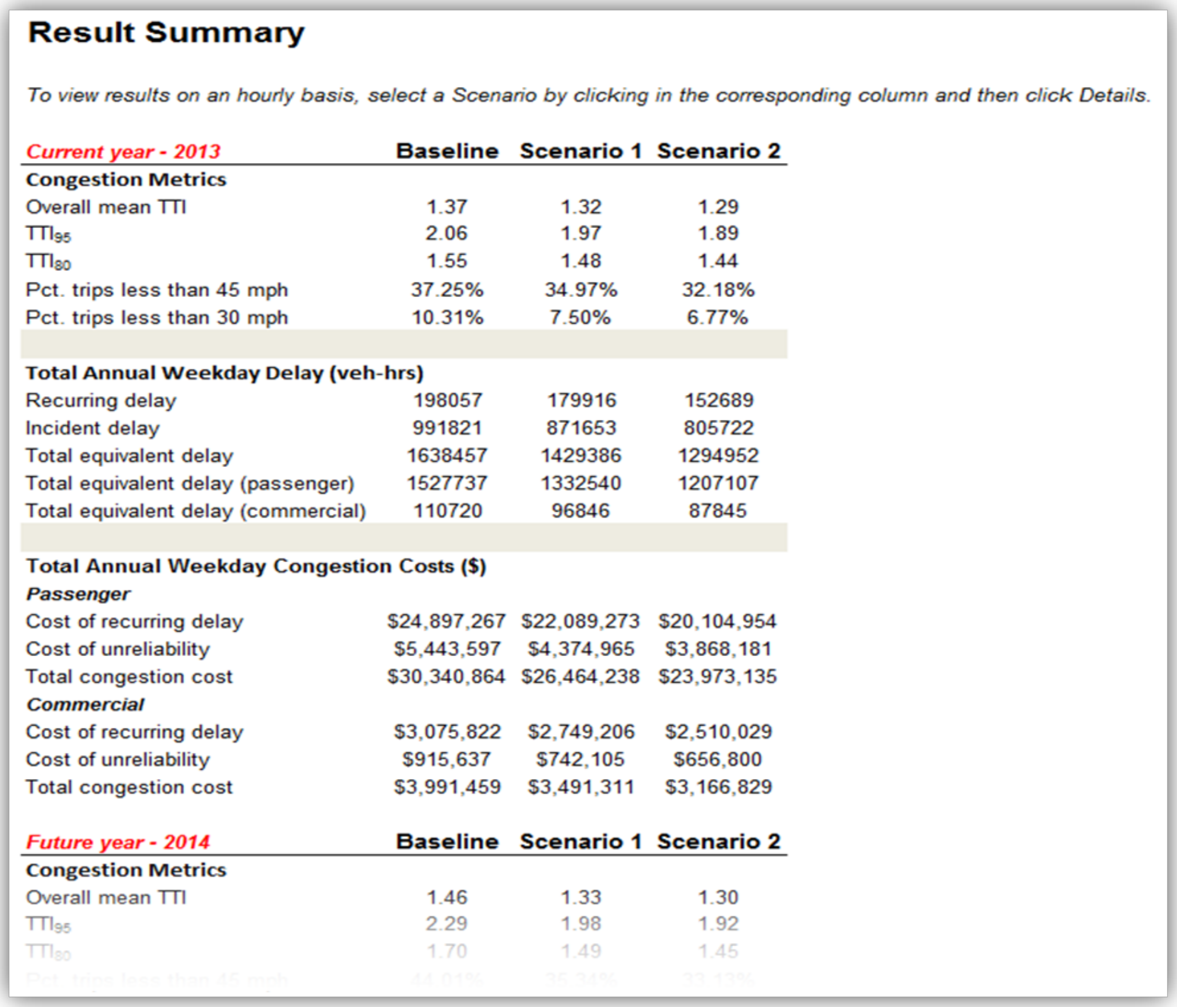
Scenario Name: I-210 Eastbound - Scenario 1

Scenario Data
Time Horizon: 1 years
Analysis Period: 6:00 AM to 7:00 PM
Highway Type: Freeway
Beg. Milepoint: 29.843
End Milepoint: 40.077
No. of Lanes (One-way): 4
Free Flow Speed: 65 mph
Using speed limit ☐

Traffic Data
Current AADT: 195540
Estimated Annual Traffic Growth Rate: 1 %
Truck Data
Pct. Trucks in Traffic: 5.887 %
Capacity Data
Enter either one-way capacity based on HCM
Peak Capacity: 5960 pcph
or select terrain type
Terrain: Flat

Travel Time Unit Cost
Personal: 19.86 $/hr
Commercial: 36.05 $/hr
Effect of Incident Management Strategy
Reduction in Incident Frequency: 0 %
Reduction in Incident Duration: 0 %
Reliability Ratio
Value of Reliability over Value of Travel Time
Personal: 0.8
Commercial: 1.1
Route Information (optional)
Route:
Beg. Landmark:
End Landmark:

Figure 5.1. Project C11 Reliability Analysis Tool user interface.



Result Summary

To view results on an hourly basis, select a Scenario by clicking in the corresponding column and then click Details.

Current year - 2013	**Baseline**	**Scenario 1**	**Scenario 2**
Congestion Metrics			
Overall mean TTI	1.37	1.32	1.29
TTI_{95}	2.06	1.97	1.89
TTI_{80}	1.55	1.48	1.44
Pct. trips less than 45 mph	37.25%	34.97%	32.18%
Pct. trips less than 30 mph	10.31%	7.50%	6.77%
Total Annual Weekday Delay (veh-hrs)			
Recurring delay	198057	179916	152689
Incident delay	991821	871653	805722
Total equivalent delay	1638457	1429386	1294952
Total equivalent delay (passenger)	1527737	1332540	1207107
Total equivalent delay (commercial)	110720	96846	87845
Total Annual Weekday Congestion Costs ($)			
Passenger			
Cost of recurring delay	$24,897,267	$22,089,273	$20,104,954
Cost of unreliability	$5,443,597	$4,374,965	$3,868,181
Total congestion cost	$30,340,864	$26,464,238	$23,973,135
Commercial			
Cost of recurring delay	$3,075,822	$2,749,206	$2,510,029
Cost of unreliability	$915,637	$742,105	$656,800
Total congestion cost	$3,991,459	$3,491,311	$3,166,829

Future year - 2014	**Baseline**	**Scenario 1**	**Scenario 2**
Congestion Metrics			
Overall mean TTI	1.46	1.33	1.30
TTI_{95}	2.29	1.98	1.92
TTI_{80}	1.70	1.49	1.45
Pct. trips less than 45 mph	44.01%	35.34%	33.13%

Figure 5.2. Project C11 Reliability Analysis Tool result summary screen.

5.2 Limitations of the C11 Reliability Analysis Tool

In the course of tool testing, the study team observed a number of tool limitations that impact both the accuracy of results and ease of use. The section below discusses the tool limitations in general in order to provide the SHRP 2 Reliability program with an idea of tool fixes necessary to support SHRP 2 implementation. The results of the tool testing are presented after the tool limitations.

Input Limitations

Difficult to Calibrate

The tool and its associated user’s guide (Cambridge Systematics et al. 2013a) do not provide instructions on how to calibrate the tool to real-world conditions. Instructions on how to calibrate the tool are necessary for tool implementation, since tool calibration is the first step of any real-world application. As shown in an example in the “Baseline Condition Estimation of the C11 Reliability Analysis Tool” section (Section 5.3), the study team eventually discovered that the tool can be calibrated to the observed conditions on the facility by adjusting the peak capacity and the hourly distribution of demand.

ADJUSTING PEAK CAPACITY

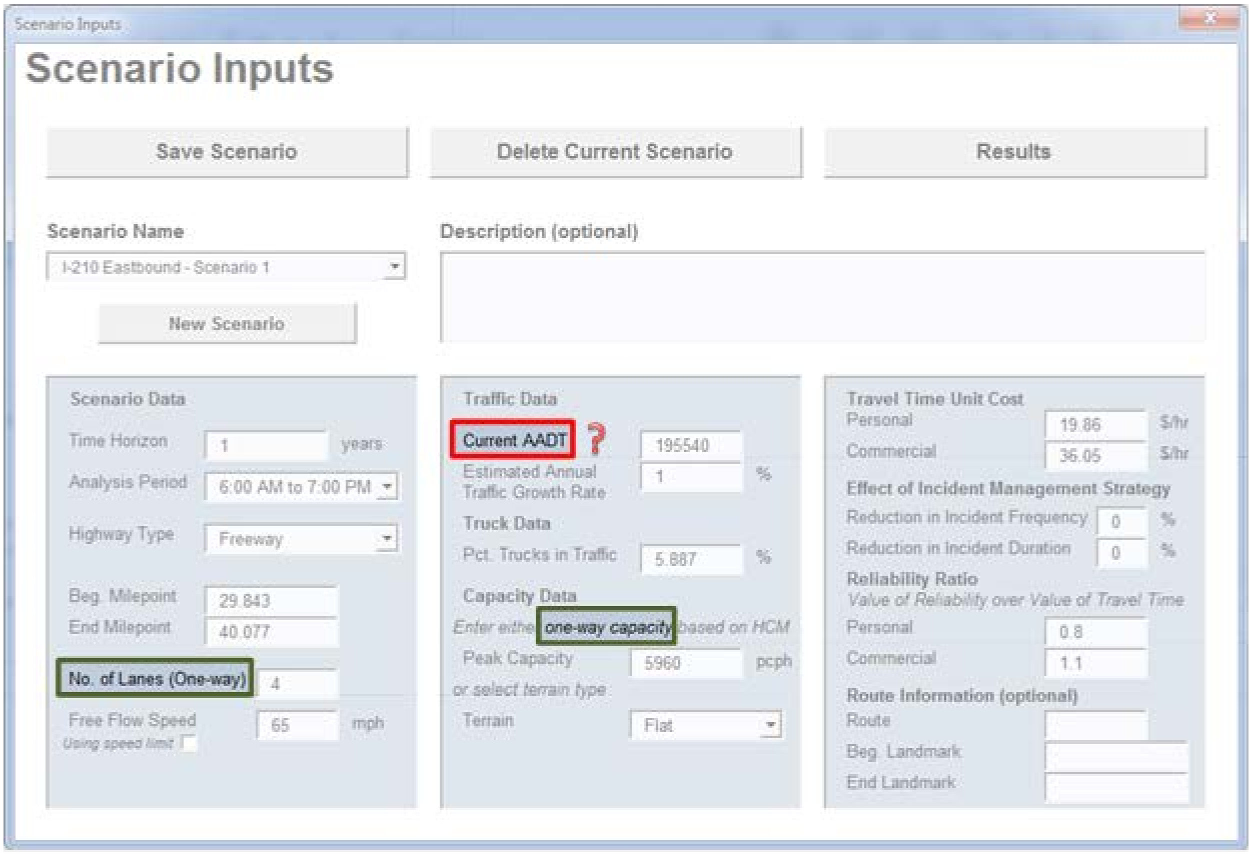
Although the study team was able to calibrate the tool by adjusting the peak capacity for both the I-210 and I-5 facilities, the peak capacities used were unrealistically low. For example, in order to calibrate the tool, capacities as low as 1,300 vehicles per hour per lane were used, which is well below the known flow rate at capacity for these two facilities (but probably indicative of throughput during congestion). For purposes of technical integrity, the tool should provide a clear and technically solid method of calibration that does not involve calibration utilizing unrealistic peak capacities.

ADJUSTING HOURLY DISTRIBUTION OF DEMAND

The tool’s interface does not allow the user to input the hourly distribution of demand. Only after going into a hidden password-protected tab was the study team able to discover the default distribution assumed in the tool and adjust the distribution to match the actual volume found on the facilities. The default distribution in the tool assumes a bidirectional demand with an a.m. and p.m. peak. Neither the default distribution nor the assumption of bidirectional demand was an accurate assumption for the facilities tested by the team. As described in Chapter 3, both facilities exhibit congestion during both peak periods with some directions reporting higher congestion and unreliability. For purposes of accuracy, the tool should include the ability for users to effortlessly view and adjust the hourly distribution of demand as needed. This should be provided in a user input section that does not require a password.

DIFFICULT TO UNDERSTAND SOME INPUT FIELDS

The tool’s user interface is generally easy to understand, but some input fields may be confusing to users because some values must be entered for only one direction of travel and other values need to be entered for both directions. For example, Figure 5.3 shows that the *No. of Lanes* and *Peak Capacity* fields specify that one-way values should be entered. Through trial and error, the team discovered that the *Current AADT*, for which the tool provides no instructions on the number of directions, requires an aggregated average annual daily traffic (AADT) for both directions. For ease of use and accuracy in input data, the tool should include clear instructions on whether fields require one-directional or bidirectional data.



Scenario Inputs

Scenario Name: I-210 Eastbound - Scenario 1

Description (optional):

Scenario Data

Time Horizon: 1 years

Analysis Period: 6:00 AM to 7:00 PM

Highway Type: Freeway

Beg. Milepoint: 29.843

End Milepoint: 40.077

No. of Lanes (One-way): 4

Free Flow Speed: 65 mph

Using speed limit ☐

Traffic Data

Current AADT: 195540

Estimated Annual Traffic Growth Rate: 1 %

Truck Data

Pct. Trucks in Traffic: 5.887 %

Capacity Data

Enter either one-way capacity based on HCM

Peak Capacity: 5960 pcph

or select terrain type

Terrain: Flat

Travel Time Unit Cost

Personal: 19.86 $/hr

Commercial: 36.05 $/hr

Effect of Incident Management Strategy

Reduction in Incident Frequency: 0 %

Reduction in Incident Duration: 0 %

Reliability Ratio

Value of Reliability over Value of Travel Time

Personal: 0.8

Commercial: 1.1

Route Information (optional)

Route:

Beg. Landmark:

End Landmark:

Figure 5.3. Unclear input directions in the C11 Reliability Analysis Tool.

INFLEXIBLE ANALYSIS PERIODS

The tool's user interface includes preset analysis periods from which to choose, but users may need to analyze a different time period based on facility characteristics, organizational standards, or other factors. For example, the a.m. or p.m. peak periods along a particular facility may not conform to the analysis periods provided in the tool. Alternatively, a user may want to adjust the analysis period to be consistent with other analyses. For the Southern California pilot site, the study team tried to match analyses to ones previously conducted in microsimulation models for the CSMPs. These models used specific time periods for each facility. The C11 tool should provide flexibility in allowing users to choose their own start and end times for analysis.

CONFUSION IN SETTING TIME HORIZON

The user sets the time horizon for the analysis as part of the scenario inputs. The time horizon is entered as the number of years after the current year for the future year. For example, if the current year is 2014, entering 20 years for the time horizon will result in a future year of 2034. This terminology is inconsistent with the number of years in a benefit-cost life cycle. The previous example has a time horizon of 20 years but produces beginning and ending years for a 21-year life cycle.

The C11 tool allows the user to enter different time horizons for each scenario in a C11 workbook. The tool appears to calculate the benefits correctly, but the future year is labeled according to the time horizon for the last scenario. The mismatch in calculations and labeling can be a source of confusion. A best practice would be to select a single time horizon and use that time horizon for all scenarios in a C11 workbook. The calculation page, which is typically hidden from the user, includes a global setting for the time horizon. However, changing the global setting does not change the time horizon in an analysis.

The C11 tool automatically selects the current year according to the computer's clock. The user is unable to change this setting. As a result, if a user wanted to analyze a project to be constructed in a future year, the scenario input data would need to be entered for the future year, while ignoring the labeling on the output page.

TRAVEL TIME UNIT COSTS AND AVERAGE VEHICLE OCCUPANCY

The travel time unit costs appear to be on a per vehicle basis. Neither the C11 user's guide (Cambridge Systematics et al. 2013a) nor the technical documentation (Cambridge Systematics et al. 2013b) refers to average vehicle occupancy (i.e., the average number of people per vehicle). In addition, the C11 tool does not provide an input for entering the average number of occupants in personal vehicles on the facility. As a result, the travel time cost entered into the tool should include the average vehicle occupancy (AVO). If an agency estimates travel time costs on a per person basis, these costs should be multiplied by the AVO and entered as the travel time costs in the C11 tool. In the future, the C11 tool should include an AVO input.

VALUE OF TIME LABELING

The C11 tool refers to the value of time associated with trucks as "commercial value of time." This nomenclature could be confused with on-the-clock travel, which includes automobiles used for business purposes. At the top of the detailed results page, the "commercial value of time" is inconsistently called the "truck unit cost." The tool should be changed to refer consistently to the "truck value of time."

DESCENDING MILE MARKERS

The C11 tool assumes that the user enters a beginning milepoint smaller than the ending milepoint. If the user enters a beginning milepoint larger than the ending milepoint, the tool will produce negative results. Since agencies sequentially number mile markers in one direction, they will be in descending order in the opposite direction. The tool should automatically take the absolute value of the difference in the milepoints entered.

Output Limitations

Difficult to Correlate Benefit Results to TTI

Although the results are generally easy to understand, the tool does not specify which set of reliability data are used to calculate the benefits. The study team eventually discovered that the benefits are based on 50th and 80th percentile travel time indices (TTIs) after review of the C11 technical documentation (Cambridge Systematics et al. 2013b). The C11 tool that was tested by the study team did not provide 50th percentile TTI results. Only the mean, 80th percentile, and 95th percentile TTI values are reported, which did not allow the team to correlate TTI values to the benefits values reported by the tool. An updated version of the tool (not tested by the pilot study team) does include the 50th percentile, to allow users to calculate their own monetized reliability benefits from the tool's reliability estimates. This will help ensure that the calculations are consistent with their own benefit-cost framework.

Multiple Definitions of Recurring Delay

The results summary (see Figure 5.2) in the version of the C11 tool tested by the pilot study team used inconsistent definitions of recurring delay. When reporting the recurring delay associated with "Total Annual Weekday Delay (veh-hrs)," the C11 Reliability Analysis Tool defined recurring delay as the travel time (estimated using speed-volume planning relationships) greater than the free-flow time. This recurring delay ignores the travel times associated with incidents or other sources of travel time variability.

This relationship is shown on page 15 of the C11 technical documentation (Cambridge Systematics et al. 2013b) in the following equations:

Equation 1: $$RecurringDelayRate = t - \left(\frac{1}{FreeFlowSpeed}\right)$$

Equation 2: $$t = \frac{\left(1+\left(0.1225o\left(\frac{v}{c}\right)^2\right)\right)}{FreeFlowSpeed}, for\,\frac{v}{c} \leq 1.40,$$

where t = travel rate (hours per mile)
v = hourly volume
c = capacity (for an hour)

Note: v/c should be capped at 1.40

In comparison, the recurring reliability reported in the "Total Annual Weekday Congestion Costs ($)" included more delay than reported earlier in the vehicle-hours of delay, which was likely to include a portion of the incident-related delay. The C11 tool calculates the cost of unreliability as the monetized delay associated with the difference in the 50th and 80th percentile TTI figures. The recurring delay is the 50th percentile TTI compared to the free-flow travel time. The C11 tool estimates the 50th percentile TTI using the data poor equations from the SHRP 2 L03 project, and these estimates include incidents.

The inconsistency in these definitions of recurring delay presents two problems. First, the user cannot multiply the vehicle-hours of delay shown in the Results Summary (see Figure 5.2 for an example) by the appropriate value of time and reliability ratio to estimate the congestion costs. Second, the value of recurring delay reported by the C11 tool includes incident-related delay and *does not* correspond to the delay benefits reported in traditional benefit-cost models. As a result, adding the cost of unreliability (as reported by the C11 tool) to the delay benefits in a standard benefit-cost model would underestimate the benefits by ignoring the incident-related delay savings.

Difficult to Use Reliability Ratios from Other Sources

As described above, the C11 tool estimates the cost of unreliability as the difference in the 50th and 80th percentile TTI figures. This can be seen in the way that the model estimates travel time equivalents. Equation 3 shows the relationship provided in the C11 technical documentation (Cambridge Systematics et al. 2013b):

Equation 3: $\mathrm{TTI}_{e(\mathrm{VT})} = \mathrm{TTI}_{50} + \alpha \times (\mathrm{TTI}_{80} - \mathrm{TTI}_{50})$,
where
$\mathrm{TTI}_{e(\mathrm{VT})}$ is the TTI equivalent on the segment
α is the Reliability Ratio (value of reliability/value of time)

In this equation, the reliability ratio is defined as the difference in the 50th percentile and 80th percentile TTI. Other recent studies of the value of reliability (especially those in Europe) define the reliability ratio in terms of a single standard deviation in travel time. This is roughly equivalent to the difference in the 50th and 84th percentile TTI (assuming a one-tailed normal distribution). Through discussions with the C11 development team, the study team determined that the C11 tool uses a value for the reliability ratio from a U.S. study that defined reliability in terms of the 50th and 80th percentiles. So the tool estimates reliability benefits correctly, using this estimation of the reliability ratio.

However, if a user were to change the reliability ratio to use a locally adopted value, the user should make sure it is defined in terms of the 50th and 80th percentile. By way of comparison, the L07 tool (described next in this report) uses a reliability ratio defined in terms of the standard deviation. This definition is consistent with more recent valuation studies.

5.3 Baseline Condition Estimation of the C11 Reliability Analysis Tool

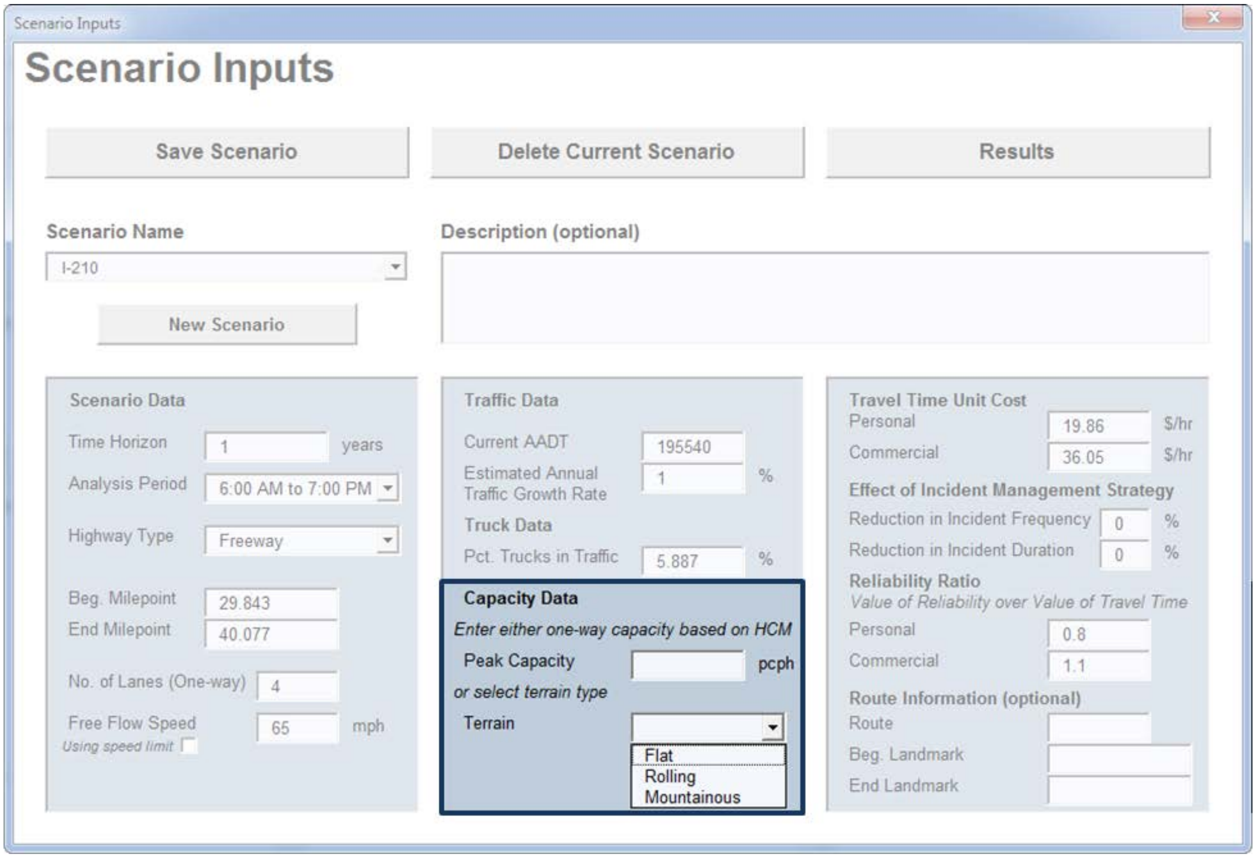
The first step in testing the C11 Reliability Analysis Tool was to make sure that the tool estimated reliability measures consistent with real-world conditions on the facilities. As indicated previously, the study team was able to calibrate the C11 tool to baseline conditions by adjusting the peak capacity and the hourly distribution of demand.

The calibration process consisted of running the tool with no adjustments, and then adjusting the peak capacity and hourly distribution of demand until the tool's TTI results were as close as possible to real-world conditions. Real-world conditions were measured using Caltrans PeMS. The PeMS data consists of infrastructure-based sensor recordings along each of the freeway facilities over multiple years. The study team used data for 2010 as the baseline year for consistency with the CSMPs developed for the facilities.

As seen in Figure 5.4, the C11 tool allows the user to utilize one of two options to input capacity:

1. Enter the peak capacity manually, or
2. Select the terrain type, allowing the tool to automatically calculate peak capacity.

The pilot team initially estimated reliability using the terrain type method. These results were later adjusted by using the manual peak capacity method.



Scenario Name: I-210
Description (optional):

Scenario Data
Time Horizon: 1 years
Analysis Period: 6:00 AM to 7:00 PM
Highway Type: Freeway
Beg. Milepoint: 29.843
End Milepoint: 40.077
No. of Lanes (One-way): 4
Free Flow Speed: 65 mph
Using speed limit ☐

Traffic Data
Current AADT: 195540
Estimated Annual Traffic Growth Rate: 1 %
Truck Data
Pct. Trucks in Traffic: 5.887 %

Capacity Data
Enter either one-way capacity based on HCM
Peak Capacity: pcph
or select terrain type
Terrain:

Travel Time Unit Cost
Personal: 19.86 $/hr
Commercial: 36.05 $/hr
Effect of Incident Management Strategy
Reduction in Incident Frequency: 0 %
Reduction in Incident Duration: 0 %
Reliability Ratio
Value of Reliability over Value of Travel Time
Personal: 0.8
Commercial: 1.1
Route Information (optional)
Route:
Beg. Landmark:
End Landmark:

Figure 5.4. Capacity data input in the C11 Reliability Analysis Tool.

Initial Run

In the initial run of the tool for the I-210 facility, the team allowed the tool to determine the peak capacity based on terrain and made no adjustments to the tool's default hourly distribution.

When *Flat* was entered in the *Terrain* field, the tool calculated a peak capacity of 2,233 vehicles per hour per lane (vphpl). The resulting TTI curve (represented by the nearly level blue line in Figure 5.5) showed values near 1.0 for the entire day. This result is not representative of the actual baseline TTI curve, which is calculated using PeMS data and represented by the red line. The PeMS data indicate an increase in TTI in the p.m. peak period until 5:00 p.m., after which the TTI gradually decreases back to a value of 1.2 by 7:00 p.m.

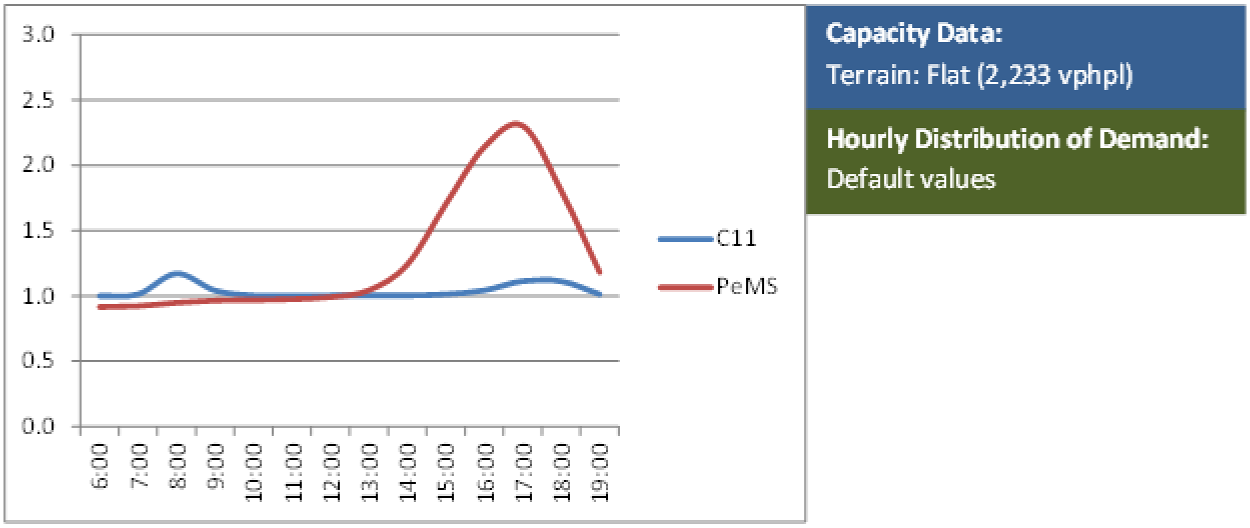
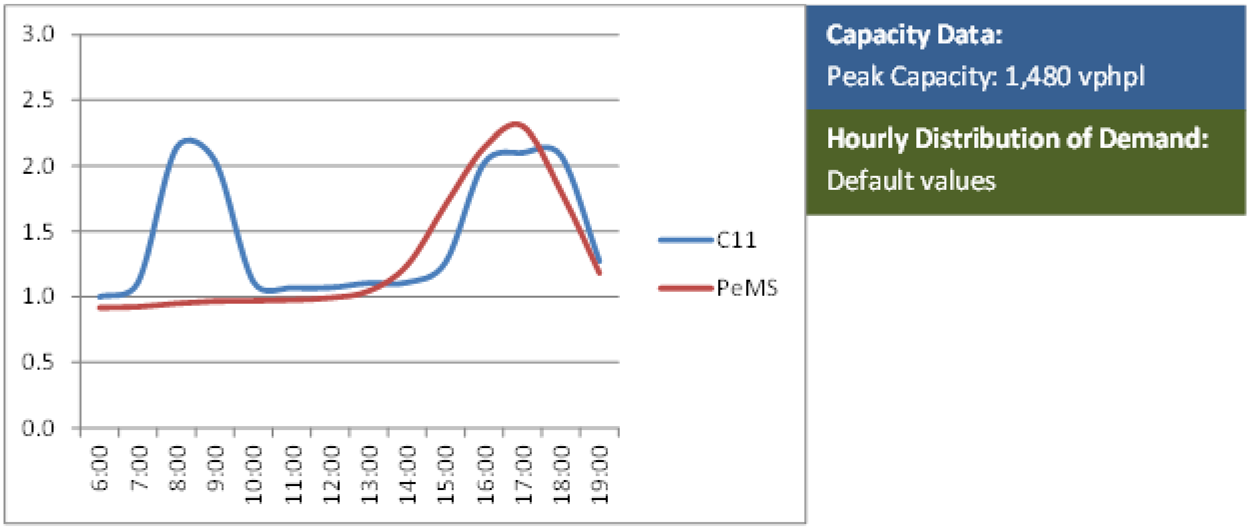


Figure 5.5. Mean TTI on the I-210 with no adjustments.

Adjusting Peak Capacity

Instead of utilizing the tool's automatic peak capacity calculation based on terrain type, the team then attempted to manually enter in a lower peak capacity value to force the TTI values upward to match the PeMS TTI curve. As seen in Figure 5.6, this strategy was effective in bringing the p.m. peak values up to match PeMS values, but it also caused the tool's a.m. TTI values to peak in a manner that does not correspond to the actual baseline TTI values, which are at or near 1.0.



Capacity Data:
Peak Capacity: 1,480 vphpl

Hourly Distribution of Demand:
Default values

Figure 5.6. Mean TTI on the I-210 with adjustment to peak capacity only.

Adjusting Peak Capacity and Hourly Distribution of Demand

After realizing that the TTI hump in the a.m. peak was likely the result of the C11 tool applying a standard hourly distribution of demand to all runs, the study team discovered a default hourly distribution of demand in a hidden password-protected tab. Once these figures were modified to reflect the hourly distribution of traffic volumes along the facility (as a proxy for demand) and the peak capacity was readjusted, the tool was able to produce a curve that, while far from perfect, more closely resembled PeMS data (Figure 5.7).

However, the tool still produced a small TTI hump in the a.m. peak period that cannot be found in the baseline TTI data from PeMS. In addition, the TTI peak in the p.m. peak period occurs approximately 2 hours earlier than the actual hump that occurs in the baseline TTI data reported in PeMS. The observations do not render the C11 tool unfit for practical application, but they do suggest that the algorithms for estimating reliability are inadequate to closely capture reliability along the I-210 facility. The tool does a better job of estimating reliability for the I-5 facility, as described in the next section.

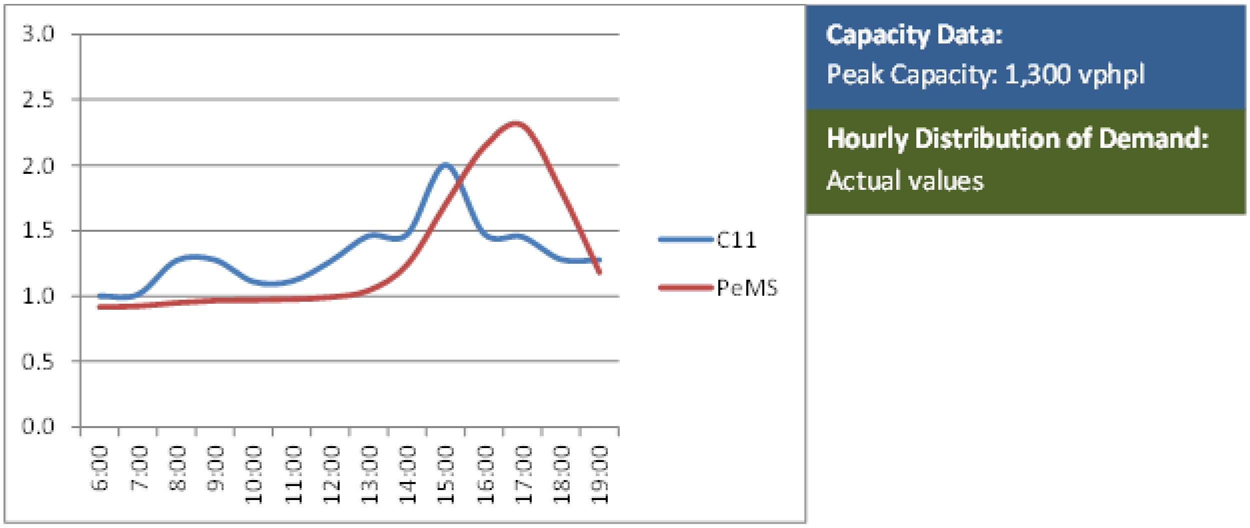


Figure 5.7. Mean TTI on the I-210 with adjustment to peak capacity and hourly distribution.

5.4 Results of the I-5 Scenario Testing

The team tested a variety of scenarios using two facilities in Southern California with low levels of reliability. The first of these facilities tested is the I-5 facility in Orange County. As shown in Figure 5.8, I-5 is a 45-mile facility with four to six mixed-flow lanes and one to two barrier-separated high-occupancy vehicle lanes in each direction. There are also auxiliary lanes throughout the facility. Congestion is heaviest in the northbound direction during the p.m. peak period. Congestion in the southbound direction is similar for both a.m. and p.m. peak periods. Queuing can extend 12 to 15 miles and last for 4 to 6 hours.

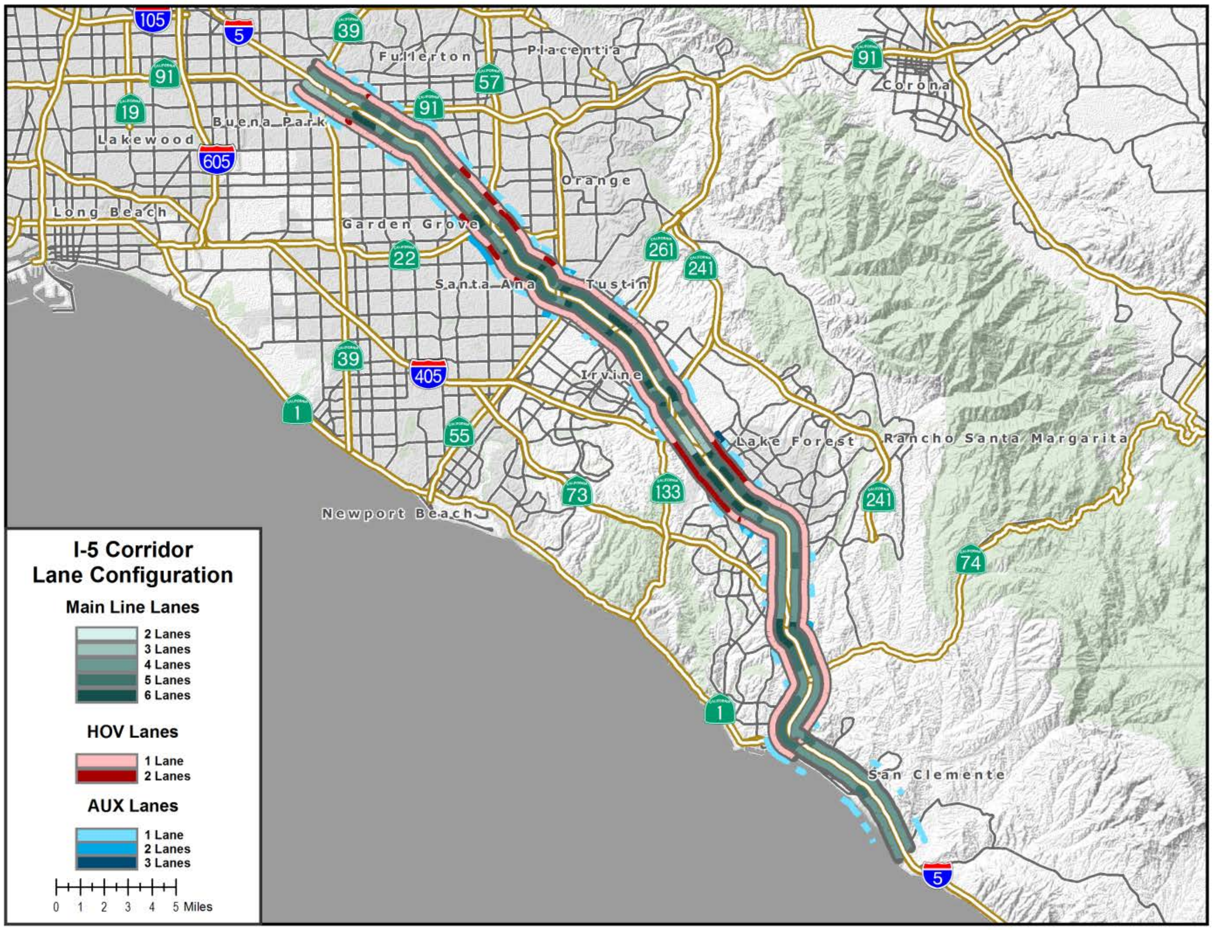


Figure 5.8. Map of I-5 facility in Orange County.

Selected Test Segment

The geometry of the I-5 facility varies greatly along its 45-mile stretch. In an effort to produce results more comparable to real-world conditions, the study team selected a 6.5-mile segment with consistent characteristics to test using the C11 tool. The selected segment has five lanes in each direction from Jeffrey Road interchange to north of the SR-55 interchange. This segment (shown in Figure 5.9) was also selected because it is one of the most congested segments within the entire facility.

5-lane segment
6.5 miles

Figure 5.9. I-5 northbound test segment.

The reliability results for the 6.5-mile segment are shown in Figure 5.10. The study team adjusted the default peak capacity of the tool until the TTI figures matched the PeMS baseline. In addition, the study team entered the actual hourly demand distributions to achieve hourly results better calibrated to the baseline conditions reported in PeMS.

As can be seen in Figure 5.10, these adjustments resulted in TTI estimates very close to the actual baseline conditions. Unlike on the I-210 facility, the timing of the unreliability in the p.m. peak mirrored the actual TTI data. However, the onset of the unreliability in the p.m. occurred earlier than estimated by the C11 tool.

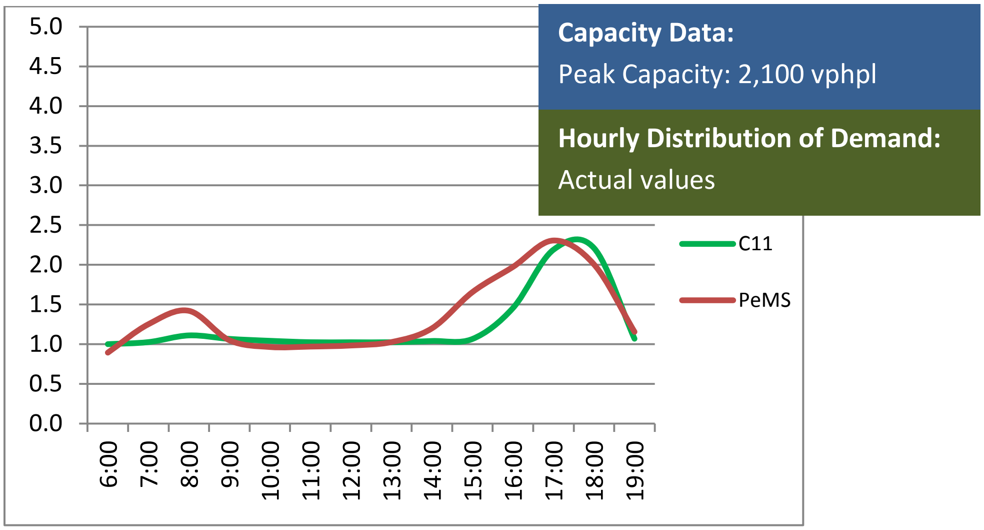
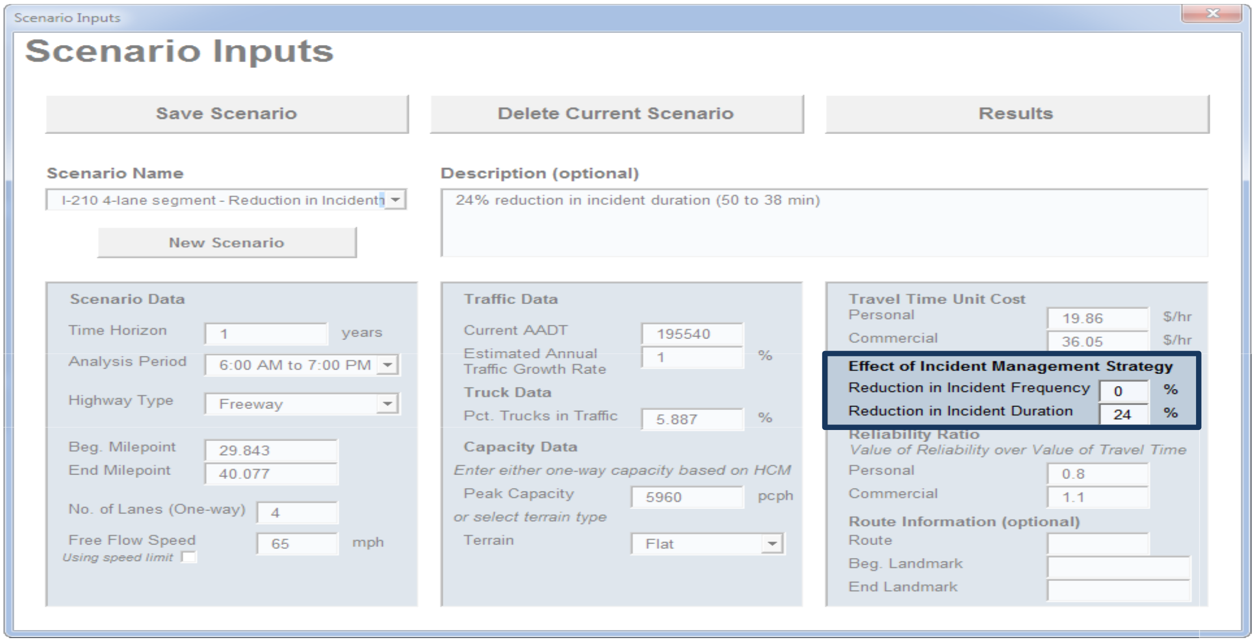


Figure 5.10. Mean TTI on I-5 for 6.5-mile segment

Scenario Test #1: Incident Management

Once the baseline conditions were calibrated, the study team tested various project scenarios previously identified as part of the I-5 CSMP (Caltrans 2012). The first scenario tested the effects of incident management (IM) on the facility. In this scenario, it is assumed that improved incident management leads to a 33 percent reduction in duration of a major collision from 45 minutes to 30 minutes. As shown in Figure 5.11, the C11 Reliability Analysis Tool allows for the input of a percent reduction in incident duration, so the percent reduction figures were used. The C11 tool estimated a noticeable improvement in reliability due to the reduction in incident duration. These results are shown in Figures 5.12 and 5.13.



Scenario Inputs

Scenario Name: I-210 4-lane segment - Reduction in Incident

Description (optional): 24% reduction in incident duration (50 to 38 min)

Scenario Data

Time Horizon: 1 years

Analysis Period: 6:00 AM to 7:00 PM

Highway Type: Freeway

Beg. Milepoint: 29.843

End Milepoint: 40.077

No. of Lanes (One-way): 4

Free Flow Speed: 65 mph

Using speed limit ☐

Traffic Data

Current AADT: 195540

Estimated Annual Traffic Growth Rate: 1 %

Truck Data

Pct. Trucks in Traffic: 5.887 %

Capacity Data

Enter either one-way capacity based on HCM

Peak Capacity: 5960 pcph

or select terrain type

Terrain: Flat

Travel Time Unit Cost

Personal: 19.86 $/hr

Commercial: 36.05 $/hr

Effect of Incident Management Strategy

Reduction in Incident Frequency: 0 %

Reduction in Incident Duration: 24 %

Reliability Ratio

Value of Reliability over Value of Travel Time

Personal: 0.8

Commercial: 1.1

Route Information (optional)

Route:

Beg. Landmark:

End Landmark:

Figure 5.11. Incident management scenario input.

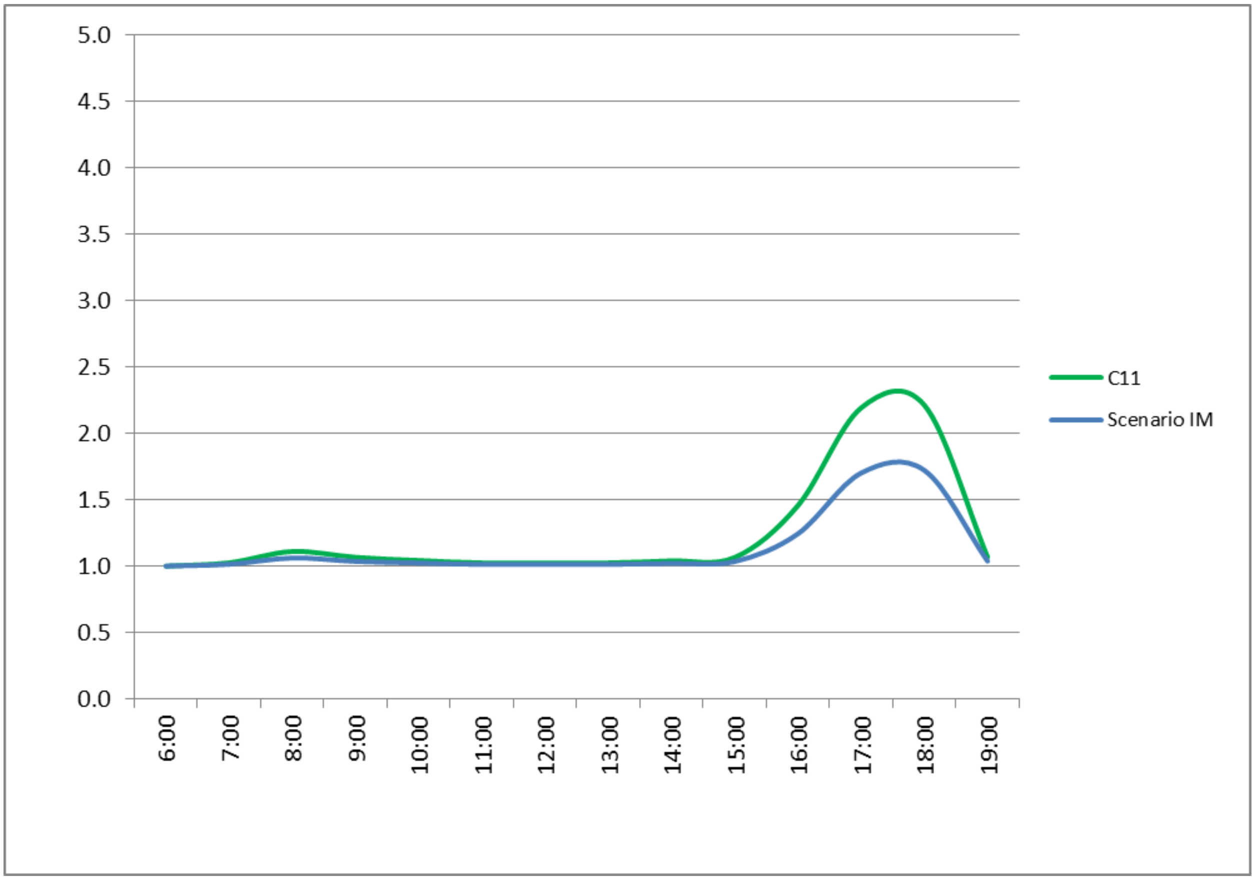


Figure 5.12. Mean TTI on I-5 for incident management test.

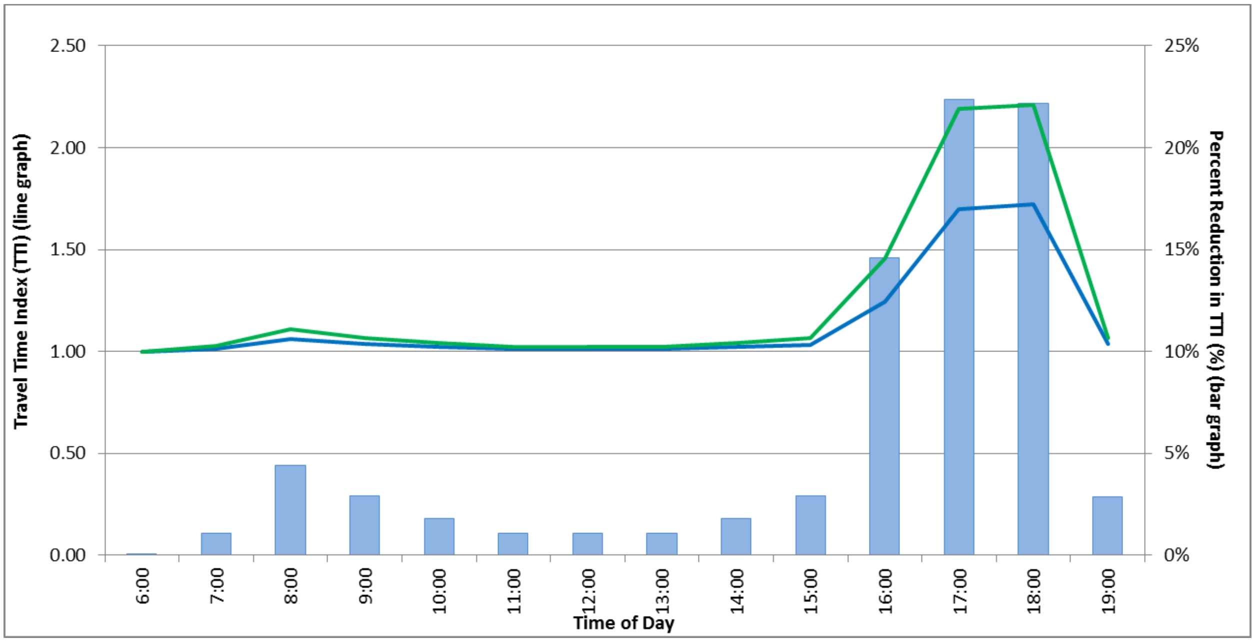


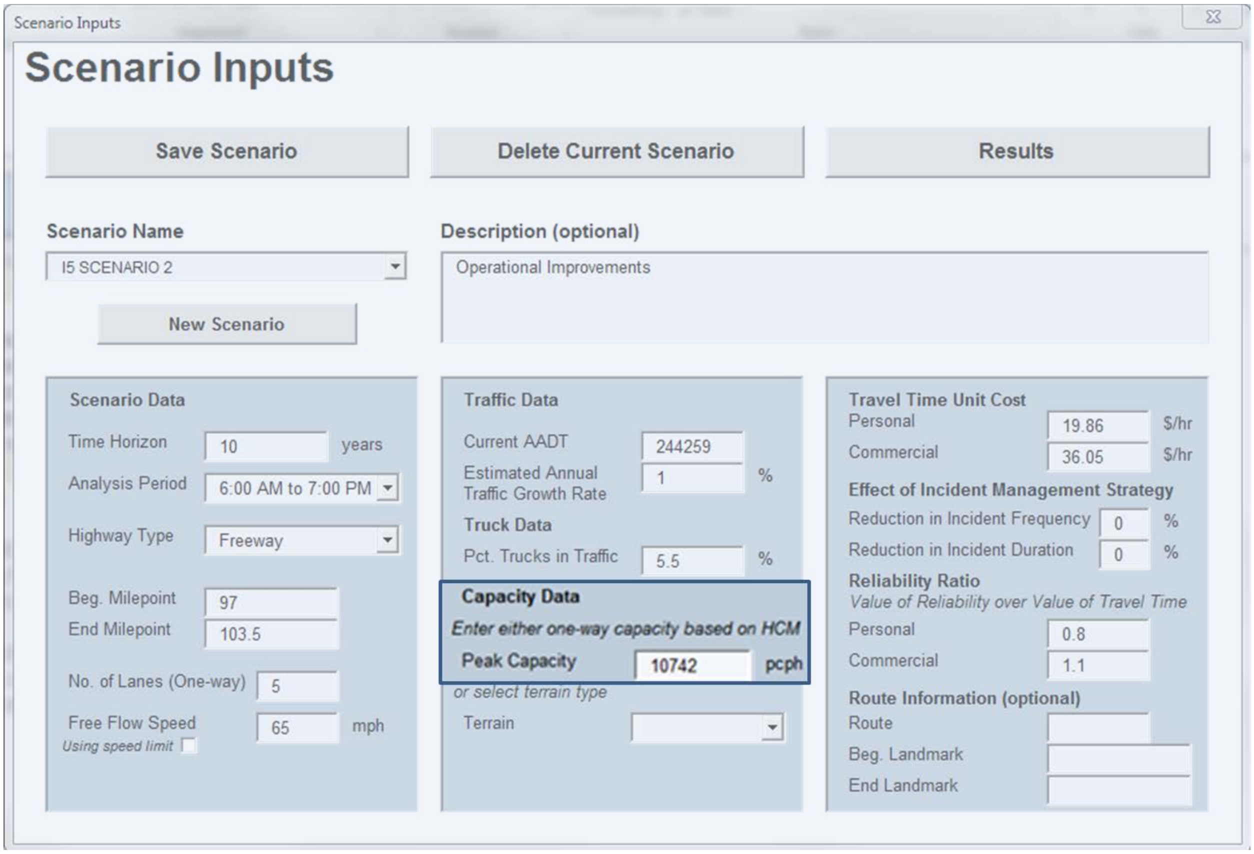
Figure 5.13. Comparison of mean TTI and percent reduction on I-5 for incident management test.

Scenario Test #2: Operational Improvements

In the second scenario, the study team tested a combination of operational improvements along the facility. These improvements include constructing an auxiliary lane, widening an off-ramp, and creating a left turn lane to access an on-ramp. Unlike the incident management strategy previously tested, the C11 tool does not provide any automatic methods for modeling the effect of operational improvements.

The study team decided to simulate the improvements in the C11 tool as an increase in capacity along the facility. One method to estimate the capacity improvement would be to use rules of thumb from case studies. In the case of the I-5 facility, the study team had available the results of microsimulation modeling for the I-5 CSMP. The microsimulation modeling showed (using changes in VMT) that the facility was able to handle more traffic after the operational improvements are made.

As a result, the study team increased the capacity in the C11 tool by 2.3 percent (the percent VMT change estimated in the microsimulation) to 10,742 passenger cars per hour (pcph) as shown in Figure 5.14. This is a small change in capacity, but it reflects the significant congestion along the facility that operational improvements alone are unable to resolve. Figures 5.15 and 5.16 show the results of this change. Figure 5.16 shows that the scenario slightly improves reliability, with the biggest improvement observed at 4:00 p.m. An examination of the benefit-cost results suggests that the reliability improvement will be a small contributor to the overall project benefits. These benefit-cost impacts are discussed in more detail in Chapter 8 of this report.



Scenario Inputs

Scenario Name: I5 SCENARIO 2

Description (optional): Operational Improvements

Scenario Data

Time Horizon: 10 years

Analysis Period: 6:00 AM to 7:00 PM

Highway Type: Freeway

Beg. Milepoint: 97

End Milepoint: 103.5

No. of Lanes (One-way): 5

Free Flow Speed: 65 mph

Using speed limit ☐

Traffic Data

Current AADT: 244259

Estimated Annual Traffic Growth Rate: 1 %

Truck Data

Pct. Trucks in Traffic: 5.5 %

Capacity Data

Enter either one-way capacity based on HCM

Peak Capacity: 10742 pcph

or select terrain type

Terrain:

Travel Time Unit Cost

Personal: 19.86 $/hr

Commercial: 36.05 $/hr

Effect of Incident Management Strategy

Reduction in Incident Frequency: 0 %

Reduction in Incident Duration: 0 %

Reliability Ratio

Value of Reliability over Value of Travel Time

Personal: 0.8

Commercial: 1.1

Route Information (optional)

Route:

Beg. Landmark:

End Landmark:

Figure 5.14. Operational improvement scenario input.

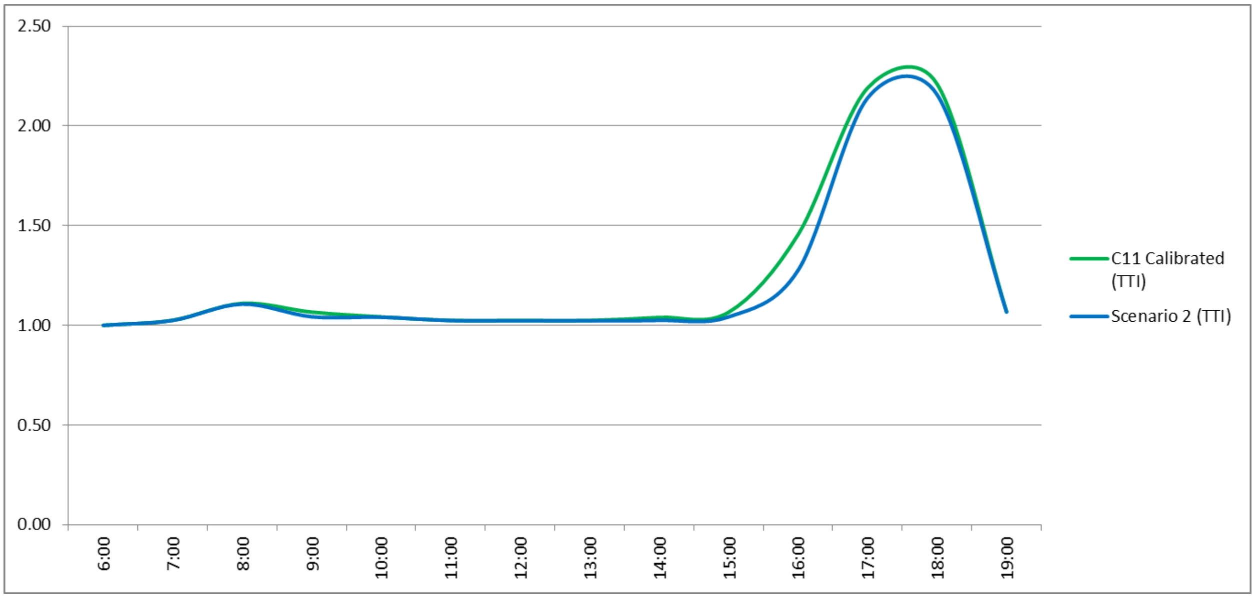


Figure 5.15. Mean TTI on I-5 for operational improvements test.

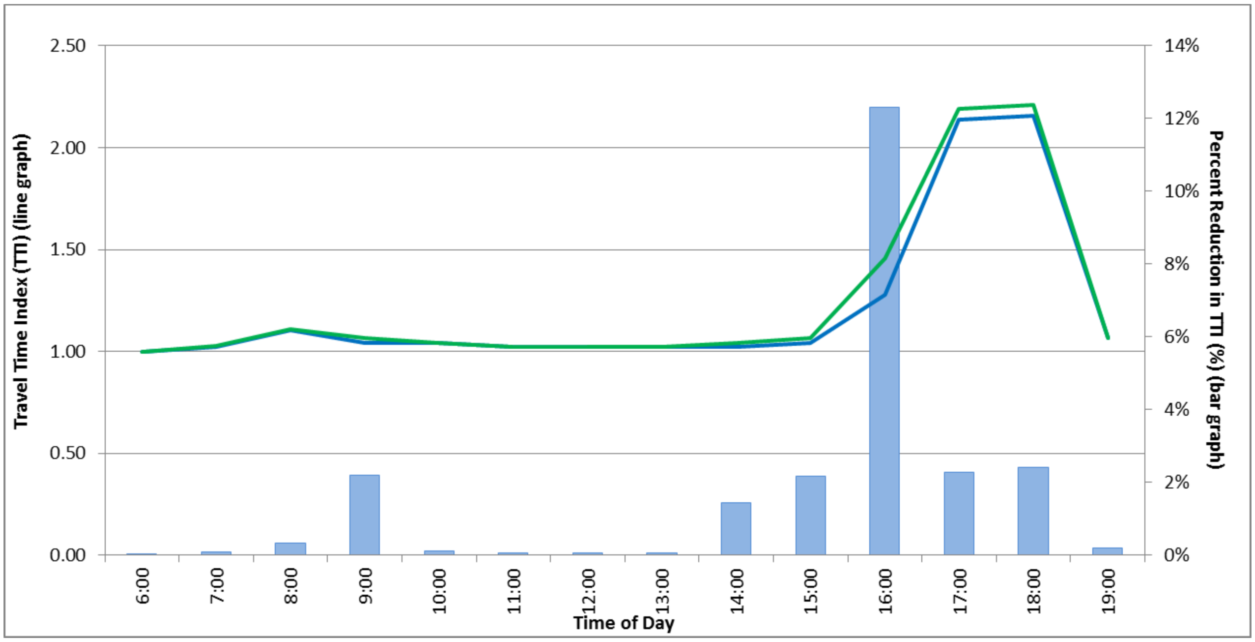


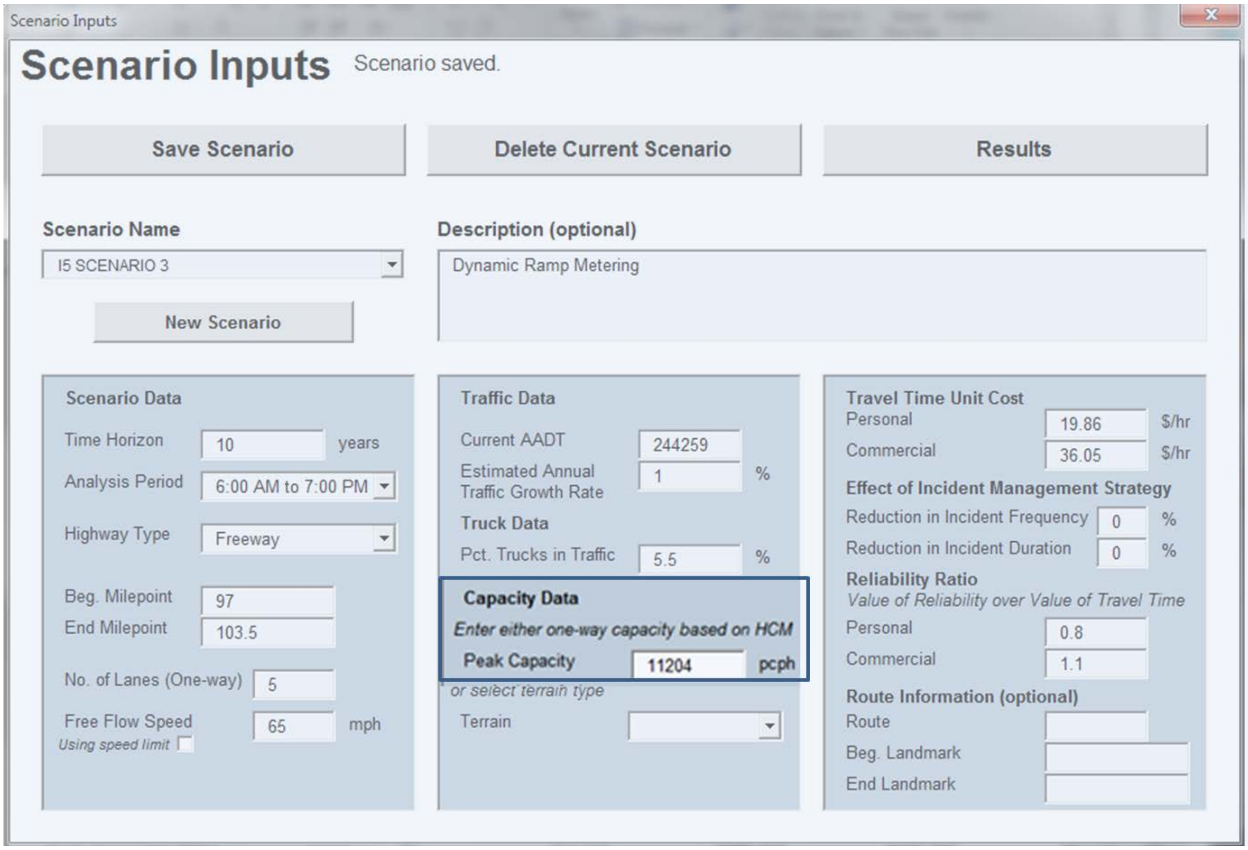
Figure 5.16. Comparison of mean TTI and percent reduction on I-5 for operational improvements test.

Scenario Test #3: Dynamic Ramp Metering

In the third scenario, the study team tested the implementation of dynamic ramp metering along the facility. The facility already has pre-timed ramp metering and a dynamic algorithm is expected to be more effective in reducing congestion and improving reliability. As with the previous scenario, the C11 tool does not have a lever to model dynamic ramp metering directly.

The study team decided to model the scenario by increasing capacity (using estimates of VMT changes from microsimulation model). This scenario further increased the capacity along the facility by 6.3 percent to 11,204 pcph as shown in Figure 5.17.

Figure 5.18 shows the results of this scenario compared to the baseline calibrated model. As can be seen in the figure, the dynamic ramp metering led to a further improvement in reliability. Figure 5.19 shows that the biggest improvement in reliability is predicted to occur at 4:00 p.m., followed by some improvements at 5:00 and 6:00 p.m. As with the previous scenario, the reliability benefits are predicted to be a small portion of overall project benefits.



Scenario Inputs Scenario saved.

Scenario Name: I5 SCENARIO 3

Description (optional): Dynamic Ramp Metering

Scenario Data

Time Horizon: 10 years

Analysis Period: 6:00 AM to 7:00 PM

Highway Type: Freeway

Beg. Milepoint: 97

End Milepoint: 103.5

No. of Lanes (One-way): 5

Free Flow Speed: 65 mph

Using speed limit ☐

Traffic Data

Current AADT: 244259

Estimated Annual Traffic Growth Rate: 1 %

Truck Data

Pct. Trucks in Traffic: 5.5 %

Capacity Data

Enter either one-way capacity based on HCM

Peak Capacity: 11204 pcph

or select terrain type

Terrain:

Travel Time Unit Cost

Personal: 19.86 $/hr

Commercial: 36.05 $/hr

Effect of Incident Management Strategy

Reduction in Incident Frequency: 0 %

Reduction in Incident Duration: 0 %

Reliability Ratio

Value of Reliability over Value of Travel Time

Personal: 0.8

Commercial: 1.1

Route Information (optional)

Route:

Beg. Landmark:

End Landmark:

Figure 5.17. Dynamic ramp metering scenario input.

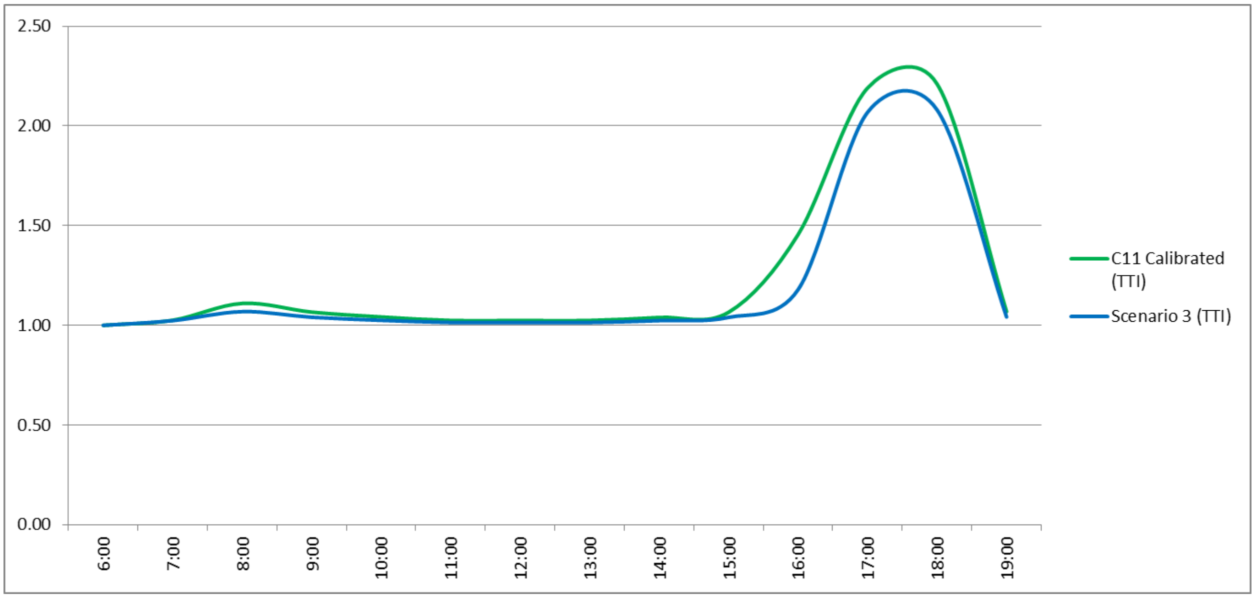


Figure 5.18. Mean TTI on I-5 for dynamic ramp metering test.

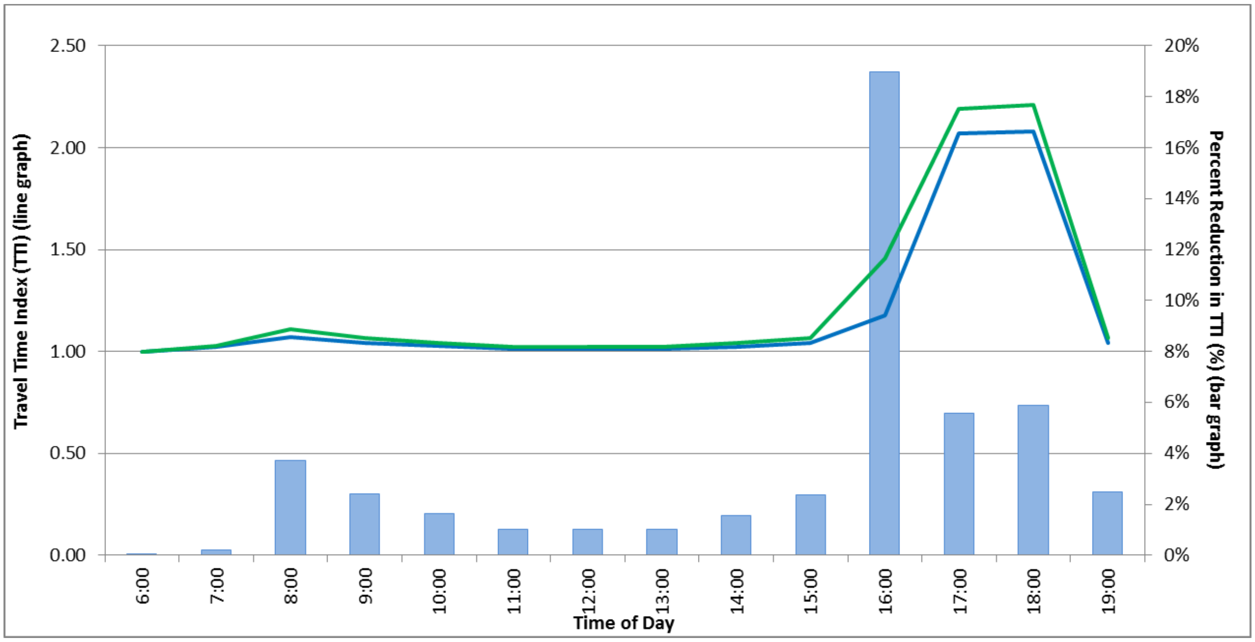
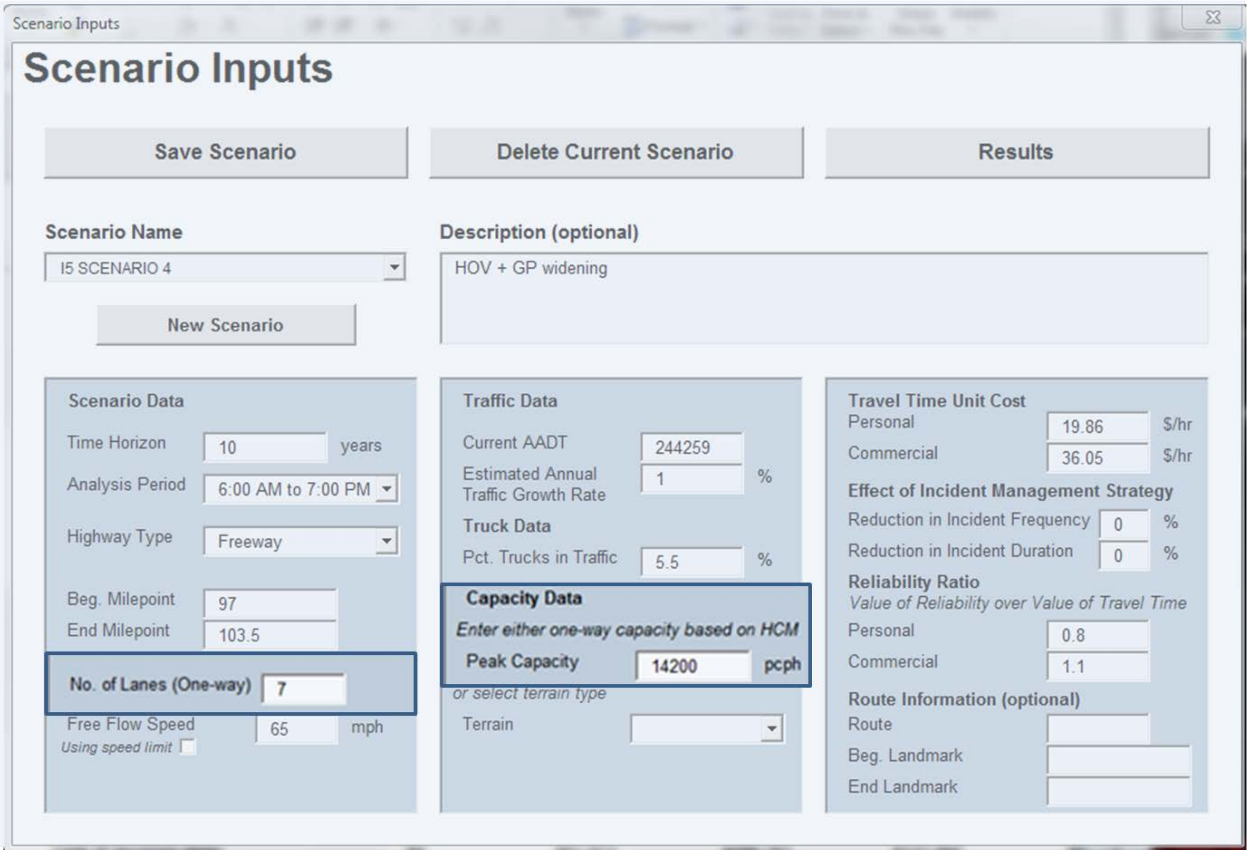


Figure 5.19. Comparison of mean TTI and percent reduction on I-5 for dynamic ramp metering test.

Scenario Test #4: High-Occupancy Vehicle + General Purpose (GP) Widening Test

In the fourth scenario, the study team tested widening the I-5 facility by adding a high-occupancy vehicle and a general-purpose lane in each direction. Testing this scenario was more straightforward than the previous scenarios, since the C11 tool allows the number of lanes to be adjusted. As shown in Figure 5.20, the study team increased the number of lanes in each direction to seven and increased the capacity to 14,200 pcph. These calculations do not take into account the previous improvements or the differences in capacity between general-purpose and high-occupancy vehicle lanes.

Figure 5.21 shows the results of this scenario compared to the baseline calibrated model. As can be seen in this figure, these improvements are expected to improve reliability significantly. This is because the C11 tool estimates reliability impacts using volume-capacity ratios, and the improvements provide significantly more capacity on the facility. Figure 5.22 shows that the scenario improves reliability by over 45 percent for the entire p.m. peak period.



Scenario Inputs

Scenario Name: I5 SCENARIO 4

Description (optional): HOV + GP widening

Scenario Data

Time Horizon: 10 years

Analysis Period: 6:00 AM to 7:00 PM

Highway Type: Freeway

Beg. Milepoint: 97

End Milepoint: 103.5

No. of Lanes (One-way): 7

Free Flow Speed: 65 mph

Using speed limit ☐

Traffic Data

Current AADT: 244259

Estimated Annual Traffic Growth Rate: 1 %

Truck Data

Pct. Trucks in Traffic: 5.5 %

Capacity Data

Enter either one-way capacity based on HCM

Peak Capacity: 14200 pcph

or select terrain type

Terrain:

Travel Time Unit Cost

Personal: 19.86 $/hr

Commercial: 36.05 $/hr

Effect of Incident Management Strategy

Reduction in Incident Frequency: 0 %

Reduction in Incident Duration: 0 %

Reliability Ratio

Value of Reliability over Value of Travel Time

Personal: 0.8

Commercial: 1.1

Route Information (optional)

Route:

Beg. Landmark:

End Landmark:

Figure 5.20. High-occupancy vehicle + GP widening scenario input.

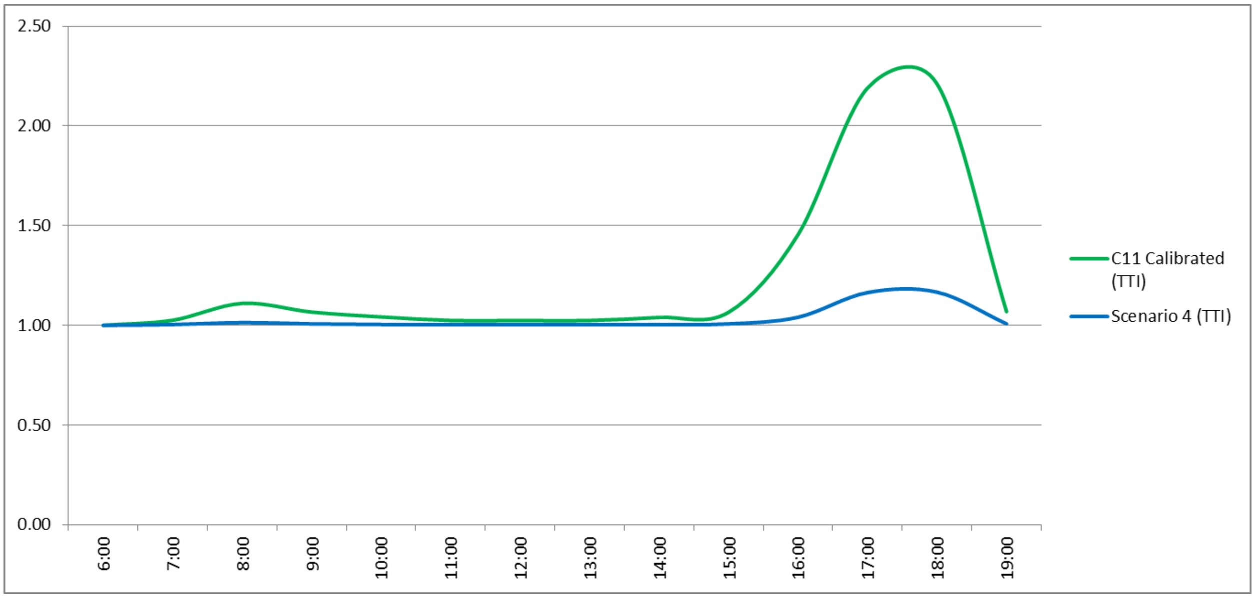


Figure 5.21. Mean TTI on I-5 for high-occupancy Vehicle + GP widening test.

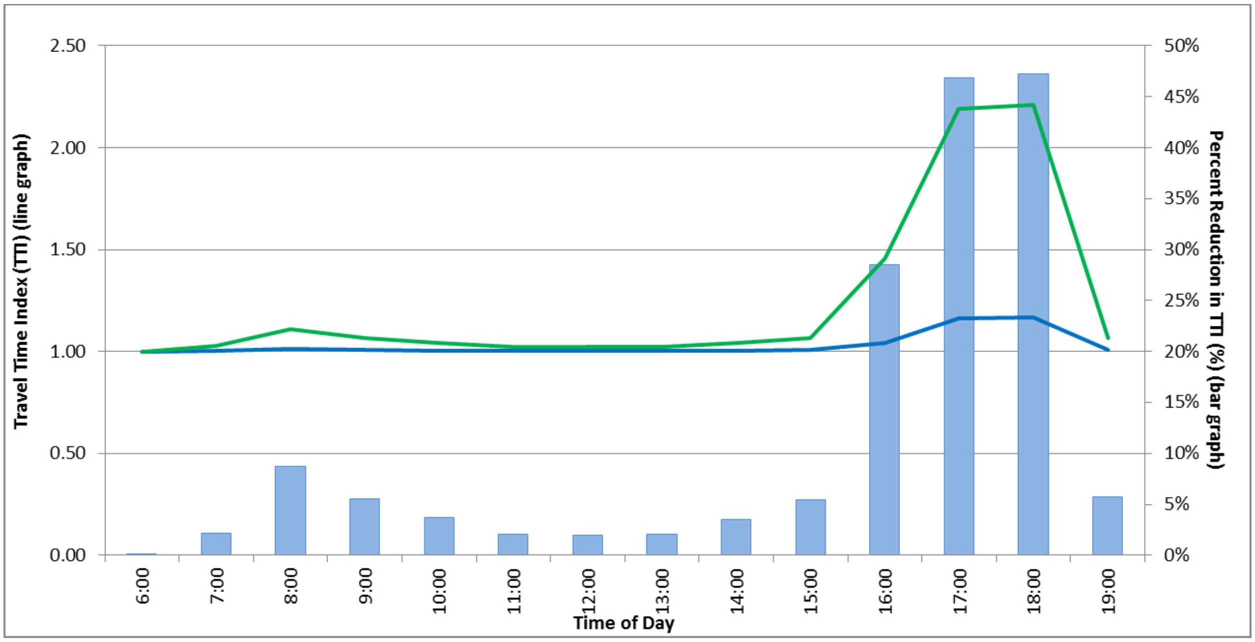


Figure 5.22. Comparison of mean TTI and percent reduction on I-5 for high-occupancy Vehicle + GP widening test.

5.5 Results of the I-210 Scenario Testing

The second facility tested was the 16-mile congested urban segment of I-210 in Los Angeles County (see Figure 5.23). This facility has four to five mixed-flow lanes in each direction, as well as barrier-separated high-occupancy vehicle and auxiliary lanes. Congestion exists on the facility 6 hours per day per direction. This congestion is heavily directional due to the location of major job centers toward the west and primarily residential communities toward the east.

All scenarios on the I-210 facility were tested in the eastbound direction. As a result, they reflect congestion mainly in the p.m. peak period when travelers are returning home from work.

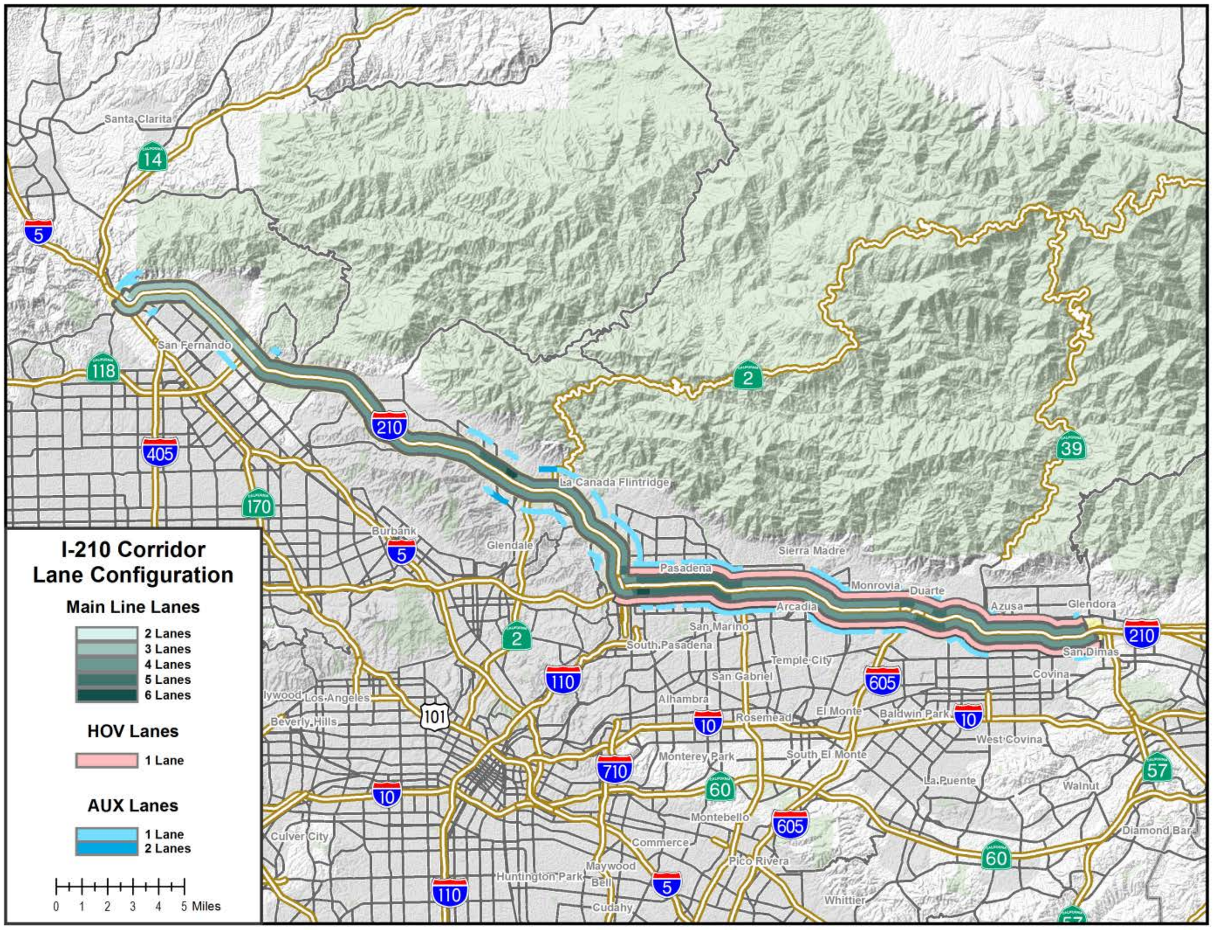


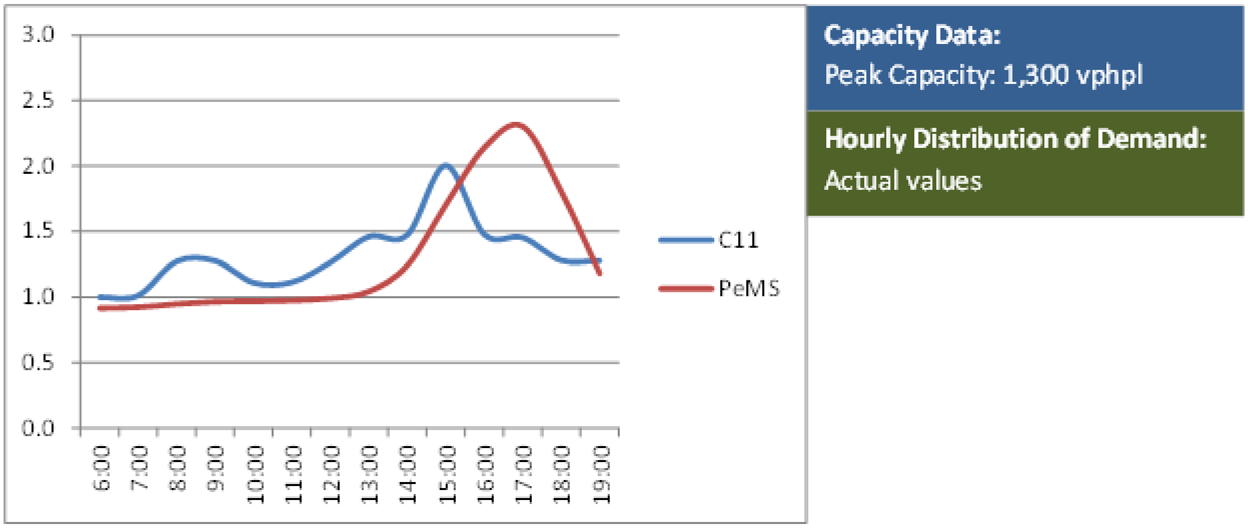
Figure 5.23. Map of I-210 facility in Los Angeles County.

Split Segment Test

Following the initial run of the entire 16-mile facility, the team split the facility into smaller segments to determine whether the tool would produce more accurate results with smaller segments. Since the tool requires the user to input a single *Number of Lanes* value for each test, the facility was split into two segments based on the number of lanes in each segment (Figure 5.24).

Figure 5.24. I-210 eastbound segmentation.

The reliability results of the full 16-mile segment of the urbanized area of I-210 are shown in Figure 5.25 (same chart as Figure 5.7 from “Baseline Condition Estimation” section).



Capacity Data:
Peak Capacity: 1,300 vphpl

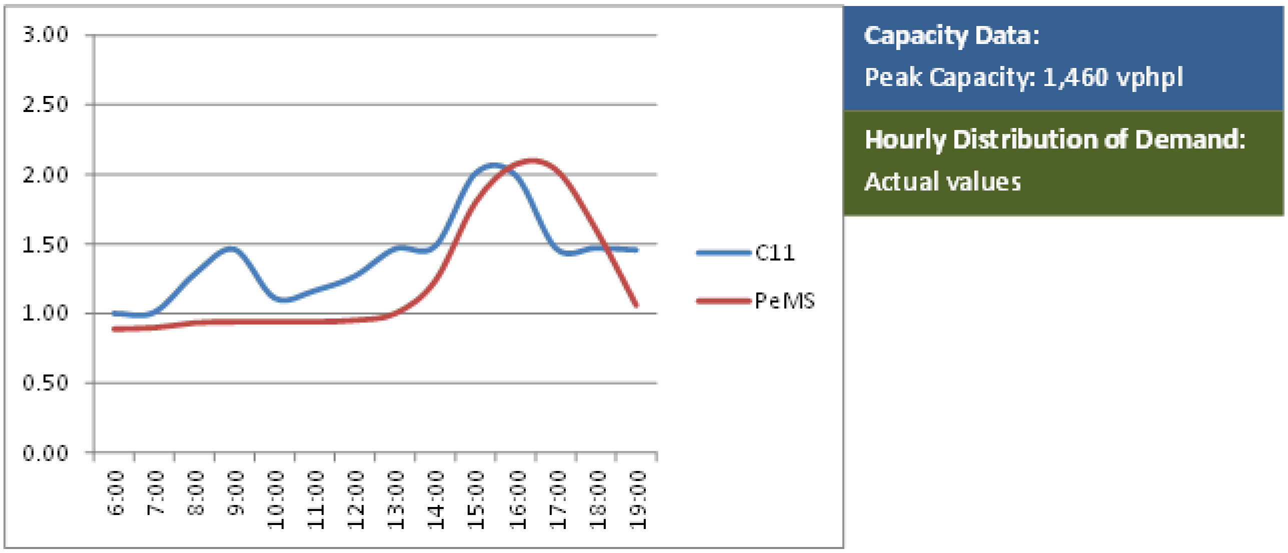
Hourly Distribution of Demand:
Actual values

Figure 5.25. Mean TTI on the I-210 for full 16-mile segment.

For each of the two smaller segments, the study team conducted the same exercise as in the baseline condition estimation. The actual hourly distribution of traffic volumes was entered into the tool as the hourly variation in demand, and the results were calibrated to the actual baseline conditions reported in PeMS by adjusting peak capacity.

Figures 5.26 and 5.27 show the results of these tests. As can be seen in the figures, the calibration seems to improve slightly from the full 16-mile facility to the five-lane segment. However, the calibration for the 4-mile segment does not improve significantly. In both cases, the segmentation is unable to correct the key inaccuracies of the slight hump in TTI in the a.m. peak period and horizontal shift in TTI in the p.m. peak.

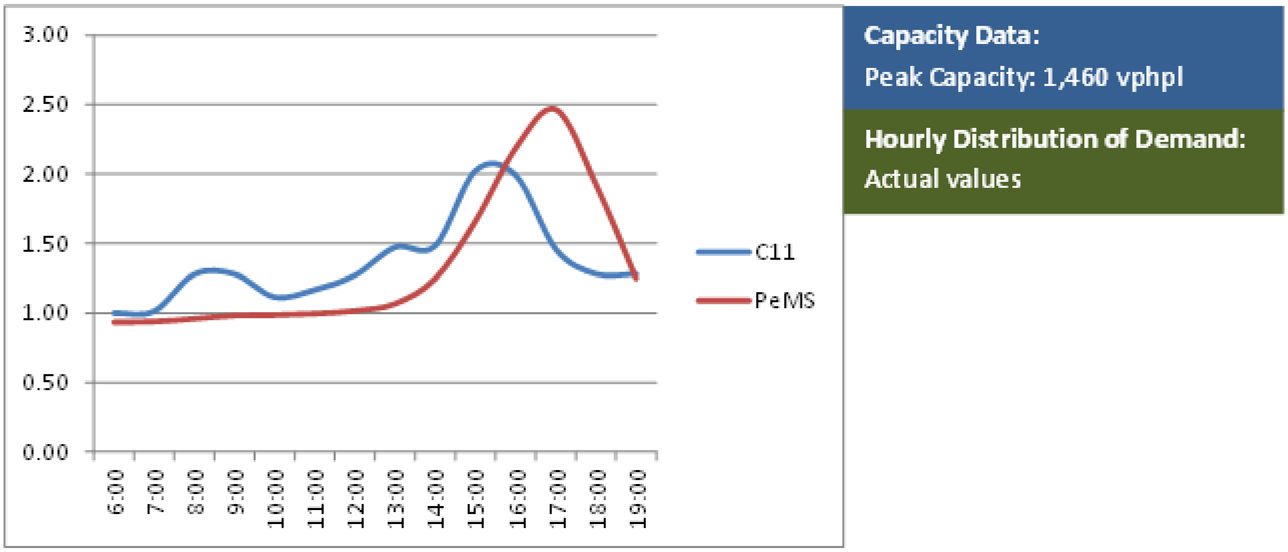
Interestingly, the reliability estimates from the C11 tool for the four-lane segment and the five-lane segment are more similar to each other than to the baseline conditions. These results suggest that breaking up the facility into similar segments does not significantly improve the calibration, and even finer segmentation is probably not worth the effort when modeling the reliability impact of projects in the C11 tool.



Capacity Data:
Peak Capacity: 1,460 vphpl

Hourly Distribution of Demand:
Actual values

Figure 5.26. Mean TTI on the I-210 for 5.3-mile five-lane segment.



Capacity Data:
Peak Capacity: 1,460 vphpl

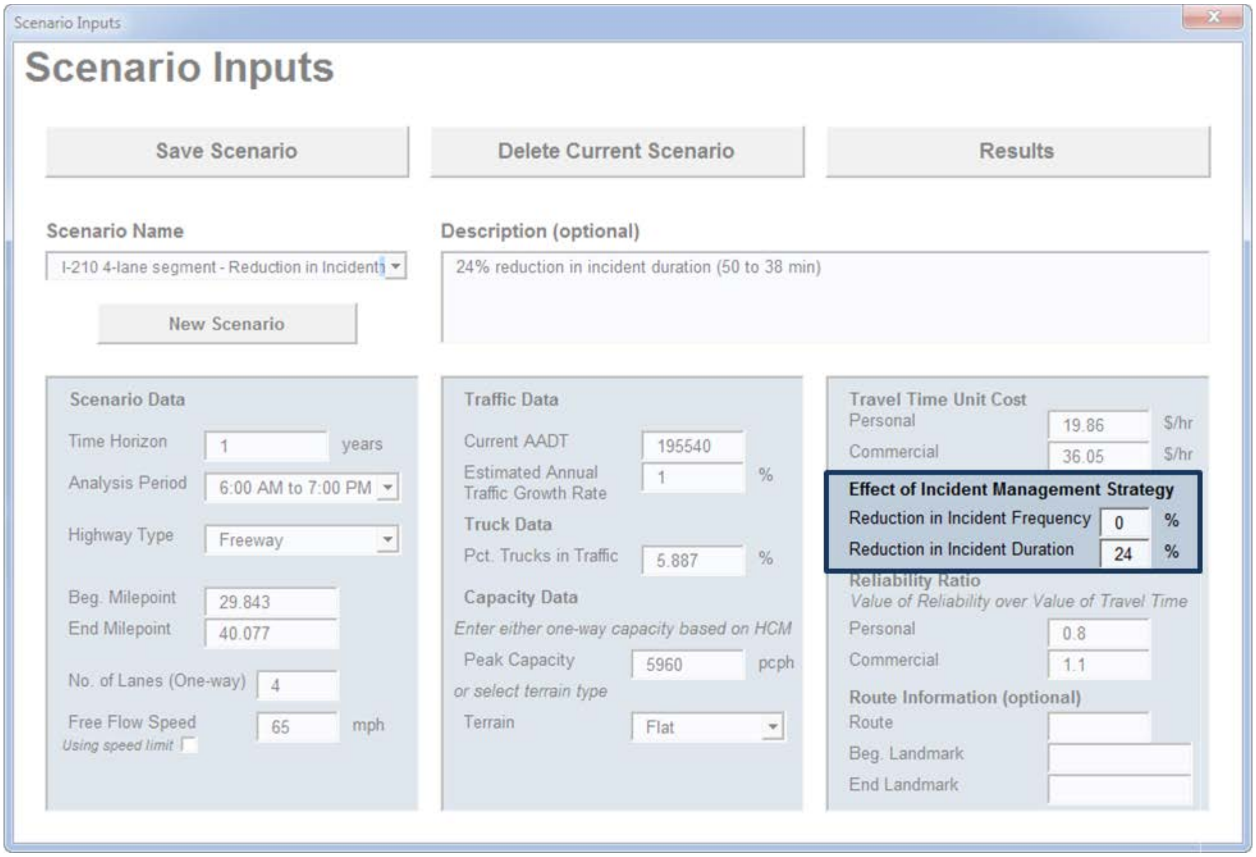
Hourly Distribution of Demand:
Actual values

Figure 5.27. Mean TTI on the I-210 for 10.2-mile four-lane segment.

As seen later in Section 6.5, the same I-210 segmentation was tested using the L07 tool. In that tool, the four-lane segment was able to be calibrated far more closely to PeMS conditions than the five-lane segment. Given that the C11 tool produces relatively similar reliability results for the four-lane and five-lane segments, the study team decided to perform all future tests utilizing only the four-lane segment to allow for comparability between the tools.

Incident Duration Tests

The study team utilized the C11 Reliability Analysis Tool to test the effects of a reduction in incident duration that had been tested in the Caltrans I-210 CSMP. In that CSMP scenario, a collision duration of 50 minutes was reduced to 38 minutes. As seen in Figure 5.28, the C11 Reliability Analysis Tool allows for the input of a percent reduction in incident duration. Therefore, a percent reduction of 24 percent (the reduction from 50 to 38 minutes) was used for this test.



Scenario Name: I-210 4-lane segment - Reduction in Incident

Description (optional): 24% reduction in incident duration (50 to 38 min)

Scenario Data

Time Horizon: 1 years
Analysis Period: 6:00 AM to 7:00 PM
Highway Type: Freeway
Beg. Milepoint: 29.843
End Milepoint: 40.077
No. of Lanes (One-way): 4
Free Flow Speed: 65 mph
Using speed limit ☐

Traffic Data

Current AADT: 195540
Estimated Annual Traffic Growth Rate: 1 %

Truck Data

Pct. Trucks in Traffic: 5.887 %

Capacity Data

Enter either one-way capacity based on HCM
Peak Capacity: 5960 pcph
or select terrain type
Terrain: Flat

Travel Time Unit Cost

Personal: 19.86 $/hr
Commercial: 36.05 $/hr

Effect of Incident Management Strategy

Reduction in Incident Frequency: 0 %
Reduction in Incident Duration: 24 %

Reliability Ratio

Value of Reliability over Value of Travel Time
Personal: 0.8
Commercial: 1.1

Route Information (optional)

Route:
Beg. Landmark:
End Landmark:

Figure 5.28. Incident management strategy input.

As shown in Figure 5.29, the results exhibit a noticeable improvement in reliability as a result of the incident reduction. Figure 5.30 shows the percent reduction in TTI was generally greater when the original TTI value was greater. This does not appear to be universally true, however; although the original TTI at 3:00 p.m. was higher than the original TTI at 4:00 p.m., the 3:00 p.m. TTI saw a smaller percent reduction than the 4:00 p.m. TTI.

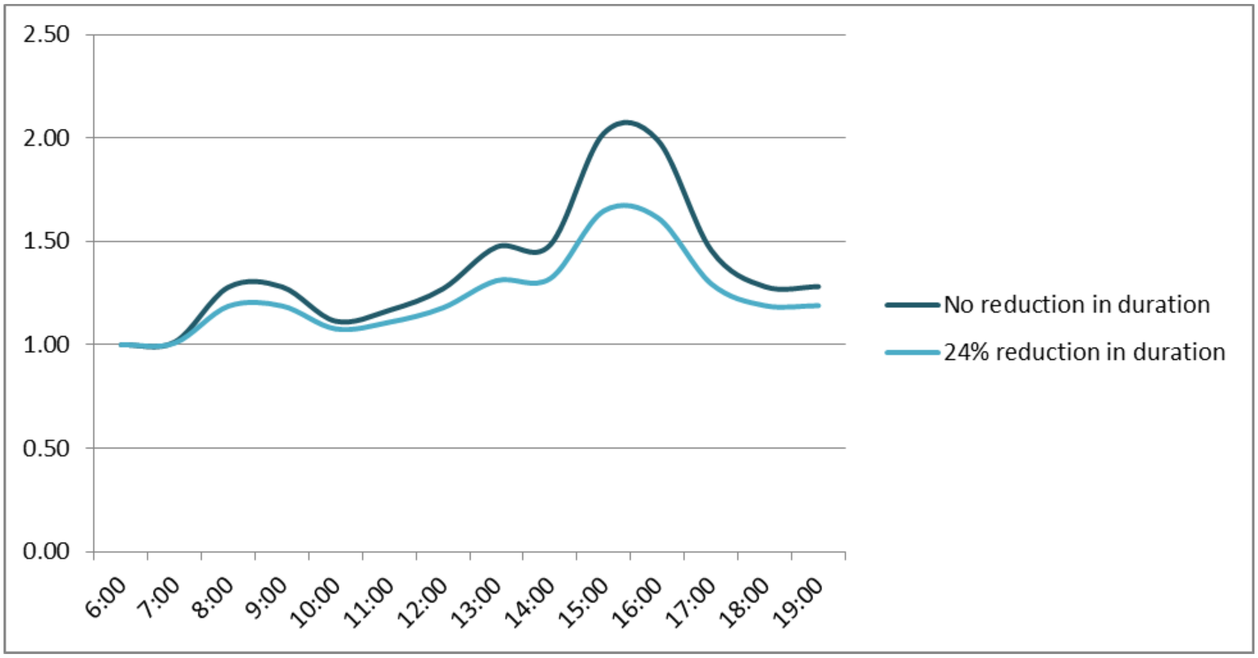


Figure 5.29. Mean TTI on the I-210 for incident duration test.

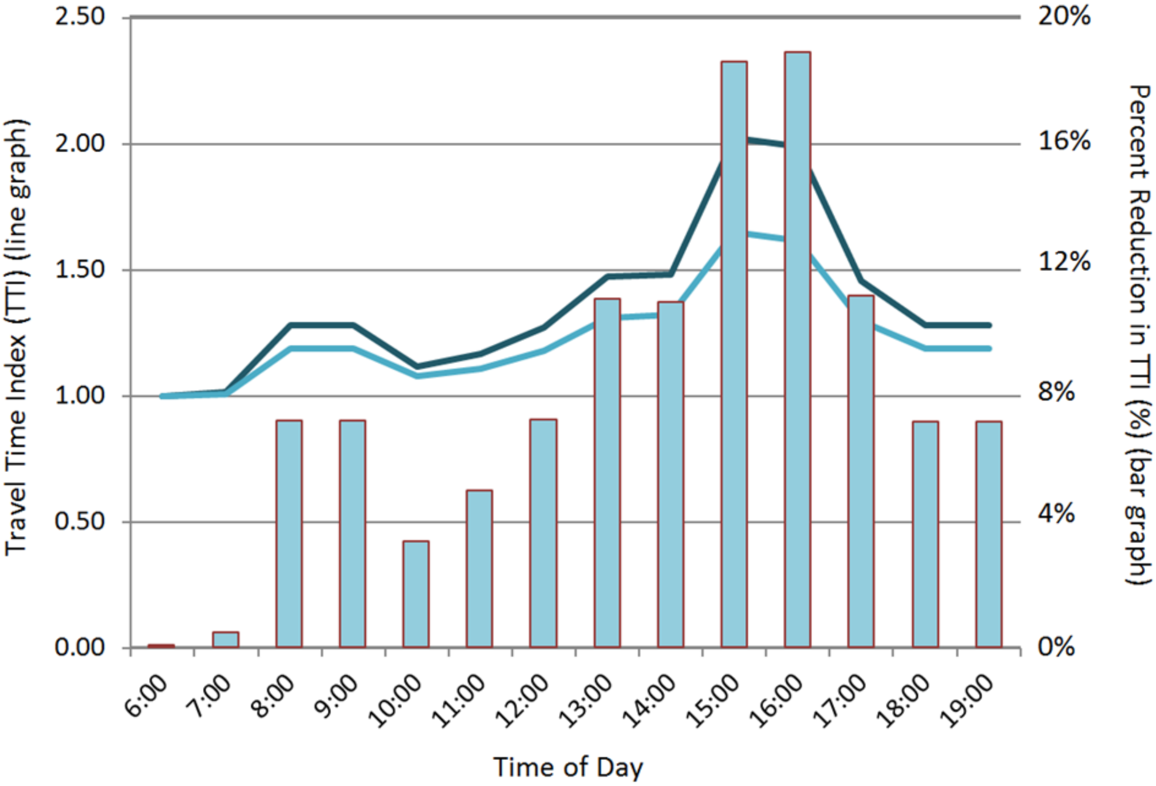
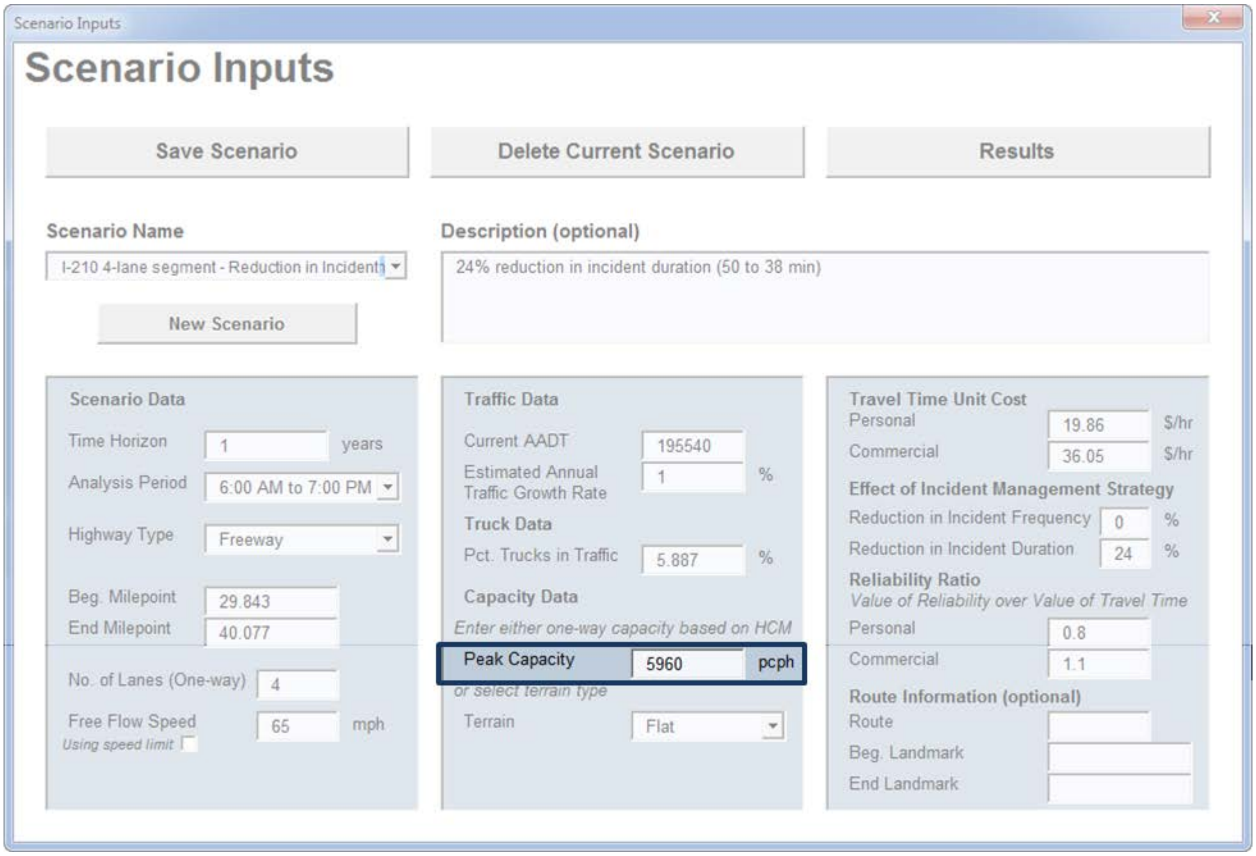


Figure 5.30. Comparison of mean TTI and percent reduction on the I-210 for incident duration test.

Peak Capacity Tests

The study team also tested several additional scenarios identified in the I-210 CSMP (SCAG and Caltrans 2010) using the C11 tool's *Peak Capacity* input feature (see Figure 5.31). To estimate the improvement in the capacity for each scenario, the study team estimated the increase in total VMT in the corresponding microsimulation runs from the CSMP. The results of these tests are shown in Figures 5.32 through 5.36. The capacity adjustments were used later when the entire facility was reanalyzed for the benefit-cost analysis. This analysis is described in Chapter 8.



Scenario Name: I-210 4-lane segment - Reduction in Incident

Description (optional): 24% reduction in incident duration (50 to 38 min)

Scenario Data

Time Horizon: 1 years

Analysis Period: 6:00 AM to 7:00 PM

Highway Type: Freeway

Beg. Milepoint: 29.843

End Milepoint: 40.077

No. of Lanes (One-way): 4

Free Flow Speed: 65 mph

Using speed limit ☐

Traffic Data

Current AADT: 195540

Estimated Annual Traffic Growth Rate: 1 %

Truck Data

Pct. Trucks in Traffic: 5.887 %

Capacity Data

Enter either one-way capacity based on HCM

Peak Capacity: 5960 pcph

or select terrain type

Terrain: Flat

Travel Time Unit Cost

Personal: 19.86 $/hr

Commercial: 36.05 $/hr

Effect of Incident Management Strategy

Reduction in Incident Frequency: 0 %

Reduction in Incident Duration: 24 %

Reliability Ratio

Value of Reliability over Value of Travel Time

Personal: 0.8

Commercial: 1.1

Route Information (optional)

Route:

Beg. Landmark:

End Landmark:

Figure 5.31. Peak capacity input.

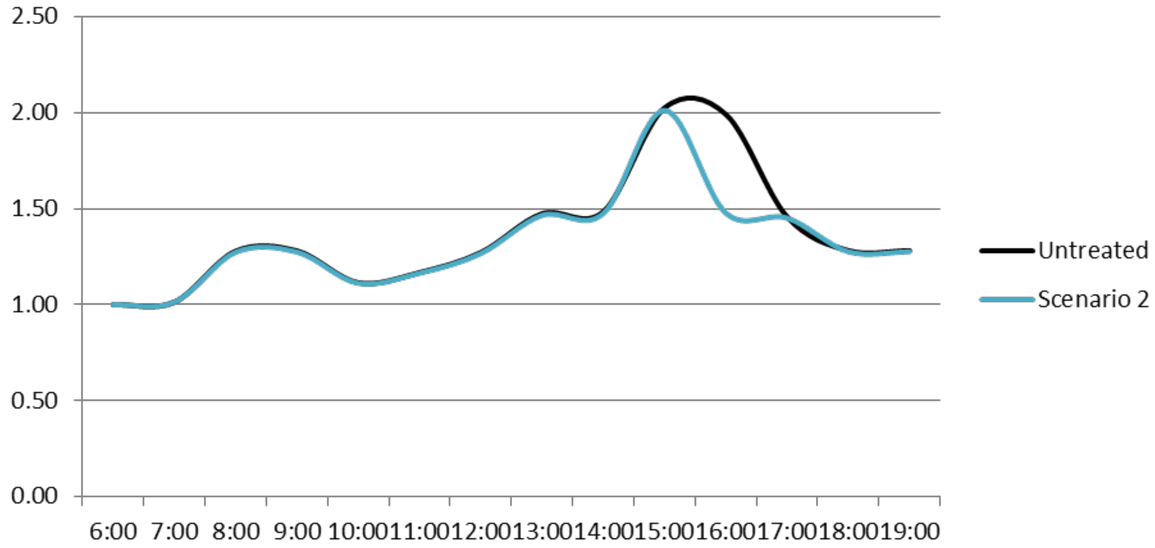


Figure 5.32. Mean TTI on the I-210 for ramp metering test (Scenarios 1 and 2).

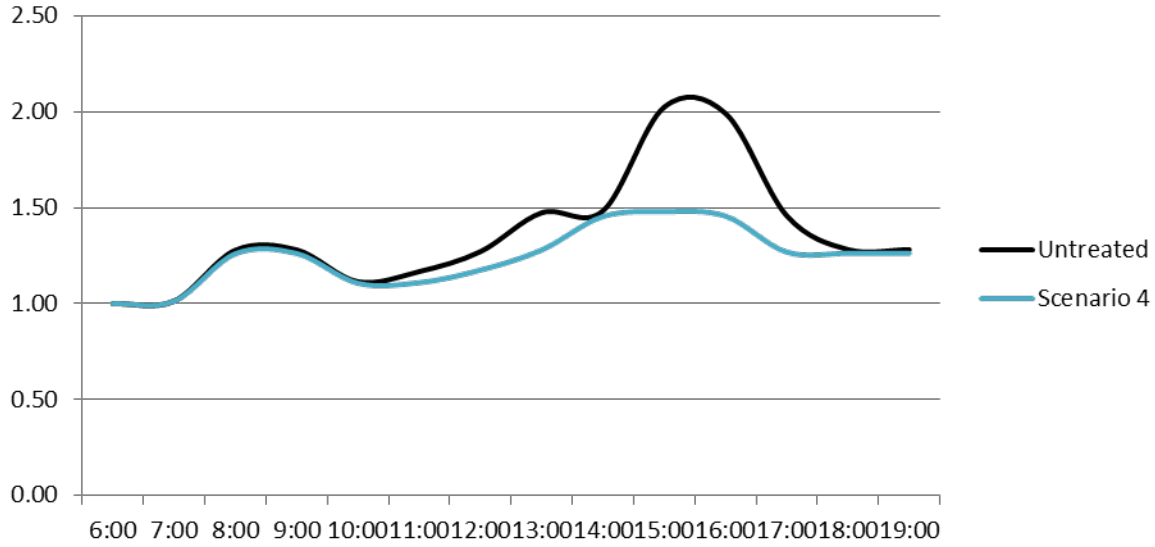


Figure 5.33. Mean TTI on the I-210 for advanced ramp metering test (Scenarios 3 and 4).

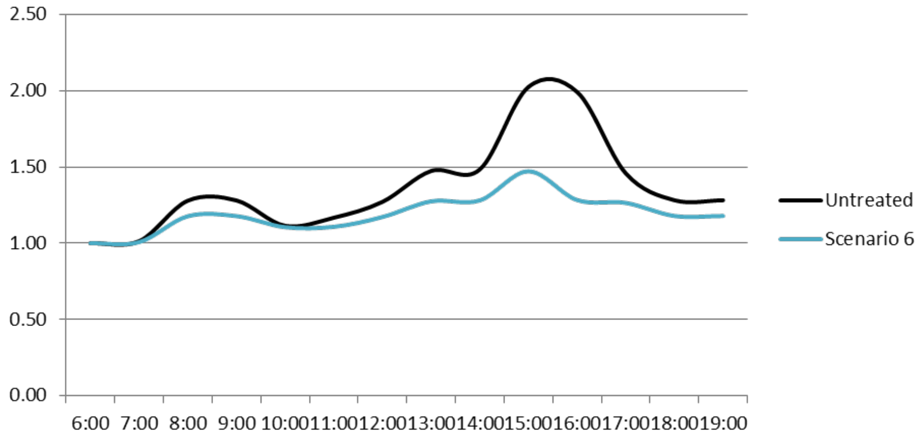


Figure 5.34. Mean TTI on the I-210 for auxiliary lane test (Scenarios 5 and 6).

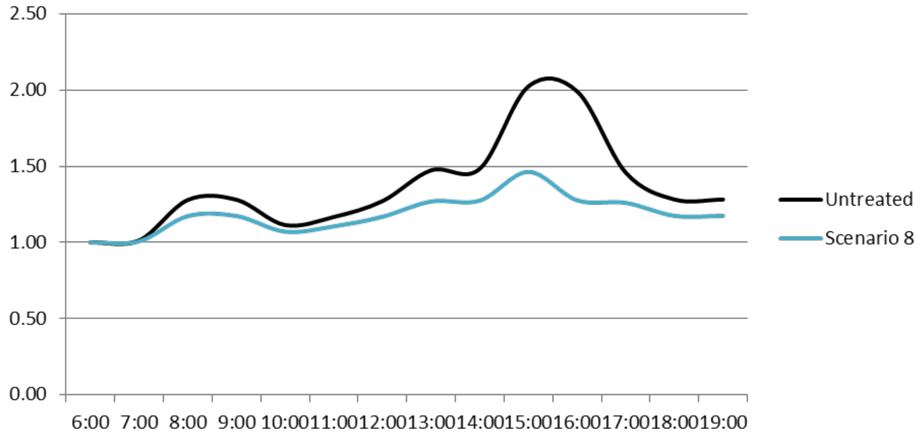


Figure 5.35. Mean TTI on the I-210 for ramp closure test (Scenarios 7 and 8).

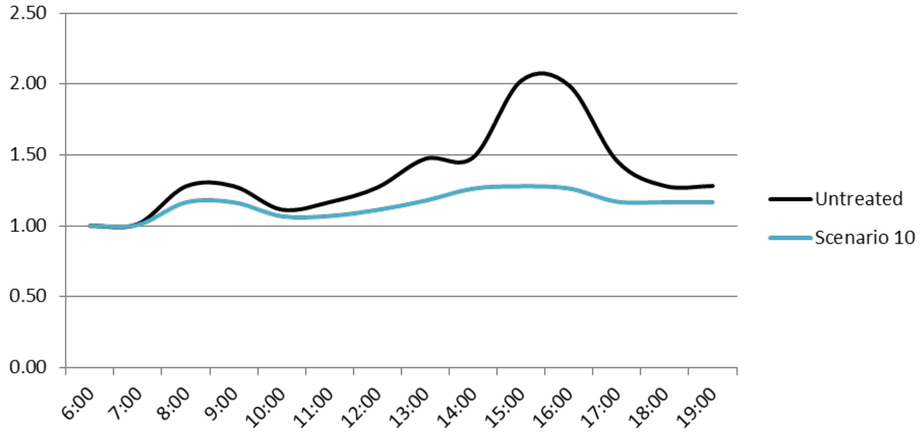


Figure 5.36. Mean TTI on the I-210 for on-ramp and auxiliary lane test (Scenarios 9 and 10).

CHAPTER 6

L07 Analysis Tool

6.1 Overview of the L07 Analysis Tool

The analysis tool developed under **Project L07** is more complex than the C11 Reliability Analysis Tool. The L07 Analysis Tool is designed to analyze the effects of highway geometric design treatments on nonrecurrent congestion using a reliability framework. It provides an easy-to-read user interface that allows for a wide array of site inputs:

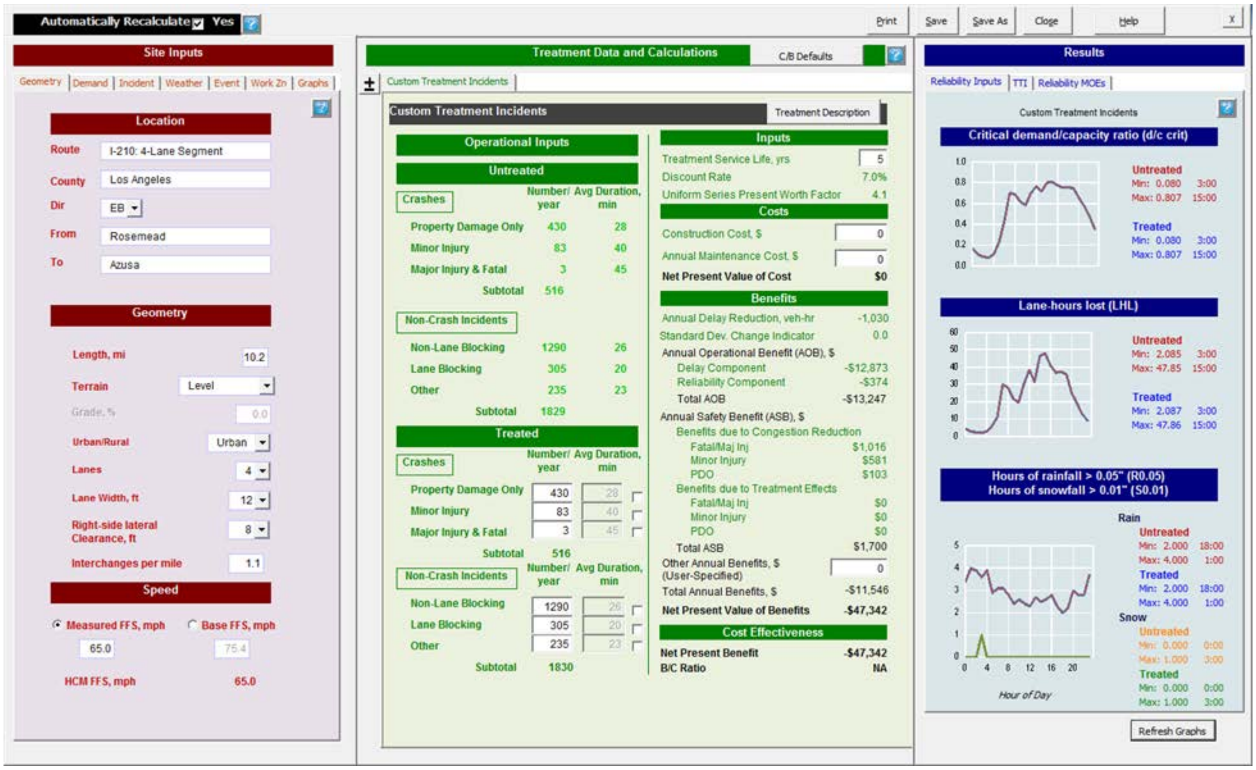
- Site geometry
- Traffic demand
- Incident history
- Weather
- Special events
- Work zones

The L07 Analysis Tool was originally designed to illustrate the benefits of various operational design strategies, since these benefits were difficult to show without modeling. As a result, the tool has built-in custom algorithms for modeling 16 different treatments using relatively simple input data on the treatment effects and cost parameters. These algorithms are based upon rules of thumb identified from literature reviews. They replace the need for the user to make adjustments, such as the ones described earlier for the C11 tool (if an appropriate treatment is available in the tool).

In addition, the tool includes three custom treatments that allow the user to tailor the analysis if a specific treatment is not available for the strategy being tested. These three custom treatments plus the 16 tailored treatments result in 19 treatments available to the user for modeling:

- Accessible shoulder
- Alternating shoulder
- Anti-icing systems
- Blowing sand
- Control (gated) turnarounds
- Crash investigation site
- Drivable shoulder
- Emergency access
- Emergency crossovers
- Emergency pull-off
- Extra high median barrier
- Incident screen
- Moveable cable barrier
- Runaway truck ramp
- Snow fence
- Wildlife crash reduction
- Custom treatment flow
- Custom raw treatment
- Custom treatment incidents

The L07 Analysis Tool provides several outputs, including TTI along with the net present benefit and cost-effectiveness of the treatment selected. Figure 6.1 provides a snapshot of the user interface.



Location

Route: I-210: 4-Lane Segment
County: Los Angeles
Dir: EB
From: Rosemead
To: Azusa

Geometry

Length, mi: 10.2
Terrain: Level
Grade, %: 0.0
Urban/Rural: Urban
Lanes: 4
Lane Width, ft: 12
Right-side lateral Clearance, ft: 8
Interchanges per mile: 1.1

Speed

● Measured FFS, mph: 65.0
○ Base FFS, mph: 75.4
HCM FFS, mph: 65.0

Custom Treatment Incidents

Operational Inputs

Untreated

Crashes	Number/ year	Avg Duration, min
Property Damage Only	430	28
Minor Injury	83	40
Major Injury & Fatal	3	45
Subtotal	516	

Non-Crash Incidents	Number/ year	Avg Duration, min
Non-Lane Blocking	1290	26
Lane Blocking	305	20
Other	235	23
Subtotal	1829	

Treated

Crashes	Number/ year	Avg Duration, min	
Property Damage Only	430	28	☐
Minor Injury	83	40	☐
Major Injury & Fatal	3	45	☐
Subtotal	516		

Non-Crash Incidents	Number/ year	Avg Duration, min	
Non-Lane Blocking	1290	26	☐
Lane Blocking	305	20	☐
Other	235	23	☐
Subtotal	1830		

Inputs

Treatment Service Life, yrs	5
Discount Rate	7.0%
Uniform Series Present Worth Factor	4.1

Costs

Construction Cost, $	0
Annual Maintenance Cost, $	0
Net Present Value of Cost	**$0**

Benefits

Annual Delay Reduction, veh-hr	-1,030
Standard Dev. Change Indicator	0.0
Annual Operational Benefit (AOB), $	
Delay Component	-$12,873
Reliability Component	-$374
Total AOB	-$13,247
Annual Safety Benefit (ASB), $	
Benefits due to Congestion Reduction	
Fatal/Maj Inj	$1,016
Minor Injury	$581
PDO	$103
Benefits due to Treatment Effects	
Fatal/Maj Inj	$0
Minor Injury	$0
PDO	$0
Total ASB	$1,700
Other Annual Benefits, $ (User-Specified)	0
Total Annual Benefits, $	-$11,546
Net Present Value of Benefits	**-$47,342**

Cost Effectiveness

Net Present Benefit	**-$47,342**
B/C Ratio	**NA**

Custom Treatment Incidents

Critical demand/capacity ratio (d/c crit)

Untreated
Min: 0.080 3:00
Max: 0.807 15:00

Treated
Min: 0.080 3:00
Max: 0.807 15:00

Lane-hours lost (LHL)

Untreated
Min: 2.085 3:00
Max: 47.85 15:00

Treated
Min: 2.087 3:00
Max: 47.86 15:00

Hours of rainfall > 0.05" (R0.05)
Hours of snowfall > 0.01" (S0.01)

Rain
Untreated
Min: 2.000 18:00
Max: 4.000 1:00
Treated
Min: 2.000 18:00
Max: 4.000 1:00
Snow
Untreated
Min: 0.000 0:00
Max: 1.000 3:00
Treated
Min: 0.000 0:00
Max: 1.000 3:00

Figure 6.1. Project L07 Analysis Tool user interface.

6.2 Limitations of the L07 Analysis Tool

Despite the ease of use with the user interface, the tool has various limitations in its site and treatment input modules that affect the tool's accuracy or usability. These are detailed below.

Site Input Limitations

The L07 Analysis Tool provides a comprehensive set of site inputs in the six areas listed in the previous section. While these tabs provide users with the ability to input relatively specific characteristics of a facility, they also contain several limitations that affect their accuracy or usability.

Difficult to Obtain All Required Input

Due to the complexity of this tool relative to the C11 tool, the study team found gathering several pieces of data required by the L07 Analysis Tool to be time-consuming and, at times, difficult.

DEMAND INPUT

For example, the L07 Analysis Tool requires that the *Demand* fields (Figure 6.2) be populated with the 30th highest hourly demand of the year for each hour of the day. Producing this information involves a substantial amount of work in downloading and processing data from PeMS. The data inputs would be much simpler if the tool required average demand. Although the 30th highest hour is typical for design applications, it is unclear why this is necessary for travel time reliability estimation.

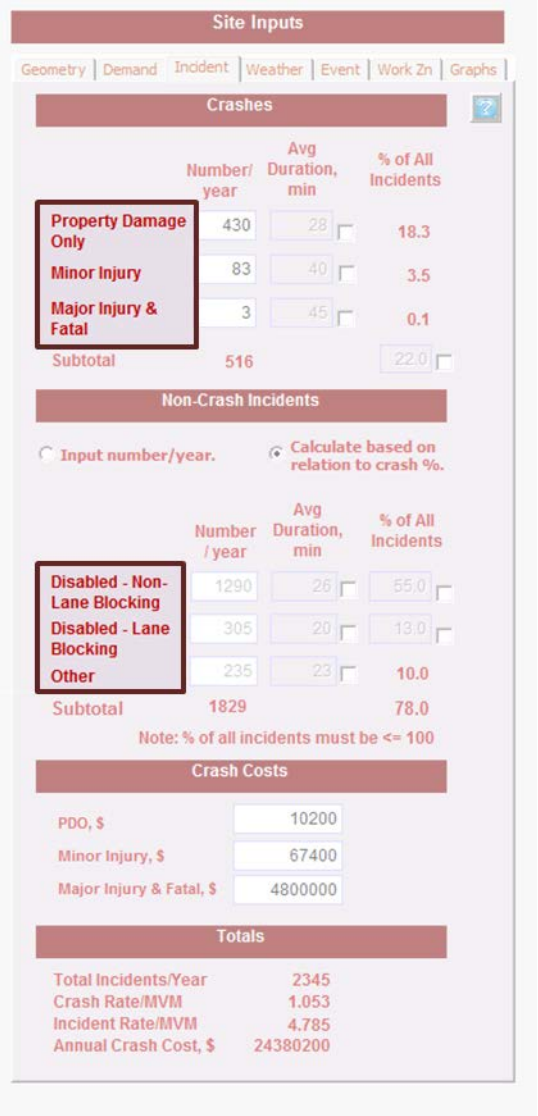
	Demand (vph)	PHF	% Trucks	% RVs	Demand flow rate (pcph)
0:00	1,757	1.00	7.8	0.0	1,826
1:00	1,153	1.00	7.8	0.0	1,198
2:00	929	1.00	7.8	0.0	965
3:00	826	1.00	7.8	0.0	858
4:00	1,183	1.00	7.8	0.0	1,229
5:00	2,398	1.00	7.8	0.0	2,492
6:00	4,517	1.00	7.8	0.0	4,693
7:00	7,282	1.00	7.8	0.0	7,566
8:00	7,119	1.00	7.8	0.0	7,397
9:00	6,368	1.00	7.8	0.0	6,616
10:00	6,056	1.00	7.8	0.0	6,292
11:00	7,309	1.00	7.8	0.0	7,594
12:00	7,885	1.00	7.8	0.0	8,193
13:00	7,420	1.00	7.8	0.0	7,709
14:00	8,291	1.00	7.8	0.0	8,614
15:00	8,358	1.00	7.8	0.0	8,684
16:00	8,031	1.00	7.8	0.0	8,344
17:00	7,791	1.00	7.8	0.0	8,095
18:00	7,831	1.00	7.8	0.0	8,136
19:00	7,731	1.00	7.8	0.0	8,033
20:00	6,788	1.00	7.8	0.0	7,053
21:00	5,969	1.00	7.8	0.0	6,202
22:00	4,964	1.00	7.8	0.0	5,158
23:00	3,687	1.00	7.8	0.0	3,831
Total	131,643				136,778

Figure 6.2. Demand input for L07 Analysis Tool.

INCIDENT INPUT

In addition, the *Incident* inputs require frequencies and average durations to be entered according to specific types of incidents (see Figure 6.3). Incident frequency data are available from PeMS or standard analysis tables directly from the Caltrans Traffic Accident Surveillance and Analysis System (TASAS). However, Caltrans does not collect data on incident duration. This must be estimated by manually examining California Highway Patrol (CHP) logs. This is quite time-consuming and, as described in Chapter 4, there is no guarantee that the timing of the CHP logs corresponds to the actual impact of the incident on traffic conditions.

Since it was difficult for the study team to obtain incident duration information by incident type, the study team decided to use the defaults in the tool.



Crashes

	Number/ year	Avg Duration, min	% of All Incidents
Property Damage Only	430	28 ☐	18.3
Minor Injury	83	40 ☐	3.5
Major Injury & Fatal	3	45 ☐	0.1
Subtotal	516		22.0 ☐

Non-Crash Incidents

○ Input number/year. ● Calculate based on relation to crash %.

	Number / year	Avg Duration, min	% of All Incidents
Disabled - Non-Lane Blocking	1290	26 ☐	55.0 ☐
Disabled - Lane Blocking	305	20 ☐	13.0 ☐
Other	235	23 ☐	10.0
Subtotal	1829		78.0

Note: % of all incidents must be <= 100

Crash Costs

PDO, $	10200
Minor Injury, $	67400
Major Injury & Fatal, $	4800000

Totals

Total Incidents/Year	2345
Crash Rate/MVM	1.053
Incident Rate/MVM	4.785
Annual Crash Cost, $	24380200

Figure 6.3. Incident input for L07 Analysis Tool.

Time Consuming to Input Demand

The L07 Analysis Tool's *Demand* input screen requires that users individually enter values such as percent trucks and percent recreational vehicles (RVs) for each hour of the day (see Figure 6.4). Given that many users may derive this information via spreadsheet calculations, the tool should allow for these values to be copied and pasted, or imported, from an external spreadsheet. This would not only increase the user friendliness of the tool, but also reduce the risk of human error from manual entry. In its current form, the L07 tool requires users to enter each figure manually.

	Demand (vph)	PHF	% Trucks	% RVs	Demand flow rate (pcph)
0:00	1,757	1.00	7.8	0.0	1,826
1:00	1,153	1.00	7.8	0.0	1,198
2:00	929	1.00	7.8	0.0	965
3:00	826	1.00	7.8	0.0	858
4:00	1,183	1.00	7.8	0.0	1,229
5:00	2,398	1.00	7.8	0.0	2,492
6:00	4,517	1.00	7.8	0.0	4,693
7:00	7,282	1.00	7.8	0.0	7,566
8:00	7,119	1.00	7.8	0.0	7,397
9:00	6,368	1.00	7.8	0.0	6,616
10:00	6,056	1.00	7.8	0.0	6,292
11:00	7,309	1.00	7.8	0.0	7,594
12:00	7,885	1.00	7.8	0.0	8,193
13:00	7,420	1.00	7.8	0.0	7,709
14:00	8,291	1.00	7.8	0.0	8,614
15:00	8,358	1.00	7.8	0.0	8,684
16:00	8,031	1.00	7.8	0.0	8,344
17:00	7,791	1.00	7.8	0.0	8,095
18:00	7,831	1.00	7.8	0.0	8,136
19:00	7,731	1.00	7.8	0.0	8,033
20:00	6,788	1.00	7.8	0.0	7,053
21:00	5,969	1.00	7.8	0.0	6,202
22:00	4,964	1.00	7.8	0.0	5,158
23:00	3,687	1.00	7.8	0.0	3,831
Total	131,643				136,778

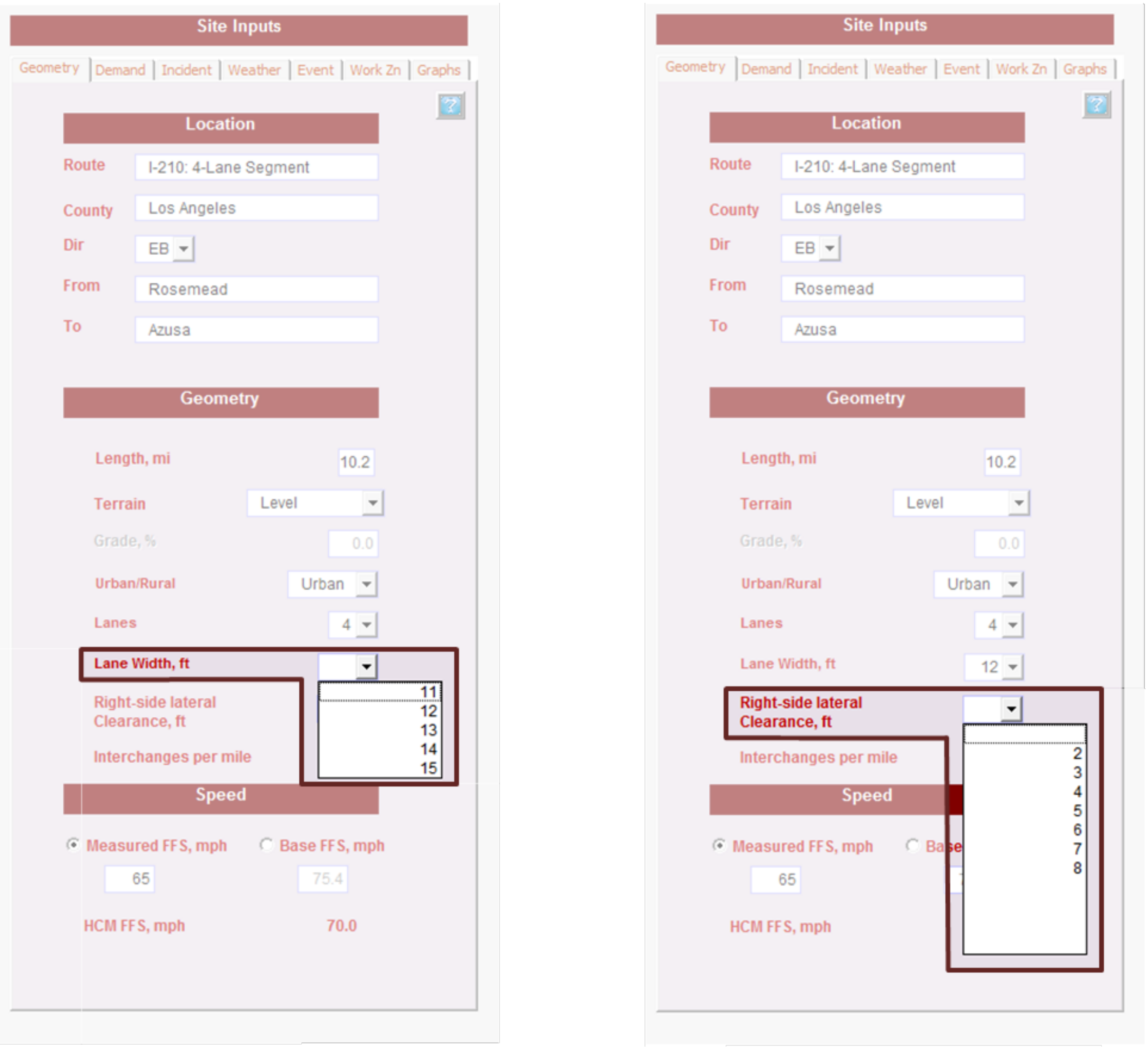
Figure 6.4. Time-consuming demand input.

Difficult to Understand Event Inputs

The study team had difficulty understanding what type of events should be included in the *Event* input screen. While the L07 Analysis Tool user's guide (MRIGlobal 2013a) provides direction that *Demand* data should be entered only for non-holiday weekdays, it does not provide similar direction for special events. The special event patterns will vary for weekdays and weekends as well as for holidays. However, given that the demand data are required only for weekdays, the tool may require special event data only for weekdays. The user's guide is not clear.

Limited Geometry Input Options

The L07 Analysis Tool provides a limited number of choices for *Lane Width* and *Lateral Clearance* via dropdown boxes (see Figure 6.5). For greater accuracy, the tool should provide more options for these fields. Many older urban highways have lanes that are only 10 feet wide, but the tool does not provide this width as an option. Many highways also have right-side lateral clearances greater than 8 feet, but the maximum option provided is 8 feet.



Route: I-210: 4-Lane Segment
County: Los Angeles
Dir: EB
From: Rosemead
To: Azusa
Length, mi: 10.2
Terrain: Level
Grade, %: 0.0
Urban/Rural: Urban
Lanes: 4
Lane Width, ft: 11, 12, 13, 14, 15
Right-side lateral Clearance, ft
Interchanges per mile
● Measured FFS, mph: 65
○ Base FFS, mph: 75.4
HCM FFS, mph: 70.0

Route: I-210: 4-Lane Segment
County: Los Angeles
Dir: EB
From: Rosemead
To: Azusa
Length, mi: 10.2
Terrain: Level
Grade, %: 0.0
Urban/Rural: Urban
Lanes: 4
Lane Width, ft: 12
Right-side lateral Clearance, ft: 2, 3, 4, 5, 6, 7, 8
Interchanges per mile
● Measured FFS, mph: 65
○ Base
HCM FFS, mph

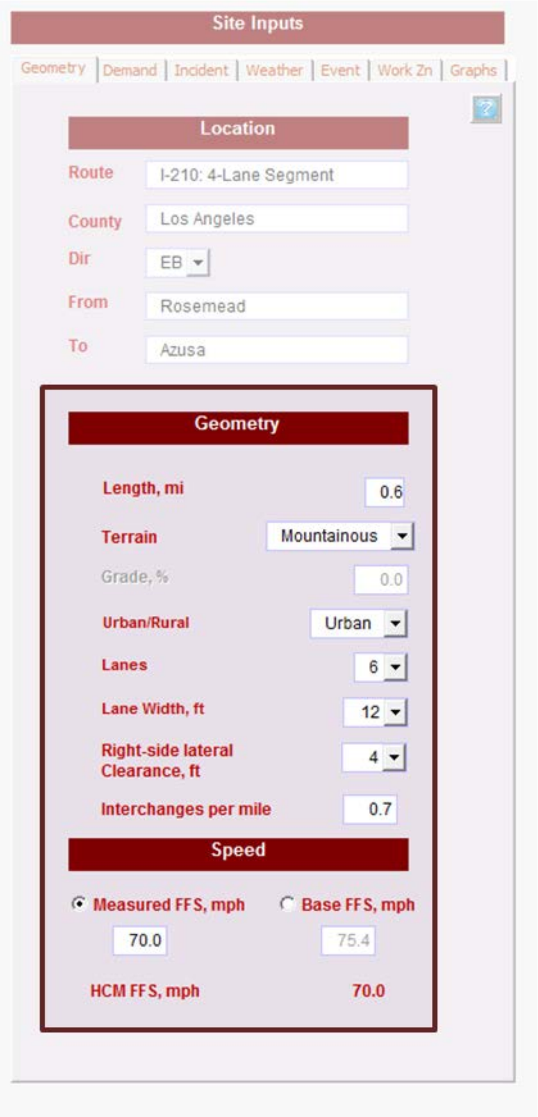
Figure 6.5. Geometry input for L07 Analysis Tool.

Inputs Are Not Saved Unless Cursor Exits Field

Each time a user inputs data into a field, the user must move the cursor out of the field for the tool to accept the entry. If the user runs the tool after entering a value into a field without first moving the cursor, the tool will not recognize the newly entered value and perform the run without the entered value (even though the value appears in the field). The L07 Analysis Tool should be modified to recognize all entered fields upon the initiation of each new run.

Geometry and Speed Inputs Cannot Be Saved

Each time the tool is saved, closed, and reopened, the *Geometry* and *Speed* inputs (Figure 6.6) revert to their default values, while other values are properly saved. The tool should retain values in all fields when saved by the user.



Location

Route: I-210: 4-Lane Segment
County: Los Angeles
Dir: EB
From: Rosemead
To: Azusa

Geometry

Length, mi: 0.6
Terrain: Mountainous
Grade, %: 0.0
Urban/Rural: Urban
Lanes: 6
Lane Width, ft: 12
Right-side lateral Clearance, ft: 4
Interchanges per mile: 0.7

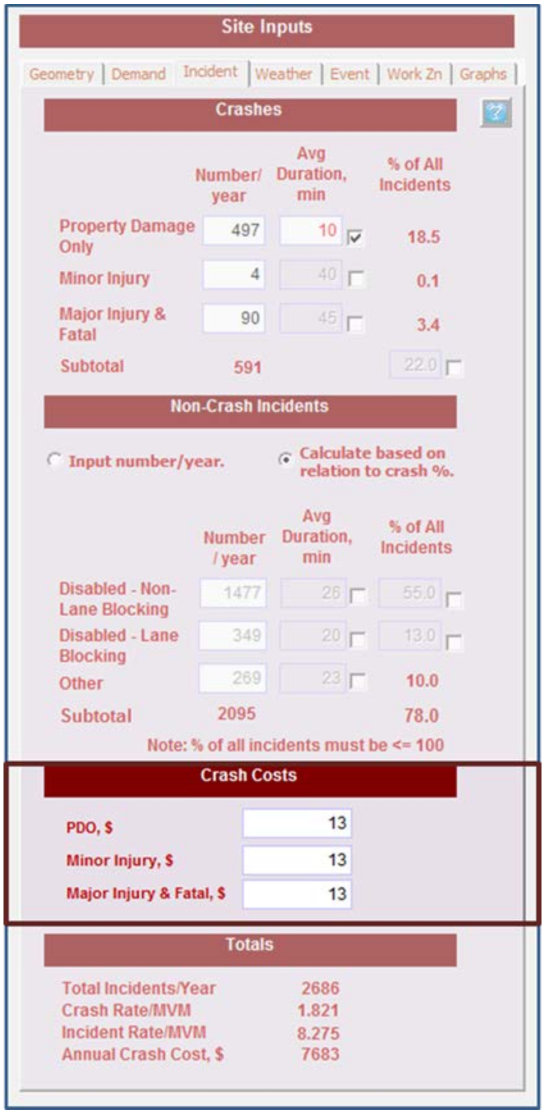
Speed

● Measured FFS, mph: 70.0
○ Base FFS, mph: 75.4
HCM FFS, mph: 70.0

Figure 6.6. Geometry and speed input for L07 Analysis Tool.

Crash Costs Inputs Cannot Be Saved

Similar to the Geometry and Speed inputs, *Crash Costs* inputs in the *Incident* inputs (Figure 6.7) tab cannot be saved. Each time the tool is saved, closed, and reopened, crash costs default to $13 for all three types of crash costs (PDO, Minor Injury, and Major Injury & Fatal). This is particularly problematic when scenarios are tested, because the user must remember to check and re-enter these values between the baseline calibration and the scenario analysis. The L07 Analysis Tool should retain values in all fields when saved by the user.



Crashes

	Number/ year	Avg Duration, min		% of All Incidents
Property Damage Only	497	10	☑	18.5
Minor Injury	4	40	☐	0.1
Major Injury & Fatal	90	45	☐	3.4
Subtotal	591			22.0 ☐

Non-Crash Incidents

○ Input number/year. ● Calculate based on relation to crash %.

	Number / year	Avg Duration, min		% of All Incidents
Disabled - Non-Lane Blocking	1477	26	☐	55.0 ☐
Disabled - Lane Blocking	349	20	☐	13.0 ☐
Other	269	23	☐	10.0
Subtotal	2095			78.0

Note: % of all incidents must be <= 100

Crash Costs

PDO, $	13
Minor Injury, $	13
Major Injury & Fatal, $	13

Totals

Total Incidents/Year	2686
Crash Rate/MVM	1.821
Incident Rate/MVM	8.275
Annual Crash Cost, $	7683

Figure 6.7. Crash costs input for L07 Analysis Tool.

Difficult to Calibrate

As with the C11 Reliability Analysis Tool, the L07 tool and its associated user's guide (MRIGlobal 2013a) provide little instruction on how to calibrate the tool to real-world conditions. As shown in Section 6.3, the study team originally attempted to calibrate the L07 tool by adjusting the free-flow speed (FFS) of the facility. However, through trial and error, the study team learned that changing the FFS caused the tool to use a different capacity for the facility. This method of "tricking" the tool into utilizing a different capacity by adjusting the FFS was not effective, since the range of possible capacities was limited to the ones found in the FFS-to-capacity correspondence table of the tool.

After finding the correspondence table behind the user interface, the study team was able to calibrate the tool more accurately by directly adjusting the capacity, as was done for the C11 tool. However, for purposes of technical integrity, the tool should provide a clear and technically solid method of calibration that does not involve calibration "by force" using capacity. If the capacity method is the best way for calibration, then the L07 Analysis Tool should also allow users to adjust the capacity via the user interface without having to go "behind the tool."

Demand Growth

The L07 Analysis Tool does not provide an input box for demand growth. As a result, all analyses assume that demand remains constant over time. The tool provides a life-cycle analysis of project benefits, but these benefits do not take into account the growth in traffic demand over the project life cycle. To estimate the project benefits accurately, the user would need to estimate project benefits for the base year and a future year in the tool separately and then interpolate the benefits (with discounting) outside of the model. This would be a time-consuming exercise, so most users would opt to ignore demand growth. The L07 tool should provide a demand growth input either as a separate set of future demand figures by hour or as a single growth percentage.

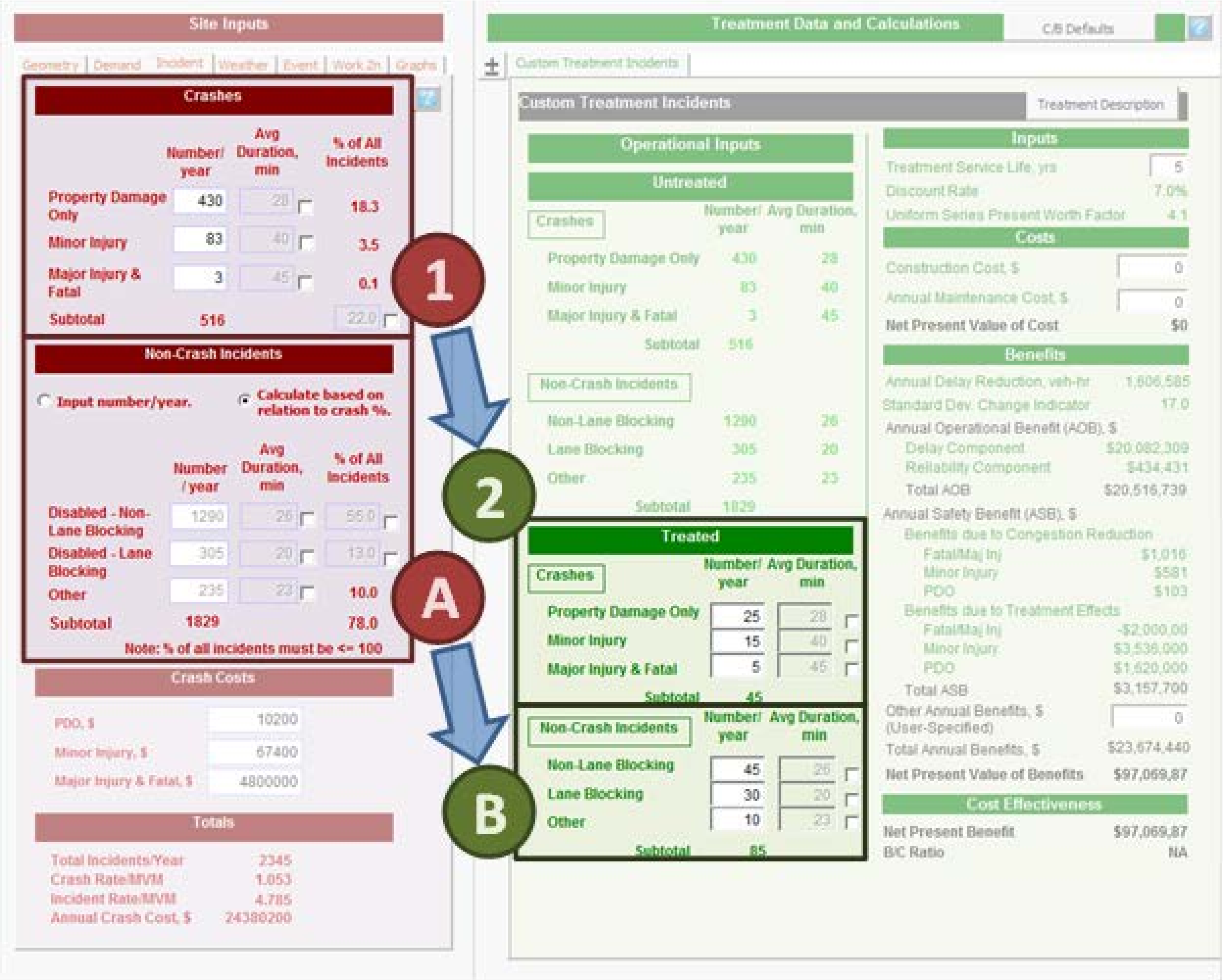
Treatment Input Limitations

As indicated in Section 6.1, the tool provides 19 treatment modules that can be used to test a variety of project types. While this provides users with a wide array of treatments to test, some treatment modules contain limitations that could affect their accuracy or usability.

Risk of Inaccuracies in Utilizing Custom Treatment Incidents Module

In the *Incidents* tab of the *Site Inputs* section, the user is given the option of allowing the tool to calculate the numbers of *Non-Crash Incidents*, based on the relation to crash percentage (Figure 6.8, Box A). However, this option does not exist in the *Treated Non-Crash Incidents* section of the *Custom Treatment Incidents* tab (Figure 6.8, Box B). Therefore, if users wish to maintain a constant number of incidents and test other factors, such as incident duration time, users must manually enter the numbers of *Treated Non-Crash Incidents* (Box B). The tool calculates the number of *Untreated Non-Crash Incidents* (Box A) as decimal values, but displays only the rounded integers, giving the user no way of entering the number of *Treated Non-Crash Incidents* (Box B) similar to the number of *Untreated Non-Crash Incidents* (Box A).

The tool should give users the option of allowing the tool to calculate the number of *Treated Non-Crash Incidents* (Box B) in the same manner that it calculates the numbers of *Untreated Non-Crash Incidents* (Box A). In order to prevent confusion, the default values in the *Treated Crash Incidents* (Box 2) and *Treated Non-Crash Incidents* (Box B) sections should correspond to values in the *Untreated Crash Incidents* (Box 1) and *Untreated Non-Crash Incidents* sections, respectively.



Crashes

	Number/ year	Avg Duration, min		% of All Incidents	
Property Damage Only	430	28	☐	18.3	
Minor Injury	83	40	☐	3.5	
Major Injury & Fatal	3	45	☐	0.1	
Subtotal	516			22.0	☐

Non-Crash Incidents

○ Input number/year. ● Calculate based on relation to crash %.

	Number / year	Avg Duration, min		% of All Incidents	
Disabled - Non-Lane Blocking	1290	26	☐	55.0	☐
Disabled - Lane Blocking	305	20	☐	13.0	☐
Other	235	23	☐	10.0	
Subtotal	1829			78.0	

Note: % of all incidents must be <= 100

Crash Costs

PDO, $	10200
Minor Injury, $	67400
Major Injury & Fatal, $	4800000

Totals

Total Incidents/Year	2345
Crash Rate/MVM	1.053
Incident Rate/MVM	4.785
Annual Crash Cost, $	24380200

Custom Treatment Incidents

Operational Inputs

Untreated

Crashes	Number/ year	Avg Duration, min
Property Damage Only	430	28
Minor Injury	83	40
Major Injury & Fatal	3	45
Subtotal	516	

Non-Crash Incidents		
Non-Lane Blocking	1290	26
Lane Blocking	305	20
Other	235	23
Subtotal	1829	

Treated

Crashes	Number/ year	Avg Duration, min	
Property Damage Only	25	28	☐
Minor Injury	15	40	☐
Major Injury & Fatal	5	45	☐
Subtotal	45		

Non-Crash Incidents	Number/ year	Avg Duration, min	
Non-Lane Blocking	45	26	☐
Lane Blocking	30	20	☐
Other	10	23	☐
Subtotal	85		

Inputs

Treatment Service Life, yrs	5
Discount Rate	7.0%
Uniform Series Present Worth Factor	4.1

Costs

Construction Cost, $	0
Annual Maintenance Cost, $	0
Net Present Value of Cost	**$0**

Benefits

Annual Delay Reduction, veh-hr	1,606,585
Standard Dev. Change Indicator	17.0
Annual Operational Benefit (AOB), $	
Delay Component	$20,082,309
Reliability Component	$434,431
Total AOB	$20,516,739
Annual Safety Benefit (ASB), $	
Benefits due to Congestion Reduction	
Fatal/Maj Inj	$1,016
Minor Injury	$581
PDO	$103
Benefits due to Treatment Effects	
Fatal/Maj Inj	-$2,000.00
Minor Injury	$3,536,000
PDO	$1,620,000
Total ASB	$3,157,700
Other Annual Benefits, $ (User-Specified)	0
Total Annual Benefits, $	$23,674,440
Net Present Value of Benefits	**$97,069,87**

Cost Effectiveness

Net Present Benefit	**$97,069,87**
B/C Ratio	NA

Figure 6.8. Incident site and treatment inputs for L07 Analysis Tool.

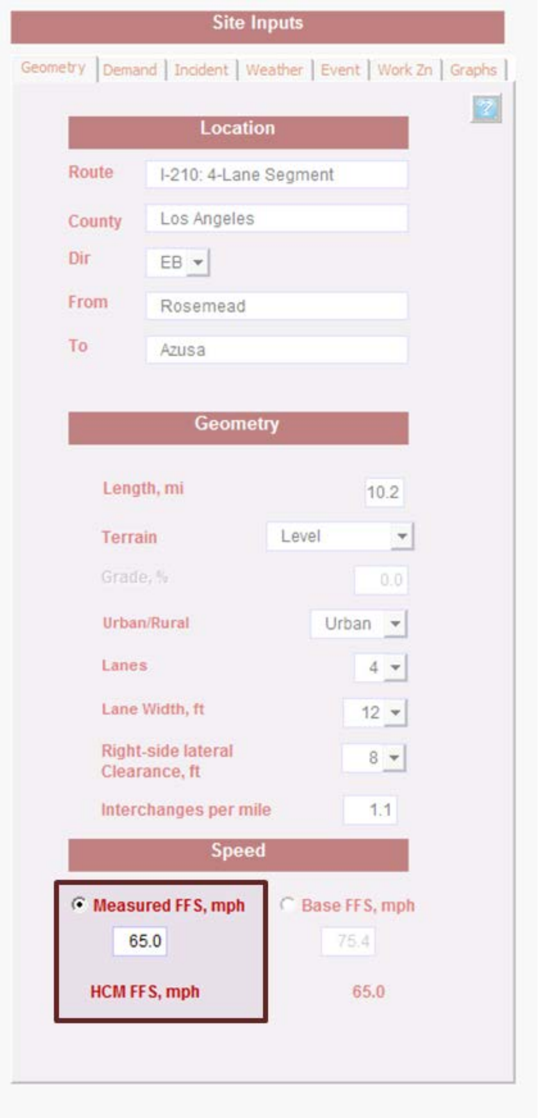
Limited Urban Area Operational Strategies

While the L07 Analysis Tool provides a broad array of treatment options, the tool does not include several of the common operational strategies that can benefit urban facilities. The study team wanted to test several strategies not found in the tool: advanced ramp metering, auxiliary lanes, and ramp modifications. These are strategies commonly used by Caltrans and its partners in Southern California. As a result, the study team was required to estimate adjustments similar to those used for the C11 tool to estimate the benefits of these strategies.

The L07 Analysis Tool would benefit from having a longer list of treatments that the user can test directly. The tool should be modified to include strategies tested at the four SHRP L38 pilot sites.

6.3 Baseline Condition Estimation of the L07 Analysis Tool

As indicated previously, the team originally attempted to establish an estimation of baseline conditions by adjusting the FFS (see Figure 6.9).



Location

Route: I-210: 4-Lane Segment

County: Los Angeles

Dir: EB

From: Rosemead

To: Azusa

Geometry

Length, mi: 10.2

Terrain: Level

Grade, %: 0.0

Urban/Rural: Urban

Lanes: 4

Lane Width, ft: 12

Right-side lateral Clearance, ft: 8

Interchanges per mile: 1.1

Speed

● Measured FFS, mph: 65.0

○ Base FFS, mph: 75.4

HCM FFS, mph: 65.0

Figure 6.9. Free-flow speed input for L07 Analysis Tool.

Adjusting the FFS makes the tool select a different capacity for the facility according to the correspondence table shown in Table 6.1. This correspondence table is found in a part of the tool hidden from the user. A password is needed to view and modify the correspondence table.

Table 6.1. Free-Flow Speed/Capacity Correspondence Table

Freeway Capacity *2010 HCM (pg. 11-3&4)*	
mi/h	*pc/h/ln*
55	2250
60	2300
65	2350
70	2400
75	2400

As indicated earlier, the method of tricking the tool into utilizing a different capacity by adjusting the FFS was not effective, since the range of possible capacities is limited to those in the FFS-to-capacity correspondence table (Table 6.1). Following the discovery of the correspondence table, the study team was able to calibrate the tool by typing new capacities in the correspondence table. As seen in Figure 6.10, calibrating by FFS was somewhat successful (pink line), but calibrating the model by adjusting the capacity directly was even more effective (blue line).

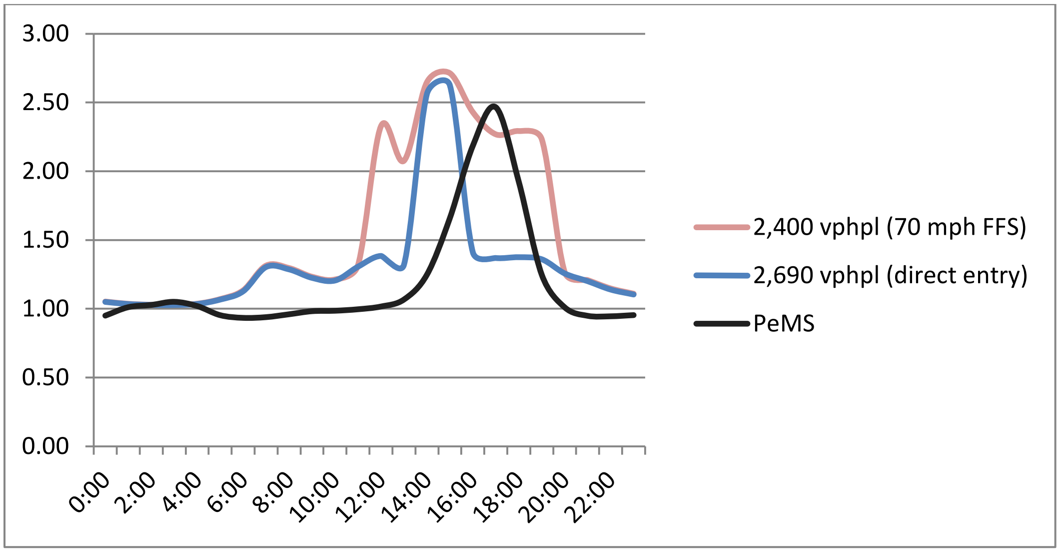


Figure 6.10. Mean TTI results for I-210 baseline condition estimation runs.

Unlike the C11 tool's calibration exercise, the L07 tool did not require an adjustment of the hourly distribution of demand, since this hourly distribution is already a required input. Also, unlike the C11 tool's calibration exercise, the L07 tool's calibration effort could be accomplished with a more realistic capacity of 2,690 vphpl (the C11 tool was calibrated to 1,300 vphpl) for the I-210 facility. However, neither capacity corresponds to the maximum throughput measured in PeMS for the facility. This discrepancy stems from the definition of capacity in the *Highway*

Capacity Manual (HCM) being different from maximum throughput. The user should keep this in mind while using the tool. The standard capacity of 2,400 vphpl corresponding to a FFS of 70 mph was used for the I-5 facility.

6.4 Results of the I-5 Scenario Testing

As with the C11 Reliability Tool, the L07 Analysis Tool was run with scenarios on both the I-5 facility in Orange County and the I-210 facility in the urbanized area of Los Angeles County. For the I-5 facility, several scenarios were tested:

- Baseline Calibration Test
- Initial Treatment Tests
- Incident Management (Custom Treatment Incidents) Test
- Operational Improvements (Custom Treatment Flow) Test
- Dynamic Ramp Metering (Custom Treatment Flow) Test
- High-Occupancy Vehicle + GP Widening (Custom Treatment Flow) Test

The initial treatments tested were only those applicable for implementation in an urban freeway facility. Of the 19 available L07 tool treatment strategies, 14 treatment strategies were tested. Wildlife crash reduction, anti-icing systems, snow fence, blowing sand, and custom raw treatments were not tested, since they were considered inappropriate for the I-5 facility.

The reliability results of the 6.5-mile I-5 facility segment are shown in Figure 6.11. The L07 Analysis Tool's TTI estimates did not match the baseline conditions measured in PeMS as well as the results produced by the C11 tool. This may be due in part to the differences in capacity used. The C11 tool estimated reliability based on a capacity of 2,100 passenger cars per hour per lane (pcphpl) while the L07 tool estimated reliability based on a capacity of 2,400 vphpl. Therefore, the L07 tool-adjusted capacity is even higher. This results in a baseline condition that is not as well-calibrated.

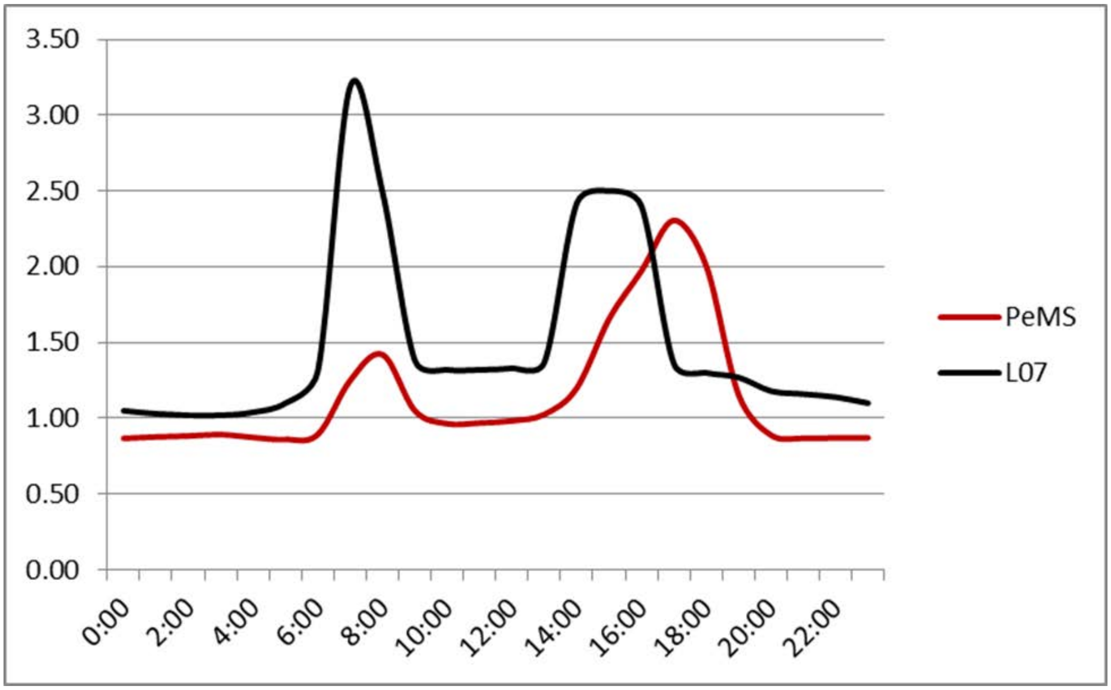


Figure 6.11. Mean TTI results for I-5 baseline condition.

Initial Treatment Tests

The team evaluated the applicability of the L07 analytic tool’s 19 available treatments to the I-5 facility. Four treatments (i.e., wildlife crash reduction, anti-icing systems, snow fence, and blowing sand) were deemed to be inapplicable to Southern California conditions. Additionally, Customer Raw Treatment was not tested, as it was not applicable to the project scenarios tested in the I-5 CSMP (Caltrans 2012). The study team performed initial runs on each of the remaining 14 treatments utilizing the tool’s default input values. (Two additional custom treatments also were run.) Figure 6.12 provides a summary of the results of these runs.

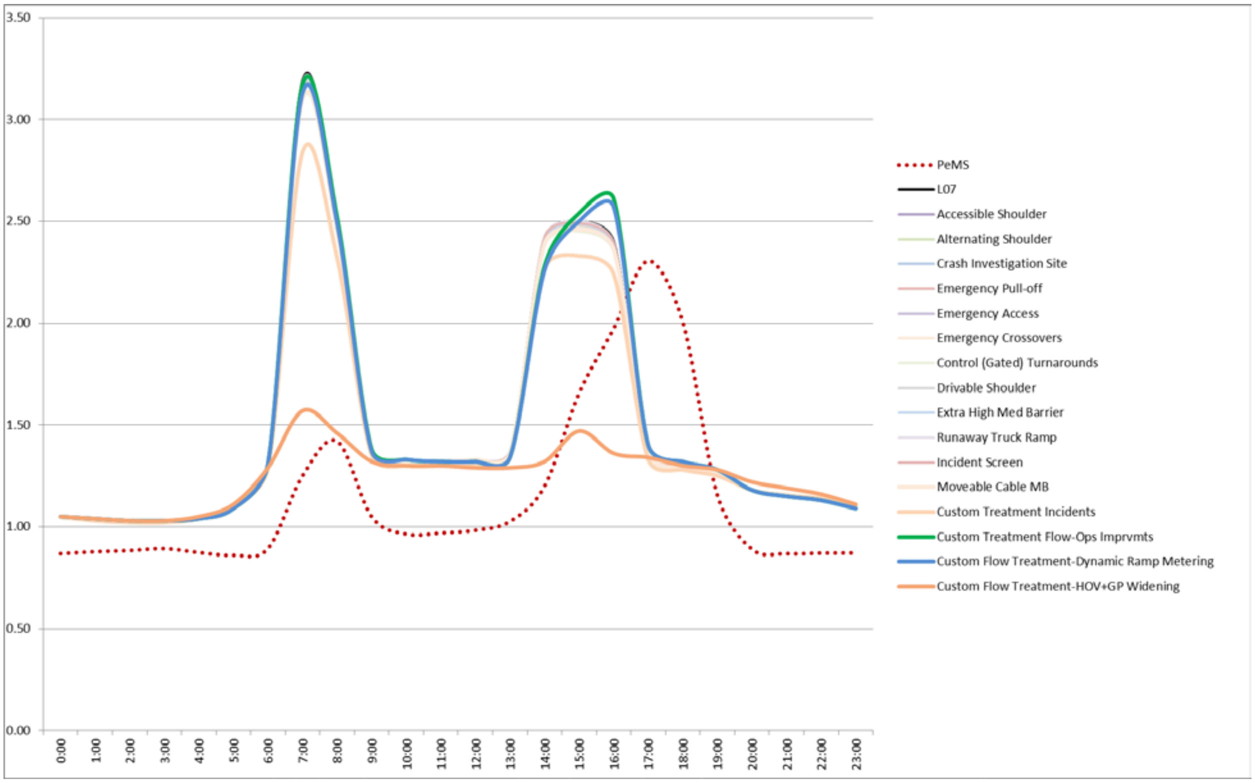


Figure 6.12. Summary TTI results of initial treatment tests for I-5.

Figure 6.13 summarizes the present value of reliability benefits for 12 default design treatments tested for the I-5 facility. The largest reliability benefits are due to control turnarounds, moveable cable barriers, emergency crossovers, emergency access, and drivable shoulders. The L07 tool includes default costs for each of these design treatments. As shown in Figure 6.14, these costs result in unreasonably high benefit-cost ratios, with many in the 100s. The lowest benefit-cost ratio is for an alternating shoulder with a benefit-cost ratio of 8.7. These high ratios are due to low default costs in the tool relative to right-of-way costs in Southern California and the currently high unreliability along the facility.

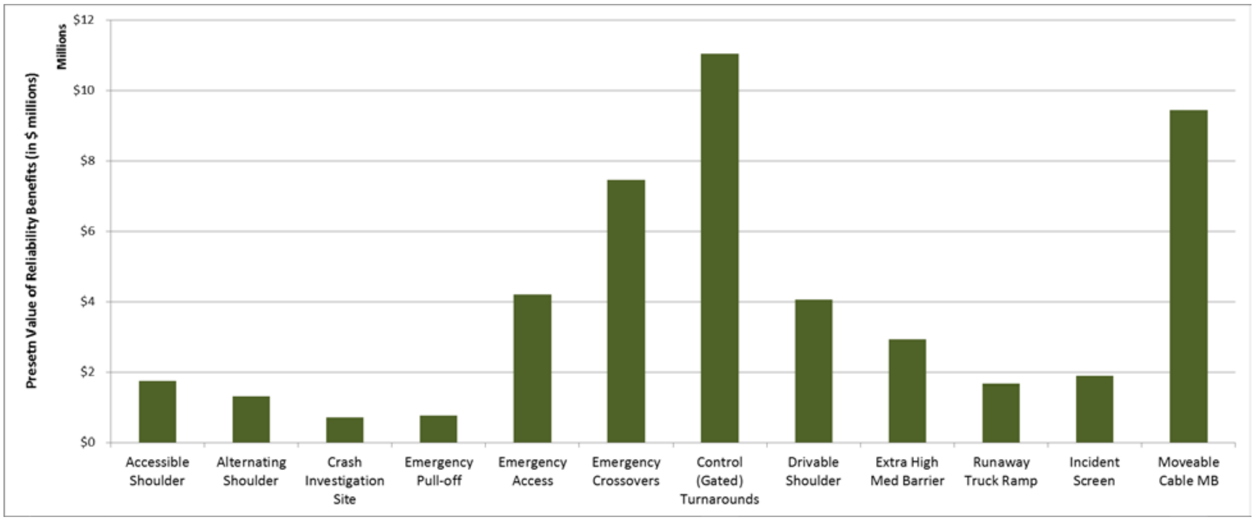


Figure 6.13. Present value of reliability benefits for L07 default design treatments on I-5.

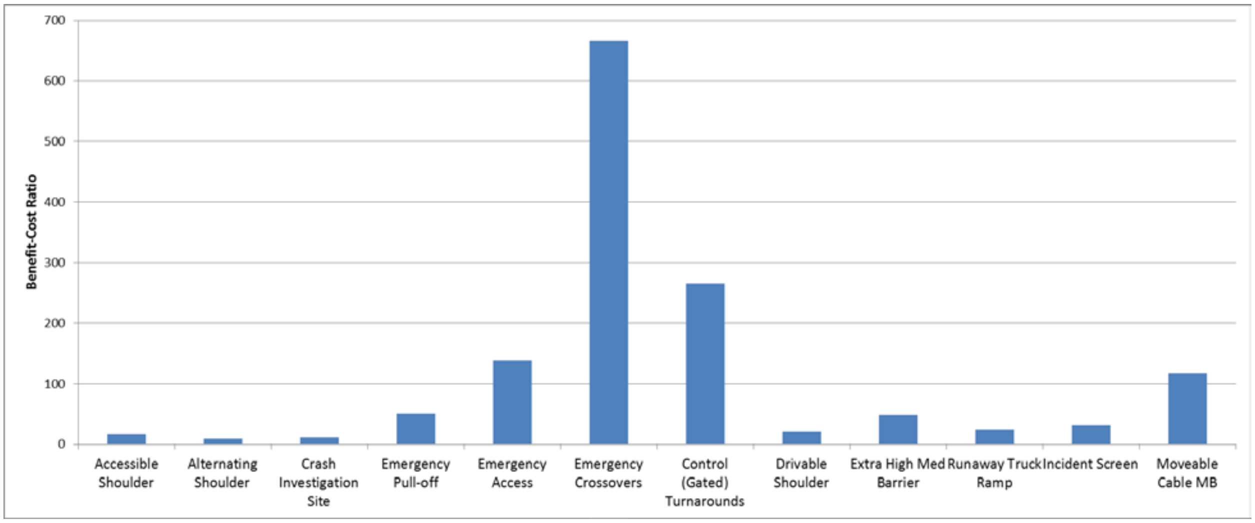
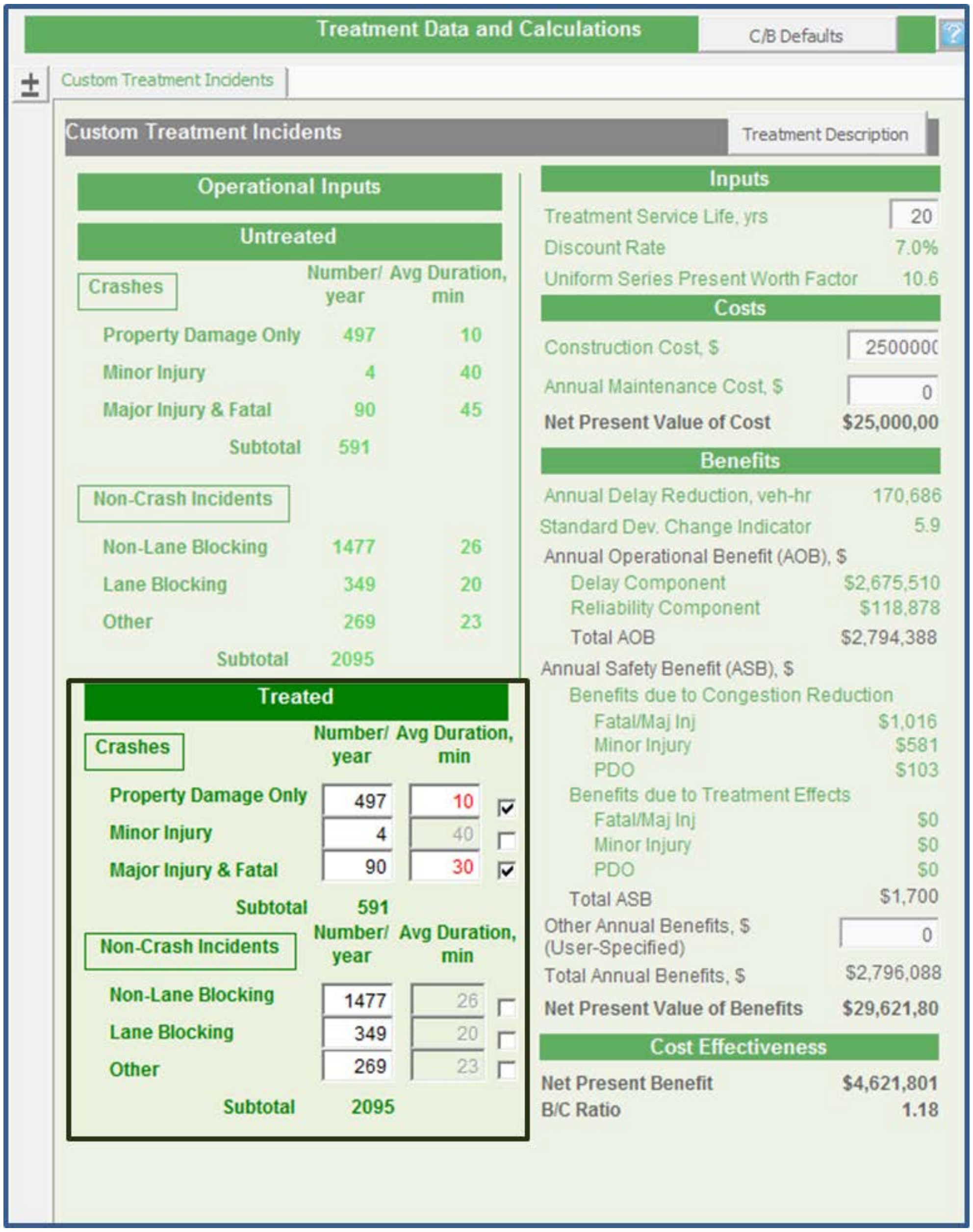


Figure 6.14. Benefit-cost ratios for L07 default design treatments on I-5 using model costs.

Incident Management Test

As with the C11 tool, the team used the L07 tool to test the effects of a reduction in incident duration that had been tested earlier in the I-5 CSMP (Caltrans 2012). This test assumes that enhanced incident management will reduce the average duration of a severe incident from 45 minutes to 30 minutes. As seen in Figure 6.15, the L07 tool provides a *Custom Treatment Incidents* module that allows for the input of average incident durations. Given that the CSMP scenario was intended to apply to severe collisions, the team applied the incident duration reduction to *Major Injury & Fatal* crashes only. A run was performed with average durations of 45 minutes for those types of crashes, and another run with durations of 30 minutes for the same types of crashes.



Custom Treatment Incidents

Operational Inputs

Untreated

Crashes	Number/ year	Avg Duration, min
Property Damage Only	497	10
Minor Injury	4	40
Major Injury & Fatal	90	45
Subtotal	591	

Non-Crash Incidents		
Non-Lane Blocking	1477	26
Lane Blocking	349	20
Other	269	23
Subtotal	2095	

Treated

Crashes	Number/ year	Avg Duration, min	
Property Damage Only	497	10	☑
Minor Injury	4	40	☐
Major Injury & Fatal	90	30	☑
Subtotal	591		

Non-Crash Incidents	Number/ year	Avg Duration, min	
Non-Lane Blocking	1477	26	☐
Lane Blocking	349	20	☐
Other	269	23	☐
Subtotal	2095		

Inputs	
Treatment Service Life, yrs	20
Discount Rate	7.0%
Uniform Series Present Worth Factor	10.6
Costs	
Construction Cost, $	250000C
Annual Maintenance Cost, $	0
Net Present Value of Cost	$25,000,00
Benefits	
Annual Delay Reduction, veh-hr	170,686
Standard Dev. Change Indicator	5.9
Annual Operational Benefit (AOB), $	
Delay Component	$2,675,510
Reliability Component	$118,878
Total AOB	$2,794,388
Annual Safety Benefit (ASB), $	
Benefits due to Congestion Reduction	
Fatal/Maj Inj	$1,016
Minor Injury	$581
PDO	$103
Benefits due to Treatment Effects	
Fatal/Maj Inj	$0
Minor Injury	$0
PDO	$0
Total ASB	$1,700
Other Annual Benefits, $ (User-Specified)	0
Total Annual Benefits, $	$2,796,088
Net Present Value of Benefits	$29,621,80
Cost Effectiveness	
Net Present Benefit	$4,621,801
B/C Ratio	1.18

Figure 6.15. Custom treatment incidents inputs for I-5 incident management test.

As seen in Figure 6.16, the L07 tool estimates that enhanced incident management results in improved reliability. When compared with the earlier results from the C11 tool (see Figure 5.12), the L07 tool appears to be less sensitive to incident reduction times than the C11 tool. As seen in Figure 6.17, the percent reduction in TTI was greatest during peak periods.

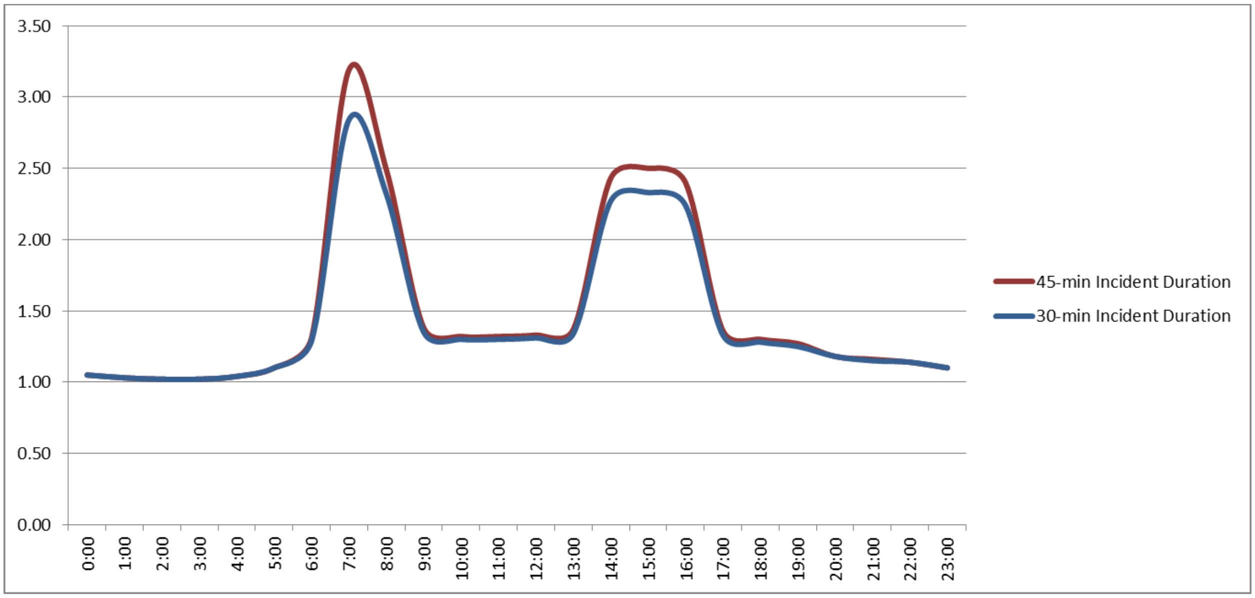


Figure 6.16. Mean TTIs on I-5 for incident management test.

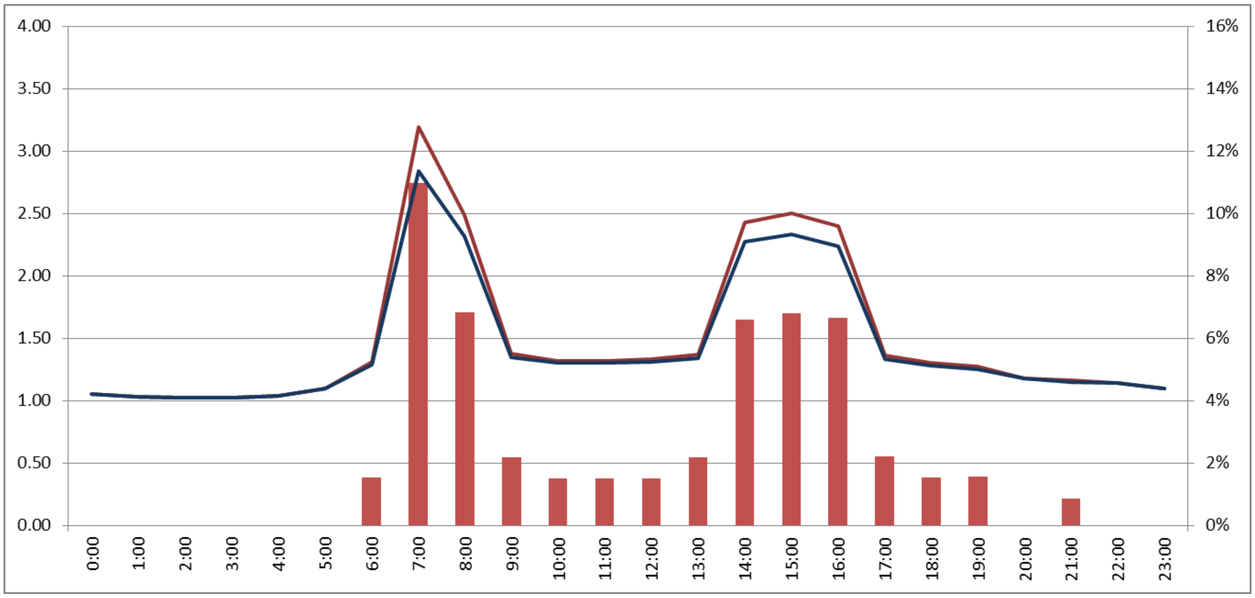
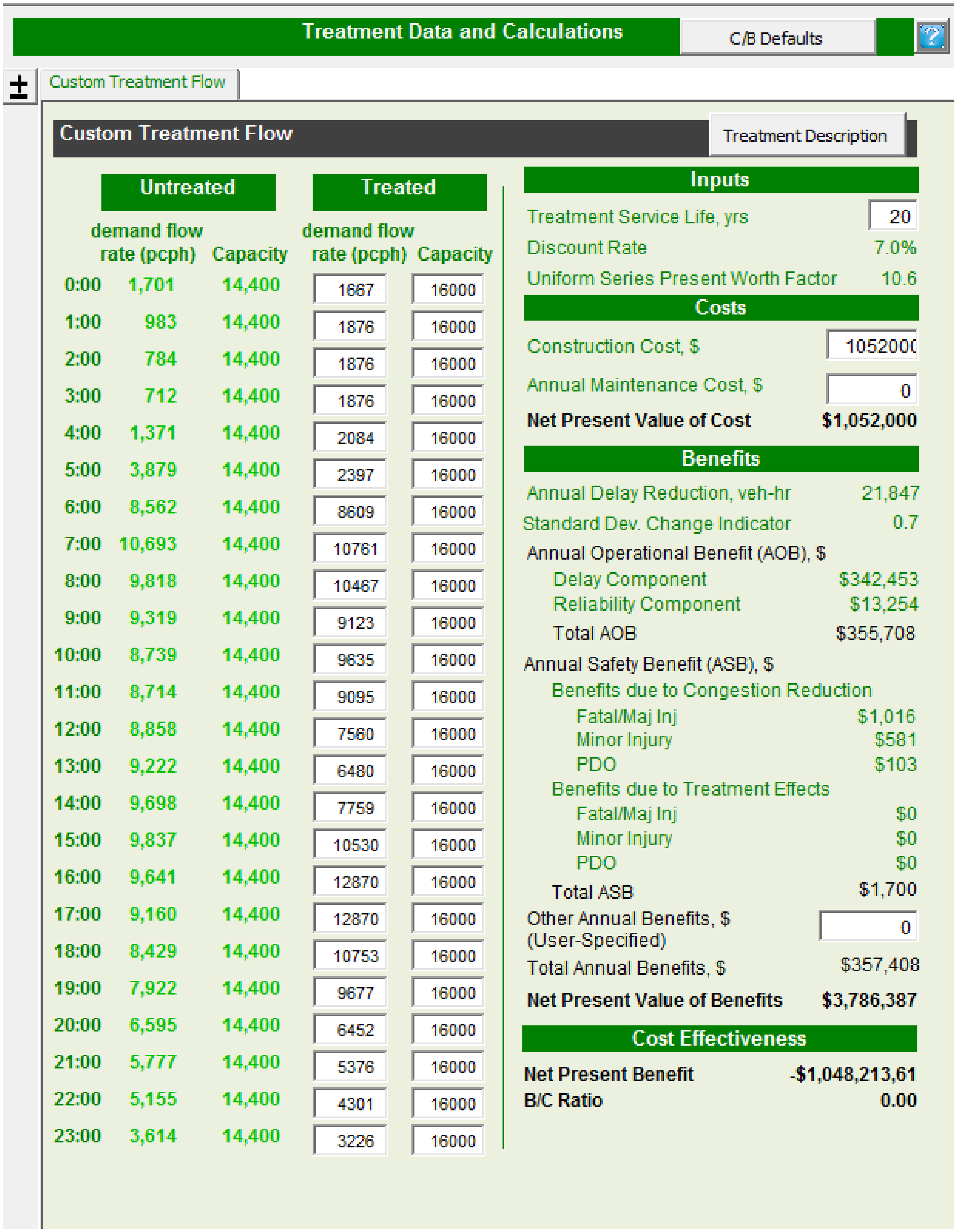


Figure 6.17. Comparison of mean TTI and percent reduction on I-5 for incident management test.

Capacity Adjustment Tests

The team also utilized the L07 tool's *Custom Treatment Flow* module to test several additional scenarios identified in the I-5 CSMP. Figure 6.18 shows the capacity adjustments for the high-occupancy vehicle plus GP widening projects.



	Untreated		Treated	
	demand flow rate (pcph)	Capacity	demand flow rate (pcph)	Capacity
0:00	1,701	14,400	1667	16000
1:00	983	14,400	1876	16000
2:00	784	14,400	1876	16000
3:00	712	14,400	1876	16000
4:00	1,371	14,400	2084	16000
5:00	3,879	14,400	2397	16000
6:00	8,562	14,400	8609	16000
7:00	10,693	14,400	10761	16000
8:00	9,818	14,400	10467	16000
9:00	9,319	14,400	9123	16000
10:00	8,739	14,400	9635	16000
11:00	8,714	14,400	9095	16000
12:00	8,858	14,400	7560	16000
13:00	9,222	14,400	6480	16000
14:00	9,698	14,400	7759	16000
15:00	9,837	14,400	10530	16000
16:00	9,641	14,400	12870	16000
17:00	9,160	14,400	12870	16000
18:00	8,429	14,400	10753	16000
19:00	7,922	14,400	9677	16000
20:00	6,595	14,400	6452	16000
21:00	5,777	14,400	5376	16000
22:00	5,155	14,400	4301	16000
23:00	3,614	14,400	3226	16000

Inputs	
Treatment Service Life, yrs	20
Discount Rate	7.0%
Uniform Series Present Worth Factor	10.6
Costs	
Construction Cost, $	1052000
Annual Maintenance Cost, $	0
Net Present Value of Cost	**$1,052,000**
Benefits	
Annual Delay Reduction, veh-hr	21,847
Standard Dev. Change Indicator	0.7
Annual Operational Benefit (AOB), $	
Delay Component	$342,453
Reliability Component	$13,254
Total AOB	$355,708
Annual Safety Benefit (ASB), $	
Benefits due to Congestion Reduction	
Fatal/Maj Inj	$1,016
Minor Injury	$581
PDO	$103
Benefits due to Treatment Effects	
Fatal/Maj Inj	$0
Minor Injury	$0
PDO	$0
Total ASB	$1,700
Other Annual Benefits, $ (User-Specified)	0
Total Annual Benefits, $	$357,408
Net Present Value of Benefits	**$3,786,387**
Cost Effectiveness	
Net Present Benefit	**-$1,048,213,61**
B/C Ratio	**0.00**

Figure 6.18. Custom treatment flow inputs for I-5 capacity adjustment tests.

6.5 Results of the I-210 Scenario Testing

To date, the team has tested various scenarios of the L07 tool utilizing the I-210 facility in an effort to better understand the tool's behavior:

- Split Segment Test (complete)
- Initial Treatment Tests (complete)
- Incident Duration Test (complete)
- Peak Capacity Tests (in progress)

Split Segment Test

As with the C11 tool, the L07 tool was run initially using the full 16-mile urbanized segment of the I-210 facility. Then it was run separately for two smaller segments to determine whether the tool would produce more accurate results with smaller segments. The study team used the same method for testing the smaller segments as it had in the C11 tool testing. As shown in Figure 6.19, the facility was split into segments according to the number of lanes in one direction of travel.

Figure 6.19. I-210 eastbound segmentation.

The reliability results of the full 16-mile urbanized segment of I-210 are shown in Figure 6.20. Note that the TTI curves in this figure differ from those founding in Figure 6.10 (Baseline Condition Estimation) since the baseline condition estimation was ultimately performed for the four-lane segment rather than for the full 16-mile facility.

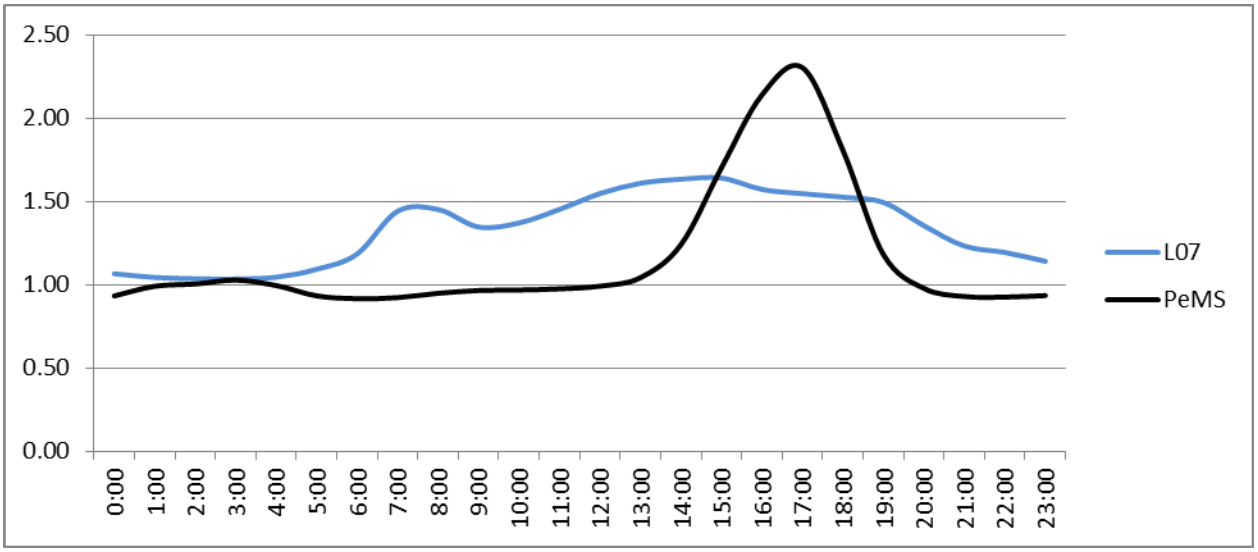


Figure 6.20. Mean TTI on the I-210 for full 16-mile segment.

Unlike the C11 tool, the L07 tool produced TTI results closer to PeMS data for the full 16-mile segment (Figure 6.20) than for the five-lane segment (Figure 6.21). The team attributed this in part to the five-lane segment being a short (5.3-mile) segment with non-standard traffic patterns due to the proximity of the I-210/SR-134 interchange as well as high demand both entering and exiting the freeway through the heart of the City of Pasadena.

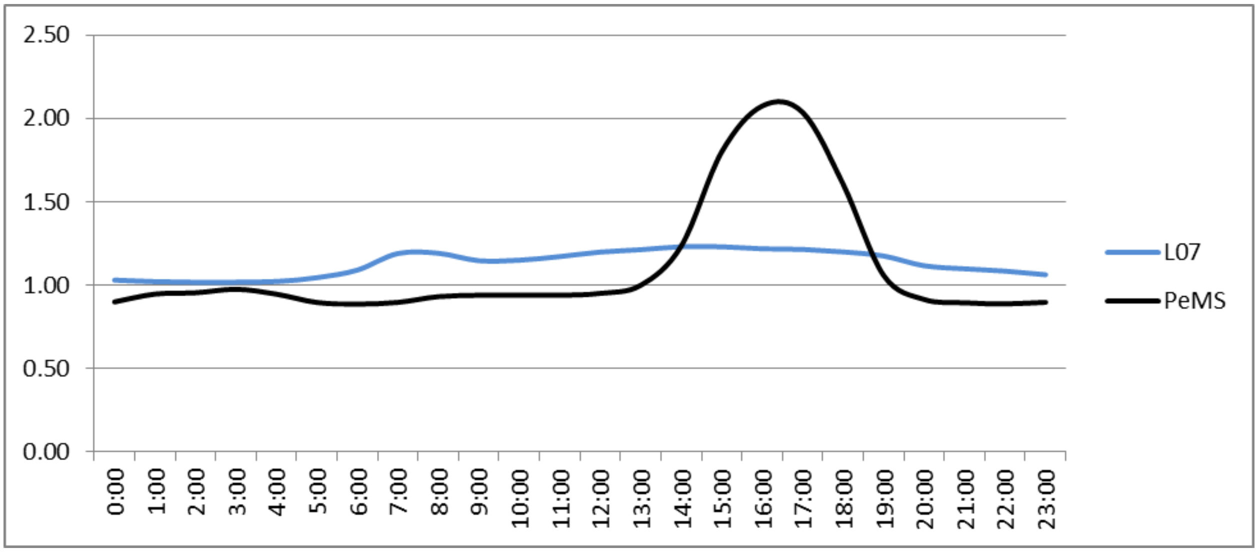


Figure 6.21. Mean TTI on the I-210 for 5.3-mile five-lane segment.

Results for the four-lane segment (Figure 6.22) were much closer to PeMS than either the original 16-mile or the five-lane segment (Figures 6.20 and 6.21). Given the relative quality of the four-lane segment's results, the team decided to perform all future tests using only the four-lane segment.

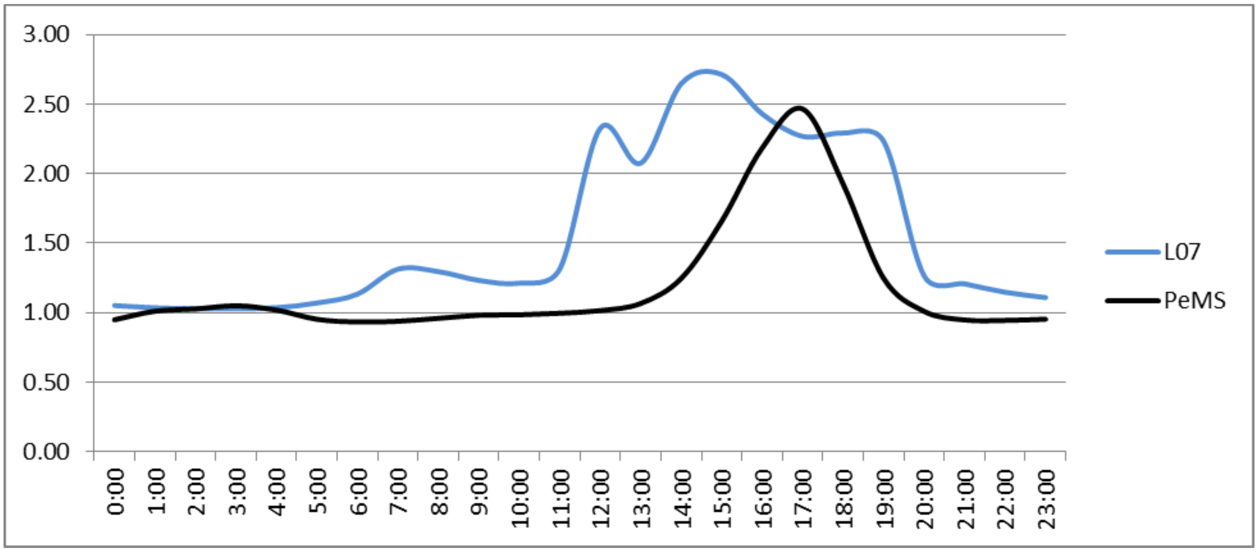


Figure 6.22. Mean TTI on the I-210 for 10.2-mile four-lane segment.

Initial Treatment Tests

The study team evaluated the applicability of the L07 tool's 19 available treatments for the I-210 facility. Four treatments (i.e., wildlife crash reduction, anti-icing systems, snow fence, and blowing sand) were deemed inapplicable. Initial runs were performed on each of the remaining 15 treatments using the tool's default input values. Figure 6.23 provides a summary of the results of these runs.

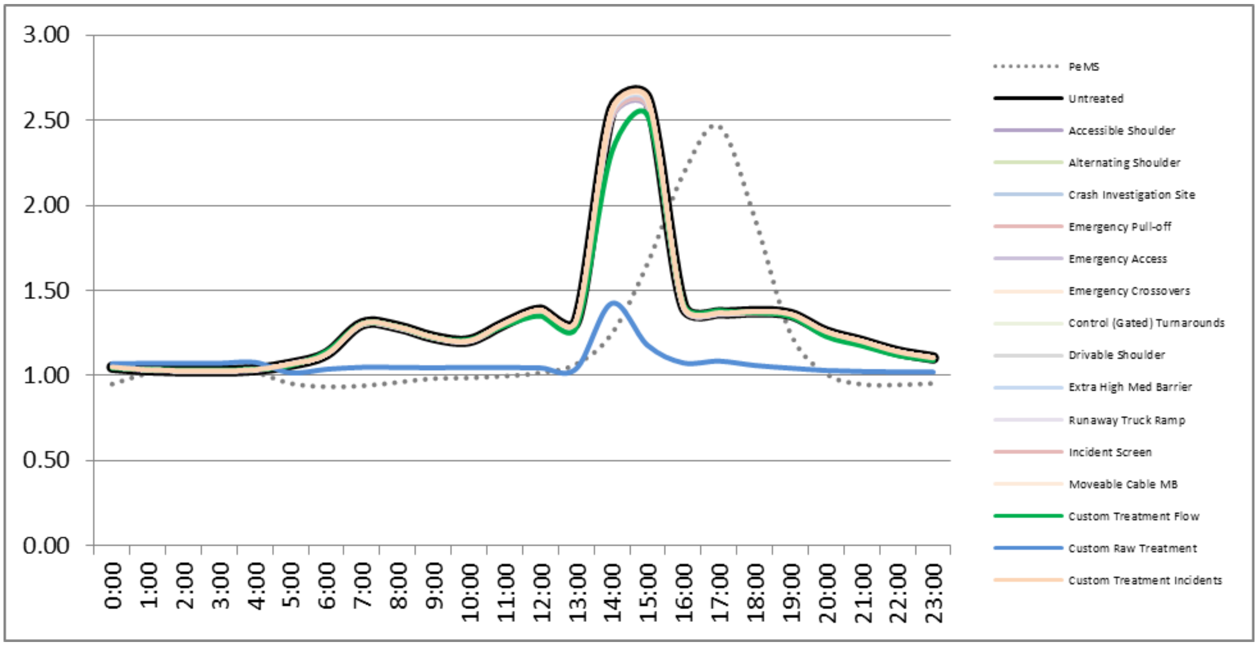


Figure 6.23. Summary TTI results of initial treatment tests on the I-210.

The tool appeared to provide little reliability benefit for most treatments, with the only real exception being *Custom Raw Treatment*. Given that these initial runs used the tool’s default input values, these results are intended merely to serve as a reference for future tests performed using any of these treatments. However, the relatively small impacts of these strategies on reliability suggest that the strategies or the inclusion of reliability benefits would not be very compelling to stakeholders.

Figure 6.24 summarizes the present value of reliability benefits on the I-210 facility of 12 default design treatments. The largest reliability benefits are due to accessible shoulders, alternating shoulders, crash investigation sites, and emergency pullovers. Using the default costs in the L07 tool for these design treatments results in the benefit-cost ratios shown in Figure 6.25. As with the I-5 facility, the tool generates unreasonably high benefit-cost ratios, with many above 50. The lowest benefit-cost ratio is for a drivable shoulder with a benefit-cost ratio of 3.0.

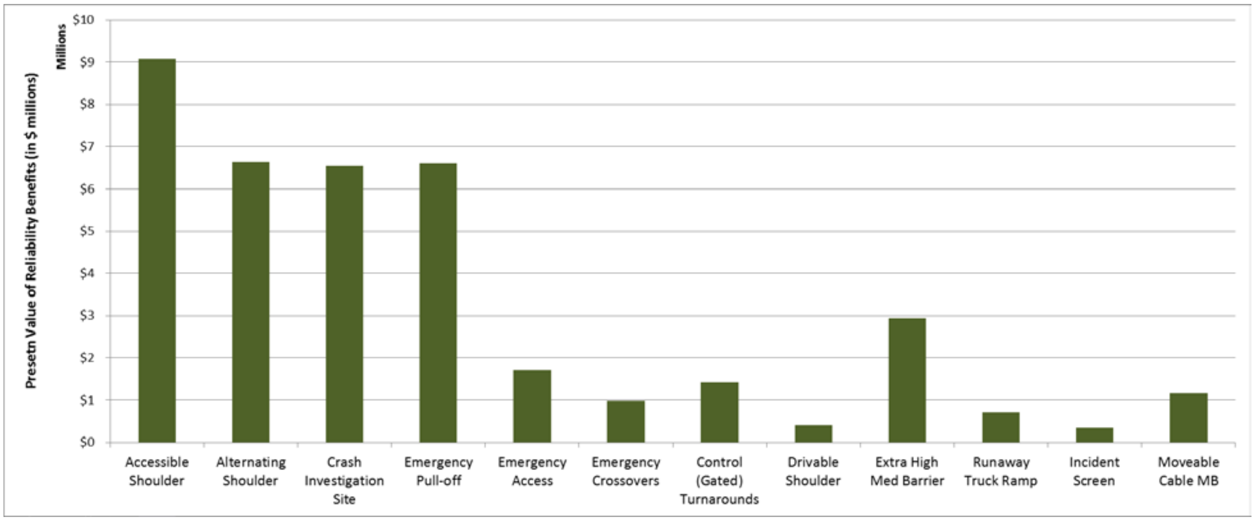


Figure 6.24. Present value of reliability benefits for L07 default design treatments on the I-210.

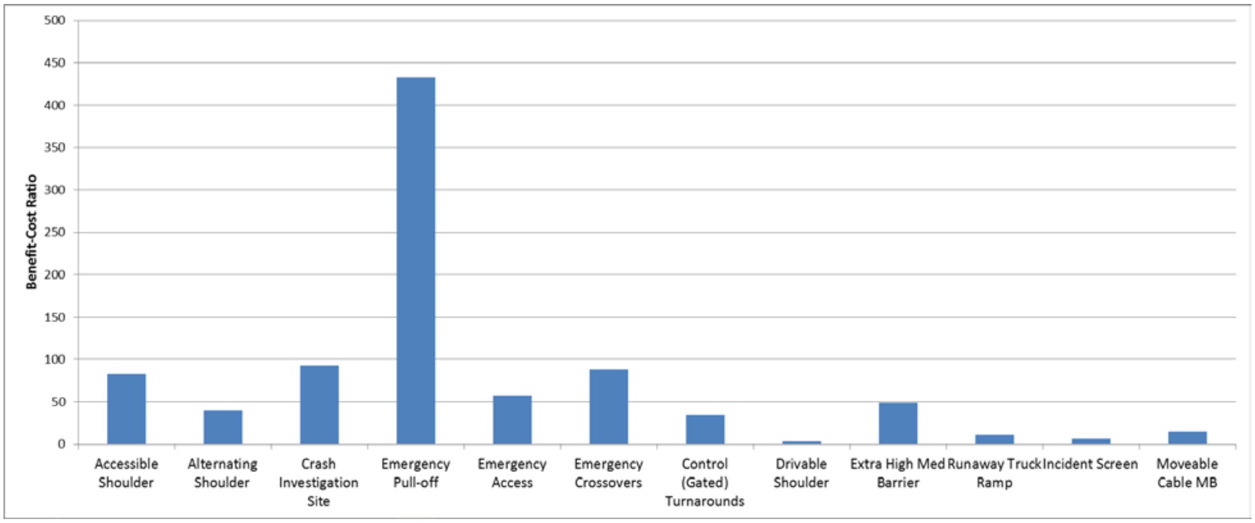
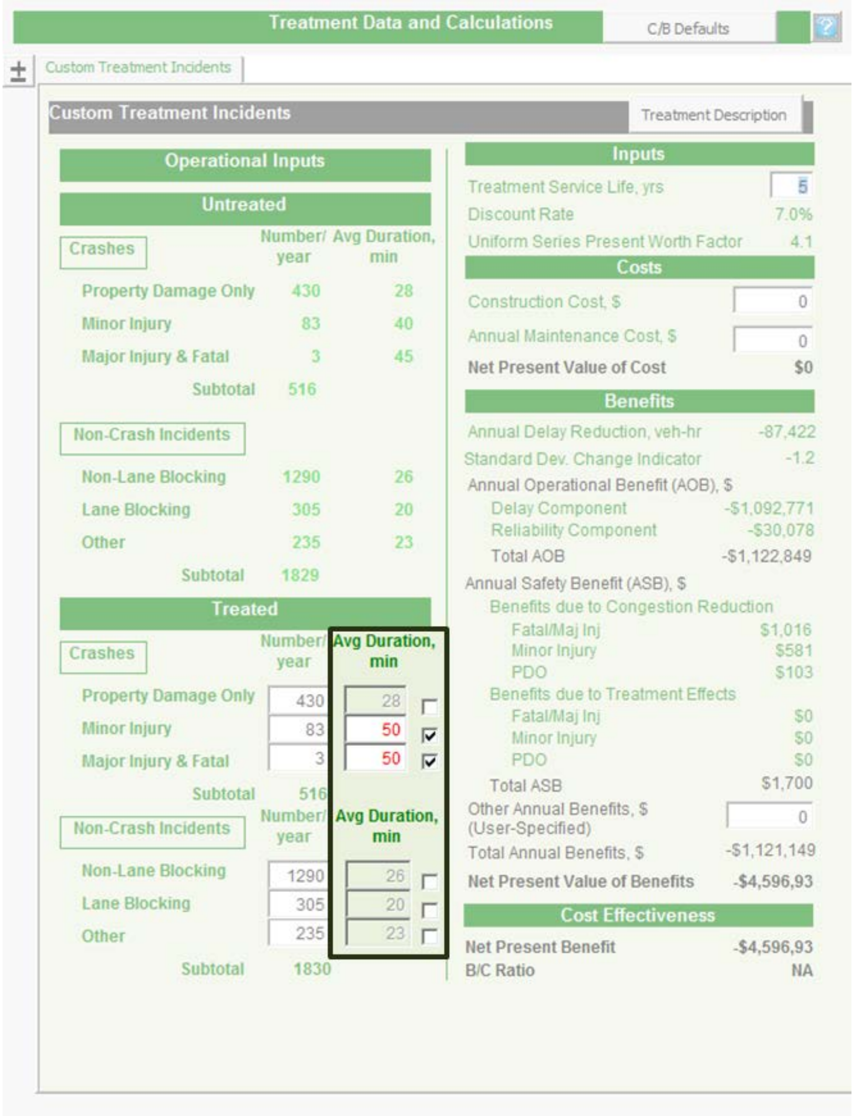


Figure 6.25. Benefit-cost ratios for L07 default design treatments on the I-210 using model costs.

Incident Duration Test

The study team also used the L07 tool to test the effects of using enhanced incident management to reduce the average duration of a severe incident from 50 minutes to 38 minutes (using the same assumptions as in I-210 CSMP). Since the CSMP scenario applied only to serious collisions, the team applied reductions to *Minor Injuries* and *Major Injury & Fatal* crashes (see Figure 6.26). Runs were performed with average durations of 50 minutes and 38 minutes for those types of crashes (SCAG and Caltrans 2010).



Custom Treatment Incidents

Operational Inputs

Untreated

Crashes	Number/ year	Avg Duration, min
Property Damage Only	430	28
Minor Injury	83	40
Major Injury & Fatal	3	45
Subtotal	516	

Non-Crash Incidents	Number/ year	Avg Duration, min
Non-Lane Blocking	1290	26
Lane Blocking	305	20
Other	235	23
Subtotal	1829	

Treated

Crashes	Number/ year	Avg Duration, min	
Property Damage Only	430	28	☐
Minor Injury	83	50	☑
Major Injury & Fatal	3	50	☑
Subtotal	516		

Non-Crash Incidents	Number/ year	Avg Duration, min	
Non-Lane Blocking	1290	26	☐
Lane Blocking	305	20	☐
Other	235	23	☐
Subtotal	1830		

Inputs	
Treatment Service Life, yrs	5
Discount Rate	7.0%
Uniform Series Present Worth Factor	4.1
Costs	
Construction Cost, $	0
Annual Maintenance Cost, $	0
Net Present Value of Cost	**$0**
Benefits	
Annual Delay Reduction, veh-hr	-87,422
Standard Dev. Change Indicator	-1.2
Annual Operational Benefit (AOB), $	
Delay Component	-$1,092,771
Reliability Component	-$30,078
Total AOB	-$1,122,849
Annual Safety Benefit (ASB), $	
Benefits due to Congestion Reduction	
Fatal/Maj Inj	$1,016
Minor Injury	$581
PDO	$103
Benefits due to Treatment Effects	
Fatal/Maj Inj	$0
Minor Injury	$0
PDO	$0
Total ASB	$1,700
Other Annual Benefits, $ (User-Specified)	0
Total Annual Benefits, $	-$1,121,149
Net Present Value of Benefits	**-$4,596,93**
Cost Effectiveness	
Net Present Benefit	**-$4,596,93**
B/C Ratio	**NA**

Figure 6.26. Custom treatment incidents inputs for I-210 incident duration test.

As seen in Figure 6.27, reducing incident durations results in a similarly shaped TTI curve with slightly lower TTI during the p.m. peak. Based on these results, the L07 tool appears to be less sensitive to incident reduction times than the C11 tool (see Figure 5.29).

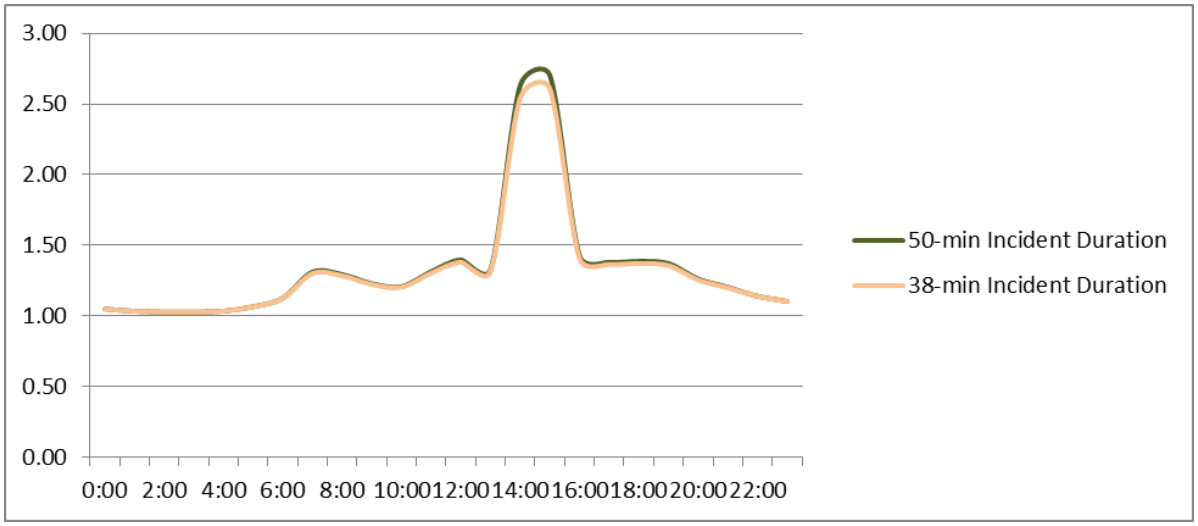


Figure 6.27. Mean TTIs on the I-210 for incident duration test.

As seen in Figure 6.28, the greatest percent reductions occurred when the initial TTIs were high.

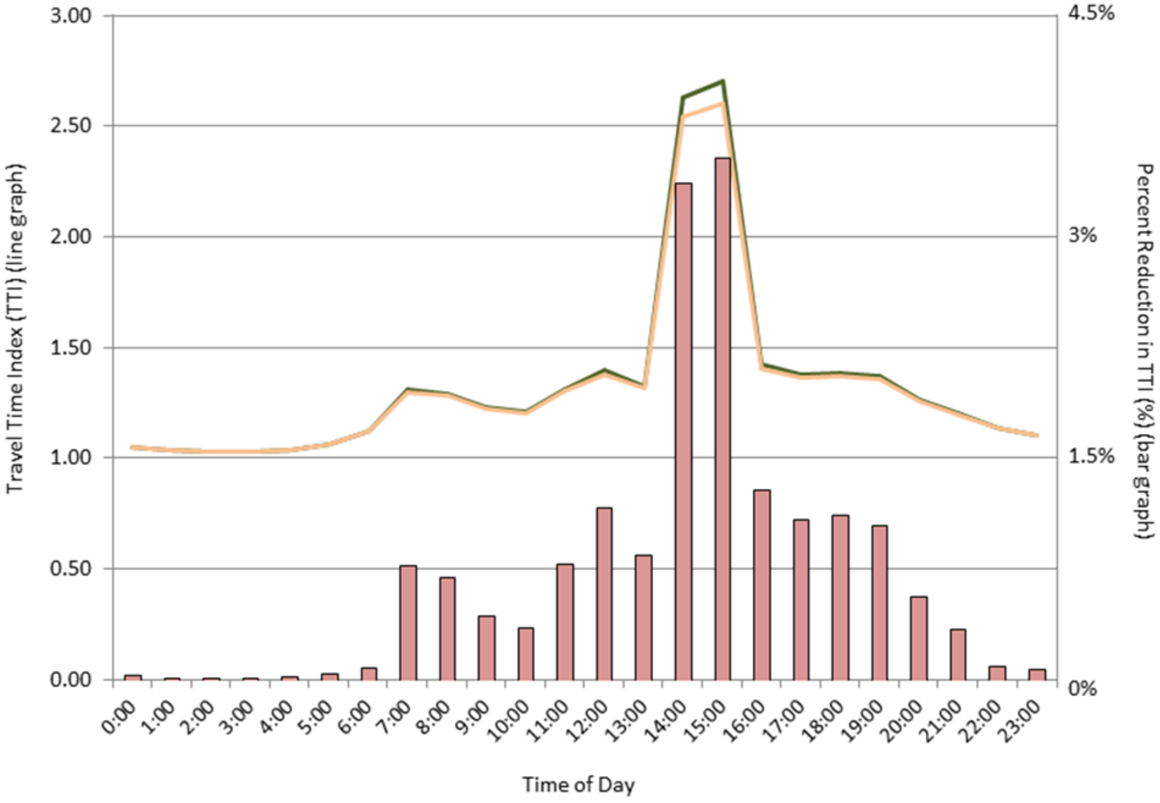
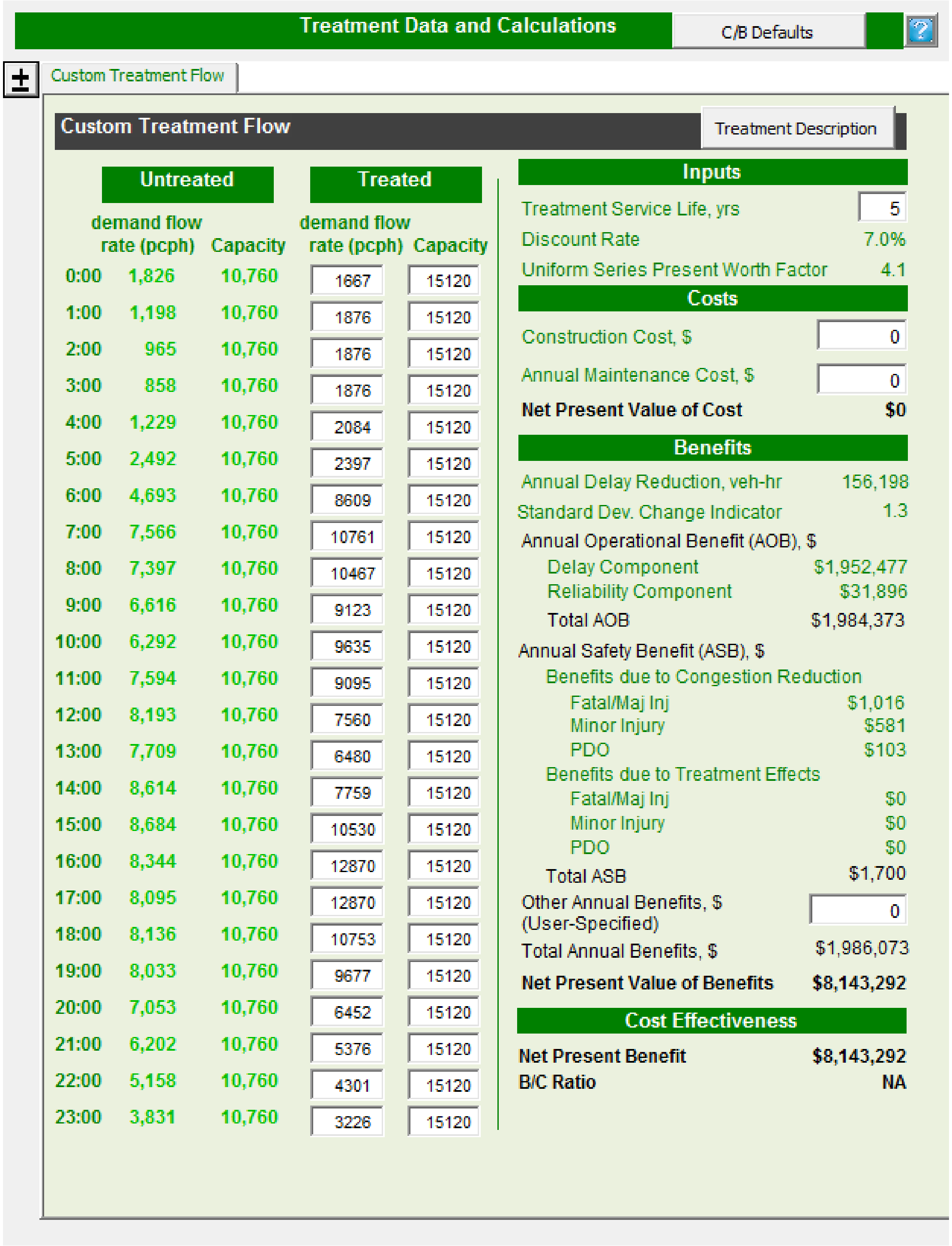


Figure 6.28. Comparison of mean TTI and percent reduction on the I-210 for incident duration test.

Capacity Adjustment Tests

As with the C11 tool, the study team also tested additional scenarios identified in the I-210 CSMP (SCAG and Caltrans 2010) by using the L07 tool's *Custom Treatment Flow* module (Figure 6.29). The results of these tests are shown in Figures 6.30 to 6.34. These tests show much smaller improvements than the comparable ones conducted using the C11 tool (see Figures 5.32 to 5.36). As a result of this analysis, the study team decided to use the C11 tool for the benefit-cost analysis shown in Chapter 9.



	Untreated		Treated	
	demand flow rate (pcph)	Capacity	demand flow rate (pcph)	Capacity
0:00	1,826	10,760	1667	15120
1:00	1,198	10,760	1876	15120
2:00	965	10,760	1876	15120
3:00	858	10,760	1876	15120
4:00	1,229	10,760	2084	15120
5:00	2,492	10,760	2397	15120
6:00	4,693	10,760	8609	15120
7:00	7,566	10,760	10761	15120
8:00	7,397	10,760	10467	15120
9:00	6,616	10,760	9123	15120
10:00	6,292	10,760	9635	15120
11:00	7,594	10,760	9095	15120
12:00	8,193	10,760	7560	15120
13:00	7,709	10,760	6480	15120
14:00	8,614	10,760	7759	15120
15:00	8,684	10,760	10530	15120
16:00	8,344	10,760	12870	15120
17:00	8,095	10,760	12870	15120
18:00	8,136	10,760	10753	15120
19:00	8,033	10,760	9677	15120
20:00	7,053	10,760	6452	15120
21:00	6,202	10,760	5376	15120
22:00	5,158	10,760	4301	15120
23:00	3,831	10,760	3226	15120

Inputs	
Treatment Service Life, yrs	5
Discount Rate	7.0%
Uniform Series Present Worth Factor	4.1
Costs	
Construction Cost, $	0
Annual Maintenance Cost, $	0
Net Present Value of Cost	**$0**
Benefits	
Annual Delay Reduction, veh-hr	156,198
Standard Dev. Change Indicator	1.3
Annual Operational Benefit (AOB), $	
Delay Component	$1,952,477
Reliability Component	$31,896
Total AOB	$1,984,373
Annual Safety Benefit (ASB), $	
Benefits due to Congestion Reduction	
Fatal/Maj Inj	$1,016
Minor Injury	$581
PDO	$103
Benefits due to Treatment Effects	
Fatal/Maj Inj	$0
Minor Injury	$0
PDO	$0
Total ASB	$1,700
Other Annual Benefits, $ (User-Specified)	0
Total Annual Benefits, $	$1,986,073
Net Present Value of Benefits	**$8,143,292**
Cost Effectiveness	
Net Present Benefit	**$8,143,292**
B/C Ratio	**NA**

Figure 6.29. Custom treatment flow inputs for I-210 capacity adjustment tests.

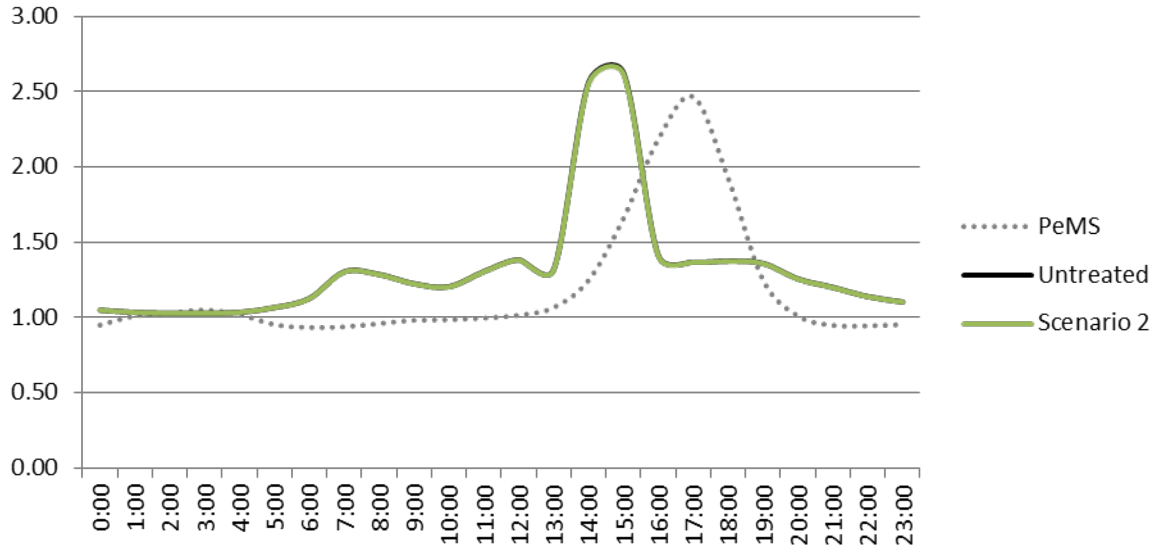


Figure 6.30. Mean TTI on the I-210 for ramp metering test (scenarios 1 and 2).

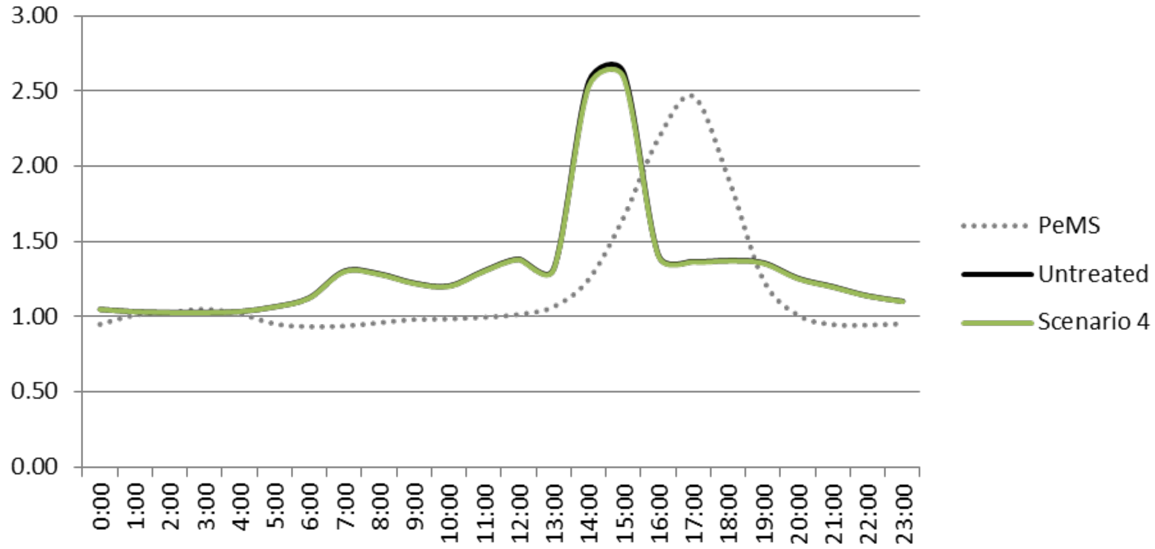


Figure 6.31. Mean TTI on the I-210 for advanced ramp metering test (Scenarios 3 and 4).

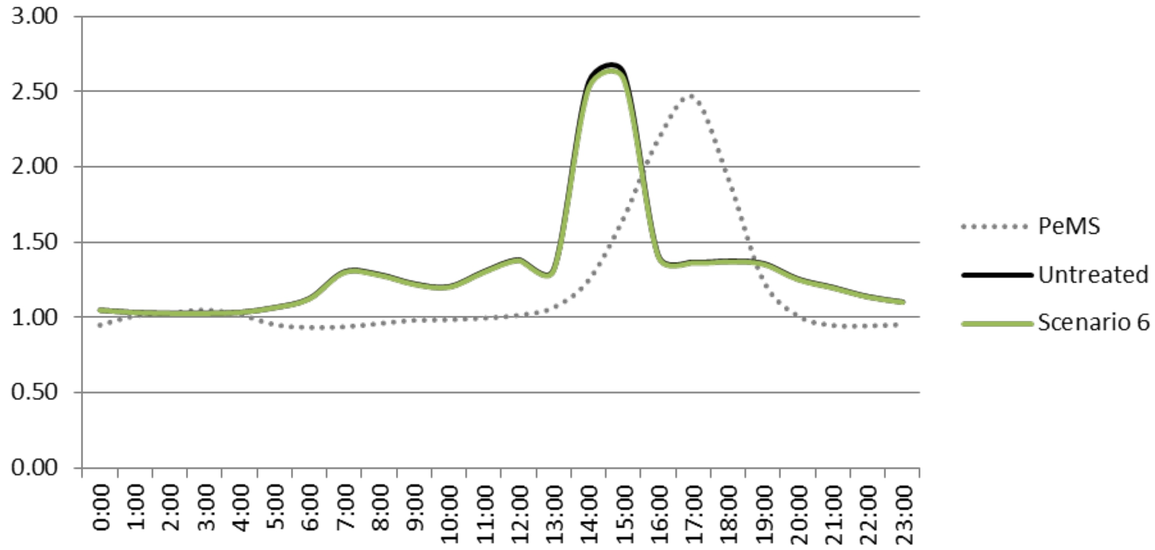


Figure 6.32. Mean TTI on the I-210 for auxiliary lane test (Scenarios 5 and 6).

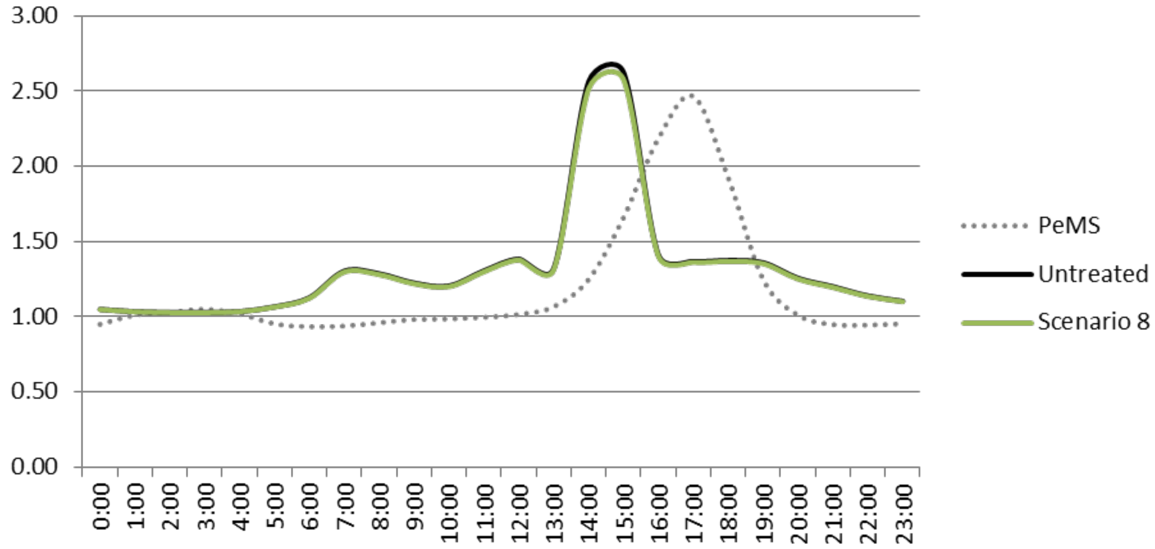


Figure 6.33. Mean TTI on the I-210 for ramp closure test (Scenarios 7 and 8).

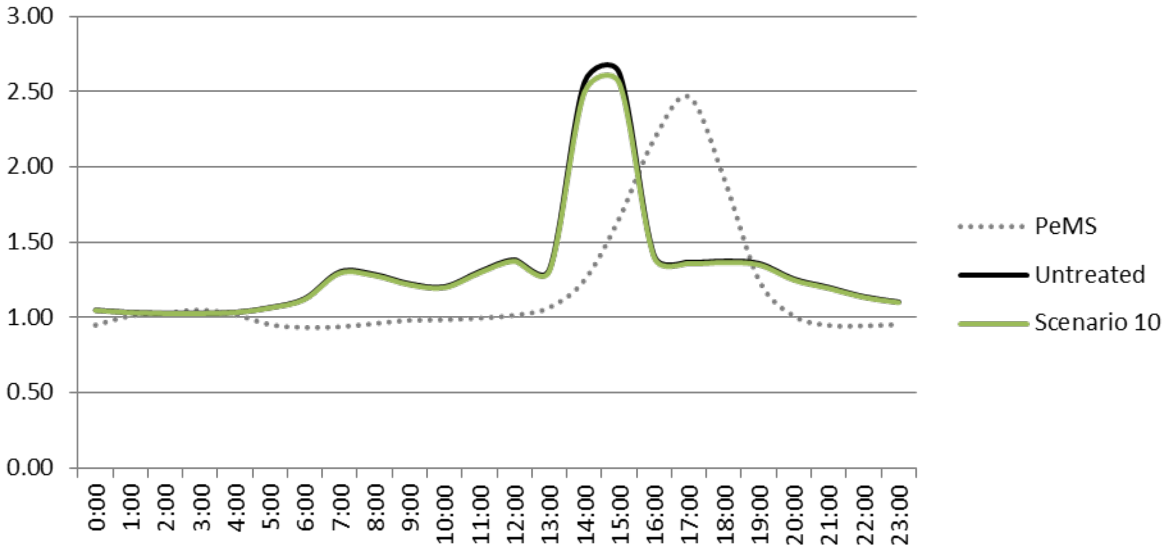


Figure 6.34. Mean TTI on the I-210 for on-ramp and auxiliary lane test (Scenarios 9 and 10).

CHAPTER 7
L08: FREEVAL-RL

7.1 Overview of FREEVAL-RL

The L08 product, FREEVAL-RL, is a much more complicated tool than either the C11 Reliability Analysis Tool or the L07 Analysis Tool. The FREEVAL-RL tool is based upon the FREEVAL model, which implements the freeway modeling methodologies founding the 2010 *Highway Capacity Manual* (HCM). The FREEVAL-RL version of FREEVAL enables the user to test the reliability impacts of projects by dynamically modeling multiple operating scenarios along the facility using a Monte Carlo–type strategy. Under this strategy, a scenario generator reruns a seed file multiple times to simulate different days along the facility.

Since FREEVAL-RL is a more complicated tool, it has the potential to model reliability on a facility more accurately. The tool requires the user to designate and define several highway segments along the facility. This allows the tool to match the traffic impact in each segment and traffic queuing to spread from one segment to the rest. The study team found that this level of detail requires significantly more time to calibrate than the other SHRP 2 reliability tools. The calibration process is roughly comparable to that of a microsimulation model in terms of time and technical knowledge required.

7.2 Limitations of FREEVAL-RL

Based on its testing of the FREEVAL-RL and communication with the tool developer, the study team found some limitations with the tool. These limitations are described in more detail below. In addition, the study team provides suggestions on how to address these limitations and improve the tool for implementation.

Inefficiency of Data Inputs

The FREEVAL-RL tool requires the user to enter various input data (including geometry data, segment type data, and demand flow data) cell by cell. This data entry method is slow and time-consuming. It is also easy for the user to make mistakes. Preferred methods are to allow the user to copy and paste data or allow the user to import the network geometry and demand flows stored in an Excel or text file.

Segment Types and Study Period Time Cannot Be Changed

Once the user creates a seed file, the study network and its study periods are configured and cannot be changed. This creates a number of limitations in the use of FREEVAL-RL for testing the reliability impacts of alternative strategies or projects:

- The user may want to increase or decrease the number of segments for an existing FREEVAL-RL model. This is particularly common as the seed file is generated and the user tries to calibrate the seed file to baseline facility conditions. Currently, the user must re-input all data if the number of segments in the facility modeled is changed.

- The user may want to model both a.m. and p.m. periods, which may include different numbers of hours. If the user already has an a.m. model, it is tempting to base the p.m. model on the already coded a.m. model. However, the current version of FREEVAL-RL requires the user to create an entirely new model (i.e., the seed file) and re-enter all input data for the p.m. period.

It would be more efficient to allow the user to edit the number of time intervals and the number of segments in the program. Such a change would support seed file calibration and alternatives testing.

Maximum Number of Lanes

FREEVAL-RL allows the user to define a mainline segment with one to six lanes in one direction. In addition, the maximum number of on-ramp and off-ramp lanes is limited to two lanes. Southern California freeways frequently have segments with more than six lanes in one direction as well as on-ramp or freeway-to-freeway connectors with more than two lanes. The study team understands that the FREEVAL-RL analytics are based on HCM 2010 and the tool shares its limitations, but extrapolating the methodologies and allowing the user to enter more lanes is essential for FREEVAL-RL to fit the real-world geometries found in Southern California.

Through a detailed analysis of the FREEVAL-RL seed file results and trial and error, the study team found that the user can paste higher numbers (e.g., seven lanes for a freeway mainline segment and three for an on-ramp or off-ramp segment) in the file. FREEVAL-RL is able to use a higher capacity for a freeway mainline segment with more than six lanes. So it is possible to trick the model for these wider highway segments.

However, the tool is not able to model the demands for a three-lane on-ramp despite the ability to paste three lanes in the highway segment definition. The study team found that a workaround is to model a short two-lane on-ramp segment followed by a second one-lane on-ramp segment. Given the prior limitation in changing the segment types, the study team had to re-enter the seed file data multiple times to find the appropriate workaround.

FREEVAL-RL should be modified or the user guide (ITRE 2013) updated to document these model limitations or workarounds.

Model Freeway Connectors

FREEVAL-RL is not able to serve the demands from a three-lane freeway-to-freeway connector with high flow. The study team found that a workaround is to model a short two-lane on-ramp segment followed by another one-lane on-ramp segment.

No Network Geometry Viewer and Audit Tool

It is easy to make mistakes when entering network geometries, particularly for large networks. FREEVAL-RL does not provide a graphical tool that can assist users in visualizing the results of segment coding. For example, the study team found that the wrong number of lanes had been entered for a highway segment after working on a model for several months.

The team suggests developing a simple computer-aided design (CAD) map, such as the one found in FREQ, to show the number of lanes and other geometry data after the user inputs the geometry data. It will help the user develop models efficiently and help reviewers check the accuracy of models.

In addition, the ability to associate highway postmiles with segment limits in FREEVAL-RL would help with auditing FREEVAL-RL coding and results.

High-Occupancy Vehicle Lane or Managed Lane

In California, high-occupancy vehicle lanes can be configured as either continuous-access or limited-access. The continuous-access configuration allows drivers to enter high-occupancy vehicle lanes at any time. The limited-access configuration limits high-occupancy vehicle ingress and egress to designated points spaced every few interchanges. Southern California freeways use the limited-access configuration exclusively, and nearly every freeway in Southern California has high-occupancy vehicle lanes. This means that to model improvements in Southern California, FREEVAL-RL must be able to handle the weaving and merging associated with limited-access high-occupancy vehicle lanes.

In addition, PeMS data show that high-occupancy vehicle lanes typically have lower maximum throughput or capacity than other mainline freeway lanes do. According to the developer, FREEVAL-RL does not support any type of managed lane facility. As a result, one of the great challenges in using FREEVAL-RL for Southern California freeways is to find a way to model the limited-access high-occupancy vehicle lanes found in the region.

The study team found an imperfect solution to modeling freeways with limited-access high-occupancy vehicle lanes after many months of trial and error. The solution is to ignore the travel conditions on the high-occupancy vehicle lanes and focus solely on the weaving and merging on the mainline freeway. The high-occupancy vehicle ingress/egress area is treated as a weaving segment with only the general-purpose (GP) lanes on the segment. Then, the weaving flows are estimated manually using rules of thumb (since these are rarely available from observed flows). The weaving from high-occupancy vehicle lanes to GP lanes is treated as an on-ramp flow, while the weaving from GP lanes to high-occupancy vehicle lanes is treated as an off-ramp flow. In addition, the traffic continuing on the high-occupancy vehicle lanes is treated as a ramp-to-ramp flow and set to a very low positive value. This ensures that the scenario generation does not result in negative flows.

The study team arrived at this solution with the help of the FREEVAL-RL developers after running into problems with two other approaches to modeling high-occupancy vehicle lanes:

- The study team initially treated the high-occupancy vehicle ingress/egress segment as a standard weaving segment with a lane added to the adjacent GP lanes. This solution required estimating the weaving flow for the segment. Yet the scenario testing still failed with zero densities for some segments and unreasonable results for others. According to the developer, this was because the ramp-to-ramp flow (i.e., high-occupancy vehicle to high-occupancy vehicle flow for the high-occupancy vehicle ingress/egress segment) cannot be too high in FREEVAL-RL. However, for most high-occupancy vehicle ingress/egress segments on the test facilities (and for most freeways in the real world), the majority of the high-occupancy vehicle lane flow will continue on the high-occupancy vehicle lane rather than merging at the access point.
- The study team then coded the high-occupancy vehicle ingress/egress segment as a weaving segment with the same number of lanes as the GP lanes at the location with zero ramp-to-ramp flow. However, the team found that there was a slight chance that the scenario testing would lead to zero densities for some segments and unreasonable results in scenario runs. According to the developer, the team needed to avoid having zero ramp-to-ramp flow. This was fixed by assuming a slightly positive ramp-to-ramp flow.

Even with the final solution adopted by the study team, the weaving segment function in FREEVAL-RL needs to be improved to deal with the various cases that may arise without crashing the program. In the longer term, the model would benefit from having an algorithm that handles limited-access high-occupancy vehicle lanes or managed lanes. Solving this problem will not only make the model more usable for Southern California, but also accommodate the growing interest in managed lanes across the nation.

Weaving Segment and Volume Input

When the study team ran a seed file, a weaving dialog box (called the “Weaving Volume Calculator”) would appear after clicking on the “Run the Seed File/Go to the Main Menu” button. The team had to define the parameters for every weaving segment manually and adjust the weaving volumes for each interval. A more frustrating constraint was that the weaving segment inputs could not be saved for future use. This meant that reruns required recalculating and re-inputting the weaving volumes. Again, since most Southern California freeways have limited-access high-occupancy vehicle lanes, the weaving dialog box is critical to modeling Southern California facilities.

The study team found this procedure to be very time-consuming and inefficient. If a weaving segment for a single time interval needed to be modified, the team had to re-enter all weaving data from the beginning. This procedure would be much more efficient if the weaving segment data could be entered, saved, and modified (perhaps through external spreadsheet files or in the initial seed file). Another innovation would be to allow the user to say “yes to all” when allowing FREEVAL-RL to use the calculated weaving volumes (rather than forcing the user to review the weaving volume for every segment along the facility).

High Default Capacity

Through extensive calibration testing, the study team found that the default capacity value in FREEVAL-RL was too high for the tested facility. This capacity can be modified through adjustments to the capacity adjustment factor (CAF) until the capacities calibrate to real-world traffic flows. The study team used PeMS data to perform this calibration. However, detection errors may result in a biased CAF estimate. As a result, the study team spent an extended effort on obtaining and processing sensor data from PeMS to estimate CAFs. The team further adjusted the estimated CAFs to achieve relatively reasonable results. Through this process, the team found the CAFs need to be adjusted for all segments. This suggests that the procedures used in FREEVAL-RL (and the HCM 2010) may overestimate capacity.

Although the CAF procedure appears to be the correct fix, the study team found that after adjusting CAFs in the seed file, they were overwritten by the FREEVAL-RL engine and replaced with the default values (i.e., CAF = 1.0) during scenario testing. The study team has reported this problem to the developer, who has confirmed that it is a bug that will be fixed.

Unexpected Results by Revising Result File

There are two ways to generate a result file. The first is to run a seed file. The second is to modify an existing result file. Revising a result file would be a useful approach to implementing some of the workarounds described above. However, the study team found that the output from revising a result file was unpredictable and could produce different outputs than running the seed file, even if the inputs were the same. This is a potential programming error. To avoid this issue, the study team had to output results from the seed file. This was very time-consuming because the team had to go through the “Weaving Volume Calculator” procedure each time.

Speed Contour Map

The study team found the three-dimensional speed contour maps produced automatically in FREEVAL-RL hard to read. As a result, the team reviewed the values in the speed tab manually and generated speed contour maps externally using its own tools. The speed contour maps presented in this chapter were generated using these external tools.

Ramp Merging Model

The on-ramp flow for mainline segments in congestion may not be fully served because HCM 2010 gives the mainline flow a higher priority than the on-ramp flow. The study team found through its testing that the FREEVAL-RL model does not allow the vehicles on the ramp to merge to the freeway mainline if the mainline is congested and the on-ramp flow is high. As a result, not all of the on-ramp vehicles can be served, and the queues on the mainline were shorter than those found in real-world conditions. The ramp merging module (or the HCM 2010 algorithms) need to be adjusted to acknowledge the equal priority given to both mainline vehicles and merging vehicles.

Inability to Reflect Capacity Drop

FREEVAL-RL does not have the ability to model capacity drop, which is a traffic flow characteristic observed from real-world point detector data. The study team found that the traffic flow performance is different when a queue is built up and when a queue is dissipated. Higher capacity is normally achieved when the queue is built up. Figure 7.1 shows a volume-occupancy plot based on data collected from a few days. Each data point is shown as a dot with different colors in the plot. The color theme is shown on the right. The figure clearly shows that at a certain occupancy level, the data points with higher volumes are collected in the early morning when the queue or congestion is forming. The data points with lower volumes are collected in the late morning when the queue or congestion is dissipating.

FREEVAL-RL only allows users to provide a certain capacity value throughout the study period. Thus, the user may need to calibrate the model to have a relatively lower capacity in order to replicate the congestion period. Otherwise, the congestion will not remain as long as it should.

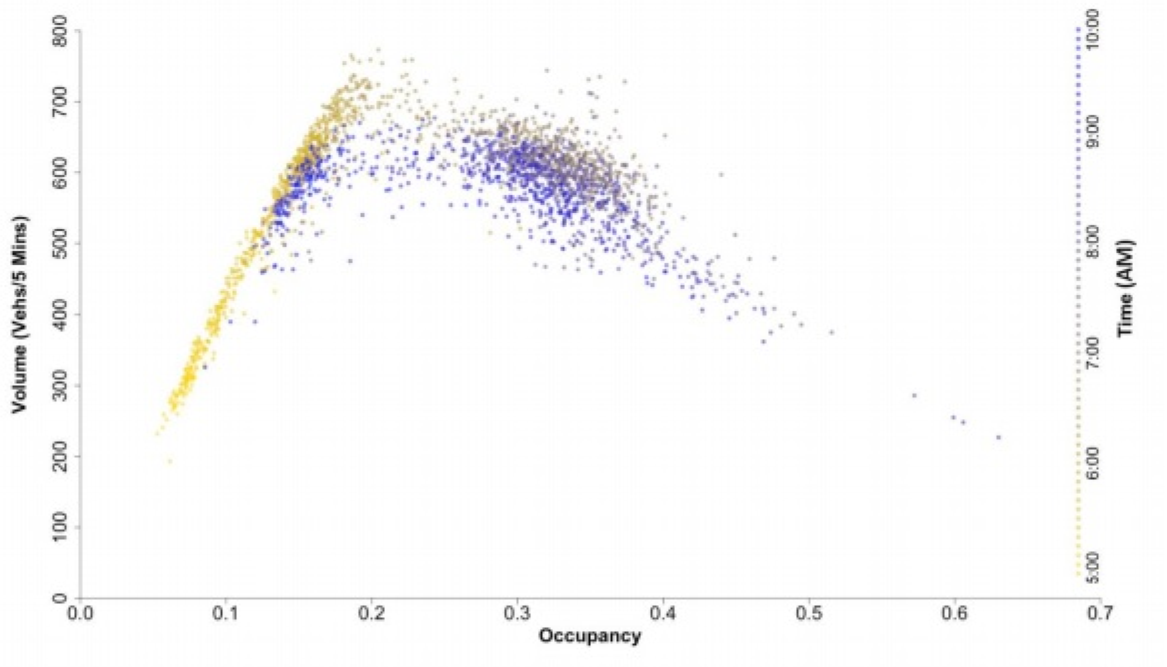


Figure 7.1. Capacity drop.

Documentation, Manuals, and Examples

The study team reviewed the FREEVAL-RL documentation (ITRE 2013) extensively during its model testing. The team offers the following observations about the model documentation:

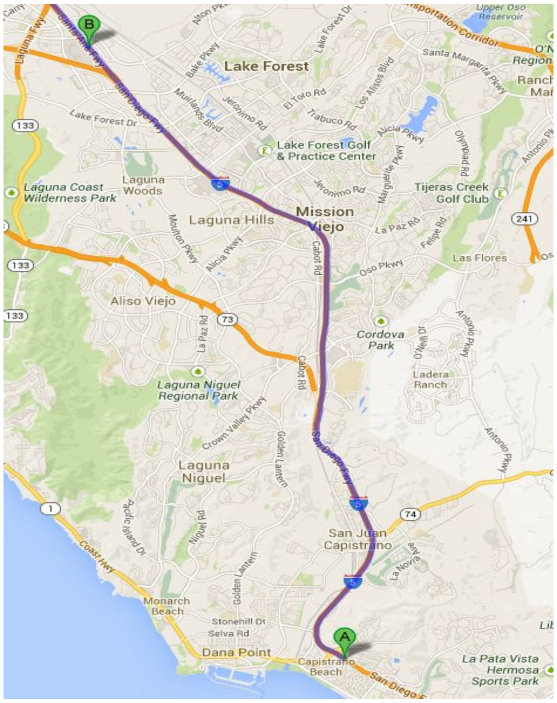
- It would be very useful for the model documentation to provide examples of model networks.
- The documentation should provide information on how FREEVAL-RL develops different scenarios during the scenario runs.
- The current version of the manual states that the user needs to run the seed file to generate scenarios and then run scenarios. However, the manual should refer to the results file from the seed file rather than the seed file itself.
- The manual should document known model limitations and workarounds. For example, the HCM 2010 does not support on-ramp segments with more than two on-ramp lanes and six mainline lanes.

7.3 Base Model Development

Study Site

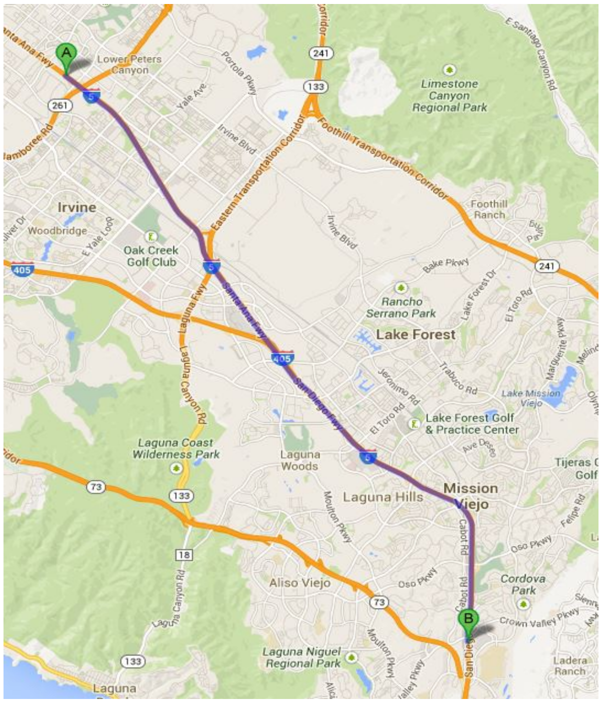
The study team originally intended to test the FREEVAL-RL tool for both the I-210 and the I-5 facilities. However, after encountering setbacks due to the model limitations described above, the team decided to limit the model testing to only the I-5 facility. Even in this case, the team could not model the entire facility, because FREEVAL-RL has a limit on the number of segments included in an individual model, and the overall facility must start and end in free-flow conditions.

After analyzing the existing congestion on the facility relative to FREEVAL-RL model limitations, the study team decided to develop a northbound (NB) for the a.m. peak period and a southbound (SB) model for the p.m. peak period. As shown in Figure 7.2, the northbound model extends from the State Route 1 (SR-1) on-ramp (postmile 79.1 or p.m. 79.1) to the Alton off-ramp (p.m. 93.7). The southbound model extends from the Jamboree on-ramp (p.m. 99.62) to the Crown Valley off-ramp (p.m. 86.18). The study periods are from 6:00 to 10:00 a.m. for the a.m. model and from 3:00 to 8:00 p.m. for the p.m. model. The boundary limits of the two models are located in free-flow areas at the beginning and ending of each analysis time interval.



© Google Maps

(a) NB model coverage



©Google Maps

(b) SB model coverage

Figure 7.2. Coverage of northbound and southbound I-5 models.

Source: Google Maps. google.com

Geometric Data Preparation

The study team obtained geometric data for both FREEVAL-RL models from a Paramics microsimulation model developed earlier for the I-5 CSMP. The I-5 Paramics model covered a portion of the freeway from the San Diego county line (p.m. 73) to the Chapman interchange, which is north of the SR-55 interchange (p.m. 107). Having the geometry data already available from the microsimulation model saved the team from extensive data collection and field visits. Even so, the study team had to verify some distances using Google Earth, since the model geometry in the microsimulation model did not correspond exactly to the FREEVAL-RL model requirements. Table 7.1 provides an example of the data extracted from the Paramics model for the northbound model. As can be seen in the table, this information included the number of lanes, length of each segment, and the starting and ending point for each segment.

Table 7.1. Example of Extracted Geometry Data for Northbound I-5 Model

Start	End	type	#Lanes	Length (ft)
Crown Valley On 1	Crown Valley On 2	ML	4	1607.9
Crown Valley On 2	Oso Pkwy Off	ML	5	4015.7
Oso Pkwy Off	High-Occupancy Vehicle Start	ML	4	296.8
High-Occupancy Vehicle Start	High-Occupancy Vehicle End	ML	5	1221.5
High-Occupancy Vehicle End	Oso Pkwy On1	ML	4	456.3
Oso Pkwy On 1	Oso Pkwy On2	ML	4	1311.2
Oso Pkwy On 2	La Paz Off	ML	4	4302

Segment Type Determination

Based on its understanding of FREEVAL-RL segment type definitions from the FREEVAL-RL manual and related chapters of HCM 2010 (ITRE and CMT 2011), the team converted the geometric data into a format that could be used in the model. Table 7.2 provides an example of the geometric data inputted into FREEVAL-RL. Unfortunately, the segment definitions in FREEVAL-RL required the study team to collect additional data not available in the microsimulation model. The team obtained acceleration and deceleration lengths for each on-ramp and off-ramp through Google Earth.

Table 7.2. Example of Southbound I-5 Geometric Data for FREEVAL-RL

Segment Number	1	2	3	4	5	6	7
Segment Starting Point	JamborreeOn2		Culver Off	After HOV_End_500ft	CulverOn1	CulverOn2	
Segment Type	B	OFR	W	B	ONR	ONR	B
#Lanes	6	6	6	5	5	5	5
Length (ft)	1087.4	1500	1938.5	152.8	1246.3	1500	4127
Acc/Dec Length					217.8	285.7	

The study team paid careful attention to determining the segment type based on its understanding of HCM 2010. FREEVAL-RL is designed to analyze the freeway mainline. However, many freeways in California have a parallel high-occupancy vehicle facility, which may be limited-access or continuous-access. For the limited-access high-occupancy vehicle lane along I-5, there is an ingress/egress area where high-occupancy vehicle drivers can change lanes. According to the developer of FREEVAL-RL, the tool does not support any managed lane evaluation. The study team conducted extensive evaluations to find possible solutions that would allow FREEVAL-RL to model the high-occupancy vehicle ingress and egress areas.

Table 7.3 summarizes the number of segments by type for the two FREEVAL-RL models developed for the I-5 facility. For the NB model, there are 59 segments, including 10 weaving segments (Type W), 16 basic segments (Type B), 15 on-ramp segments (Type ONR), 14 off-ramp segments (Type OFR), and 4 overlapping ramp segments (Type R). For the SB model, there are 51 segments, including 12 weaving segments (Type W), 13 basic segments (Type B), 16 on-ramp segments (Type ONR), 9 off-ramp segments (Type OFR), and 1 overlapping ramp segment (Type R).

Table 7.3. Number of Segments by Type in I-5 Models

Segment Type	NB Model	SB Model
B	16	13
R	4	1
W	10	12
ONR	15	16
OFR	14	9
Total	59	51

Traffic Flow Data Preparation

FREEVAL-RL requires users to provide traffic flow data at all cordon points in the modeled area. These cordon points include: (1) all on-ramps and off-ramps, and (2) the upstream end of the freeway mainline. For the high-occupancy vehicle ingress/egress weaving segment, the high-occupancy vehicle on-ramp flow and off-ramp flow were needed.

FREEVAL-RL uses the flow data at the cordon points to calculate the demand for each segment and for each time interval. If the demand is higher than the capacity calculated based on HCM 2010, there will be congestion. Thus, if there is any data error for an on-ramp or off-ramp, the error may be amplified. For this reason, correct input flow data are very important to the analysis.

A well-prepared I-5 CSMP dataset was utilized in this project. The dataset used different data sources, including Caltrans detector data from PeMS, turning movement data obtained from the Orange County Transportation Authority (OCTA), and data previously collected by data collection firms for the I-5 CSMP. The Caltrans detector dataset includes 29 days (i.e., Tuesdays, Wednesdays, and Thursdays from October 5, 2010, to December 16, 2010) and the median flow and speed values were used for model calibration.

For the I-5 CSMP microsimulation model, the Caltrans detectors were the primary data source. However, the study team found that detectors were not present at some locations for the FREEVAL-RL testing. In addition, the detector data do not appear to be accurate for some locations. In these cases, the study team substituted data from another source. This was a time-consuming process to collect, compile, and analyze the data. Nevertheless, it was critical to get the correct data, because the input flow data are so important to FREEVAL-RL analysis.

FREEVAL-RL models 15-minute time intervals and requires comparable input flow data. For the PeMS data, the study team only had 5-minute and hourly data previously generated for the I-5 CSMP. As a result, the study team had to improve its existing software tool to generate 15-minute data based on the 5-minute data directly from PeMS. The other data sources provided information in 15-minute intervals, so the raw data could be used directly. Estimates for the on-ramps (ingress) and off-ramps (egress) for the high-occupancy vehicle weaving segments came from high-occupancy vehicle detectors with good data quality upstream and downstream of the segments.

7.4 Model Calibration

Initial Testing

Figure 7.3 shows a speed contour map for the NB model in the a.m. period using observed data from PeMS. Figure 7.4 shows a comparable speed contour map from a FREEVAL-RL model calibrated using default parameters. While the real-world data show extensive congestion and queuing in the middle of the facility, no congestion is observed on the FREEVAL-RL speed contour map. The team decided not to use the speed contours provided by FREEVAL-RL, because the three-dimensional projection was hard to read. Figure 7.5 provides an example of a

FREEVAL-RL speed contour. The speed contour shown in Figure 7.4 was generated using a program developed by the study team to read the FREEVAL-RL speed output data and draw the speed contour based on a postmile-segment lookup table.

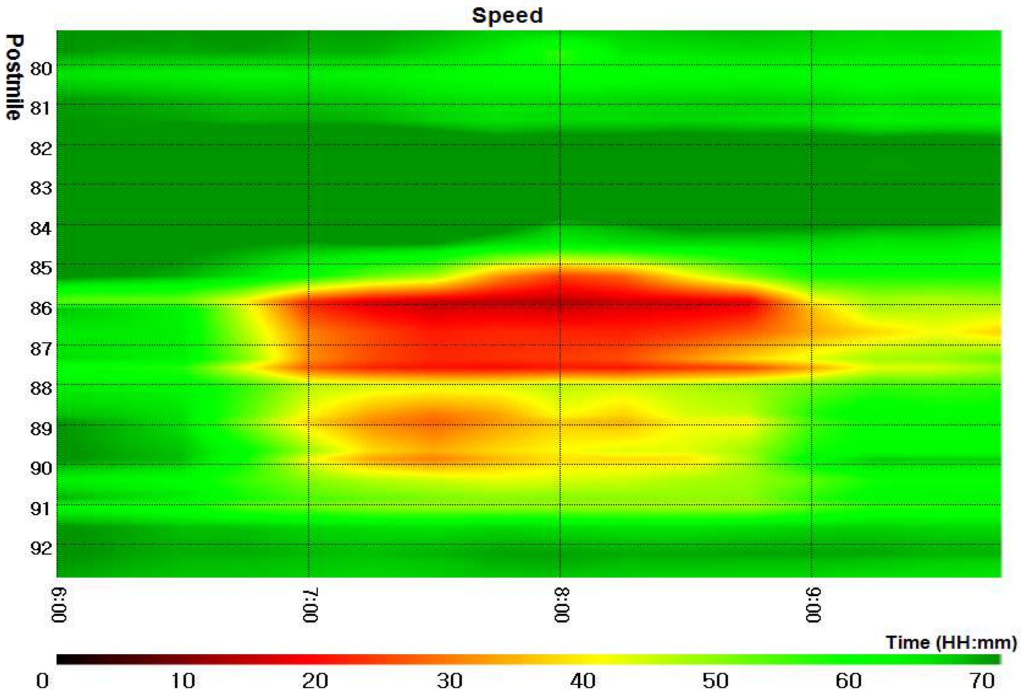


Figure 7.3. Real-world speed contour map for the NB I-5 a.m. model.

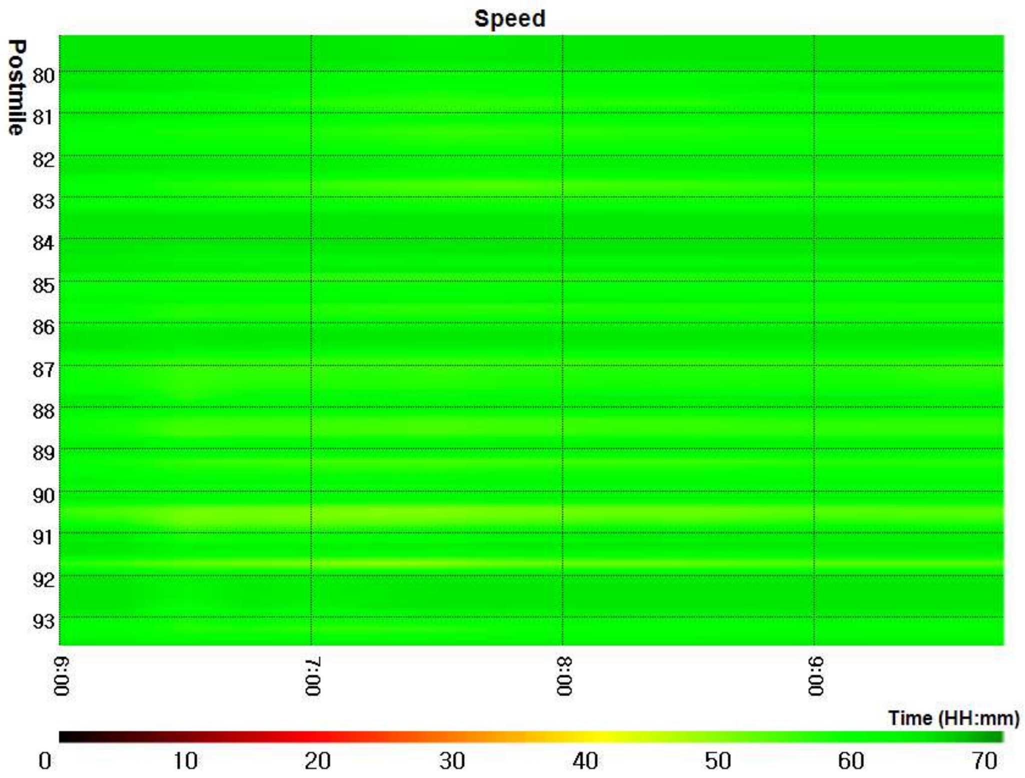


Figure 7.4. Speed contour map from NB I-5 a.m. FREEVAL-RL model using default parameters.

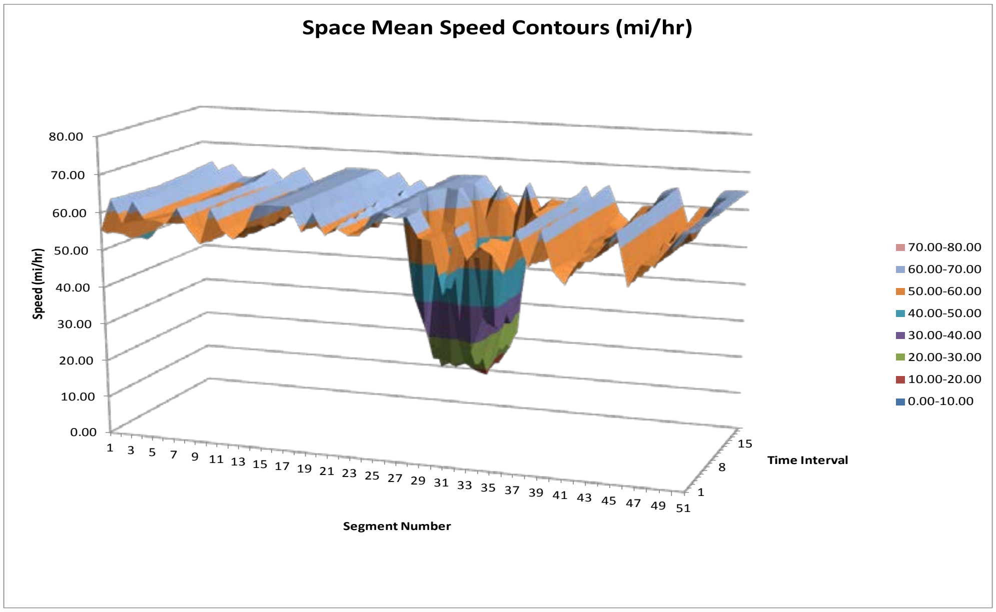


Figure 7.5. Example speed contour map from NB I-5 a.m. FREEVAL-RL model.

Model Refinement and Calibration

To investigate the cause of the unmatched speed contours, the team checked the correctness of all cordon or demand flow input data, manually calculated the demands for each segment and time interval, and compared the calculated demands from FREEVAL-RL with the observed 15-minute flows from aggregated PeMS data for all segments. However, after fixing incorrect inputs found in on-ramp and off-ramp flow data, the team still could not replicate the real-world traffic congestion using FREEVAL-RL.

After further examination of documentation in HCM 2010, the team found that FREEVAL-RL uses the highway capacity methodology, which overestimates capacity for this facility (which has four to five GP lanes and one to two high-occupancy vehicle lanes in the modeled area). Figure 7.6 shows the base capacities found in HCM 2010. By comparison, Figure 7.7 shows the speed-flow relationship for a mainline segment using 15-minute observed data collected from PeMS. As can be seen in the second figure, the maximum throughput for the facility is about 1,787 vehicles per hour per lane (vphpl). However, FREEVAL-RL estimates a capacity of about 2,293 vphpl for this segment.

Free-Flow Speed (mi/h)	Base Capacity (pc/h/in)
75	2,400
70	2,400
65	2,350
60	2,300
55	2,250

Figure 7.6. Base capacity from HCM 2010.

Source: Highway Capacity Manual, 2010.

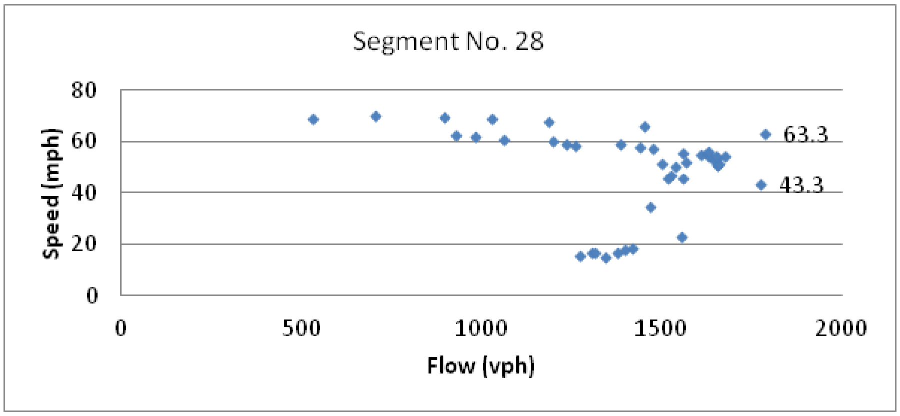


Figure 7.7. Flow-speed relationship on I-5 based on 15-minute observed data.

The study team decided that it needed to calibrate the capacity in FREEVAL-RL to reflect the observed maximum throughputs in the PeMS data. FREEVAL-RL has the capacity adjustment factor (CAF), which can be used to adjust the capacity of a given segment. The CAF is equal to the actual capacity divided by the FREEVAL-RL capacity and by default is set to 1.0. By analyzing the 15-minute flow and speed relationship (as shown in Figure 7.7), the study team estimated the capacity by assuming that the maximum flow achieved is the actual capacity of the segment when congestion occurs.

The study team was able to estimate the CAFs for segments having recurrent traffic congestion and detectors with good data (e.g., Segments 28 through 52 for the NB a.m. model). These CAFs were analyzed further to obtain a CAF pattern that associates a CAF value with the number of lanes and segment type, as shown in Figure 7.8. The CAF pattern was developed to help determine appropriate CAF values applied to segments (e.g., Segments 1-27 and 53-59 for the NB a.m. model) without traffic congestion in the base year. This CAF pattern is site specific and cannot be applied to other freeways or states that have different driver behaviors or roadway designs.

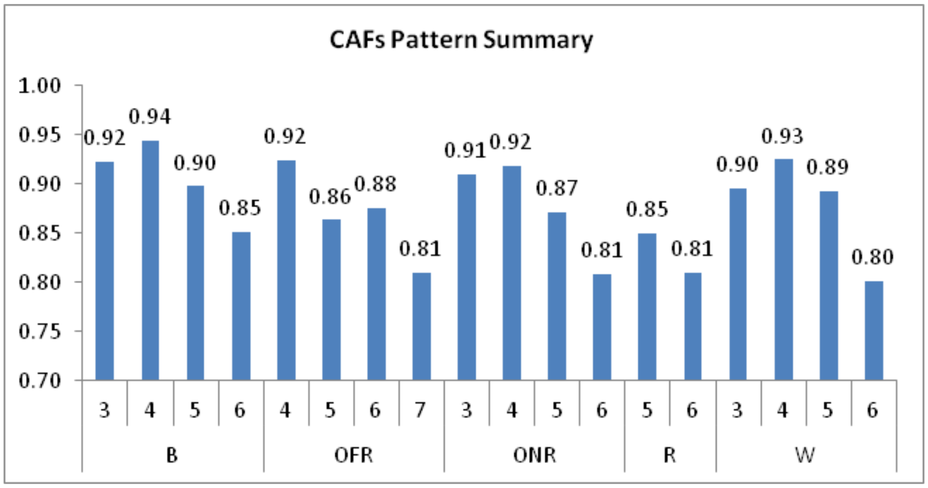


Figure 7.8. CAF pattern on I-5.

Model Calibration Results

By applying the CAFs calculated above and further refining CAFs for some segments, FREEVAL-RL was able to produce much better results. For the NB a.m. model, the speed contour map from the finalized FREEVAL-RL seed file is as shown in Figure 7.9. Although it looks more reasonable, the traffic congestion occurs earlier and lasts longer than observed in the PeMS data (see Figure 7.3).

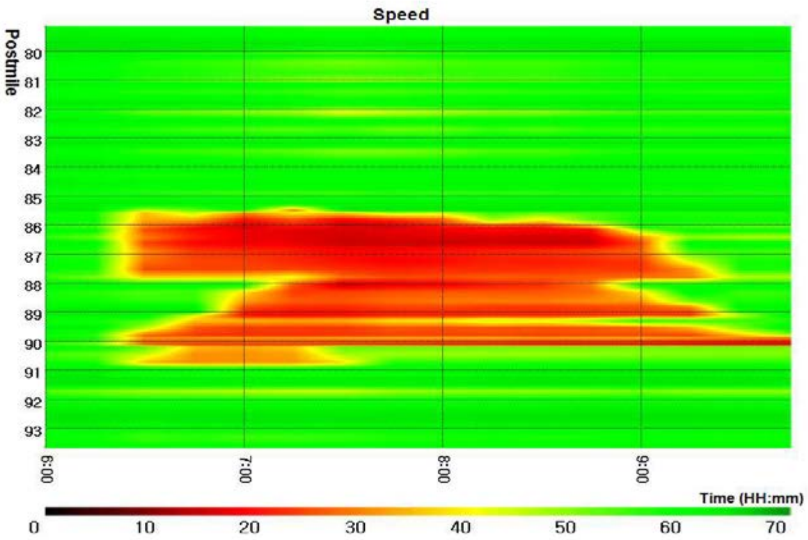


Figure 7.9. Speed contour map from the NB a.m. I-5 FREEVAL-RL model with CAF adjustment.

For the SB p.m. model, the speed contour map from the finalized FREEVAL-RL seed file is shown in Figure 7.10. Compared with the real-world speed contour map shown in Figure 7.11, the calibrated FREEVAL-RL seed file results show less congestion. A detailed analysis indicated that the ramp merge model in FREEVAL-RL has the following limitations:

- FREEVAL-RL supports a maximum of two-lane on-ramps. The SB p.m. model has a major freeway-to-freeway connector at I-405. This connector has three lanes with more than 4,000 vphpl. A workaround suggested by the developer was to model the connector on-ramp as two continuous on-ramps.
- The merging model in FREEVAL-RL does not give priority to the traffic from the on-ramp, which causes the demands from on-ramps (especially around the I-405 interchange area) to be not fully served during congestion. As a result, the queue on the mainline is unrealistically short.

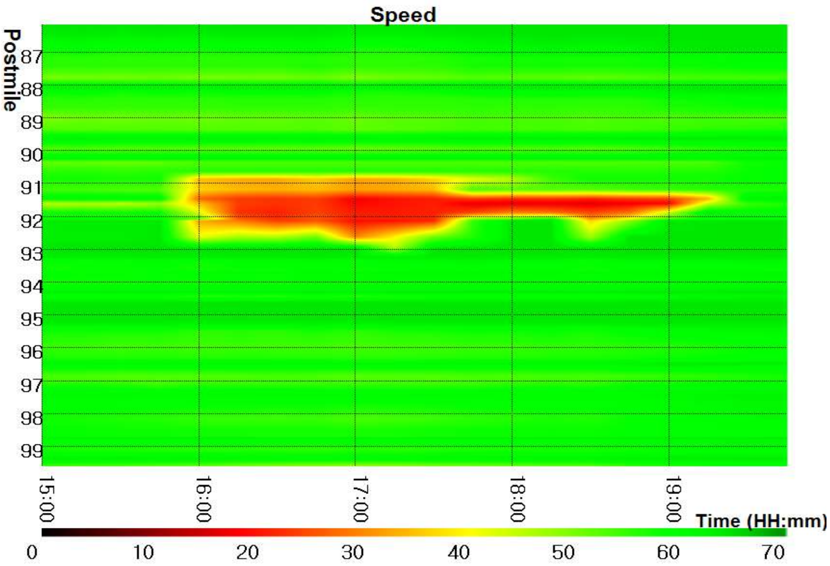


Figure 7.10. Speed contour map from the SB p.m. I-5 FREEVAL-RL model with CAF adjustment.

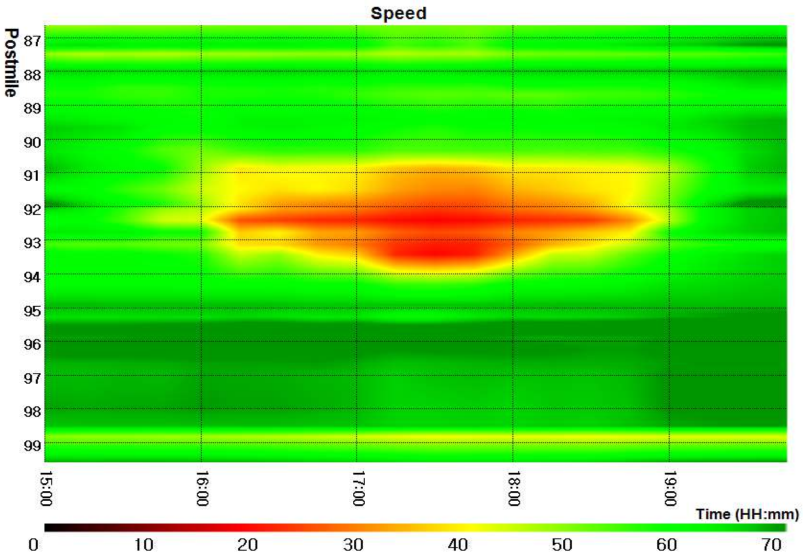


Figure 7.11. Real-world speed contour map for the southbound I-5 in the p.m. period.

7.5 Scenario Testing

CSMP Scenario Development

The objective of the scenario testing is to evaluate if FREEVAL-RL can model the reliability of various investment scenarios found in the I-5 CSMP. Each CSMP scenario is a combination of several improvement projects. Due to the limitations of FREEVAL-RL and the limited size of the area that can be modeled in the tool, not all of the CSMP projects could be modeled and evaluated. Table 7-4 lists the CSMP scenarios and the corresponding projects for each test run. The table also indicates whether the scenario can be modeled and evaluated by FREEVAL-RL.

Table 7.4. I-5 CSMP Scenario Summary

CSMP Scenarios	Projects	Applicability		Notes
		a.m.	p.m.	
1 (2010 Demand) & 2 (2020 Demand)	Continuous-access high-occupancy vehicle conversion from Tustin to Red Hill	N/A	N/A	Outside study area; high-occupancy vehicle not considered
	Estrella interchange improvement	N/A	N/A	Outside study area
	Camino Capistrano interchange improvement	N/A	N/A	Outside study area
	La Paz interchange improvement	N/A	N/A	Improved locations outside study area
	Jamboree interchange improvement	N/A	N/A	Outside study area
	SR-74 interchange improvement	YES	N/A	AM: Add one NB on-ramp for the traffic from EB Ortega Highway and related detectors and ramp metering
3 (2010 Demand) & 4 (2020 Demand)	Advanced ramp metering with queue control	N/A	N/A	Outside study area; ramp metering strategy not considered
	Connector metering on SR-57, SR-22, and SR-55 interchanges	N/A	N/A	Outside study area; ramp metering strategy not considered
5 (2010 Demand) & 6 (2020 Demand)	a.m. Model: incident clearance time reduction at NB I-5 postmile 18.50	YES	N/A	
	p.m. Model: incident clearance time reduction at SB I-5 postmile 18.50	N/A	YES	

CSMP Scenarios	Projects	Applicability		Notes
		a.m.	p.m.	
7 (2020 Demand)	Add a second high-occupancy vehicle lane within existing high-occupancy vehicle facility in the City of Tustin and Santa Ana	N/A	N/A	Outside study area; high-occupancy vehicle not considered.
	Add 1 GP lane in both directions and improve the interchanges between I-5 truck bypass and SR-55 interchange	N/A	YES	Add 1 GP lane in both directions between I-5 truck bypass and SR-55 interchanges; Alternative 2B option 1 selected for interchanges reconfiguration, including Alton Pkwy., Sand Canyon Ave., Jeffrey Rd., Culver Dr., Jamboree Rd., Tustin Ranch, and Red Hill Ave interchanges.
	Operational improvements between El Toro and Junipero Serra interchange	YES	YES	Add 1 GP lane in both directions between El Toro Rd. and Junipero Serra Rd. interchanges; Add new auxiliary lanes from north of SR-73 connectors to NB Avery off-ramp, and from Oso Pkwy on-ramp to La Paz off-ramp; Not applicable to # of lane more than 6; high-occupancy vehicle lanes are not under consideration for study purposes.
	Add 1 high-occupancy vehicle lane in both directions from Avenida Pico to San Juan Creek Rd., and reconfigure interchanges	N/A	N/A	High-occupancy vehicle not considered; interchange realignment not applicable in FREEVAL.

Figure 7.12 shows the flowchart of I-5 CSMP scenarios to be evaluated in FREEVAL-RL. This is a modification of the flowchart shown in Figure 3.8, which lists all of the scenarios tested in the I-5 CSMP microsimulation modeling (Caltrans 2012). Scenarios 3 and 4 could not be tested in FREEVAL-RL, because the improvements fall outside the study area. As in the CSMP modeling, the scenarios were tested for two model years: base year (2010) and horizon year (2020).

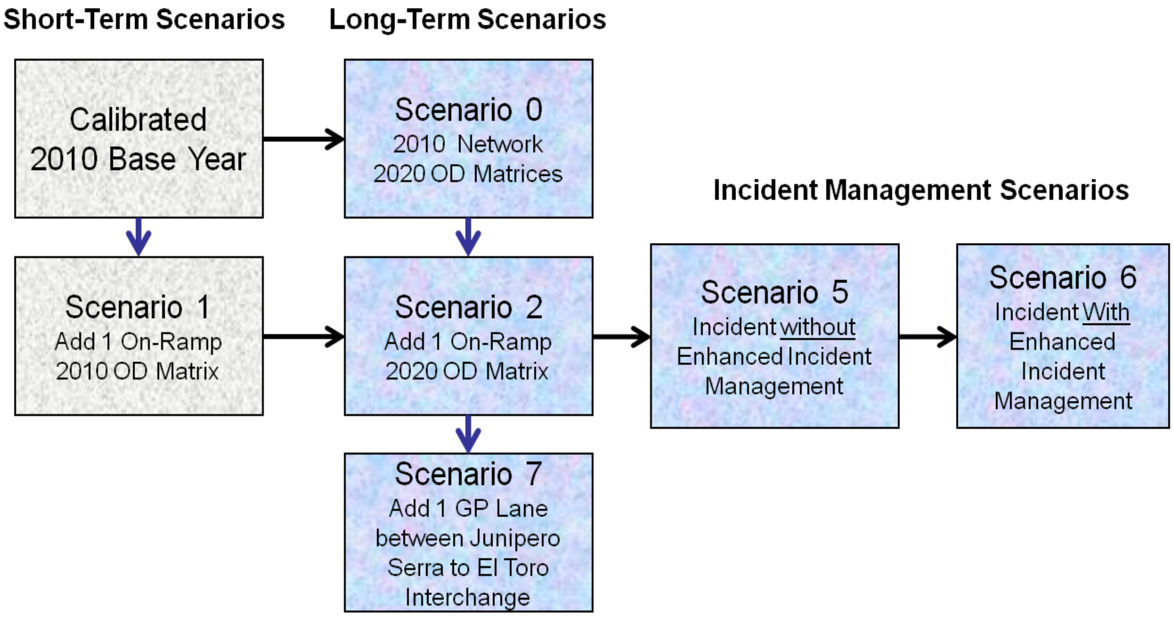


Figure 7.12. I-5 CSMP scenario to be tested in FREEVAL-RL.

For the NB a.m. model, there are seven CSMP scenarios to be tested in FREEVAL-RL:

1. Base Scenario, Base demand
2. Scenario 0, Horizon demand
3. Scenario 1, Base demand, with addition of one NB on-ramp at the SR-74 interchange
4. Scenario 2, Horizon demand, with addition of one NB on-ramp at the SR-74 interchange
5. Scenario 5, based on the Scenario 2 model, with a 45-minute incident blocking the rightmost lane at NB p.m. 18.5, affecting Segment 49 from 7:00 a.m. to 7:45 a.m.
6. Scenario 6, based on the Scenario 2 model, with a 30-minute incident blocking the rightmost lane at NB p.m. 18.5, Segment 49 from 7:00 a.m. to 7:30 a.m.
7. Scenario 7, based on the Scenario 2 model, with addition of one GP lane between El Toro and Junipero Serra interchange.

For the SB p.m. model, there are five CSMP scenarios to be tested in FREEVAL-RL:

1. Base Scenario, Base demand
2. Scenario 0, Horizon demand
3. Scenario 5, based on the Scenario 2 model, with a 45-minute incident blocking the rightmost lane at SB p.m. 90.5, affecting Segment 33 from 5:00 p.m. to 5:45 p.m.
4. Scenario 6, based on the Scenario 2 model, with a 30-minute incident blocking the rightmost lane at SB p.m. 18.5, affecting Segment 33 from 5:00 p.m. to 5:30 p.m.
5. Scenario 7, based on the Scenario 2 model, with addition of one GP lane between SR-55 interchange and I-5 truck bypass and between El Toro and Junipero Serra interchange.

Future Year Demands

The study team obtained the horizon-year demands by analyzing the origin-destination (O-D) matrix for the Paramics model developed for the I-5 CSMP. Since the network in the microsimulation model is roughly linear (as illustrated in Figure 7.13), there are limited route choices, so the team was able to calculate the demand flows at all cordon points of the FREEVAL-RL model within the study areas.

The I-5 Paramics model has an hourly O-D matrix and uses a 5-minute demand profile to represent the temporal distribution of demand. Thus, the team had to develop a procedure and method to calculate the 15-minute demand flow needed by FREEVAL-RL.

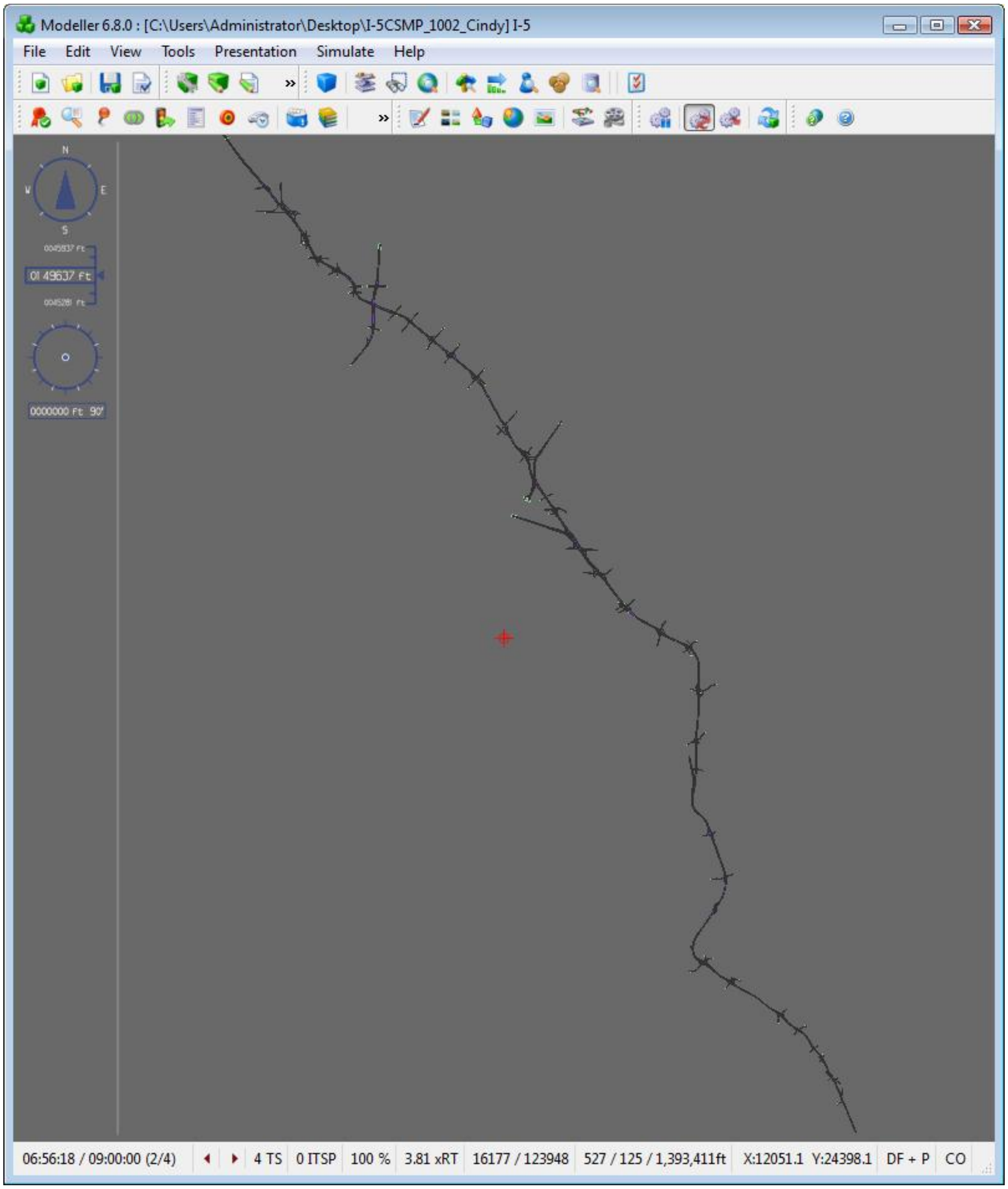


Figure 7.13. I-5 Paramics model limits.

Scenario Testing Procedure

The study team adopted the following procedure to test CSMP scenarios in FREEVAL-RL:

- Develop the seed file for the CSMP scenario based on the calibrated base model,
- Generate the seed file results and verify the reasonableness of the speed contour map by comparing against the corresponding I-5 Paramics model results, and
- Perform reliability testing for the scenario and analyze the TTI results.

Several parameters are needed for the reliability testing, including weather effects, incident effects, and demand patterns. For the weather effect, the study team chose simply to use FREEVAL-RL default values for the Los Angeles area. For the incident effects, the team decided not to consider them in the testing. It should be noted that there are two CSMP scenarios that involve incident management, which were modeled by adjusting the CAFs of the segment with the major incident for the affected time intervals.

The major parameter for reliability testing is the demand pattern. The demand pattern in FREEVAL-RL is split into two parts. The first part covers the daily and monthly demand adjustment multipliers (DMs) based on daily and monthly variability of traffic demand for the subject facility. The second part covers the overall demand pattern. The inputs are displayed in a calendar format to show the configuration of demand patterns for the subject facility. For the first part, FREEVAL-RL provides a national default for urban and rural freeways, as shown in Table 7.5. The study team derived customized DMs based on the study area and modeling hours for the NB a.m. model (as shown in Table 7.6) and the SB p.m. model (as shown in Table 7.7) using VMT data collected from PeMS for the 2010 base year.

The study team analyzed the deviations of the default DMs (as shown in Table 7.8) and customized DMs (as shown in Tables 7.9 and 7.10). The study team found that the default DMs have higher deviations or variation than the customized DMs. The study team further compared the reliability testing results using both DMs for the Base Scenario (as shown in Figure 7.14). The team found that the higher deviation in the default DMs led to higher TTIs estimated in FREEVAL-RL. These estimates were unrealistic compared to the baseline TTI measured using PeMS. As a result, the study team decided to use the customized DMs to estimate travel time reliability for all of the test scenarios.

Table 7.5. Default DMs for Urban and Rural Freeways

Default DM		Day of Week				
		Mon	Tue	Wed	Thu	Fri
Month	Jan	0.822158	0.822158	0.838936	0.864104	0.964777
	Feb	0.848710	0.848710	0.866031	0.892012	0.995936
	Mar	0.920502	0.920502	0.939288	0.967466	1.080181
	Apr	0.975575	0.975575	0.995484	1.025349	1.144807
	May	0.973608	0.973608	0.993477	1.023281	1.142499
	Jun	1.021796	1.021796	1.042649	1.073929	1.199047
	Jul	1.132925	1.132925	1.156046	1.190728	1.329453
	Aug	1.032614	1.032614	1.053688	1.085299	1.211741
	Sep	1.063101	1.063101	1.084797	1.117341	1.247516
	Oct	0.995243	0.995243	1.015554	1.046021	1.167888
	Nov	0.995243	0.995243	1.015554	1.046021	1.167888
	Dec	0.978525	0.978525	0.998495	1.028450	1.148269

Table 7.6. Customized DMs for the Northbound I-5 a.m. Model

NB a.m. DM		Day of Week				
		Mon	Tue	Wed	Thu	Fri
Month	Jan	0.9434	1.0113	0.9799	0.9690	0.8783
	Feb	0.9489	1.0277	1.0199	1.0113	0.9647
	Mar	1.0108	1.0141	1.0034	1.0097	0.9695
	Apr	1.0067	1.0058	1.0018	0.9943	0.9642
	May	0.9313	1.0283	1.0415	1.0460	1.0121
	Jun	1.0489	1.0505	1.0475	1.0517	1.0057
	Jul	0.9273	1.0253	1.0301	1.0341	0.9867
	Aug	1.0288	1.0316	1.0489	1.0394	0.9868
	Sep	0.8862	1.0423	1.0217	1.0392	1.0002
	Oct	0.9982	1.0206	0.9763	1.0103	0.9922
	Nov	1.0212	1.0303	1.0153	0.8944	0.8938
	Dec	0.9678	0.9406	0.9251	0.9552	0.8175

Table 7.7. Customized DMs for the Southbound I-5 p.m. Model

SB p.m. DM		Day of Week				
		Mon	Tue	Wed	Thu	Fri
Month	Jan	0.9288	0.9340	0.9250	0.9521	0.9394
	Feb	0.9534	0.9721	0.9944	1.0122	0.9723
	Mar	0.9813	0.9974	0.9774	1.0104	0.9801
	Apr	0.9670	0.9725	0.9876	0.9968	0.9560
	May	0.9310	1.0080	1.0037	1.0060	0.9296
	Jun	1.0031	1.0124	1.0134	0.9992	0.9915
	Jul	0.9447	1.0292	1.0248	1.0285	0.9836
	Aug	1.0001	1.0196	1.0208	1.0164	0.9808
	Sep	0.9088	1.0180	1.0257	1.0259	0.9882
	Oct	0.9890	0.9680	1.0180	1.0401	1.0086
	Nov	0.9976	1.0107	0.9907	0.9550	0.9589
	Dec	0.9433	0.9618	0.9671	0.9839	0.9250

Table 7.8. Deviation of Default DMs

Default DM		Day of Week						
		Mon	Tue	Wed	Thu	Fri	Sat	Sun
Month	Jan	-18%	-18%	-16%	-14%	-4%	N/A	N/A
	Feb	-15%	-15%	-13%	-11%	0%	N/A	N/A
	Mar	-8%	-8%	-6%	-3%	8%	N/A	N/A
	Apr	-2%	-2%	0%	3%	14%	N/A	N/A
	May	-3%	-3%	-1%	2%	14%	N/A	N/A
	Jun	2%	2%	4%	7%	20%	N/A	N/A
	Jul	13%	13%	16%	19%	33%	N/A	N/A
	Aug	3%	3%	5%	9%	21%	N/A	N/A
	Sep	6%	6%	8%	12%	25%	N/A	N/A
	Oct	0%	0%	2%	5%	17%	N/A	N/A
	Nov	0%	0%	2%	5%	17%	N/A	N/A
	Dec	-2%	-2%	0%	3%	15%	N/A	N/A
	Total	74%	74%	74%	91%	188%	N/A	N/A

Table 7.9. Deviation of Customized Northbound I-5 a.m. DMs

NB DM		Day of Week						
		Mon	Tue	Wed	Thu	Fri	Sat	Sun
Month	Jan	-6%	1%	-2%	-3%	-12%	N/A	N/A
	Feb	-5%	3%	2%	1%	-4%	N/A	N/A
	Mar	1%	1%	0%	1%	-3%	N/A	N/A
	Apr	1%	1%	0%	-1%	-4%	N/A	N/A
	May	-7%	3%	4%	5%	1%	N/A	N/A
	Jun	5%	5%	5%	5%	1%	N/A	N/A
	Jul	-7%	3%	3%	3%	-1%	N/A	N/A
	Aug	3%	3%	5%	4%	-1%	N/A	N/A
	Sep	-11%	4%	2%	4%	0%	N/A	N/A
	Oct	0%	2%	-2%	1%	-1%	N/A	N/A
	Nov	2%	3%	2%	-11%	-11%	N/A	N/A
	Dec	-3%	-6%	-7%	-4%	-18%	N/A	N/A
	Total	51%	35%	35%	43%	56%	N/A	N/A

Table 7.10. Deviation of Customized Southbound I-5 p.m. DMs

SB DM		Day of Week						
		Mon	Tue	Wed	Thu	Fri	Sat	Sun
Month	Jan	-7%	-7%	-7%	-5%	-6%	N/A	N/A
	Feb	-5%	-3%	-1%	1%	-3%	N/A	N/A
	Mar	-2%	0%	-2%	1%	-2%	N/A	N/A
	Apr	-3%	-3%	-1%	0%	-4%	N/A	N/A
	May	-7%	1%	0%	1%	-7%	N/A	N/A
	Jun	0%	1%	1%	0%	-1%	N/A	N/A
	Jul	-6%	3%	2%	3%	-2%	N/A	N/A
	Aug	0%	2%	2%	2%	-2%	N/A	N/A
	Sep	-9%	2%	3%	3%	-1%	N/A	N/A
	Oct	-1%	-3%	2%	4%	1%	N/A	N/A
	Nov	0%	1%	-1%	-4%	-4%	N/A	N/A
	Dec	-6%	-4%	-3%	-2%	-7%	N/A	N/A
	Total	46%	29%	26%	25%	40%	N/A	N/A

Base Scenario **Scenario 0**

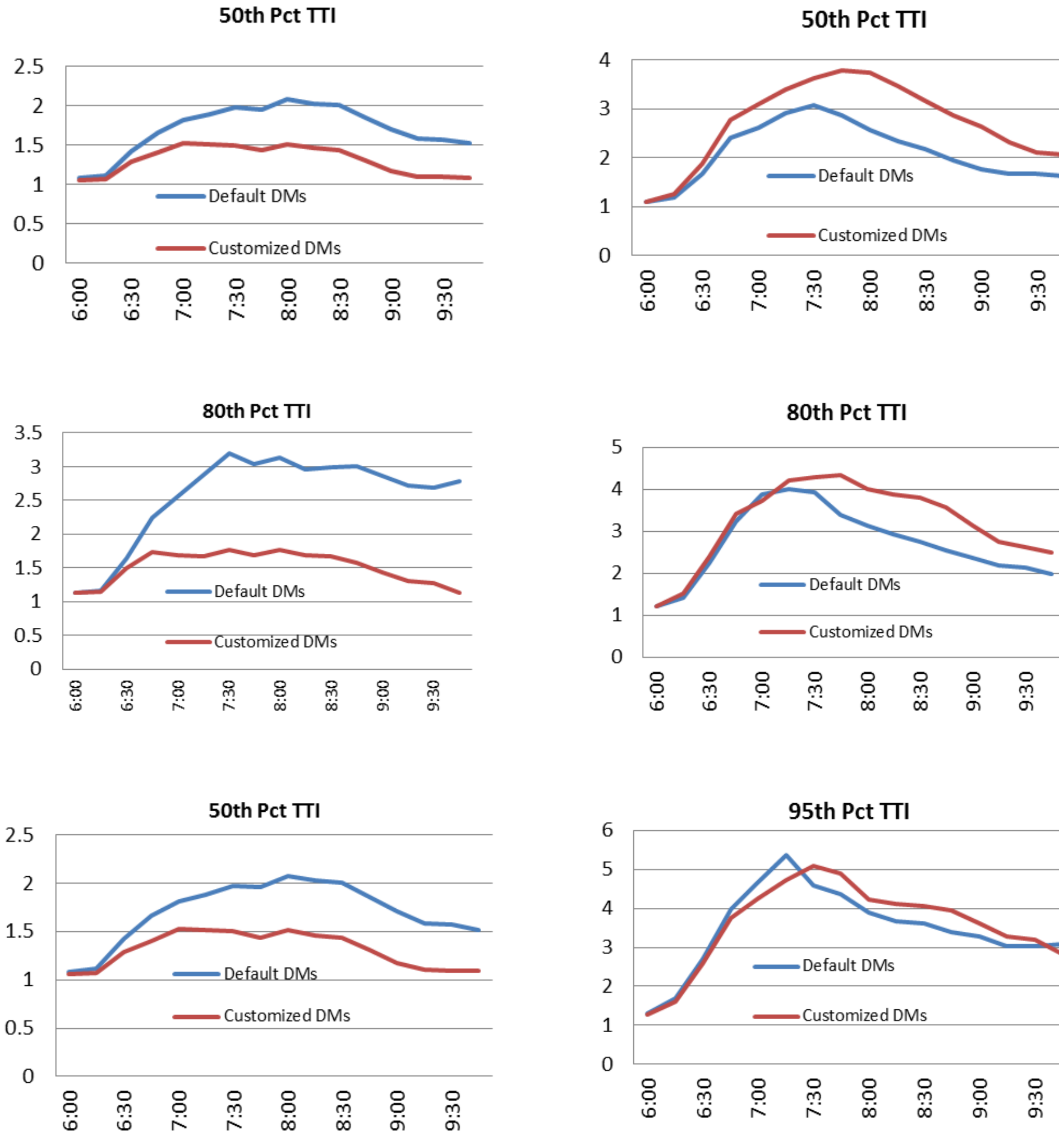


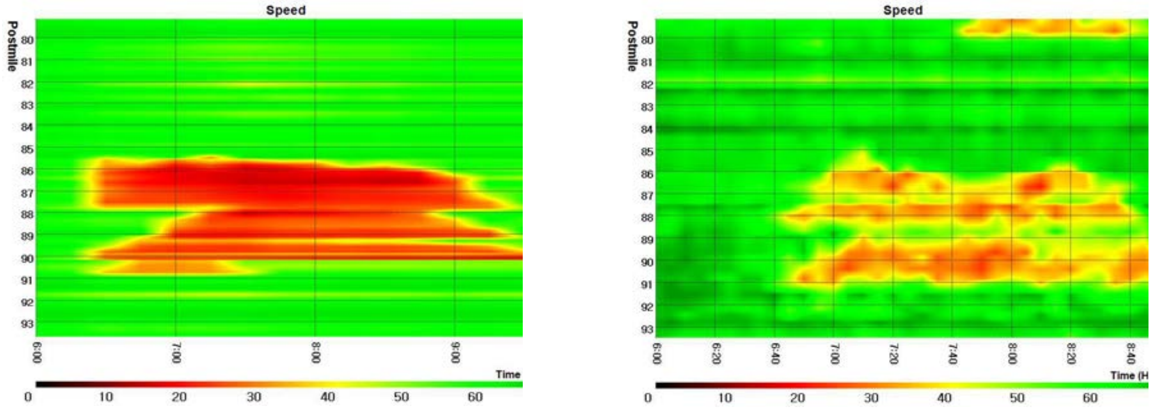
Figure 7.14. Comparison of TTI results for I-5 from default DMs and customized DMs.

Scenario Testing Results and Comparison

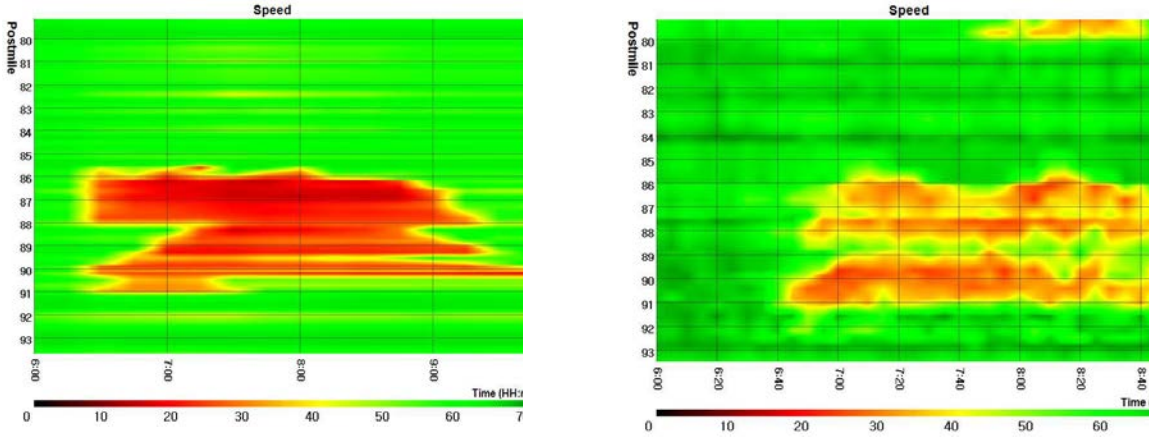
As shown in the scenario testing flow chart (Figure 7.12), the study team tested the scenarios like those in the I-5 CSMP. These scenarios included two different forecast years: a base year of 2010 and a horizon year of 2020. The base year (2010) demands were used to model the Base Scenario (i.e., no-build in the base year) and Scenario 1. The horizon-year (2020) demands were used to model Scenarios 0 (i.e., no-build in the horizon year), 2, 5, 6, and 7. The next several sections show how the different CSMP scenarios compare to the corresponding no-build scenarios modeled in FREEVAL-RL and measured in PeMS (for the base year). The study team shows speed contours and TTI estimates for the 50th, 80th, and 95th percentile.

Base Scenario and Scenario 1: NB a.m. model

Figure 7.15 shows the speed contours for the Base Scenario and Scenario 1 (i.e., the first set of investments for base year demands) from the northbound a.m. model. The figure compares the congestion results estimated in FREEVAL-RL to those estimated for the I-5 CSMP using the Paramics microsimulation model. Note that these are static analyses. However, if the static analyses look reasonable, then the dynamic scenario estimation in FREEVAL-RL may produce reasonable reliability estimates.



FREEVAL-RL Base Scenario
Paramics Base Scenario



FREEVAL-RL Scenario 1
Paramics Scenario 1

Figure 7.15. Speed contours of NB I-5 a.m. model: Base Scenario and Scenario 1.

In Scenario 1, the improvement project involves building a new on-ramp at the SR-74 interchange (at approximately p.m. 82) to improve access to the freeway. As shown in Figure

7.15, Scenario 1 performs very similarly to the Base Scenario. In addition, the FREEVAL-RL model results match the Paramics modeling fairly closely.

Figure 7.16 shows the 50th, 80th, and 95th percentile TTI for the Base Scenario and Scenario 1. As seen in the charts, the new on-ramps at the SR-74 interchange do not appear to improve 50th, 80th, or 95th percentile travel times, so reliability is largely unimproved. The figure also shows the TTI measured in PeMS. The real-world TTI is much lower than those estimated in FREEVAL-RL.

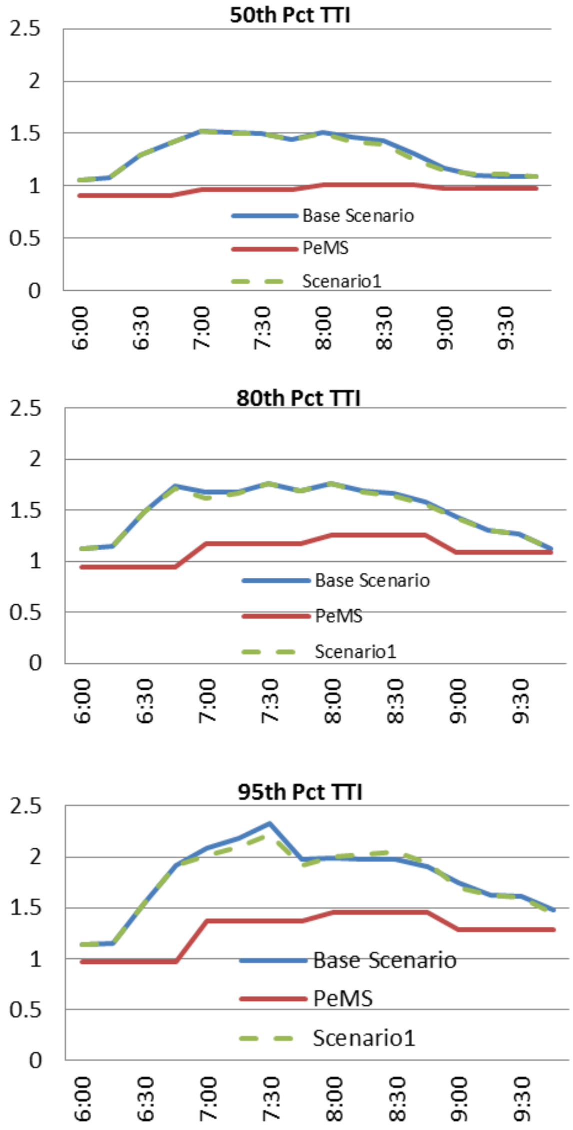
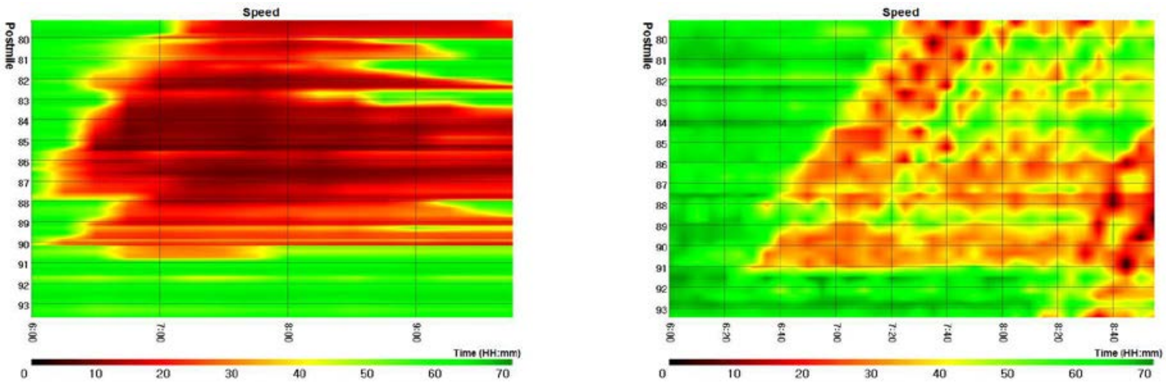


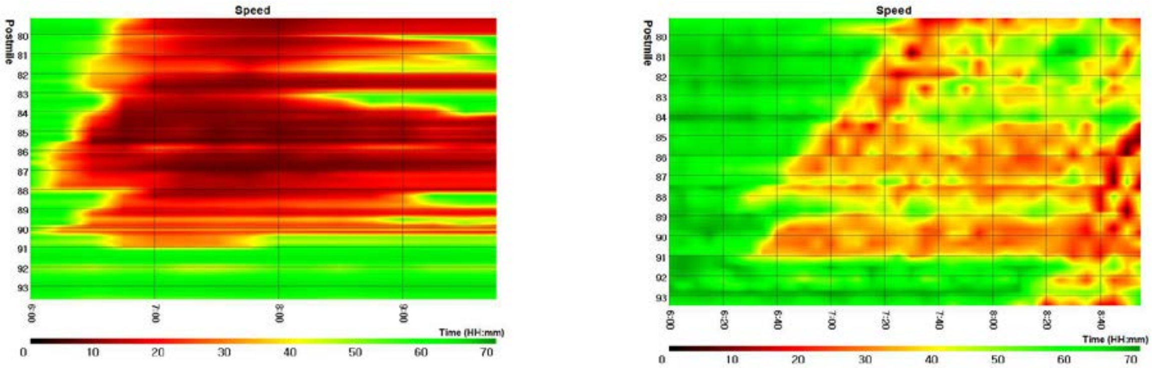
Figure 7.16. TTI results of the NB I-5 a.m. model: Base Scenario and Scenario 1.

No-Build Horizon Scenario (Scenario 0), Scenario 2, and Scenario 7: NB a.m. model

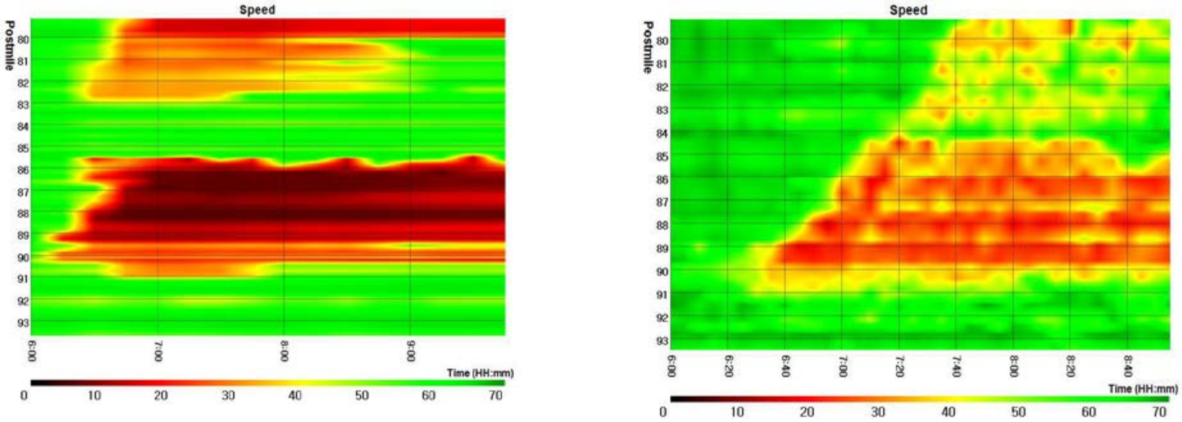
Figure 7.17 shows similar results for the horizon-year scenarios using the northbound a.m. model. Scenario 0 is the no-build, Scenario 2 corresponds to Scenario 1 (new on-ramps at SR-74 interchange), and Scenario 7 (add a single GP lane between El Toro and the Junipero Serra interchange). Scenarios 0 and 2 show very little change, but Scenario 7 improves traffic conditions. These results cover the mainline only, since the high-occupancy vehicle lanes were ignored in the FREEVAL-RL modeling. In addition, the FREEVAL-RL results for Scenario 7 are similar to the results for the Paramics microsimulation modeling. Note that the Paramics model covers a larger area than the FREEVAL-RL model, and thus its speed contour maps for Scenarios 0 and 2 shows a queue propagated backward from downstream. The FREEVAL-RL speed contours look more congested and have higher shockwave speed than those of Paramics. A possible reason is that the traffic flow characteristics of FREEVAL-RL are not able to reflect the capacity drop observed in the real world. Thus, the study team had to calibrate the model to have a relatively lower capacity in order to replicate the congestion period.



FREEVAL-RL Scenario 0 Paramics Scenario 0



FREEVAL-RL Scenario 2 Paramics Scenario 2



FREEVAL-RL Scenario 7 Paramics Scenario 7

Figure 7.17. Speed contours of NB I-5 a.m. model: Scenario 0, Scenario 2, and Scenario 7.

Figure 7.18 shows 50th, 80th, and 95th percentile TTI results for Scenarios 0, 2, and 7. These results show that Scenario 7 results in greater travel time reliability than do Scenarios 0 and 2. In comparing Scenarios 0 and 2, Scenario 2 TTIs are slightly higher (i.e., travel time reliability is slightly worse). This may occur because the improvement allows vehicles to enter the freeway mainline from SR-74 more easily and causes the mainline to be less reliable.

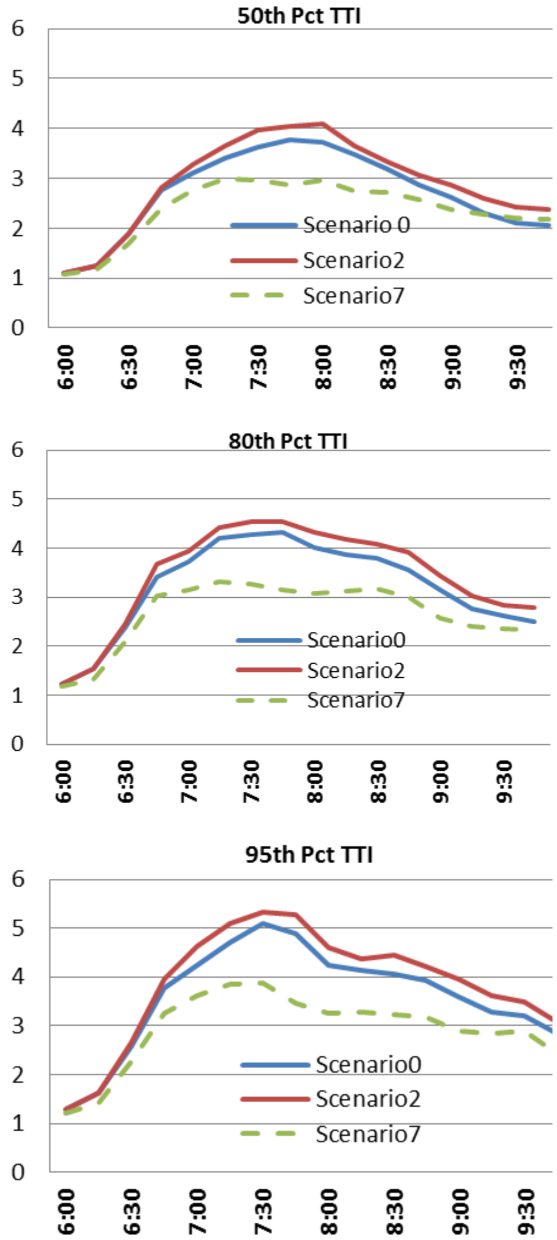
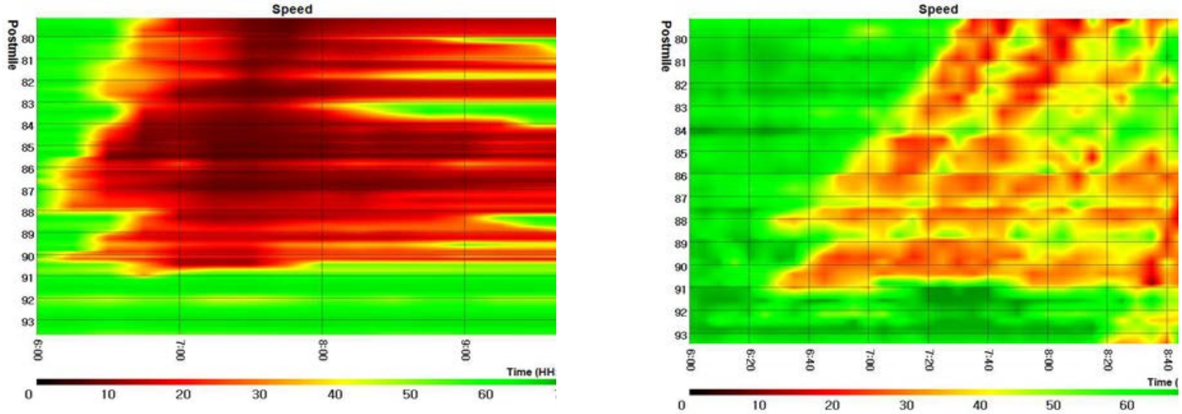


Figure 7.18. TTI results of NB I-5 a.m.: Scenario 0, Scenario 2, and Scenario 7.

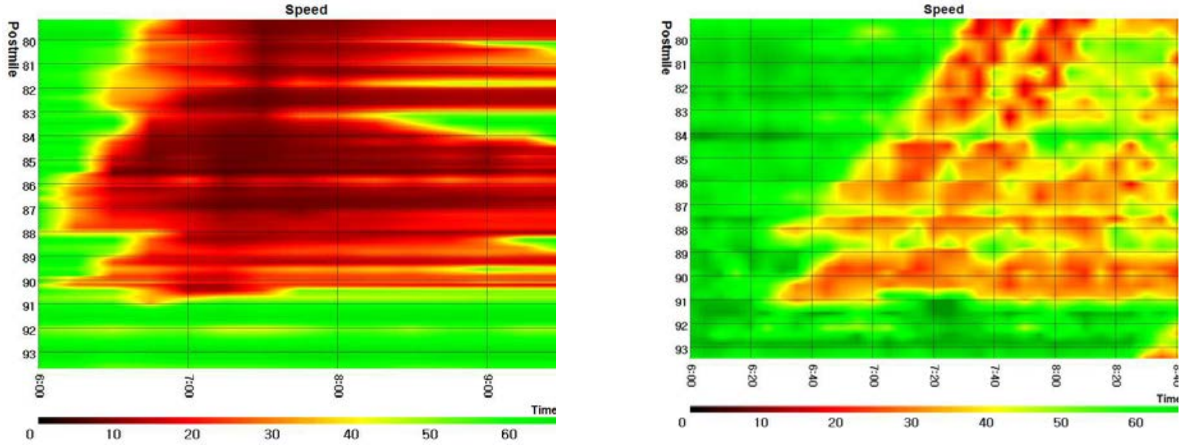
Scenarios 5 and 6: NB a.m. model

Scenarios 5 and 6 were used to test the benefits from incident management in the I-5 CSMP (Caltrans 2012). The study team implemented these two scenarios by decreasing CAFs for the segment with incident and affected time intervals. This means that the seed files for the two scenarios have lower capacities for some time intervals.

The study team applied an incident that causes one lane closure at Segment 49 (at the El Toro interchange) from 7:00 a.m. to 7:45 a.m. (corresponding to an incident duration of 45 minutes) in Scenario 5 and from 7:00 a.m. to 7:30 a.m. (corresponding to an incident duration of 30 minutes) in Scenario 6. Figure 7.19 clearly shows that congestion in Scenario 5 lasts longer than in Scenario 6. Accordingly, a significant difference can be observed in the TTI results of Scenarios 5 and 6 (as shown in Figure 7.20).



FREEVAL-RL Scenario 5 Paramics Scenario 5



FREEVAL-RL Scenario 6 Paramics Scenario 6

Figure 7.19. Speed contours of NB I-5 a.m. model: Scenario 5 and Scenario 6.

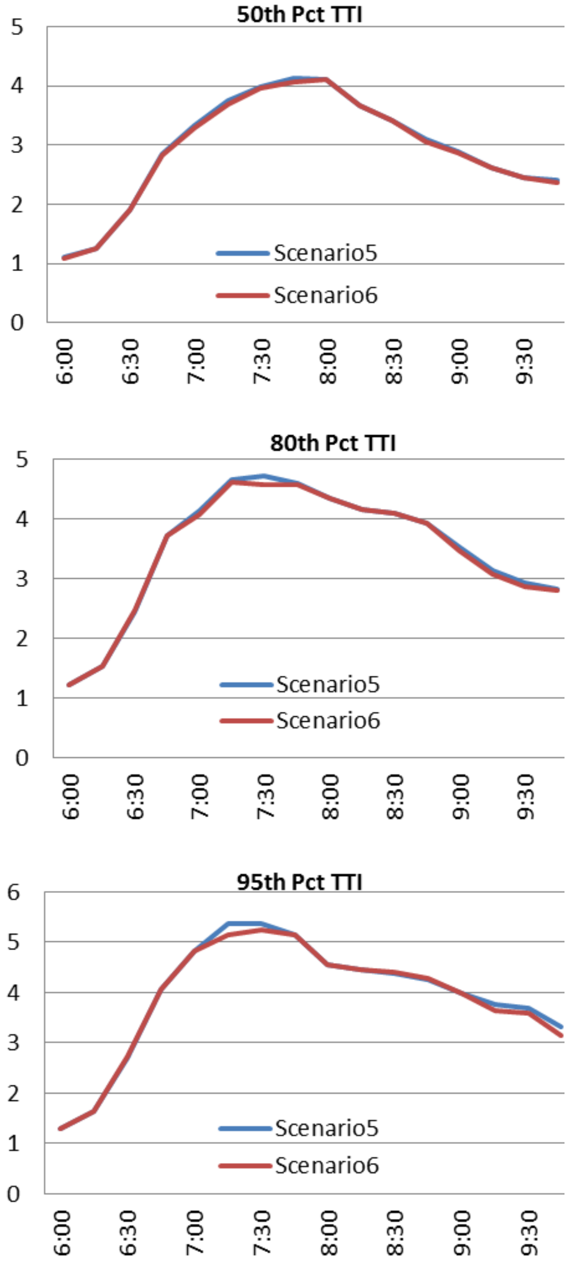
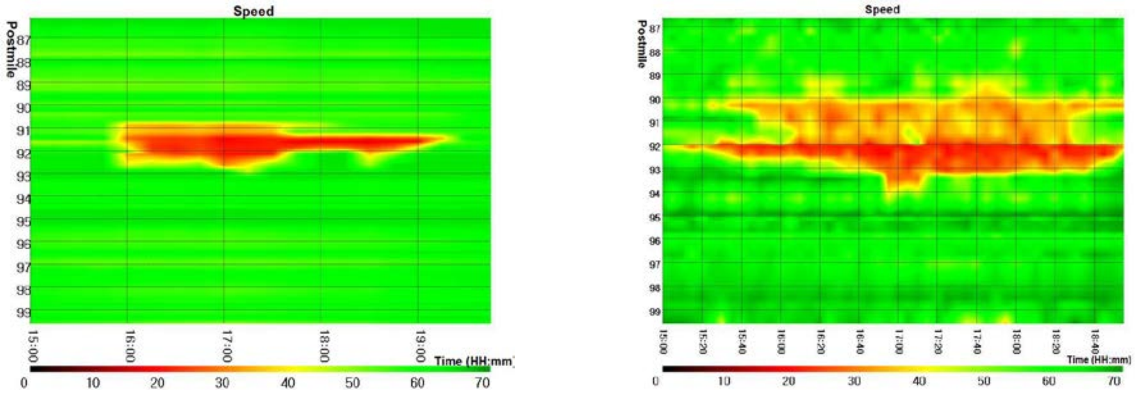


Figure 7.20. TTI Results of NB I-5 a.m. model: Scenario 5 and Scenario 6.

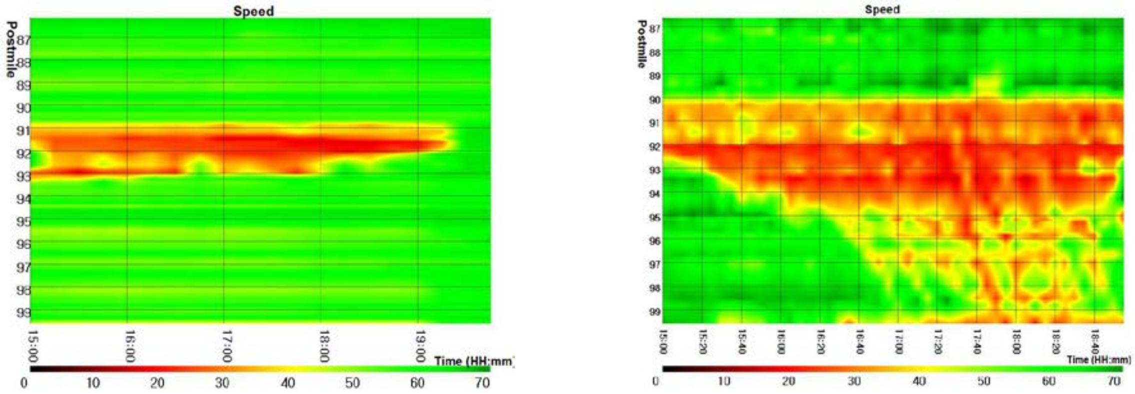
Base Scenario, No-Build Horizon (Scenario 0), and Scenario 7: SB p.m. Model

Figure 7.21 shows the speed contour maps from the FREEVAL-RL seed file results and the I-5 Paramics model for the Base Scenario, Scenario 0, and Scenario 7. The speed contour maps for these three scenarios (especially Scenario 0) are less congested, which can be seen from the comparison against the Paramics microsimulation results shown on the right side of Figure 7.21. The reason is that FREEVAL-RL has limitations on model freeway-to-freeway connector and ramp merge models. For this case, southbound has a major freeway-to-freeway connector (postmile 90) located just upstream of the bottleneck area. The connector has high flow, about 4,000 to 5,000 vehicles per hour. FREEVAL-RL cannot serve all demands from the three-lane freeway-to-freeway connector, which has been modeled as two on-ramps, based on the suggestion from the FREEVAL-RL developer. A further analysis shows that the ramp merge model does not allow the vehicles on the ramp to merge to the freeway mainline if the mainline is congested and the on-ramp flow is high.

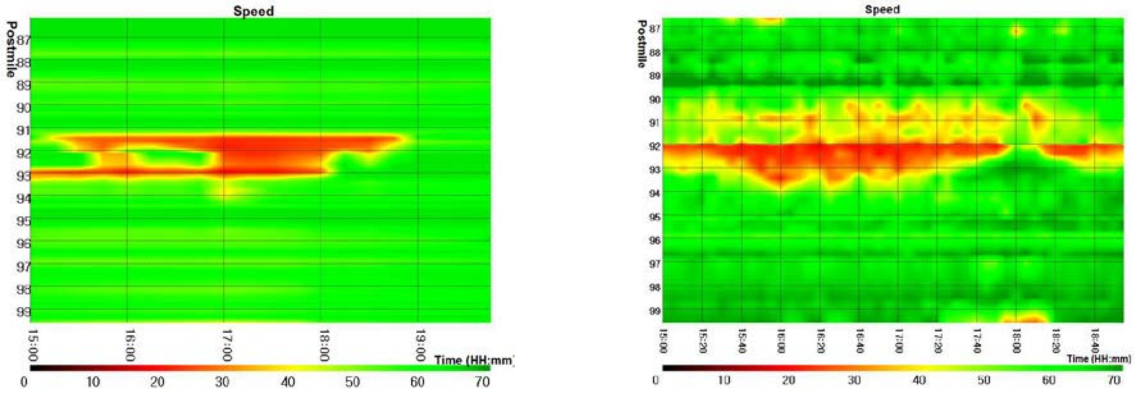
Also, the improvement applied in Scenario 7 involves the addition of one GP lane to the portions of freeway mainline between the SR-55 interchange and I-5 truck bypass and between the El Toro and Junipero Serra interchanges. The scenario is expected to increase the mainline capacity significantly and provide congestion reduction benefits. However, the speed contour map for Scenario 7 is only slightly better than that of Scenario 0. Scenario 0 shows less congestion than in the Paramics model.



FREEVAL-RL Base Scenario   Paramics Base Scenario



FREEVAL-RL Scenario 0   Paramics Scenario 0



FREEVAL-RL Scenario 7   Paramics Scenario 7

Figure 7.21. Speed contours of SB I-5 p.m. model: Base Scenario, Scenario 0, and Scenario 7.

The TTI results for these three CSMP scenarios are shown in Figure 7.22. For the Base Scenario, the 80th percentile TTIs estimated by FREEVAL are similar to the real-world PeMS TTIs, although the study team felt the SB p.m. FREEVAL-RL seed file was not well-calibrated. The TTI values for Scenarios 0 and 7 were slightly higher than the Base Scenario. However, the amount of increase is lower than expected because these seed file results were not congested enough to show benefits.

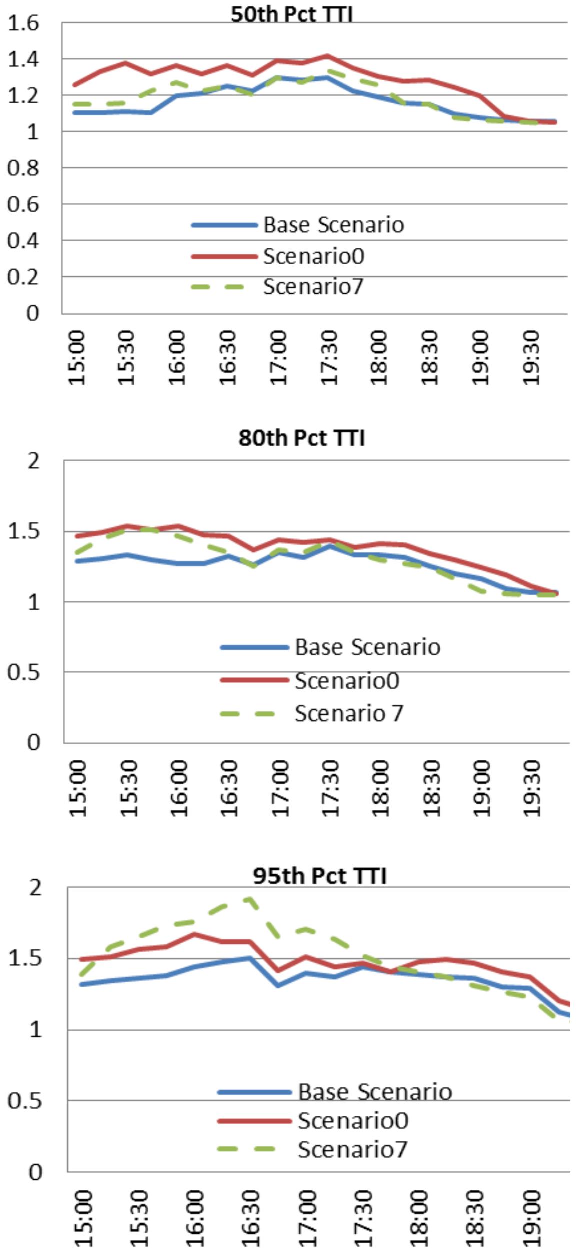
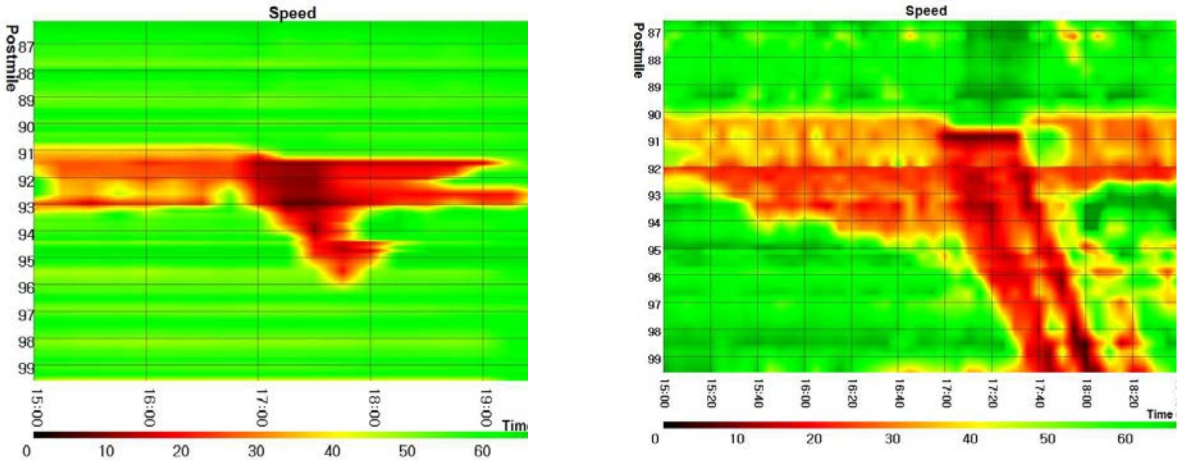


Figure 7.22. TTI Results of SB I-5 p.m. model: Base Scenario, Scenario 0, and Scenario 7.

Scenarios 5 and 6: SB p.m. Model

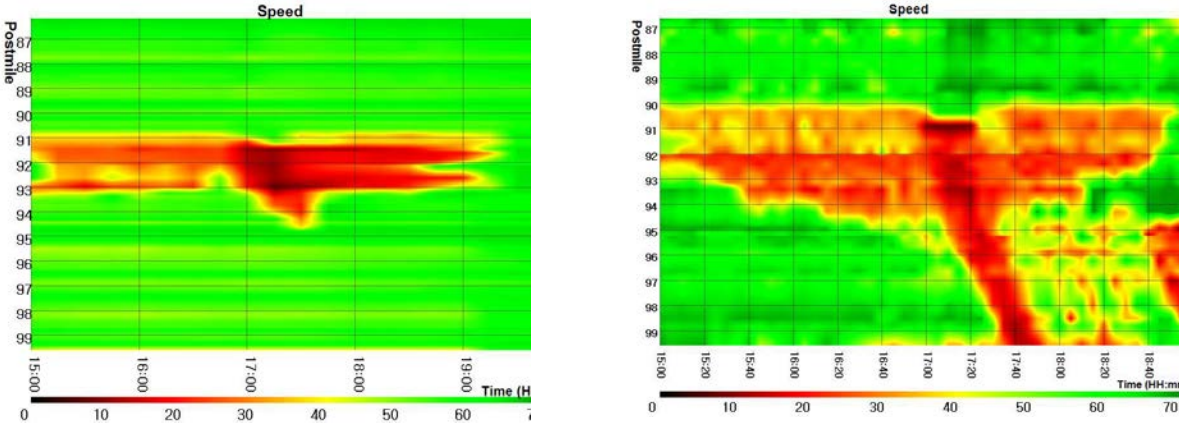
The study team ran Scenarios 5 and 6 to test benefits from incident management during the p.m. period. The scenarios were modeled by decreasing CAFs for the segment with an incident and the affected time intervals. This is the same approach as used for the CSMP modeling in Paramics.

The study team applied an incident that causes one lane closure at Segment 33 (located at the El Toro interchange) from 5:00 p.m. to 5:45 p.m. (corresponding to an incident duration of 45 minutes) in Scenario 5 and from 5:00 p.m. to 5:30 p.m. (corresponding to an incident duration of 30 minutes) in Scenario 6. As observed in Figure 7.23, the improvement provided incident management benefits. Travel time reliability also improved, as shown by the TTI results in Figure 7.24. However, the congestion benefits shown in FREEVAL-RL are significantly less than those in the Paramics microsimulations, because of the failure to serve all demands from the freeway-to-freeway connector, as previously discussed.



FREEVAL-RL Scenario 5

Paramics Scenario 5



FREEVAL-RL Scenario 6

Paramics Scenario 6

Figure 7.23. Speed Contours of SB I-5 p.m. model: Scenario 5 and Scenario 6.

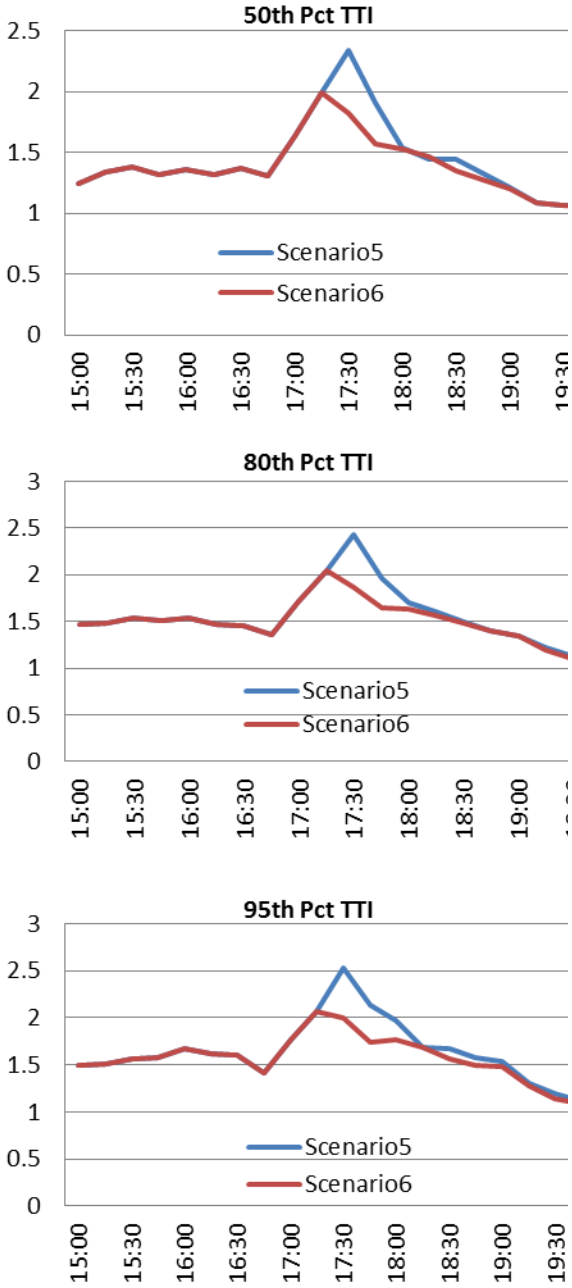


Figure 7.24. TTI Results of SB I-5 p.m. model: Scenario 5 and Scenario 6.

Tables 7.11 and 7.12 show the average hourly TTI results for all CSMP scenarios from the NB a.m. and SB p.m. models.

Table 7.11. TTI Summary for Northbound I-5 a.m. Model

NB/AM		Base	Scenario 0	Scenario 1	Scenario 2	Scenario 5	Scenario 6	Scenario 7
50th Pct	6:00	1.21	1.75	1.21	1.76	1.78	1.77	1.59
	7:00	1.49	3.47	1.49	3.73	3.79	3.77	2.89
	8:00	1.43	3.31	1.39	3.53	3.57	3.56	2.76
	9:00	1.12	2.28	1.12	2.56	2.59	2.58	2.26
80th Pct	6:00	1.37	2.14	1.37	2.22	2.24	2.24	1.91
	7:00	1.70	4.13	1.68	4.36	4.53	4.47	3.22
	8:00	1.67	3.81	1.66	4.13	4.14	4.14	3.09
	9:00	1.28	2.75	1.28	3.02	3.11	3.06	2.42
95th Pct	6:00	1.44	2.31	1.43	2.38	2.43	2.43	1.21
	7:00	2.15	4.74	2.06	5.08	5.18	5.13	3.70
	8:00	1.96	4.08	2.00	4.41	4.41	4.41	3.23
	9:00	1.61	3.23	1.59	3.54	3.69	3.63	2.76

Table 7.12. TTI Summary for Southbound I-5 p.m. Model

SB/p.m.		Base	Scenario 0	Scenario 5	Scenario 6	Scenario 7
50th Pct	15:00	1.11	1.32	1.32	1.32	1.17
	16:00	1.22	1.34	1.34	1.34	1.24
	17:00	1.28	1.39	1.97	1.75	1.30
	18:00	1.15	1.28	1.44	1.40	1.16
	19:00	1.07	1.10	1.10	1.10	1.05
80th Pct	15:00	1.31	1.50	1.50	1.50	1.45
	16:00	1.28	1.46	1.46	1.46	1.37
	17:00	1.34	1.42	2.04	1.81	1.37
	18:00	1.27	1.36	1.55	1.52	1.24
	19:00	1.10	1.15	1.19	1.18	1.06
95th Pct	15:00	1.35	1.54	1.54	1.54	1.59
	16:00	1.43	1.58	1.58	1.58	1.80
	17:00	1.40	1.46	2.13	1.90	1.58
	18:00	1.36	1.46	1.73	1.63	1.34
	19:00	1.14	1.20	1.29	1.25	1.10

Concluding Remarks

The study team has successfully demonstrated the potential of the FREEVAL-RL tool. However, the tool needs to be further improved. The most important aspects of improvement include the enhancement of its merge model, addition of the ability to model HOV lanes and on-ramps or freeway connectors with more than two lanes, and software bug fixes (such as the inability to take the calibrated capacity adjustment factor in the scenario testing process).

CHAPTER 8
Benefit-Cost Findings

After exploring the calibration and modeling capabilities of the three reliability analysis tools, the study team examined the impact of including travel time reliability in benefit-cost analysis. This is a critical test of whether travel time reliability can influence project priorities. The time frame of the SHRP L38 project is too short to follow specific projects through the planning and decision-making process. However, benefit-cost analysis provides a good proxy. If the inclusion of travel time reliability changes the relative order of projects or causes marginal projects to have benefit-cost ratios above one, then travel time reliability is likely to influence project selection.

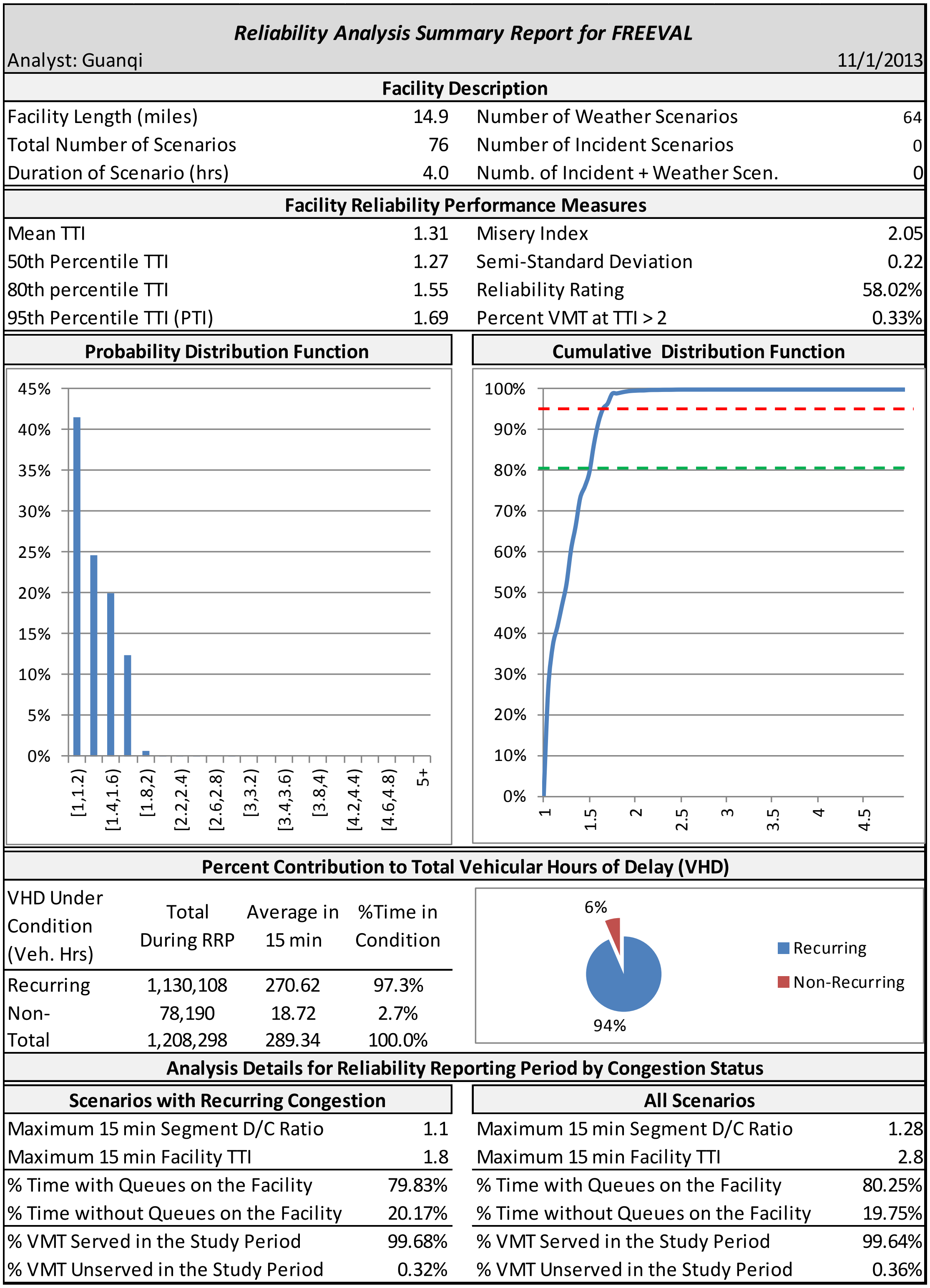
In California, benefit-cost analysis is just one factor used in project selection. Caltrans uses benefit-cost analysis when selecting projects for the interregional portion of the State Transportation Improvement Program (STIP). A quasi-benefit-cost analysis is also used to select operations projects for the State Highway Operations and Protection Program (SHOPP). Local agencies use their own processes to select and promote projects. Despite these differences, decision makers are less likely to consider travel time reliability in project selection and prioritization if the value to users of travel time reliability is low relative to other project benefits. This section describes the procedure for and the results of the benefit-cost testing conducted at the Southern California pilot site for the I-5 and I-210 facilities.

8.1 Use of the C11 Tool

The general approach for including travel time reliability was to update benefit-cost analyses from the I-5 and I-210 CSMPs. The CSMP benefit-cost analyses were built upon the microsimulation scenario testing and used the Cal-B/C framework to monetize the benefits. The Cal-B/C framework is described extensively in the Caltrans technical documentation for the model (System Metrics Group 2012). To add travel time reliability benefits, the study team used results from the SHRP 2 tools and monetized them by the Cal-B/C factors (Caltrans 2014) used for the CSMPs.

The study team focused on the C11 tool because it was easier to calibrate and generated more realistic results than the L07 tool. The study team also considered using FREEVAL-RL, but the tool does not monetize travel time reliability benefits. The study team would have had to estimate the dollar value of reliability benefits outside FREEVAL-RL. In addition, the study team was able to calibrate FREEVAL-RL for only about 14 miles of the 45-mile I-5 facility due to limitations on the time and extent of congestion handled in the model.

Although the study team did not use the FREEVAL-RL results in the benefit-cost test, the team did consider how agencies could use FREEVAL-RL output for estimating travel time reliability benefits. As shown in Figure 8.1, the FREEVAL-RL summary report lists a number of performance measures. Agencies could estimate the value of travel time reliability benefits using either the standard deviation or the 50th and 80th percentile TTI figures.



Reliability Analysis Summary Report for FREEVAL

Analyst: Guanqi 11/1/2013

Facility Description

Facility Length (miles)	14.9	Number of Weather Scenarios	64
Total Number of Scenarios	76	Number of Incident Scenarios	0
Duration of Scenario (hrs)	4.0	Numb. of Incident + Weather Scen.	0

Facility Reliability Performance Measures

Mean TTI	1.31	Misery Index	2.05
50th Percentile TTI	1.27	Semi-Standard Deviation	0.22
80th percentile TTI	1.55	Reliability Rating	58.02%
95th Percentile TTI (PTI)	1.69	Percent VMT at TTI > 2	0.33%

Probability Distribution Function

Cumulative Distribution Function

Percent Contribution to Total Vehicular Hours of Delay (VHD)

VHD Under Condition (Veh. Hrs)	Total During RRP	Average in 15 min	%Time in Condition
Recurring	1,130,108	270.62	97.3%
Non-	78,190	18.72	2.7%
Total	1,208,298	289.34	100.0%

Analysis Details for Reliability Reporting Period by Congestion Status

Scenarios with Recurring Congestion		All Scenarios	
Maximum 15 min Segment D/C Ratio	1.1	Maximum 15 min Segment D/C Ratio	1.28
Maximum 15 min Facility TTI	1.8	Maximum 15 min Facility TTI	2.8
% Time with Queues on the Facility	79.83%	% Time with Queues on the Facility	80.25%
% Time without Queues on the Facility	20.17%	% Time without Queues on the Facility	19.75%
% VMT Served in the Study Period	99.68%	% VMT Served in the Study Period	99.64%
% VMT Unserved in the Study Period	0.32%	% VMT Unserved in the Study Period	0.36%

Figure 8.1. Example of FREEVAL-RL summary report from northbound I-5 a.m. Base model.

The L07 final report (MRIGlobal 2013b) provides equations for calculating the benefits using the standard deviation on page 88 of an earlier draft version of the report. Essentially, an agency would calculate the difference in the standard deviations estimated for the build and no-build scenarios and multiply the difference by the value of reliability and total vehicle-miles traveled (VMT) along the facility. FREEVAL-RL provides VMT for the volume handled in the model in its comprehensive outputs spreadsheet. A VMT for each segment is found in the "Results Summary" tab of the spreadsheet on the row labeled "VMTV Veh-miles (Volume)." These figures can be multiplied by the segment length in miles, summed to estimate the total VMT for the facility, and used in the above calculations. The results of the calculations would be a reliability value equivalent to the method used in the L07 Analysis Tool. Using the standard deviation is the method most commonly used in recent reliability research.

Alternatively, the reliability benefits could be estimated using the difference between the 50th and 80th percentiles. The technical documentation for the C11 Reliability Analysis Tool (Cambridge Systematics et al. 2013b) provides formulas for using this inter-percentile difference on pages 16 and 17. These formulas could be modified to remove the recurrent delay portion of the calculation and may have been addressed in recent updates to the tool. The resulting formula basically multiplies the change in the inter-percentile difference by the value of reliability and the VMT. This method would estimate reliability benefits equivalent to those reported in the C11 Reliability Analysis Tool. This value would not be the same as (and likely slightly larger than) the one calculated using the L07 method.

8.2 Procedure for Estimating Reliability Benefits

Once the study team settled on using the C11 tool for estimating travel time reliability benefits, the team estimated the impact of including travel time reliability in the following steps:

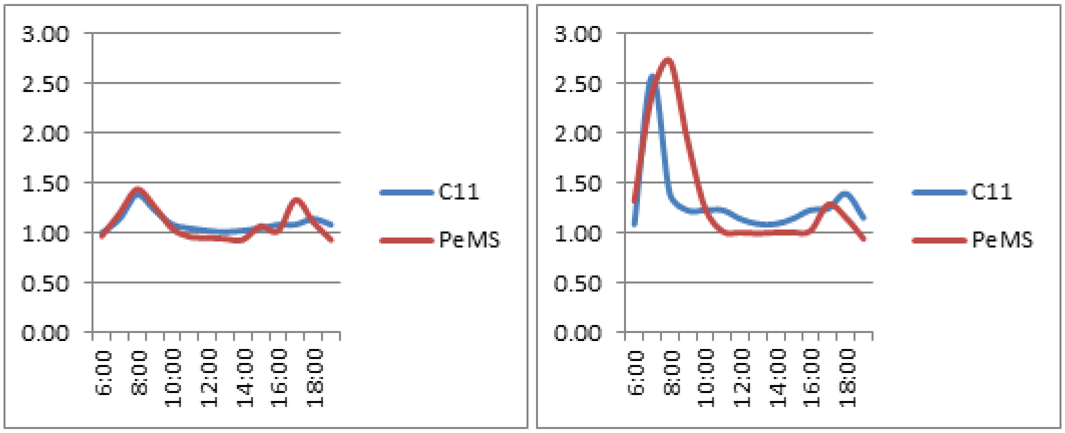
- Start with the C11 tool to estimate the cost of unreliability for each CSMP scenario.
- Calculate the travel time reliability benefit by estimating the reduction in the cost of unreliability from one scenario to the next.
- Add the reliability benefits to the CSMP benefit-cost analysis.
- Analyze the change in the overall benefit-cost ratio and the rank order of projects when reliability is included as a benefit.

This procedure required the C11 tool to be recalibrated for the I-210 and I-5 facilities. This is because the CSMP benefit-cost analyses covered entire facilities, while the C11 calibration and scenario testing discussed in Chapter 5 covered only portions of the facilities. The recalibration process was aided by the earlier calibration efforts, but it required additional work to identify appropriate segmentation.

For the I-210 facility, the study team focused on the four-lane and five-lane segments since these had proven adequate in earlier testing. Although the eastbound direction was already calibrated, the study team had to download additional PeMS data to calibrate the westbound direction. The study team knew from the earlier calibration efforts that obtaining the necessary hourly VMT and TTI data would be very time-consuming. PeMS allows only two to three weeks of each year to be downloaded at a time.

The study team decided to examine the data available for the eastbound direction and select the most representative two-week period (i.e., the first two weeks of November). The study team then downloaded the necessary hourly data for the two westbound segments and calibrated the C11 tool for these segments. Although this shortcut did not save much time for the I-210 facility, it was absolutely necessary for re-calibrating the I-5 facility.

As Figure 8.2 shows, the C11 tool calibrated fairly well to real-world conditions (as measured by PeMS) for the westbound I-210 segments. The calibration required slightly higher peak capacities for the westbound direction than the eastbound direction (roughly 1,700 to 1,900 vphpl westbound compared to 1,460 to 1,490 vphpl eastbound). This result makes sense because the westbound direction experiences less congestion (and has a lower throughput or productivity loss) than the eastbound direction.



(a) Five-lane segment (b) Four-lane segment

Figure 8.2. Calibration of westbound I-210 segments.

For the I-5 facility, the study team needed to recalibrate the entire facility, since the previous calibration had focused on a small, 6.5-mile segment. The study team decided to divide the facility into segments according to the bottleneck areas identified in the CSMP. These are shown in Figure 3.5. This resulted in seven segments in the northbound direction and nine segments in the southbound direction. This segmentation is consistent with the microsimulation modeling and aggregation of results used for the benefit-cost analysis found in the CSMP. The study team used the percent demand per hour distribution already calculated for the 6.5-mile segment for the northbound segments. The distribution for the southbound segments was calculated using a representative two-week period.

Once the calibration was completed, the study team tested each of the CSMP scenarios in the models. For the I-210 facility, this involved running the model for only the two new calibrated westbound segments. For the I-210 facility, the testing required running the C11 tool 16 times for each scenario.

The CSMP benefit-cost analyses covered a 20-year life cycle. The C11 tool does not calculate life-cycle benefits within the tool. Rather, individual year benefits are calculated for a current and future year. Ideally, reliability benefits should be calculated for each year, summed, and discounted. However, the study team decided to estimate benefits for the current year and 20 years later in the C11 tool using an ADT growth factor estimated from the CSMP microsimulation runs and travel demand models for each facility.

The study team developed a spreadsheet to interpolate the current and future year delay and reliability benefits over a 20-year life cycle. Figure 8.3 shows a snapshot from this spreadsheet for the I-5 facility. For both facilities, the benefits were interpolated and discounted using the same 4-percent discount rate used in calculating benefits for the I-5 and I-210 CSMPs.

Year	Base vs. NB S1-S2	Base vs. Total S1-S2	Base vs. NB S3-S4	Base vs. Total S3-S4	Base vs. NB Incident Mgmt	Base vs. Total Incident Mgmt	Base vs. NB S7	Base vs. Total S7
1	$1,298,209	$2,234,467	$2,134,750	$2,627,168	$4,605,747	$6,002,362	$24,520,895	$35,046,001
21	$6,144,234	$10,578,351	$14,508,886	$22,131,369	$30,437,340	$45,426,526	$24,520,895	$35,046,001
1	$1,298,209	$2,234,467	$2,134,750	$2,627,168	$4,605,747	$6,002,362	$24,520,895	$35,046,001
2	$1,481,260	$2,549,674	$2,647,554	$3,463,825	$5,670,507	$7,666,895	$23,577,784	$33,698,078
3	$1,648,310	$2,837,329	$3,117,754	$4,232,238	$6,646,548	$9,194,507	$22,670,946	$32,401,998
4	$1,800,318	$3,099,085	$3,547,869	$4,936,418	$7,539,121	$10,593,269	$21,798,986	$31,155,767
5	$1,938,195	$3,336,509	$3,940,286	$5,580,169	$8,353,203	$11,870,832	$20,960,564	$29,957,469
6	$2,062,803	$3,551,085	$4,297,268	$6,167,099	$9,093,510	$13,034,451	$20,154,388	$28,805,258
7	$2,174,959	$3,744,219	$4,620,961	$6,700,625	$9,764,514	$14,091,001	$19,379,220	$27,697,364
8	$2,275,435	$3,917,244	$4,913,399	$7,183,988	$10,370,450	$15,046,995	$18,633,865	$26,632,081
9	$2,364,966	$4,071,421	$5,176,505	$7,620,257	$10,915,331	$15,908,607	$17,917,178	$25,607,770
10	$2,444,243	$4,207,943	$5,412,104	$8,012,340	$11,402,957	$16,681,683	$17,228,056	$24,622,856
11	$2,513,924	$4,327,940	$5,621,922	$8,362,990	$11,836,927	$17,371,757	$16,565,438	$23,675,823
12	$2,574,629	$4,432,482	$5,807,594	$8,674,815	$12,220,646	$17,984,072	$15,928,306	$22,765,214
13	$2,626,945	$4,522,580	$5,970,668	$8,950,281	$12,557,338	$18,523,587	$15,315,679	$21,889,629
14	$2,671,429	$4,599,191	$6,112,606	$9,191,726	$12,850,053	$18,994,998	$14,726,614	$21,047,720
15	$2,708,604	$4,663,218	$6,234,793	$9,401,357	$13,101,675	$19,402,745	$14,160,206	$20,238,192
16	$2,738,969	$4,715,517	$6,338,540	$9,581,266	$13,314,933	$19,751,028	$13,615,583	$19,459,800
17	$2,762,990	$4,756,894	$6,425,082	$9,733,428	$13,492,405	$20,043,817	$13,091,906	$18,711,347
18	$2,781,112	$4,788,113	$6,495,591	$9,859,712	$13,636,529	$20,284,866	$12,588,372	$17,991,679
19	$2,793,753	$4,809,894	$6,551,172	$9,961,884	$13,749,607	$20,477,723	$12,104,203	$17,299,692
20	$2,801,308	$4,822,916	$6,592,868	$10,041,611	$13,833,814	$20,625,737	$11,638,657	$16,634,319
TOTAL (Present Value)	**$46,462,362**	**$79,987,721**	**$101,959,286**	**$150,283,197**	**$214,955,817**	**$313,550,934**	**$346,576,845**	**$495,338,057**

Figure 8.3. Example of interpolating benefits on the I-5 facility. (Discount Factor = 4.00%; Average Vehicle Occupancy (AVO) = 1.24)

In previous unpublished research, study team members tested the difference in interpolating model inputs compared to benefits for benefit-cost analysis and found that interpolating the benefits does not accurately estimate the results from year-by-year estimation. However, the study team chose to interpolate the benefits given the time and resources available for the L38 project. The C11 tool should be modified to estimate life-cycle benefits, so agencies do not need to interpolate benefits or engage in time-consuming year-by-year estimation of benefits.

8.3 Benefit-Cost Results

Figure 8.4 shows the original benefit-cost results from the I-5 CSMP (Caltrans 2012). The CSMP benefit-cost analysis includes all of the CSMP scenarios shown earlier in Figure 3.8, with the exception of the enhanced incident management scenarios. These scenarios were excluded from the benefit-cost analysis in the CSMP, so the study team decided not to include them in the test to include C11 reliability benefits.

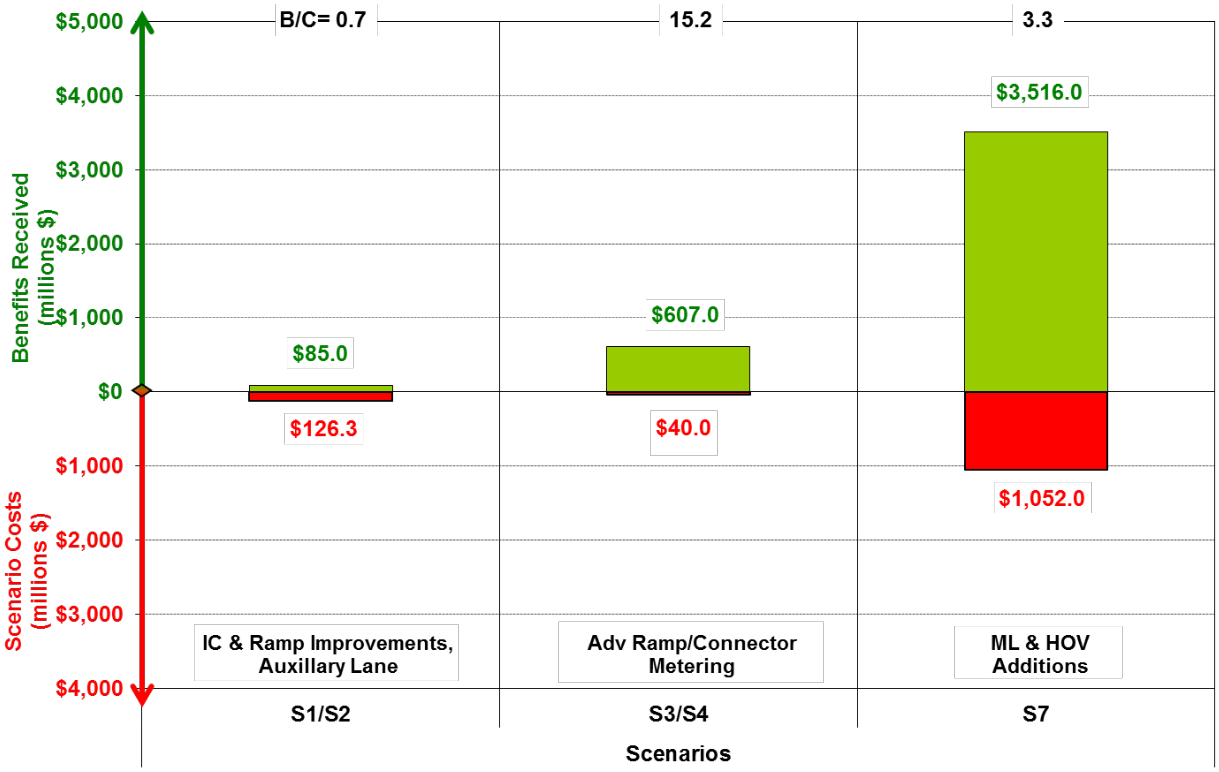


Figure 8.4. Benefit-cost results in CSMP for I-5 facility.

Source: Caltrans, I-5 CSMP.

The benefit-cost calculations shown in Figure 8.3 include three types of user benefits: travel time (or delay) savings, vehicle operating cost savings, and emission savings. These benefits were estimated using results from microsimulation runs. As can be seen in Figure 8.4, the CSMP benefit-cost analysis includes scenarios with costs ranging from $40 million for advanced ramp and connector metering to $1,052 million for additional general-purpose and high-occupancy vehicle lanes along the facility. The CSMP assumes sequential implementation starting with the interchange and ramp improvements found in Scenarios 1 and 2. The benefit-cost ratios range from 0.7 for the interchange and ramp improvements to 15.2 for low-cost ramp and connector metering.

Figure 8.5 shows the original benefit-cost results from the I-210 CSMP (SCAG and Caltrans 2010). As can be seen in the exhibit, significantly more strategies were tested on the I-

210 facility. These strategies resulted in abnormally high benefit-cost ratios due to heavy congestion on the facility and relatively low costs for improvements (ranging from $4.0 million for ramp closures to $44.0 million for auxiliary lanes and ramp improvements). The exhibit does not show two scenarios from the original CSMP benefit-cost and analysis, Scenarios 13 (interchange modification) and 14 (drop ramp and widening), which have benefit-cost ratios of 1.4 and 6.1, respectively. These scenarios included improvements on portions of the facility outside the area modeled in the C11 tool, so the scenarios were not included in the reliability test.

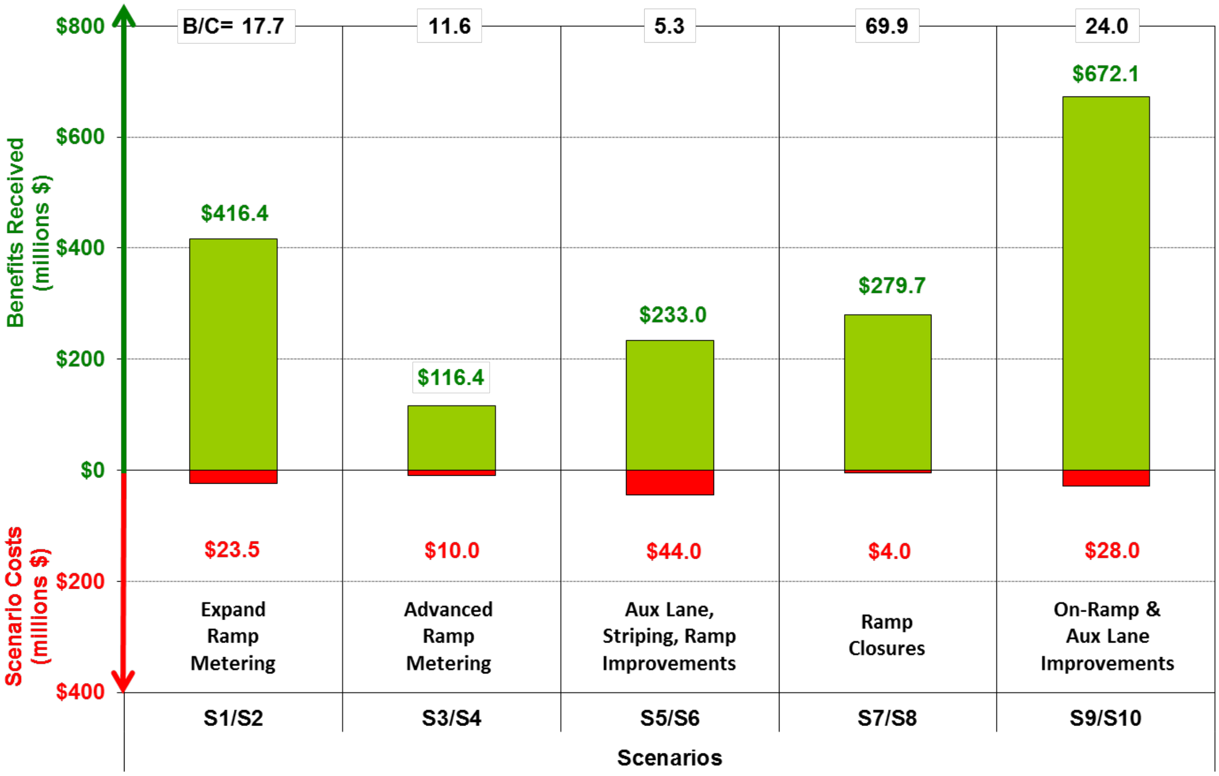


Figure 8.5. Benefit-cost results in CSMP for I-210 facility.

Source: SCAG and Caltrans, I-210 CSMP.

For both facilities, the study team estimated travel time reliability benefits using the C11 tool and added these benefits to the results shown in Figures 8.4 and 8.5. In the process of adding these benefits, the study team discovered that the C11 tool does not take into account the average vehicle occupancy (AVO) for automobiles. As a result, the value of time for personal travel should been multiplied by the AVO prior to running the C11 tool. The study team decided to adjust the mobility (recurring delay) and reliability (unreliability) benefits as part of the interpolation spreadsheet.

Figure 8.6 shows the benefit-cost ratios that resulted from including the reliability benefits estimated in the C11 tool for the I-5 facility. The shaded portion of the bar indicates benefits due to improvements in travel time reliability, while the solid portion indicates the benefits in the original benefit-cost analysis. Comparing Figure 8.6 with Figure 8.4 demonstrates that the addition of reliability benefits does not affect the rank order of the projects by their total benefit or their benefit-cost ratios. However, the addition of reliability benefits boosts the total benefits for the interchange and ramp improvements in Scenarios 1 and 2 so that the total benefit-cost ratio exceeds one. This suggests that ignoring travel time reliability benefits could make a cost-beneficial operational project be not cost-effective.

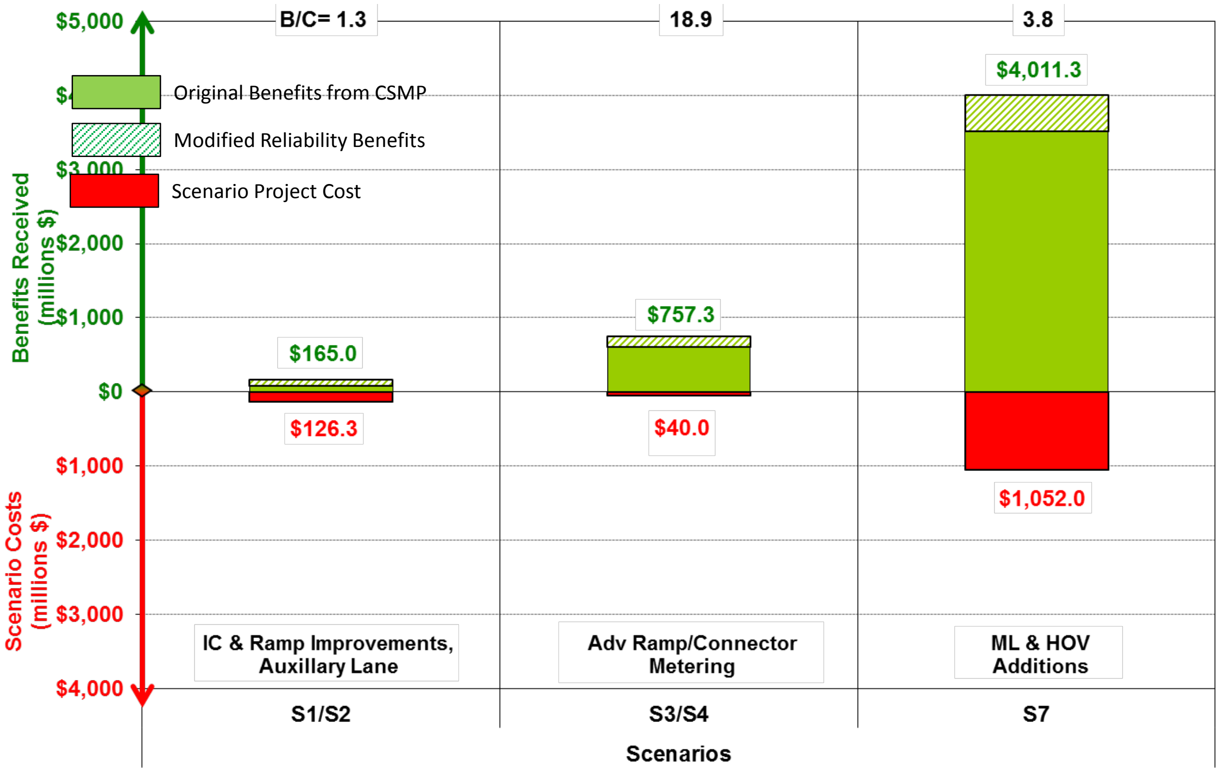


Figure 8.6. Benefit-cost results for I-5 facility with C11 reliability estimate added.

Figure 8.7 shows the result of adding the C11 reliability estimates to the benefit-cost analysis for the I-210 facility. Again, the shaded portion of the bars shows the addition of the reliability benefits. The impact is similar to that found on the I-5 facility. Adding travel time reliability does not reorder the projects in terms of total benefits or benefit-cost ratios. The advanced ramp metering project found in Scenarios 3 and 4 receives the greatest benefit from the inclusion of travel time reliability. The reliability impact on auxiliary lanes and ramp improvements is much larger in Scenarios 9 and 10 than in Scenarios 3 and 4. However, the magnitude of this change is related to the size of the overall benefits.

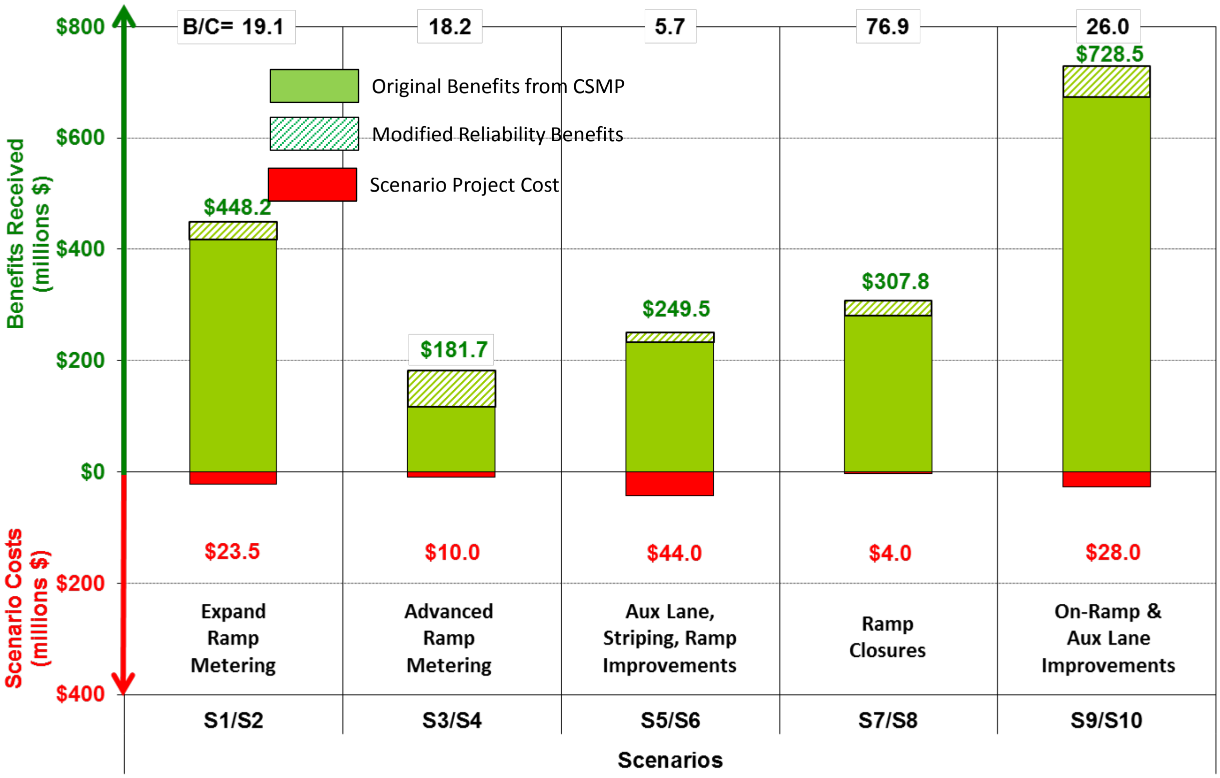


Figure 8.7. Benefit-cost results for I-210 facility with C11 reliability estimate added.

However, it may not make sense to simply add the C11 reliability benefits to the original CSMP benefit-cost analysis. As shown in Figures 8.8 and 8.9, the C11 Reliability Analysis Tool did not estimate the same mobility (recurring delay) benefits as did the CSMP microsimulation analysis. In most cases, the C11 tool underestimates mobility benefits compared to the CSMPs.

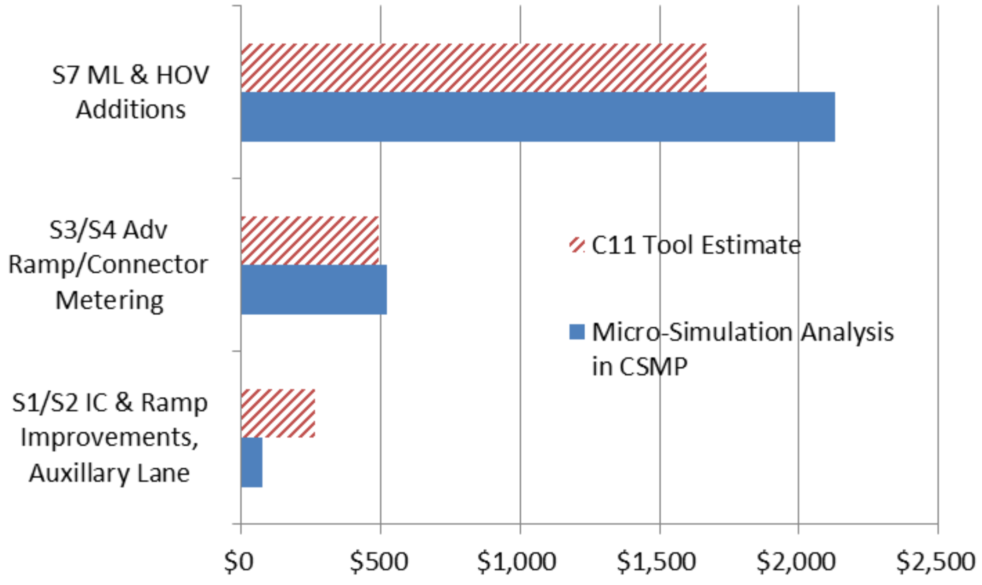


Figure 8.8. I-5 Recurring delay benefit from C11 tool compared with mobility benefit in CSMP.

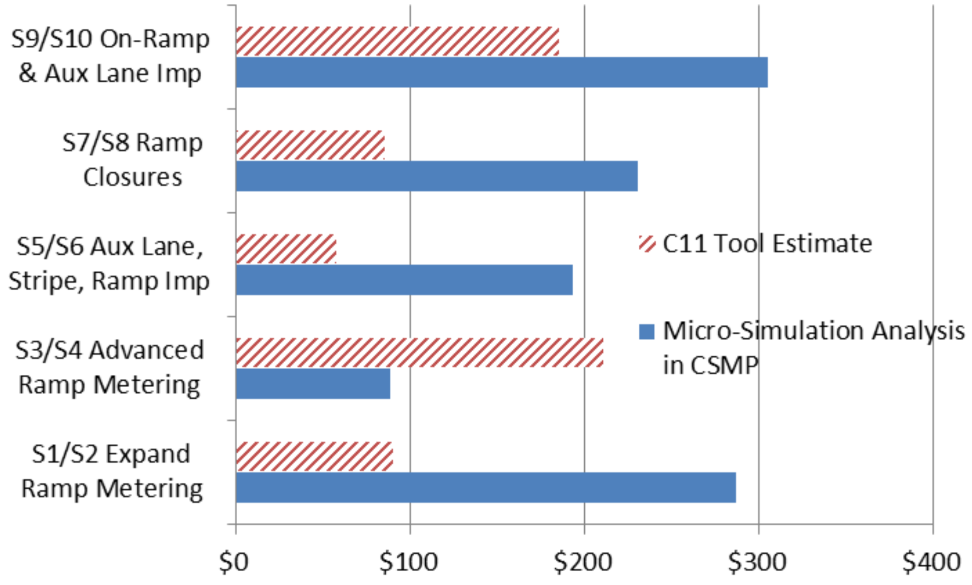


Figure 8.9. I-210 recurring delay benefit from C11 tool compared with mobility benefit in CSMP.

The CSMP benefit estimates are probably more accurate because they are based on microsimulation modeling rather than a sketch planning tool. The microsimulation modeling does a better job of capturing the impact of bottleneck relief on the operational performance of the facility. The discrepancy in the recurring delay estimates could also be due to the capacity improvement assumption used to model some scenarios in the C11 tool. For the I-210 facility, another factor is that the CSMP covered a slightly larger area than was modeled in the C11 tool.

The study team decided to adjust the C11 tool results by assuming that the microsimulation model is more accurate in modeling mobility benefits, but that the C11 tool is accurate in estimating reliability benefits relative to mobility benefits. The second assumption is based on the C11 tool using volume-to-capacity (v/c) ratios to estimate both mobility and reliability benefits. In fact, the C11 tool results suggest that reliability benefits are typically about 30 percent of the mobility benefits. This ratio ranges from 30 to 32 percent for the I-5 facility and from 29 to 36 percent for the I-210 facility.

Figures 8.10 and 8.11 show the benefit-cost results after the C11 tool outputs are adjusted to match the microsimulation results (and maintain the reliability to mobility ratio). As with the unadjusted figures, the inclusion of the reliability benefits does not impact the rank order of the improvements for either facility in terms of total benefits or benefit-cost ratios. Two differences are worth noting. First, the benefit-cost ratio of I-5 Scenarios 1 and 2 is below one, so the inclusion of travel time reliability does not make the project cost beneficial. A project closer to breaking even might have benefitted from the inclusion of travel time reliability. Second, I-5 Scenarios 3 and 4 have nearly the same total benefits as I-210 Scenarios 9 and 10, while the benefits of the I-210 scenarios were higher without reliability. Clearly, travel time reliability can make a difference in the ranking of projects that have very similar benefits.

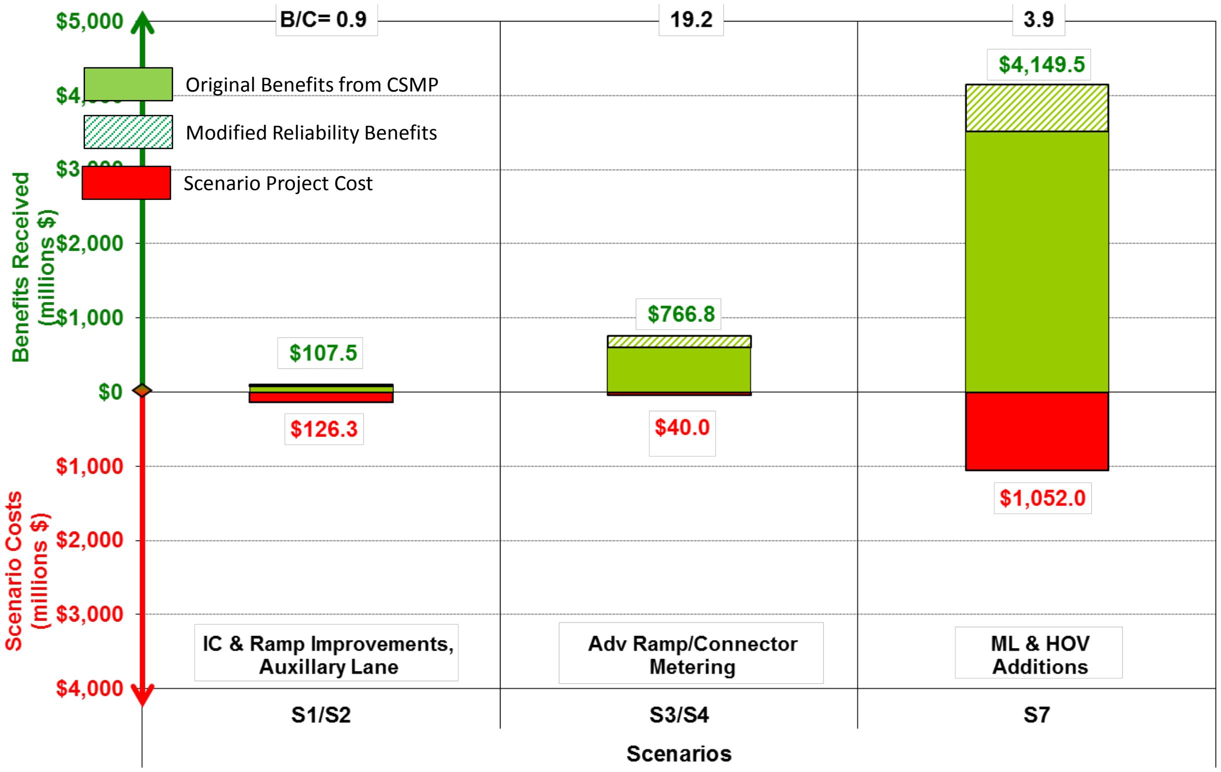


Figure 8.10. Benefit-cost results for I-5 facility with C11 reliability estimate modified.

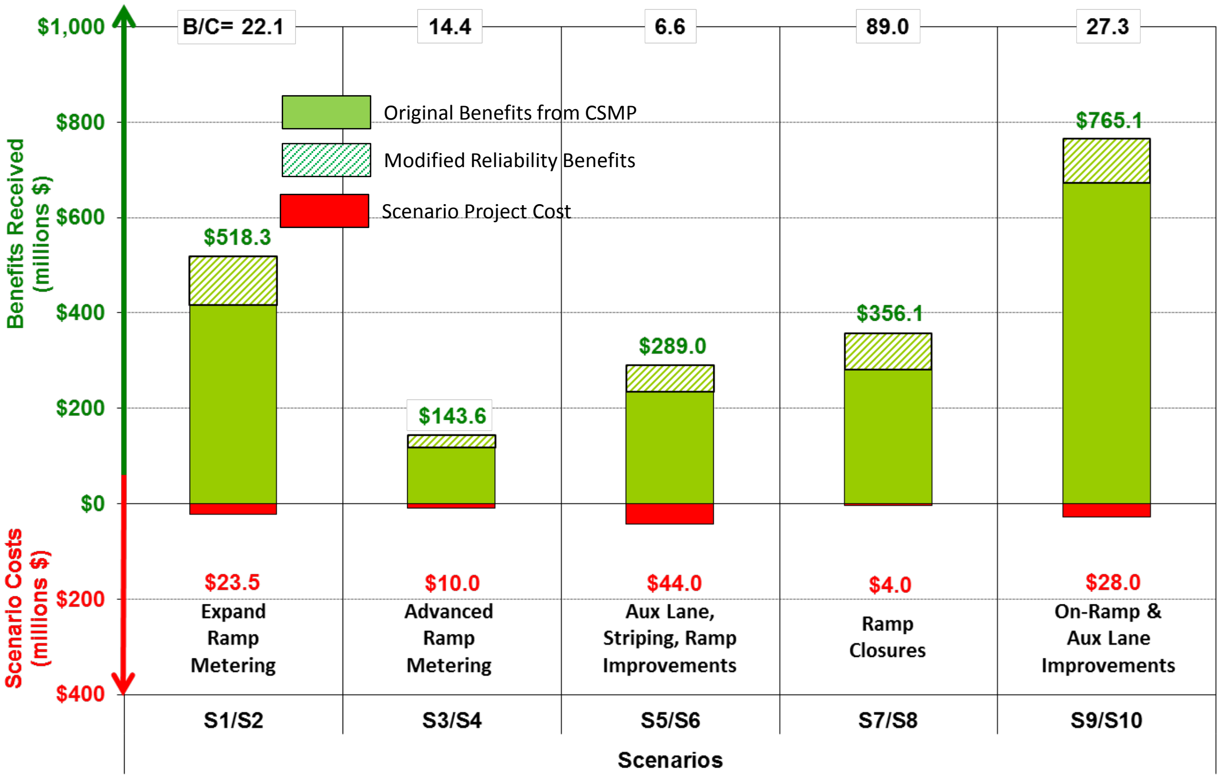


Figure 8.11. Benefit-cost results for I-210 facility with C11 reliability estimate modified.

8.4 Implications for Decision Making

Caltrans and SCAG originally chose to use microsimulation for modeling operational projects in the CSMPs because travel demand models tended to underestimate the mobility benefits. This is because traditional travel demand models are only able to look at individual links and unable to examine how relieving bottlenecks removes queuing upstream and shifts demand downstream. Perhaps then, it should not be a surprise that a link-based model like the L07 tool underestimates mobility benefits compared to microsimulation modeling.

Does including travel time reliability impact the ordering of projects? It did not for the CSMP scenarios modeled in tests described above. However, the test results suggest that including travel time reliability can make a difference for projects with similar benefit-cost ratios. It may also make a difference for marginal projects.

Is travel time reliability worth the trouble of modeling? The benefit-cost test suggests that one may be able to apply a 29 percent to 36 percent factor to account for travel time reliability. However, there was some variation between scenarios, and these results may not hold true for other facilities. Furthermore, the study team did not examine what would happen if travel time reliability benefits were estimated using FREEVAL-RL. This tool is likely to estimate higher mobility (and reliability) benefits because it is more similar to estimating the interaction between links (like a microsimulation model) than is the C11 tool. In addition, this discussion does not consider the communication aspect of being able to model travel time reliability.

What should agencies do to include travel time reliability in project analysis? The study team suggests that agencies consider using a simple approach, such as the C11 tool, if they already have detailed approaches, such as microsimulation modeling, for estimating mobility benefits. If detailed approaches are not available, the FREEVAL-RL tool may be appropriate for modeling both the mobility and the reliability benefits. However, analysis with FREEVAL-RL is data- and time-intensive, as described in Chapter 7 of this report.

CHAPTER 9

Functionality Assessment and Research Outcome

This section provides a summary assessment of the SHRP 2 products tested at the Southern California pilot site and describes the outcomes of the analysis. The study team began its assessment of technical functionality during tool testing. These observations are documented in detail in Chapters 5 through 7. The team spent considerable time learning how to use and calibrate the tools for its two study facilities.

The study team made additional observations about tool functionality while conducting the benefit-cost analysis. For example, the team discovered that the C11 tool does not explicitly include average vehicle occupancy (AVO) as part of the user costs. It is assumed that AVO is implicitly included, but the tool would benefit from having an AVO input box. This and similar observations have been added to the tool limitations described at the beginning of Chapters 5 through 7.

The assessment of agency and decision maker perceptions started with SCAG's involvement in the tool testing. SCAG technical staff calibrated and ran the tools for one facility, while other study team members focused on the other facility. This allowed SCAG staff to have hands-on experience and provide agency perspectives. The SCAG staff involved in the SHRP 2 testing is also responsible for developing the next SCAG RTP. This allowed SCAG to consider how the guidelines found in L05 might be used for selecting goals for the RTP and how the results of the other tool tests might aid in setting reasonable thresholds.

In addition, the study team conducted outreach throughout the project. Caltrans provided input into the selection of facilities, and one of the original candidate facilities was replaced based on this input. Projects had already been committed or programmed along the facility, so the pilot testing would have no chance of influencing project priorities.

After the facility analyses were completed, the study team met with Caltrans district staff to share the tool testing results and benefit-cost analysis. Transportation planners and traffic operations engineers attended the meeting, so the study team was able to gather multiple perspectives. In addition, the meeting included decision makers responsible for operations projects.

The study team sought input from other stakeholders through SCAG policy and technical committees. SCAG included a written update on the pilot testing in the consent calendar for its Transportation Committee. SCAG also provided its technical working group with an update on the project and the results of tool testing. This group has several stakeholders, including representatives from cities, counties, transportation commissions, subregional areas, Caltrans districts, and other interest groups.

The study team's assessments of SHRP 2 product functionality and decision maker perceptions includes input from all of these efforts and is organized into the following sections:

- Technical Functionality of Products
- Decision Maker Perceptions
- Impacts on Decision Making

9.1 Technical Feasibility of Products

The study team considered the relative ease of using the SHRP 2 products, their usefulness in the analysis process, and consistency among the tools. The technical evaluation includes input from study team members (including SCAG), Caltrans, and other stakeholders.

How well does the work completed to date help Southern California agencies better understand the causes of baseline reliability?

Prior to the SHRP 2 product pilot testing, California already had travel time reliability monitoring capabilities through PeMS. This system includes several years of highway performance data collected by sensors throughout the state and calculates reliability performance measures such as travel time reliability. In addition, several Southern California facilities are covered by CSMPs, which have reliability performance measures included as part of the analysis.

The L02 guide provided a number of new analysis techniques and ways of looking at reliability factors. The cumulative distribution functions (CDFs) and the semi-variance tables help to show the relative contribution of reliability factors and visualize their impact on facility reliability. The study team found that the order in which factors are assigned affects the results of the analysis. For the best results, the analysis should include categories for multiple factors (e.g., incidents and weather issues occurring simultaneously) and specifically consider factors such as work zones and lane closures. These new techniques could be incorporated into future CSMPs.

Do the tools provide reasonable results for a variety of improvement strategies focused on operations?

The bulk of the testing documented in Chapters 5 through 7 is devoted to calibrating the three reliability analysis tools (from L07, L08, and C11) and using these tools to test improvement strategies. The study team found that the tools could be calibrated to baseline conditions once appropriate calibration levers (e.g., capacity, hourly demand, and adjustment factors) were identified. None of the tools had built-in capabilities to model the types of operational projects most likely to be tested in California, including ramp metering, ramp improvements, auxiliary lanes, and freeway connectors. These operational strategies are a key component of the Caltrans Mobility Pyramid shown in Figure 9.1. A critical update to the SHRP 2 reliability tools will be the ability to handle these types of improvements.

Caltrans staff expressed interest in some of the design strategies modeled in the L07 tool, such as incident screens and drivable shoulders. However, other strategies such as snow fences and wildlife crash reduction measure do not make sense for Southern California (at least within the core urban area covered by the pilot testing). The tool also omits newer active management strategies, such as dynamic or harmonized speed limits.

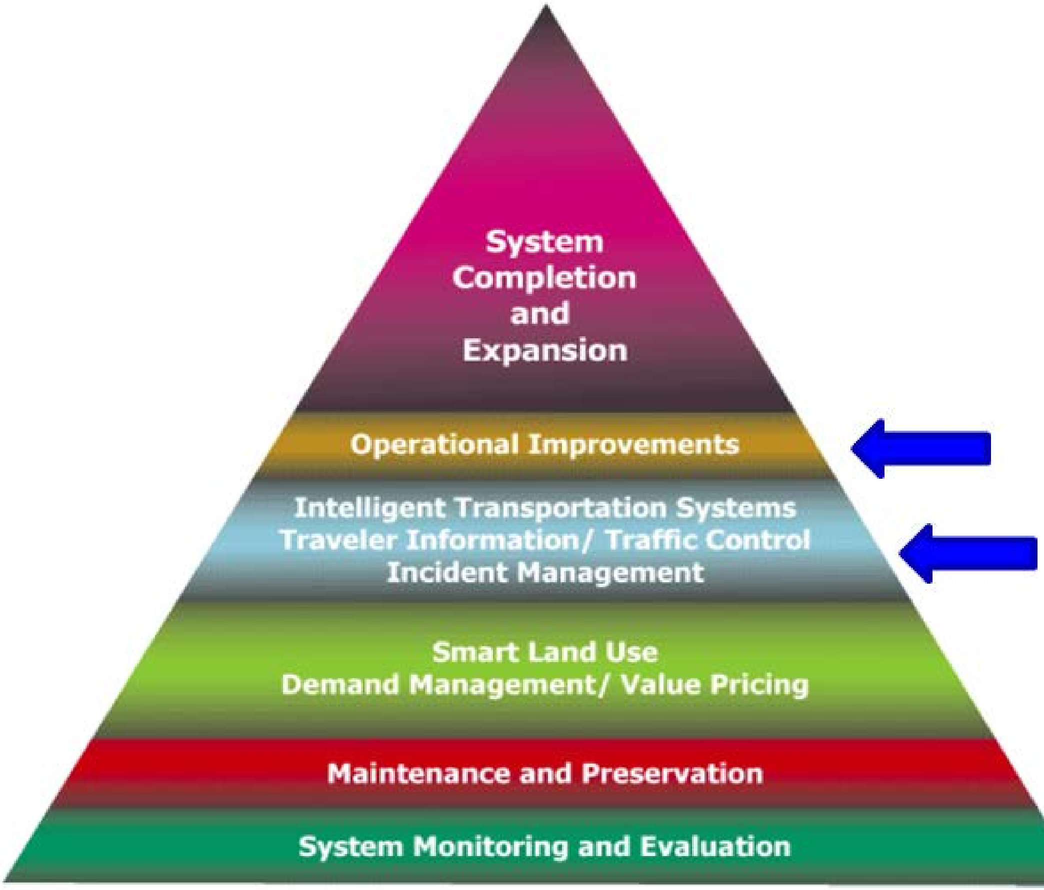


Figure 9.1. Caltrans Mobility Pyramid.

Since the tools were unable to model key operational strategies used in Southern California, the study team had to rely on microsimulation modeling to estimate the changes in capacity needed to test the strategies in the SHRP 2 tools. With these inputs, the tools estimated reliability impacts lower than expected. These impacts appeared to be highly correlated with mobility (or recurring delay) results.

Which SHRP 2 tools were easier to use?

As shown in Figure 9.2, the study team found that there was a clear order in terms of ease of use among the SHRP 2 reliability tools. The C11 and L07 tools were much easier to use than the FREEVAL-RL tool. The study team had intended to split the analysis among SCAG and other team members, so that agency and consulting staff used all of the tools. The team quickly discovered that calibrating the FREEVAL-RL tool was as complicated and time-consuming as calibrating a microsimulation model, so the calibration was assigned to modelers. In addition, the FREEVAL-RL tool took a long time to complete its probabilistic scenario runs.

Figure 9.2. SHRP 2 reliability tools by ease of use.

In contrast, the C11 and L07 tools were simple to use and generated results quickly. Caltrans planners and engineers noted that they prefer simple tools. Tools with steep learning curves or that take a long time to run are not practical options. SCAG staff expressed a similar preference.

What tools provided more reasonable results and how did these compare to baseline and microsimulation results?

The study team was able to calibrate all three tools to baseline conditions on both facilities. The C11 tool could be calibrated by adjusting the capacity and changing the demand-by-hour distribution to match the facility distribution of volume by hour. This was a fairly easy process, once the study team found the delay-by-hour table hidden among the model parameters. The L07 tool could be calibrated using the same levers, but the hourly demand table was easily accessible, while the capacity was hidden in the parameters. These limitations and others are discussed in detail in Chapters 5 through 7 of the report.

Despite similarities in calibrating the tools, the C11 tool produced more reasonable results when modeling the scenarios. In comparison, the L07 tool produced very small reliability benefits.

The FREEVAL-RL tool was much harder to calibrate to baseline conditions, due to an inability to handle limited-access high-occupancy vehicle lanes and significant congestion along the facility that exceeded the maximum extent and duration supported in FREEVAL-RL. Despite these limitations, the study team was able to calibrate FREEVAL-RL to a shorter test section. Both the baseline calibration and the scenario results seem reasonable for this test section.

How did technical members of the supporting agencies react to the work, and did it make sense to them?

SCAG and Caltrans thought that the reliability factor analysis provided useful information for understanding the causes of reliability issues along the facilities. SCAG technical staff found the C11 and L07 tools fairly easy to use.

Technical staff members were positive about the potential for improved travel time reliability analysis. However, they recognized the need to improve the analysis tools so that they are ready for agency implementation. These changes are described in detail in Chapters 5 through 7 and summarized in Chapter 10.

Was the analysis too complicated to duplicate internally at the supporting agencies?

SCAG staff participated in testing the L07, C11, and FREEVAL-RL tools. SCAG was able to use the L07 and C11 tools internally with very little support. The FREEVAL-RL tool was more complicated and would be difficult for agency planning staff to use internally (at least for Southern California facilities). The study team conducted the reliability factor analysis in a Microsoft Access database using PeMS data. SCAG staff was able to download PeMS data, but the L02 analysis guidelines would be difficult to follow for simple planning analysis.

What problems did the study team have using the different tools?

Chapters 5 through 7 document the specific problems encountered while using the tools. More generally, the calibration process took longer than anticipated because the study team needed to learn the tools and find appropriate levers for calibrating the tools to baseline conditions. Now that these levers have been identified, baseline calibration would be much faster for other facilities.

The study team had difficulty modeling the reliability impacts of projects without obvious capacity improvements or built-in methods for analyzing. Examples include ramp metering and auxiliary lane projects. The study team had to estimate the potential capacity improvement using the results of the CSMP microsimulation analyses. If the microsimulation models were not available, the study team would have been unable to model these projects.

The tools need improvements to support scenario analysis and provide better data handling (import and save scenario data). In some cases, the study team had to re-enter data because the tools would not allow analysis periods to be modified, facility segments to be adjusted, or new scenarios to be built upon previous ones.

The FREEVAL-RL tool was difficult to run for the I-5 facility. The study team encountered a number of problems with calibrating the model. Many of these problems were related to limitations in the underlying HCM 2010 methodology. For example, congestion extended over a longer section of I-5 and for a longer time period than FREEVAL-RL was able to handle. The facility also included limited-access high-occupancy vehicle lanes and an on-ramp with three lanes.

What changes would the study team recommend for the tools and why?

The beginning sections of Chapters 5 through 7 describe the limitations of the reliability tools and suggested improvements. In addition, the study team provided the SHRP 2 program with a list of quick fixes that are high priority and could be implemented quickly.

Can the tools be used without modification for benefit-cost analysis?

None of the tools produce results that can be used directly in benefit-cost analysis, but each could be made ready with minor adjustments:

- The C11 tool estimates benefits for the current year and a future year, but it does not estimate life-cycle benefits over a given time period. These can be approximated by interpolating and discounting the current and future year benefits outside the model. However, the life-cycle benefits can be estimated more accurately inside the model, if benefits are calculated for each year, summed, and discounted. The study team found that the recurring delay benefits did not match the benefits in the microsimulation models, which raises the question of whether the reliability benefits should be adjusted when detailed mobility modeling data are available.
- The L07 tool estimates life-cycle benefits by estimating benefits for the current year and assuming these benefits are constant over the life cycle. The tool needs to be modified to accommodate demand growth. The study team identified a workaround, but this involves multiple model runs and external calculations.
- The FREEVAL-RL tool does not estimate monetized user benefits using the reliability results. However, these could be calculated from the travel time reliability performance measures (i.e., standard deviation or 50th and 80th percentile TTI) and VMT data outputted by the model. The C11 and L07 tools use slightly different methods for calculating the value of the reliability benefits. One of these methods could be adopted for FREEVAL-RL.

9.2 Decision Maker Perceptions

This section describes decision maker impressions on whether the analyses were easily understood and the results credible. These impressions are based on input from SCAG and Caltrans representatives as well as other stakeholders present at outreach meetings.

How did policy makers react to the results?

SCAG and Caltrans representatives agreed that considering reliability in the decision-making process would be an important step forward. The general findings from the product testing were understood by representatives, and participants particularly liked the L02 procedures to identify contributing factors. Some stakeholders suggested that the L02 approach could be applied to other freeways in Southern California. Other stakeholders were appreciative of SCAG's involvement in the SHRP 2 testing and encouraged the results to be shared with Caltrans as a way to promote use of the products in the region.

Are the tool results consistent with agency expectations and predictions from other models?

Overall, the reliability results were consistent with agency expectations. For example, it was not surprising to Caltrans representatives that the L02 analysis showed that weather and incidents were the biggest reliability factors on I-5 in Orange County. SCAG and Caltrans representatives cited a rule of thumb that 50 percent of congestion delay is recurring and 50 percent nonrecurring, but they noted that it would be much better to measure reliability directly. In this sense, benefit-cost results that showed the total value of reliability benefits as roughly 30 percent of mobility benefits were unexpected. However, it made sense to agency representatives that reliability issues increased with congestion. Overall, they liked seeing reliability benefits added to benefit-cost analysis.

Do the L02 procedures and use cases help identify the contributions of factors to reliability and better describe reliability conditions on the facility?

SCAG and Caltrans representatives reacted positively to the cumulative distribution function (CDF) graphs and percent contribution tables as ways to summarize factors contributing to reliability. Representatives from both agencies noted that these tools would be useful to include in the Southern California CSMPs.

Caltrans representatives who were not involved in the project found the CDF graphs difficult to understand without some explanation of their meaning. SCAG and Caltrans stakeholders noted that the graphs would be easier to understand with speeds rather than travel rates plotted on the x-axis. In addition, they wanted to see particular speed thresholds plotted on the graph, such as at 45 mph and 35 mph. Transportation decision makers are simply more accustomed to seeing speed than travel rates.

Caltrans representatives thought that the CDF curves could help diagnose reliability problems and help design strategies to address those problems. They might also be used to operate the facility more efficiently. For example, the I-5 CDF curves suggest that bad weather in combination with high congestion has very large impacts on reliability. Changeable message signs (CMS) could provide traveler warnings when these conditions occur on the facility.

Caltrans representatives liked the causal factor chart and wanted to understand the measures used and how the chart was developed. They particularly appreciated that the factors added to 100 percent to cover all conditions on the facility. Stakeholders preferred to have work zones and planned lane closures identified as another factor rather than included in special events. They added that accidents and reliability issues can occur during nighttime closures.

Are the guidelines found in L05 helpful in choosing goals, in setting levels, and in picking strategies?

The study team was not able to choose reliability goals using the L05 guidelines within the time frame of the L38 project. SCAG believes that the guide will be helpful in articulating the issue of system reliability, developing a framework for incorporating reliability into its planning and decision-making processes, and communicating the results to the stakeholders, members of the public, and decision makers as part of its next RTP, which will be developed over several years. In addition, the reliability objective tree may help Caltrans set objectives for operations strategies and incorporate reliability into policy statements.

How willing were they to incorporate the results into programming decisions in the near future?

Caltrans uses a variety of performance measures to select projects, such as mobility, safety, and the environment. Caltrans representatives recognized the value of including reliability in decision making and thought reliability could be useful as one measure among many for choosing operations projects to program. Reliability may help to promote managed lane projects, since travelers tend to be paying for guaranteed travel times rather than improved mobility. Funding for operations projects has been tight over the last several years in California, but more is expected to be available in the future. Caltrans may be willing to examine travel time reliability as part of the decision-making processes if appropriate tools are available. Caltrans representatives suggested that the 29 percent to 36 percent range for reliability benefits estimated by the C11 tool, if supported by future research, may represent a useful rule of thumb to apply to other project analyses.

9.3 Impacts on Decision Making

The time frame of the L38 pilot test was too short to document impacts of the reliability analysis on project selection and funding. Typically, project programming takes a longer period of time.

Over the next two years, SCAG is working with its regional stakeholders to develop its RTP. The L05 guide will be useful in articulating the issue of system reliability, developing a framework for incorporating reliability into planning and programming, and communicating with the public. In addition, the results from the tool testing may be helpful in refining thresholds for its reliability goal, which is a focus area for the RTP update.

SCAG and Caltrans representatives agreed that the contributing factor analysis would be a useful addition to future CSMPs. They also understood the importance of including travel time reliability in benefit-cost analysis. Until the SHRP 2 tools are further refined to support scenario analysis, the 29 percent to 36 percent range serves as a simple rule of thumb for incorporating reliability benefits. Ultimately, it is better to measure reliability directly.

CHAPTER 10

Conclusions and Suggested Research

10.1 Conclusions

The study team and stakeholders involved in the Southern California pilot site agree that considering reliability in the decision-making process would be a significant step forward. Travel time reliability is important to customers, so it should be an important decision criterion for transportation agencies. Current tools, such as travel demand and microsimulation models, do not allow agencies to predict how projects will improve reliability.

The SHRP 2 research has generated a number of tools and analysis techniques to help agencies understand reliability issues and estimate the reliability impacts of projects. The study team found that that the exercise of identifying reliability factors can help agencies better understand freeway facilities. Reliability factor analysis provides useful information for understanding the causes of reliability issues along freeway facilities.

Tool Modifications

Calibrating the SHRP 2 tools to baseline conditions is a critical first step before any reliability analysis can occur. The reliability tools show promise for analyzing travel time reliability on highway facilities, but they need modifications to their user interfaces and calculation analytics before they are ready for implementation by transportation agencies.

The Southern California pilot site provided the SHRP 2 Reliability program with a list of "quick fixes" that are critical for moving the tools toward implementation. The detailed findings in this report support those quick fixes. Below are a few common threads of modifications needed across the tools:

- There needs to be *guidance for how to calibrate* each tool to baseline conditions. This guidance should cover how to identify study areas and analysis periods as well as which levers allow the tool to be calibrated.
- These *calibration levers must be easily accessible* to the user. The Southern California study team identified several variables, such as capacity, capacity adjustment factors, and demand by hour of day, that can be used to calibrate models. Other pilot sites may identify other variables. In some tools, these calibration levers are hidden from the user or not presented directly on the input pages. They need to be made more easily accessible.
- The tools need *modifications to support scenario analysis.* These modifications should include the ability to designate specific time periods and highway segments for analysis. Practitioners need the ability to tailor reliability analyses to support existing studies and analysis. In addition, tool users need to be able to adjust time periods and highway segments and then rerun analyses without having to set up the models from scratch.

- A related need is the *ability to import and save data*. The reliability tools tested in the Southern California pilot site need varying amounts of data, but generally require the user to enter information through pull-down menus or manual entry. For the tools that require large amounts of information (e.g., FREEVAL-RL), the ability to copy and paste data or import data from external spreadsheet files would significantly aid the calibration and scenario processes.
- The tools also need *analytics to support specific types of operational improvements*. For Southern California, the most common operational projects to test include ramp metering strategies, auxiliary lanes, freeway connectors, and ramp modifications. The other three pilot sites may identify additional project types. The SHRP 2 reliability tools should be able to analyze the projects that users are most likely to want to test.
- The tools need to be able to *model reliability for highly congested facilities*. Practitioners are most likely to want to test reliability on these facilities, yet the extent and duration of congestion in Southern California exceeded the ability of some SHRP 2 tools to model congestion.
- The tools need to *support life-cycle benefit-cost analysis*. Benefit-cost analysis needs the sum of user benefits over an expected life cycle. The current tools either estimate benefits for specific years or assume that the current benefits remain constant over the life cycle. The tools should be modified so that agencies can simply take the sum of the reliability benefits and add them to standard benefit-cost analysis.

Benefit-Cost Analysis

The study team found that reliability could be added to existing benefit-cost analysis, but only with external analysis of the SHRP 2 tool results. The team was unable to take the reliability benefit calculations directly from any of the SHRP 2 tools analysis, but this shortcoming can be addressed with a few simple tool modifications. The addition of reliability benefits did not change the rank order of the projects tested at the Southern California pilot site. However, reliability can change the ranking of two projects with similar benefits, and it can make marginal projects cost beneficial (i.e., increasing the benefit-cost ratio to above one).

The study team discovered that when the C11 tool is used to estimate reliability benefits, these benefits fall within the 29 percent to 36 percent range of the mobility (recurring delay) benefits. This suggests that agencies could adopt one of two techniques for including travel time reliability in benefit-cost analysis:

- *Use the C11 tool.* Agencies model facility performance using traditional tools, such as travel demand or microsimulation models. The C11 tool can be used to estimate reliability changes by logical segments (e.g., defined by bottlenecks or highway geometry). The mobility benefits are adjusted to match the traditional tools and the resulting reliability improvement is reported as part of the benefit-cost analysis.

- *Use a 30-percent rule of thumb.* Agencies estimate reliability benefits to the facility by multiplying mobility benefits by 30 percent.

Southern California stakeholders have expressed a desire to measure reliability impacts directly rather than use a rule of thumb, but the 30 percent rule was consistent for both facilities and among different project types evaluated using the C11 tool. The FREEVAL-RL tool may produce different results, but the study team was unable to use the model, given the complex geometries along the I-5 and I-210 facilities. The stakeholder agencies involved with the Southern California testing preferred the use of simpler tools for reliability analysis.

Reliability Performance Measures

There is a need for common reliability performance measures across the planning process. The SHRP 2 reliability research has resulted in different measures and tools, but it has also resulted in inconsistency if they are applied to a practical planning problem. Figure 10.1 summarizes a simple planning process and the inconsistency in measures when the SHRP 2 tools are applied.

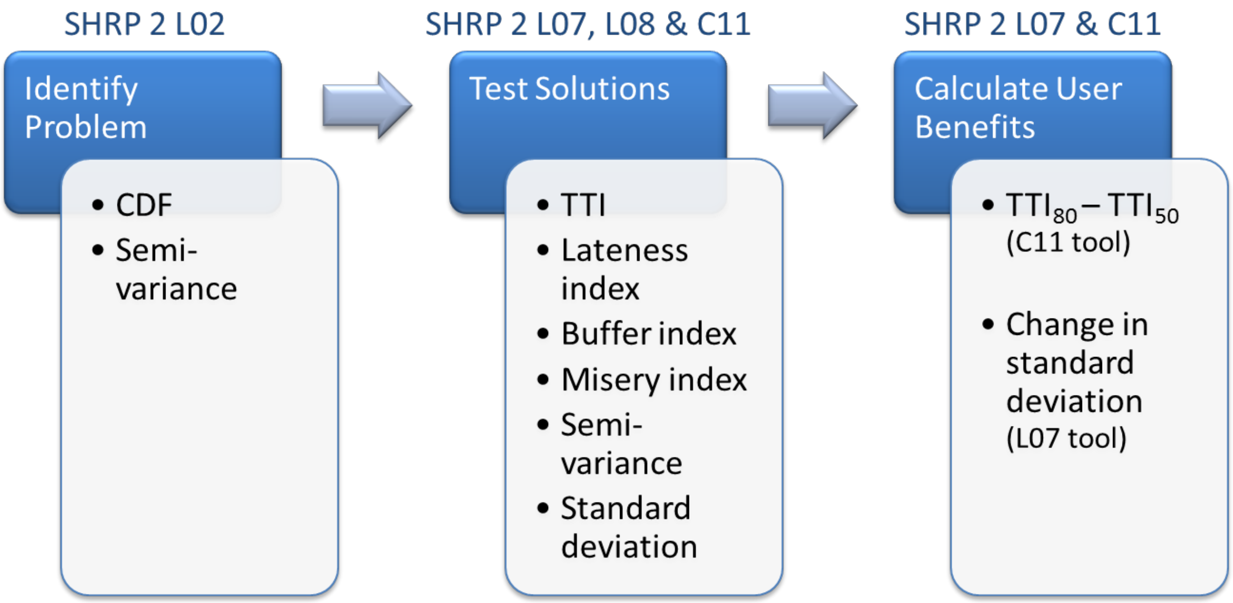


Figure 10.1. Inconsistency in performance measures for planning process.

The L02 project provides a number of methods for analyzing travel time reliability and suggests that users present results in terms of cumulative distribution functions (CDF) or semi-variance. Other SHRP 2 projects (e.g., L07, L08, and C11) provide tools for testing the reliability impacts of potential projects. While these tools summarize the reliability impacts in a variety of performance measures, the measures differ from the ones used to identify the travel time reliability problem in L02.

L07 and C11 provide methods for estimating the value of the travel time reliability benefits, but they differ in the performance measures used to estimate the value of benefits. If FREEVAL-RL is to include a value for travel time reliability benefits, it will need to adopt one of these two methods. Clearly, the process could benefit from standardization in the measures used to identify reliability problems, test solutions, and calculate user benefits.

10.2 Suggested Research

SHRP 2 implementation should involve testing of the SHRP 2 tools at additional pilot sites after the tools are modified to address the quick fixes suggested by the four pilot sites. The Southern California pilot site developed a 30 percent rule to estimate reliability benefits. This rule is based on a limited number of observations. A useful test would be to see if this rule holds true across different pilot sites and for different types of projects.

Additional pilot sites could also test the various calibration methods proposed by the four pilot sites. Most of these calibration methods are a function of changing capacity. Further research could test whether similar capacity adjustments are warranted at other sites.

The SHRP 2 tools are currently unable to test many of the common operational strategies used in Southern California. The SHRP 2 program could collect a list of operational strategies from the four pilot sites and conduct research on the impacts of these types of projects on travel time reliability following the approach adopted for L07.

It is the opinion of the Southern California Pilot Study team that integrating reliability into decision making requires additional outreach, testing, and marketing. This project (L38A) has introduced the different products developed under SHRP 2 to two agencies for two corridors in Southern California, which is not likely enough to change the decision-making process in the region. The study should be extended to additional corridors and with additional outreach to staff and management from county transportation commissions. Doing so would leverage the momentum created so far with Caltrans and SCAG, extend the use of tools for more than two corridors, and help decision makers understand the ramifications of their investment decisions on reliability.

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