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Alm, Eric

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CALIFORNIA CENTER FOR INNOVATIVE TRANSPORTATION
INSTITUTE OF TRANSPORTATION STUDIES
UNIVERSITY OF CALIFORNIA, BERKELEY

Corridor Management Plan Demonstration

Eric Alm, AICP
Senior Development Engineer, CCIT

CCIT Research Report
UCB-ITS-CWP-2007-9

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The California Center for Innovative Transportation works with researchers, practitioners, and industry to implement transportation research and innovation, including products and services that improve the efficiency, safety, and security of the transportation system.

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This work was performed by the California Center for Innovative Transportation, a research group at the University of California, Berkeley, in cooperation with the State of California Business, Transportation, and Housing Agency's Department of Transportation, and the United States Department of Transportation's Federal Highway Administration.

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California. This report does not constitute a standard, specification, or regulation.

December 2006



CCIT Task Order 3

Corridor Management Plan Demonstration

Final Report – December 2006

Prepared By:

**University of California at Berkeley's
California Center for Innovative Transportation**

in collaboration with

**University of California at Irvine
and
System Metrics Group**

For:

California Department of Transportation

**Division of Traffic Operations
Division of Transportation Planning**

University of California Berkeley
2105 Bancroft Way, Suite 300
Berkeley, CA 94720-3830

Phone:
Fax:

(510) 642-4522
(510) 642-0910
<http://www.calccit.org>

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Title: Corridor Management Plan Demonstration

Sponsor: Caltrans Division of Transportation Planning
Office of Policy Analysis and Research

Executing Organization: California Center for Innovative Transportation
2105 Bancroft Way
Berkeley, CA 94720
Phone: (510) 642-4522 – Fax: (510) 642-0910

Execution Period: 6/30/2003 – 6/30/2006

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Principal Investigators: Dr. Samer Madanat, UC Berkeley
Dr. Hamed Benouar, UC Berkeley

Center Director: Dr. Hamed Benouar
Director, CCIT

Project Manager: Erik Alm, AICP
Senior Development Engineer, CCIT

Administrative Officer: Anne Crowe
Assistant Director, CCIT

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Project Team

CCIT

Dr. Hamed Benouar, Director
Erik Alm, AICP, Project Manager
Dr. Lianyu Chu, Research Engineer
Dr. Xuegang (Jeff) Ban, Research Engineer
Dr. Koohong Chung, Postdoc Researcher
Angela Sugihara, Student Assistant

UC Irvine

Dr. R. Jayakrishnan
Hyunmyung Kim
Ji Young Park
Klayut Jintanakul
Pierre M. Auza
Tyler Bonstead
Jennifer Yoon
Chih-Lin Chung

System Metrics Group

Tarek Hatata
Tom Choe
Bill McCullough
Chris Williges

University of Minnesota/Utah State Univ.

Dr. Henry Liu
Liang Ding

Caltrans

John Wolf, HQ Operations
Pat Weston, HQ Planning
Fred Dial, HQ Operations
Steve Hague, HQ Operations
Sarah Chesebro, HQ Operations
Al Arana, HQ Planning

Juliana Gum, D4 Operations

Cesar Casteneda, D6 Operations

Farid Nowshiravan, D12 Operations

Cambridge Systematics

Vassili Alexiadis
Krista Jeannotte

Braidwood Associates

Richard Braidwood

Wiltec

Moses Wilson

Agency Participants

I-880 Corridor

- Metropolitan Transportation Commission
- AC Transit
- Alameda County Congestion Mgmt. Agency
- Bay Area Rapid Transit District
- Caltrans HQ and District 4
- City of Alameda
- City of Fremont
- City of Hayward
- City of Newark
- City of Oakland
- City of San Leandro
- City of Union City
- County of Alameda
- Port of Oakland
- Union City Transit

SR-41 Corridor

- Caltrans HQ and District 6
- City of Fresno
- Fresno Council of Governments

I-5 Corridor

- Caltrans HQ and District 12
- Orange County Transportation Authority

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Executive Summary

The Corridor Management Plan Demonstration (CMPD) aims to develop a template for corridor system management plans that can be used for both planning and operational analysis. The primary objective of CMPD is to improve traditional corridor management planning by incorporating detailed, multi-modal performance measurement and evaluation, and innovative micro-simulation modeling techniques. The template will help to address the problem of lost system productivity during congestion; it will also help to create effective corridor management plans, thus improving statewide transportation mobility, safety and productivity. CMPD represents the first attempt by the California Department of Transportation (Caltrans) to develop phased and integrated corridor system management strategies by incorporating state-of-the-art operational analysis into more traditional transportation planning processes.

This is the Final Report for CCIT Task Order 3 and is NOT intended to be a final report of CMPD. Rather, it is a summary of the progress and status of CMPD to date (June 30, 2006). The CMPD effort continues under CCIT Task Order 1015. Three corridors were selected for the corridor management study during the course of CMPD: the SR-41 corridor in Fresno, CA, the I-880 corridor in the San Francisco Bay Area, and the I-5 corridor in Orange County, CA. By the end of CCIT Task Order 3 (June 30, 2006), the project team had completed the simulation model development of SR-41, finished part of the I-880 simulation model, and started to develop the simulation model for I-5. The project team had an ambitious research agenda under TO 3, and over the course of the project encountered a number of challenges, both technical and institutional. As a result,

the expectations of what could realistically be accomplished within the original schedule and budget were adjusted. Stemming from the fact that the application of microsimulation has not been attempted at this level of corridor planning analysis before, the primary challenges encountered in Task Order 3 included:

- Data Collection issues: Unexpected gaps and network configuration issues
- Microsimulation model calibration issues: More adjustment iterations than expected
- No solid dynamic O/D estimation method: Lack of a standard, accepted practice on dynamic O/D estimation required development of new method

Caltrans has approved a continuation research proposal with an updated schedule and scope of work to accommodate the unanticipated gaps and new developments and to enable the project team to complete the three studies (CCIT Task Order 1015). More importantly, this continuation research project under TO 1015 will enable the project team to produce the template for corridor management plans by integrating all experiences achieved from the three studies.

This report focuses on the methodologies developed and results obtained by the end of Task Order 3 for CMPD, primarily covering the I-880 and SR-41 studies. The report addresses the following topic areas:

Stakeholder Needs and Corridor Selections

Methodologies were developed for addressing stakeholder needs and selecting corridors that were suitable for the study. Stakeholder needs were addressed by organizing stakeholder meetings and corridor selections were conducted by balancing stakeholder needs and resource limitations.

Data Needs and Collection

Data needs were defined for both performance evaluations and simulation model development, and methodologies were developed to resolve data accuracy and consistency issues. CMPD tasks needed corridor and traffic description data for corridor level performance evaluations and simulation model development. To reduce the effort of data collection, data sharing among stakeholders was critical. In addition, data pre-processing (especially for traffic description data) was crucial to remove erroneous data and maintain data consistency.

Corridor Performance Evaluation

Various mobility, safety, reliability and productivity measures have been defined and used for corridor level performance evaluations. The evaluation results showed that the I-880 corridor experiences heavy congestion and incidents during both AM and PM peak hours, while the SR-41 corridor only had light congestion during peak periods.

Baseline Simulation Model Development

Detailed methodologies and procedures were developed for baseline simulation model development, including network coding, origin-destination demand estimation, calibration, and model fine-tuning. The results showed a general match between observed data and simulation data.

Evaluation Scenario Generation

Based on planned and programmed projects from Caltrans Headquarters and local Districts (i.e., Districts 6), improvement scenarios were generated for the SR-41 corridor (including short-, medium-, and long-term scenarios). Preliminary scenario development began for the I-880 corridor, but was not completed by the end of Task Order 3. Finalizing and evaluation of these scenarios will be conducted in the continuation CCIT Task Order 1015.

Next Steps

CCIT Task Order 1015 will complete the three studies, and more importantly, complete the template for development of corridor management plans, as well as provide technical assistance to Caltrans staff on these corridor management planning techniques.

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1. Introduction

This report presents the methodologies developed and results obtained so far (by the end of FY 05-06) for Corridor Management Plan Demonstration (CMPD), the first phase of developing Corridor Management Plan (CMP). CMP represents the first attempt by California Department of Transportation (Caltrans) to develop phased and integrated corridor system management strategies by incorporating state-of-the-art operational analysis into more traditional transportation planning processes. Although conducted in California, the CMP research is the first of its kind in integrating operational analysis (such as dynamic traffic network modeling and traffic simulation) into the traditional planning process for urban and congested corridors.

1.1 Corridor Management Plan and Demonstration

Caltrans has been developing system management strategies with the aim of managing the California's transportation system more effectively and efficiently. As depicted in the following system management pyramid in Figure 1.1, system monitoring and evaluation are the basic foundation upon which other strategies are built. These strategies range from maintenance and preservation to system expansion and completion. This strategy pyramid represents comprehensive management strategies, including both planning and operations, for a maturing transportation system in which infrastructure expansion, although still important, is not the only strategy to address mobility and safety needs of Californians. Operational improvements and strategies, on the other hand, can help to make the most efficient use of existing transportation system. Therefore, Caltrans

recognizes the emerging needs of development systematic management strategies to get the most out of current system and to evaluate potential facility expansion if necessary.

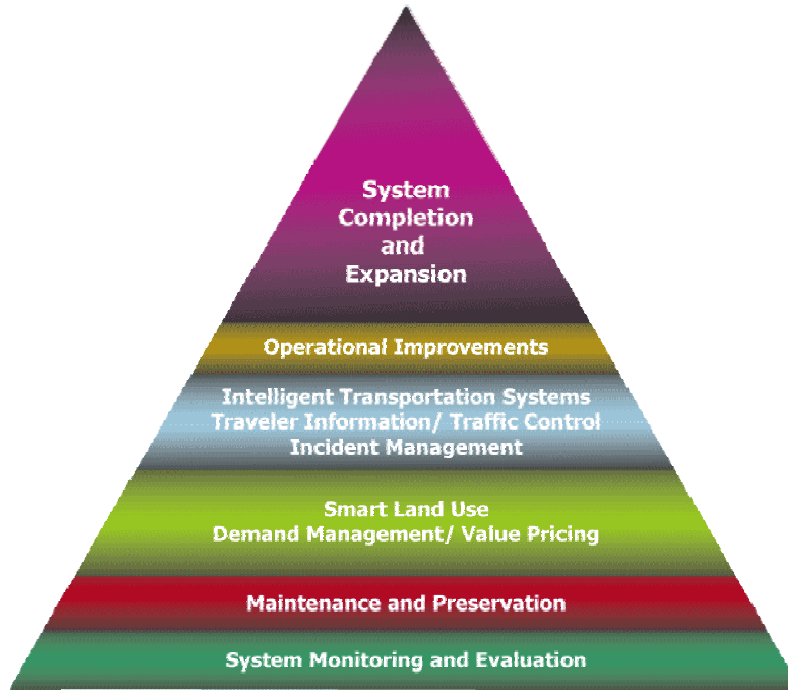


Figure 1.1 Caltrans System Management Pyramid

Guided by the system management concept in Figure 1.1, Caltrans investigated developing a Corridor Management Plan (CMP) which focuses on developing management strategies on state-wide corridors. Upon success, CMP can be a backbone for developing more comprehensive system management strategies for an entire region. CMP can be defined as:

A Corridor Management Plan is a document that identifies the recommended system management investment strategies for a State Highway facility within the context of the full multi-modal corridor. The strategies and their phased implementation are recommended based on the comprehensive performance assessment of the State Highway

facility and its interactions with other modes, and should maximize the return on the recommended investments.

To demonstrate CMP, Caltrans initialized the Corridor Management Plan Demonstration (CMPD) as the first phase to develop appropriate management strategies on selected corridors and demonstrate the feasibility of developing CMP. CMPD aims to develop a template of corridor system management plans that can be used for both planning and operations of Caltrans. The primary objective of CMPD is to improve traditional corridor management planning by incorporating detailed, multi-modal performance measurement and evaluation and operational analysis with state-of-the-art analysis and modeling techniques (e.g. microscopic traffic simulation tools). The template will help to address the problem of lost system productivity during congestion; it will also help to create effective corridor management plans, thus improving statewide transportation mobility, safety and productivity. Led by California Center for Innovative Transportation (CCIT) under University of California, Berkeley (UCB), partners involved in CMPD include regional, local and congestion-management agencies. Researchers from the University of California campuses (Berkeley and Irvine) and outside the state (Utah State University and the University of Minnesota) are supported by System Metrics Group, Inc. (SMG) and other private transportation consultancies.

1.2 Current Progress of CMPD

Three corridors have been selected for the corridor management study during the course of CMPD, reflecting a joint effort by Caltrans and multiple state and local level stakeholders, supported by the project team. The first corridor is the SR-41 network,

located in Fresno, CA. It is a mid-size network with many arterials, especially two parallel streets. This corridor currently experiences only light congestion and the purpose of the study is to provide a proof-of-concept of developing a CMP, particularly the feasibility of incorporating detailed operational analysis (e.g. dynamic traffic network modeling and micro-simulation) into traditional planning in a corridor level, an effort that has rarely been conducted before. Researchers from Utah State University and the University of Minnesota have completed the base simulation model development. Evaluating the benefits of selected short-, medium, and long-term operational improvements is on-going.

The second corridor is I-880, an inter-regional and multi-modal corridor located east of San Francisco. It is a 34-mile urban freeway route with parallel arterials and cross roads, including 143 metered lanes, 157 actuated traffic signals, and 25 fixed-time signals. Transit and inter-modal facilities (e.g., sea port and airport) serve as alternative modes of the corridor. It currently experiences heavy congestion for both AM and PM peaks and multiple traffic incidents for almost any given “typical” day. Therefore, the I-880 corridor study is a “full-scale” case for demonstrating system management concepts within the CMP. While the I-880 performance assessment was completed, the microsimulation model to evaluate improvement scenarios was not completed before the expiration of Task Order 3. In Task Order 1015 Braidwood Associates (BA) will continue finalizing the simulation study previously conducted by University of California, Irvine (UCI).

The third is the I-5 corridor in Orange County. It is of similar size to the I-880 network, and is somewhat less congested. The research team completed a highway-only

microsimulation for I-5 and is working on incorporating arterials into the model as part of Task Order 1015. The I-5 corridor will serve as a test case for verifying methodologies developed in I-880 and SR-41 studies, and will be covered in the report for Task Order 1015.

These three studies have demonstrated both the challenges and benefits of integrating planning and operations into traditional corridor management. As a result, the concept of corridor system management plans received significant attention from stakeholders and decision makers at all levels, despite the three demonstration corridor studies not being completed by the end of FY 05/06 (June 30, 2006). The project team had an ambitious research agenda; over the course of the project the team encountered a number of challenges, both technical and institutional. As a result, the expectations of what could realistically be accomplished within the original schedule and budget were adjusted. Stemming from the fact that the application of microsimulation has not been attempted at this level of corridor planning analysis before, the primary challenges encountered in Task Order 3 included:

- Data Collection issues: Unexpected gaps and network configuration issues
- Microsimulation model calibration issues: More adjustment iterations than expected
- No solid dynamic O/D estimation method: Lack of a standard, accepted practice on dynamic O/D estimation required development of new method

Caltrans has approved a continuation research proposal with an updated schedule and scope of work to accommodate the unanticipated gaps and new developments and to enable the project team to complete the three studies (CCIT Task Order 1015). More importantly, this continuation research project under TO 1015 will enable the project

team to produce the template for corridor management plans by integrating all experiences achieved from the three studies. Therefore, this report also sets up the basis for the continuation efforts of CMP development.

1.3 Organization of the Report

This report is NOT intended to be a final report of CMPD. Rather, it is a summary of the progress and status of CMPD to date (i.e., June 30, 2006). In particular, it summarizes the methodologies that have been developed for CMP and results obtained from SR-41 and I-880 corridor management studies. Due to the majority efforts put on the I-880 corridor by the project team, this report will focus primarily on the I-880 study; the developed methodologies, however, are suitable for both SR-41 and I-880 corridors in most cases. The results of the I-5 corridor will not be covered in this report; as previously noted these results will be provided in a separate report as part of the findings of CCIT Task Order 1015.

This report contains a main body summarizing the overall methodologies and results, as well as appendices of a report by SMG on developing the corridor management plan for the I-880 study (Appendix A) and a master thesis documenting the development of the simulation model for the SR-41 corridor (Appendix B).

Figure 1.2 provides a high-level overview of the methodologies (procedures) to conduct the CMPD. The main body of the report is organized as follows:

- **Stakeholder Needs and Corridor Selections (Section 2):** Describes the methodology for addressing stakeholder needs and selecting corridors that are suitable for the study;
- **Data Needs and Collection (Section 3):** Describes data needs and collection, as well as data accuracy and consistency issues, for both performance evaluations and simulation model development;
- **Corridor Performance Evaluation (Section 4):** Discusses the methods and results of performance evaluations of selected corridors;
- **Baseline Simulation Model Development (Section 5):** Details the methodology for developing the baseline simulation models;
- **Evaluation Scenario Generation (Section 6):** Presents the corridor management improvement scenario generation for the SR-41 and I-880 corridors; and
- **Next Steps (Section 7):** Summarizes activities recommended be conducted in the next steps (i.e., during the extension of CMPD).

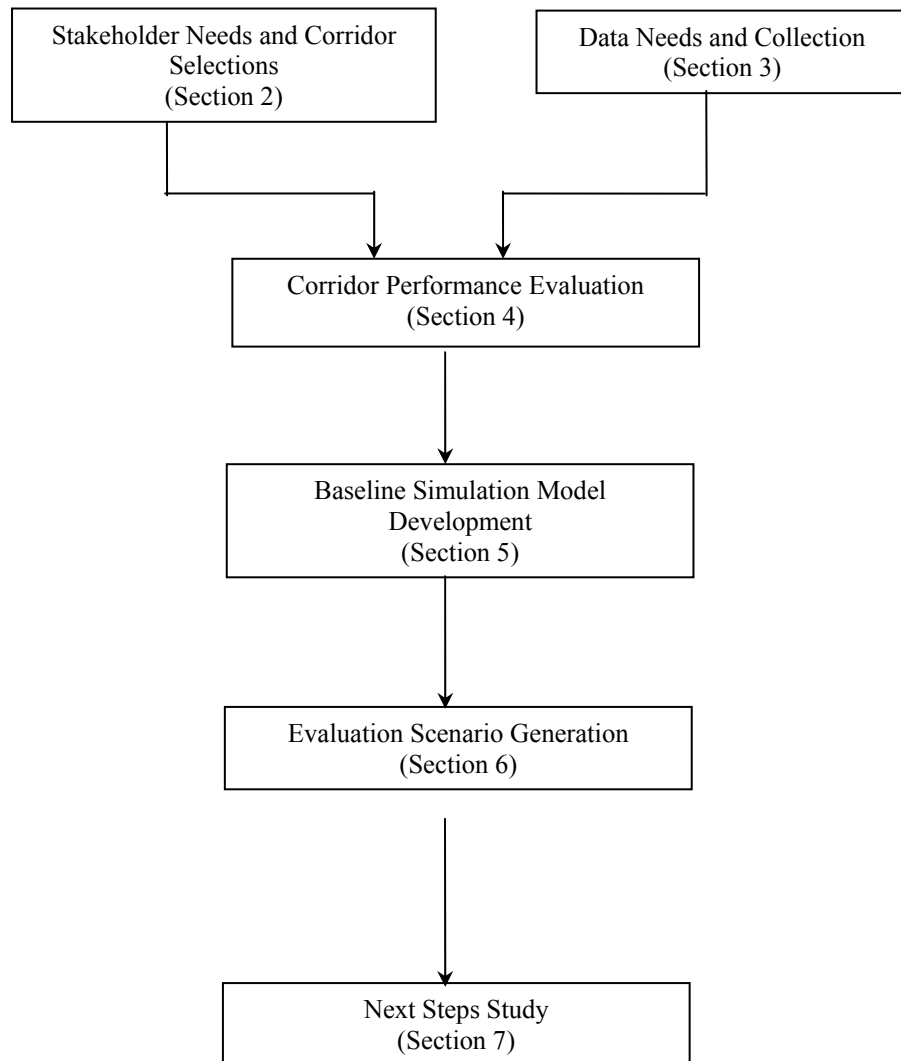


Figure 1.2 Overview of Methodology for Corridor Management Plan

2. Stakeholder Needs and Corridor Selections

This section describes the methodologies for addressing stakeholder needs regarding corridor management planning and how the studied corridors were selected.

2.1 Stakeholder Needs and Involvement

Properly addressing stakeholder needs and their regular involvement are critical to the success of any transportation related research project. This is particularly true for CMPD since it is an inter-regional project involved with Caltrans Headquarters, local districts, local transportation authorities (such as Metropolitan Transportation Commissions (MTC) in the Bay Area), cities, and transit agencies.

2.1.1 Stakeholder Needs

To adequately address stakeholder needs, the project team started with preliminary performance assessments for candidate corridors. After the initial assessment was complete, the team organized multiple stakeholder meetings to discuss the stakeholder needs and resolve possible conflicts of CMPD with previous and existing planning and project development efforts. During these meetings, findings from performance assessments were presented to stakeholders and their needs were discussed extensively and summarized by the project team. Following is a summary of general stakeholder needs in terms of corridor management plan from those stakeholder meetings:

- (1) Seeking short-term (within five years) and/or medium-term (five to 15 years) operational improvements to reduce traffic congestion in the corridor;

- (2) Seeking short-term (within five years) and/or medium-term (five to 15 years) operational improvements to improve corridor safety;
- (3) Seeking short-term (within five years) and/or medium-term (five to 15 years) operational improvements to resolve corridor-level environmental issues;
- (4) Seeking long-term (15 years and after) capital investment and/or land use strategies to better accommodate increasing traffic demands.

Discussions with stakeholders confirmed that different types of corridors require varied corridor management planning strategies. A highly urban and congested corridor (e.g., the I-880 corridor in the Bay Area) requires more analysis and modeling to evaluate short-term and/or medium-term operational improvement strategies (i.e., item (1) in the above list). On the other hand, a less urban and less congested corridor (e.g. SR-41 in Fresno) may require less modeling and more emphasis on safety and environmental issues (i.e., item (2) or (3) in the above list). The project team thus needs to develop methodologies that can accommodate all these stakeholder needs.

2.1.2 Stakeholder Involvement

Appropriate stakeholder involvement is necessary to better address stakeholder needs. It helps identify gaps of current corridor management plans and facilitates the data collection efforts of the project team. In summary, the major issues that were discussed through stakeholder involvement are listed as follows:

- **Stakeholder needs** - the major motivation of conducting CMPD;

- **Related previous and ongoing projects** - Provides the current state of the corridor and necessary documentations for the project team to identify gaps in terms of corridor management planning;
- **Corridor selections and arterial coverage** – Defines the scope of the study, and
- **Data needs and sharing** - Addresses data needs of the project team and availability of data among stakeholders. A large amount of data was needed by the project team (see Section 3). The data was obtained from PeMS (Performance Measurement System) and other dedicated sources (e.g., CHP and TASAS). Some data (e.g., signal timing and detailed corridor descriptions) was provided by stakeholders. This can significantly reduce the project team's efforts for data collection and reduce data collection costs.

In CMPD, the stakeholder involvement was conducted by organizing regular stakeholder meetings for each of the corridor studies. For example, for the I-880 study alone, more than 12 formal meetings and 20 presentations were conducted as part of the stakeholder participation efforts to date. For each stakeholder meeting, research findings and recommendations were provided by the means of presentations and handouts. At the same time, meeting minutes were developed and feedback from stakeholders was collected and integrated into the project. In addition to these meetings, regular contacts with stakeholders have been maintained by the project team, especially for data availability and collection purposes.

2.2 Corridor Selection and Arterial Coverage

2.2.1 Corridor Selections

The corridor selection for each involved District started with the list of candidate corridors provided by the District during the stakeholder meetings. Two criteria were initially used by the project team for corridor selections: potential corridor benefits and detection availability. A rough assessment of potential benefits was conducted for each candidate corridor. The assessment provided indicators based on existing and projected future traffic conditions, preliminary simulation results, and the inventory of Traffic Management System (TMS) elements currently installed. In addition, one day's detection availability was collected from PeMS to serve as the second criterion since several performance measures (e.g., reliability, productivity, delay, etc.) need detailed detection data. Additional criteria were then developed during stakeholder meetings. The identified criteria for D4 are summarized as follows:

- Primary Criterion
 - The selected corridor should not conflict with other ongoing studies.
- Secondary Criteria
 - The selected corridor should serve significant inter-regional travel.
 - The selected corridor should be multi-modal in nature.
 - Congestion on the selected corridor should be high and projected to grow.
 - The selected corridor should have a high potential for benefits.
- Final Criteria
 - The selected corridor should have a good detection data.

- o The selected corridor should serve the goods movement industry.

By evaluating 24 candidate corridors in D4, the I-880 corridor in the Bay Area (from Grand Ave in Oakland to the SR-237 interchange in Milpitas) was selected. For District 6, the SR-41 corridor in Fresno (from E Friant Rd to the SR-99 interchange) was initially selected by District staff with no extra selection effort by the project team. Figures 2.1 and 2.2 below show maps of these two corridors. In these two figures, the “star” symbols indicate the starting and ending points of the selected corridors.

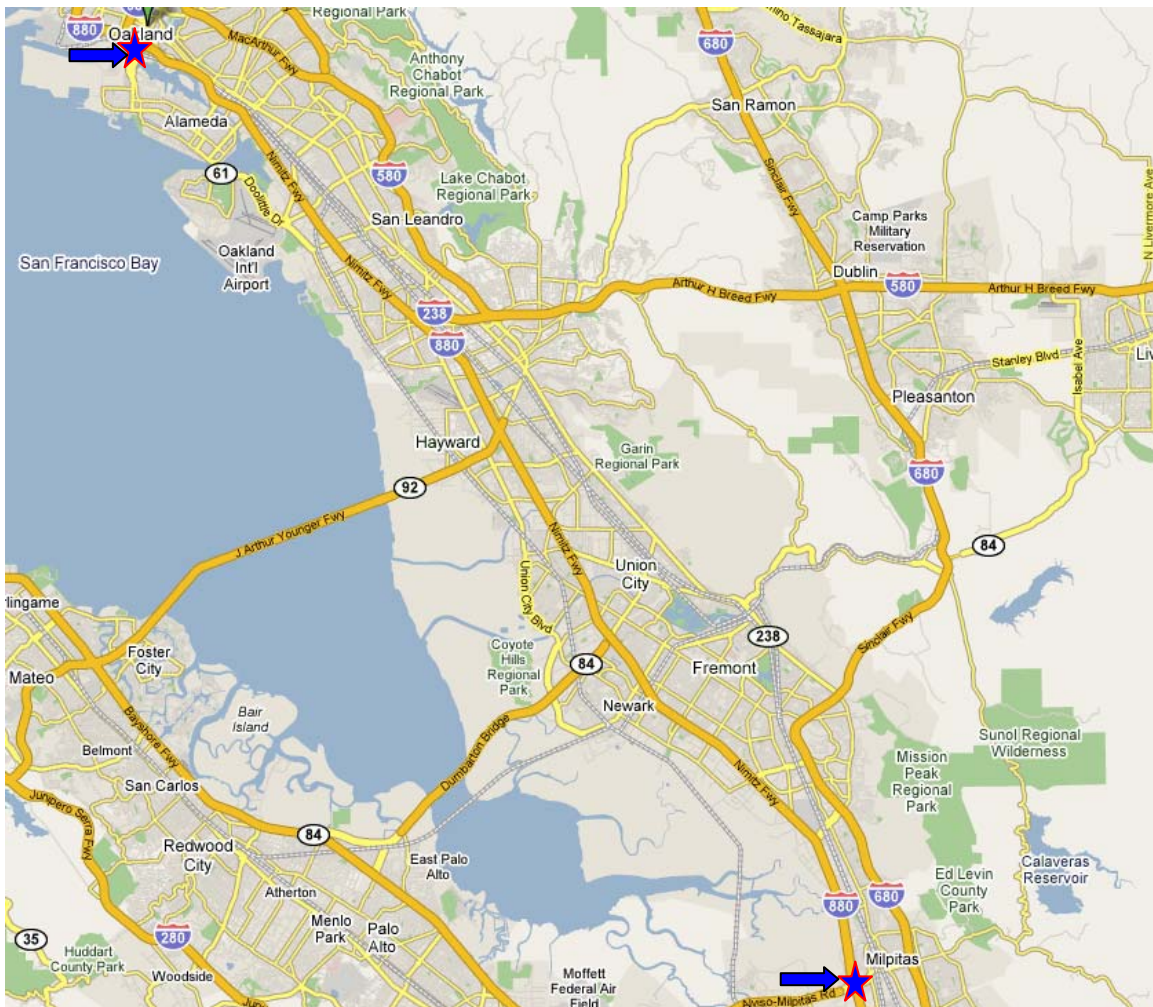


Figure 2.1 I-880 Corridor in the Bay Area

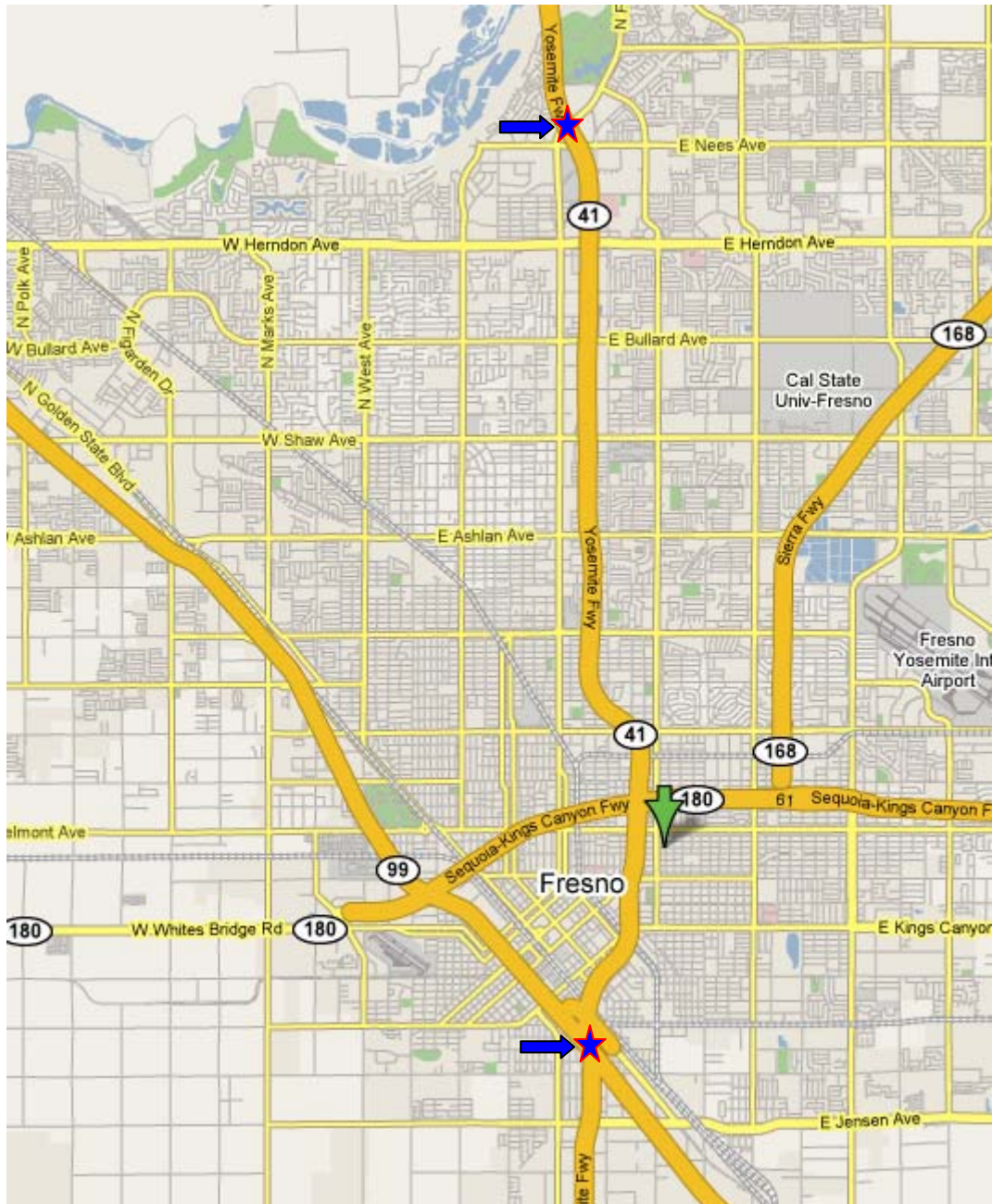


Figure 2.2 SR-41 Corridor in Fresno

2.2.2 Determination of Corridor Arterial Coverage

The arterial coverage for each selected corridor was also discussed during the stakeholder meetings. For the I-880 corridor, a major arterial was selected to be included in the modeling extent based on the following criteria:

- o Whether it could be a major diversion possibility under congestion,
- o Whether the arterial plays a significant role in distributing freeway traffic to various ramps (and vice versa to the city streets),
- o If the dynamic flows on an arterial are more affected/influenced by the freeway conditions (more than the larger network conditions), and
- o Resource constraints on collecting intersection count data and calibrating properly

To some extent, determination of the arterial coverage reflects tradeoffs between stakeholder needs and resource constraints of the project. On the one hand, many stakeholders, especially the local transportation management agencies, may prefer to have a wider arterial coverage so that more improvement strategies can be evaluated and tested. On the other hand, because of the time and budget constraints, the project team has limitations on including too broad a network of arterials into the corridor network. In particular, micro-simulation tends to have restrictions on the size of the studied network in order to run the simulation efficiently.

One lesson learned from conducting current CMPD studies is that stakeholder meetings, especially those involving a large number of stakeholder groups are essential at the

beginning of the study to get early consensus on arterial coverage. The addition of new arterials to the I-880 corridor network after the simulation team had finished the network coding caused delay to the original schedule.

The finalized arterial coverage for the two corridors represents a balance of these issues. The arterial coverage is depicted in Figure 2.3 and Figure 2.4 respectively for the I-880 and SR-41 corridors, representing the simulation networks developed in Paramics for the two corridors.

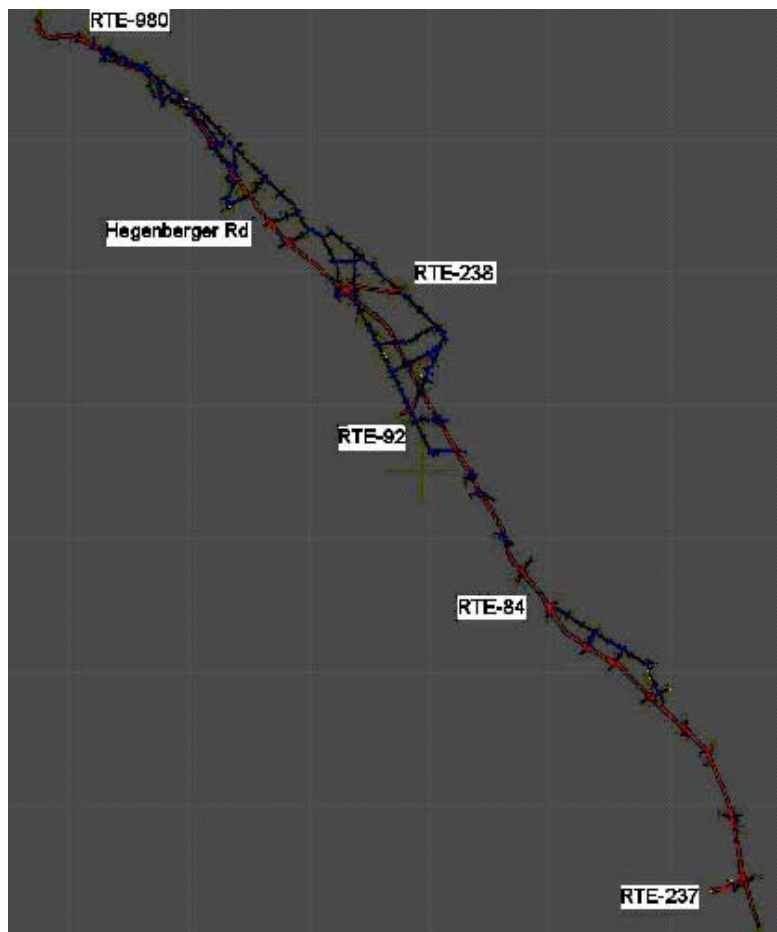


Figure 2.3 Arterial Coverage for I-880 Corridor

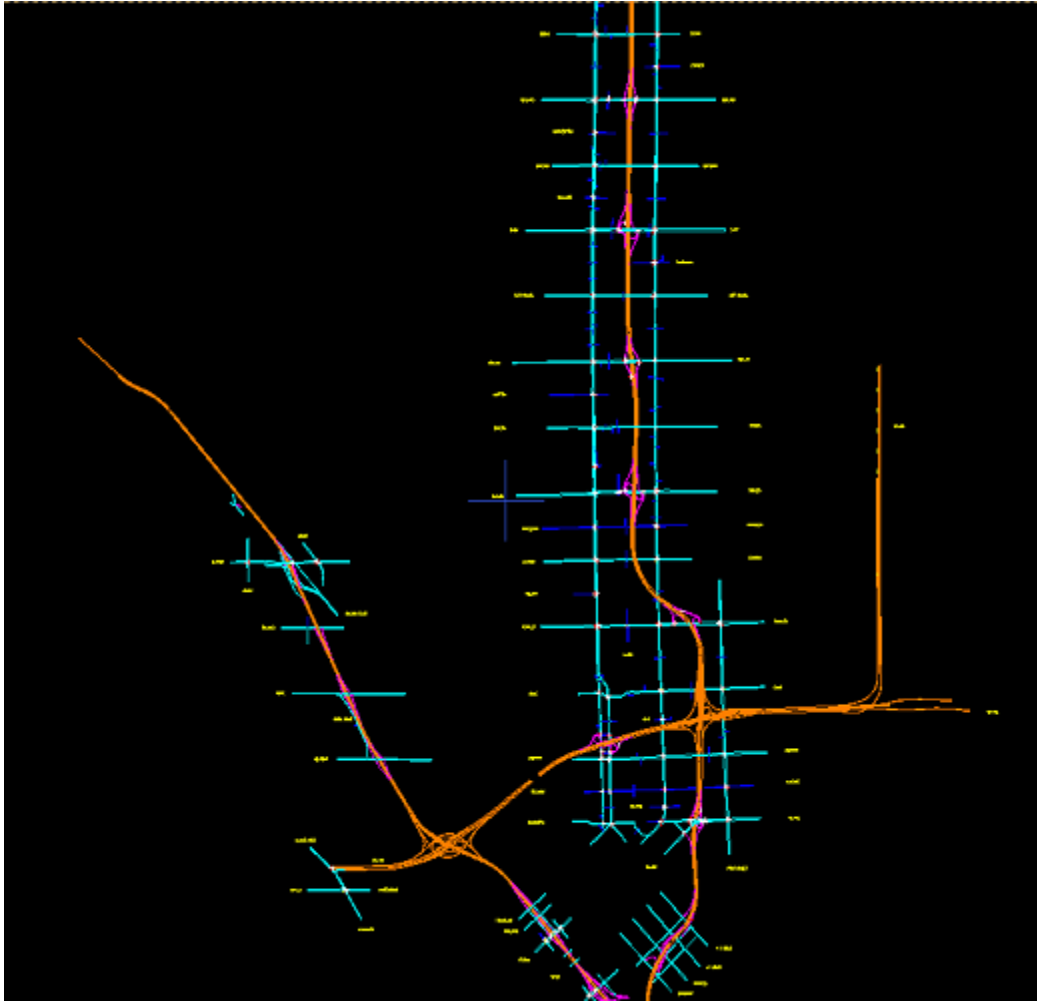


Figure 2.4 Arterial Coverage for SR-41 Corridor

In summary, Table 2.1 provides an overview of the two corridor studies.

Table 2.1 Corridor Scope Overview

		I-880 Corridor	SR-41 Corridor
Freeway scope		The Grand Street interchange in Oakland to the SR-237 interchange in Fremont Absolute Postmiles: NB: 8.073 to 45.027 SB: 45.027 to 8.105	E Friant Rd to SR-99 interchange Absolute Postmiles: NB: 121.573-137.573 SB: 137.573-121.573
Study period	AM peak hour	6:30 am – 9:30 am	*
	PM peak hour	3:30 pm – 6:30 pm	4:00 pm – 7:00 pm
Number of zones		168	210
Number of ramp meters		56 (143 metered lanes)	15
Number of pre-timed traffic signals		25	0
Number of actuated traffic signals		157	99

Transit	BART, Inter-city trains, AC Transit	N/A
Inter-modal Facility	Oakland airport, Oakland seaport	N/A

*: Caltrans D6 staff is conducting the AM study based on the methodologies developed in CMPD

2.3 Micro-simulation Based Modeling Technique

To identify gaps of traditional corridor management planning practices, the project team reviewed relevant documents, including guidelines and reports of related previous and ongoing projects. By reviewing these documents, it is clear that traditional corridor management planning in Caltrans District 4 and District 6 uses the four step modeling process (i.e., trip generation, trip distribution, modal split, and traffic assignment). The applied modeling tool is mainly travel demand models such as TP+, EMME2, TransCAD, etc. Although more advanced modeling techniques such as micro-simulation have been applied in a project by project basis (e.g., evaluation of intersection timing plan and ramp metering control algorithm), they have not yet been widely used in the corridor level. The potential advantages of micro-simulation models are summarized as follows:

- Dynamic, implying that the dynamic characteristics of traffic, which is critical especially for evaluating short-term and medium-term operational improvements, can be properly captured;
- Capable of evaluating multiple ITS-related strategies, including incident management, traveler information, traffic signal control and coordination, and ramp metering control; and
- Adding the perceived objectivity of modeling and analysis to the perceived subjectivity of staff experience and judgment to identify problem areas of the corridor.

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However, micro-simulations suffer from drawbacks such as intensive efforts for model development and extensive data needs. Therefore, to identify the proper modeling technique to better address stakeholder needs and the project objectives for CMPD, the project team used a toolbox recently developed by the Federal Highway Administration (FHWA) called *Traffic Analysis Toolbox Volume II: Decision Support Methodology for Selecting Traffic Analysis Tools*¹. The following figure depicts the results of using this toolbox for selecting appropriate tools for the I-880 study. For the SR-41 study, micro-simulation was pre-selected as the modeling tool by the District Staff. The simulation network for SR-41 had been developed by staff at District 6 in Paramics before the corridor was selected in CMPD.

Criteria Weights		Weighted Subtotals							Column 6 x Column 7						
Criteria	Weight	Sketch Plan	TDM	Analytical (HCM)	Traffic Opt	Macro Sim	Meso Sim	Micro Sim	Sketch Plan	TDM	Analytical (HCM)	Traffic Opt	Macro Sim	Meso Sim	Micro Sim
0 Analysis Context	5	-140	25	42	33	42	42	33	0	0	0	0	0	0	0
1 Geographic Scope	5	25	50	0	0	25	25	25	125	250	0	0	125	125	125
2 Facility Type	5	18	40	31	24	37	37	46	89	200	154	118	186	186	229
3 Travel Mode	5	30	45	25	25	25	40	40	150	225	125	125	125	200	200
4 Management Strategy/Applications	5	24	6	12	13	24	24	33	122	31	59	63	122	122	163
5 Traveler Response	4	25	50	-495	0	42	42	42	100	200	-1980	0	167	167	167
6 Performance Measures	5	17	22	18	18	21	26	26	87	110	91	91	104	129	129
7 Tool Cost Effectiveness	1	30	0	30	30	0	0	0	30	0	30	30	0	0	0
WEIGHTED TOTALS									793	1017	-1521	427	829	929	1012
Most Appropriate Tool Categories:									1. TDM 2. Micro Sim						

Tool Categories:

- Sketch Plan = Sketch-planning methodologies and tools
- TDM = Travel demand models
- Analytical (HCM) = Analytical/deterministic tools (HCM-based)
- Traffic Opt = Traffic optimization tools
- Macro Sim = Macroscopic simulation models
- Meso Sim = Mesoscopic simulation models
- Micro Sim = Microscopic simulation models

Please see the 'Tool Definitions' worksheet for more details

Recalculate

Figure 2.5 Output from Toolbox for I-880 Study

¹ http://www.ops.fhwa.dot.gov/trafficanalysisistools/tat_vol2/index.htm

The micro-simulation technique was recommended by the toolbox for the I-880 study. The project team adopted Paramics as the micro-simulation package recommended by Caltrans Traffic Operations. The expectation is that by using micro-simulation modeling the project team will be able to evaluate various ITS related operational improvement strategies while considering detailed dynamics of traffic flow in the studied corridors.

3. Data Needs and Collection

Compared with traditional corridor planning using travel demand models, CMPD requires significantly much richer dataset for both performance evaluations and simulation studies. This section addresses the data needs and collection issues in CMPD. We start with descriptions of basic data categories and major data providers. We then discuss in more detail the specific data needs and collection for performance evaluation and simulation model development.

3.1 Data Needs

The data needed for conducting CMPD can be grouped into the following two categories:

- Corridor Description Data – Provides a general description of the corridor geometry, traffic control and detection facilities, demand characteristics, land use, modal services, and environmental factors.
- Traffic Description Data – Describes the basic traffic flow characteristics such as origin-destination (OD) matrices, vehicle type mix, volume, occupancy, speed, travel time, traffic incidents, etc.

Each of the two categories is addressed in more detail as follows.

3.1.1 Corridor Description Data

Corridor description data provides the geometry of the corridor (including both freeways and arterials), major transportation management systems and traffic detection devices, neighboring land use, demand characteristics, and environmental scan. Although it may vary for different corridors, in general a complete corridor description should include the following elements:

Roadway Geometry

This element explains the coverage of the corridor, including the freeways, major cross-routes and parallel facilities, as well as the physical dimensions of the facilities within it. Generally, the roadway geometry should include the following components:

- The extent of the corridor (major freeway), including total lane miles and centerline miles as well as beginning and ending postmiles (e.g., for the I-880 corridor, it begins at the SR-237 interchange and ends at Grand Ave).
- Key geometric information, such as the number of lanes along the corridor in general or major sections, the presence of high-occupancy vehicle (HOV) facilities, typical lane and shoulder width, and type of medians.
- Major structures, such as bridges and overpasses.
- Key interchanges and/or intersections with other state highways and major arterials (e.g., the I-238 interchange of the I-880 corridor).

- Relevant stakeholder information, such as cities and counties, regional planning agencies, and air basins included in the corridor. For example, the I-880 corridor covers five cities, Alameda and Santa Clara counties, one regional planning agency jurisdiction and one air basin.
- Detailed arterial geometric description. This includes the major cross routes and parallel arterials. The definition of “major arterial” should be discussed with local stakeholders (see Section 2) to reach consensus. Generally, routes included in the regional planning model are a good starting point for these discussions. Once major arterials are identified, corridor descriptions should provide geometric information of arterials regarding number of lanes, presence of turn lanes, signalization and channelization, and major areas served.

Traffic Management System (TMS) Elements

TMS elements provide a summary of existing and planned traffic management and control devices within the coverage of the corridor. Major components include:

- Vehicle detection and data availability. This includes the type of detections, e.g., loop detectors or radar or probe vehicles, and its configuration such as locations of the detectors, data formats, etc. This also provides how data can be achieved, e.g., through PeMS and/or Advanced Transportation Management System (ATMS).
- Ramp metering. This includes locations of the meters and the extent of deployment (e.g., every ramp, every other ramp, a portion of the corridor, etc.), as well as the type of the ramp metering (e.g., pre-timed or traffic responsive or adaptive) and control design (one or two vehicles per green, HOV bypasses). In order for the micro-

simulation model to work properly, the detailed ramp metering control logic is also needed. The logic could be rather different for different corridors and should be provided by corresponding Caltrans local districts.

- Number and location of Changeable Message Signs (CMS) and Closed-Circuit Television Cameras (CCTV).
- Availability of Highway Advisory Radio (HAR)
- Signal timing plans and coordination for arterial intersections, as well as coordination of ramp metering and arterial traffic signals (if any).

Origins and Destinations of Travel

This element describes the primary origins and destinations of traffic that uses a given corridor. This includes Origin-Destination (OD) pairs within the corridor, from within the corridor to outside the corridor, and both outside with the corridor used as a major route. The OD information can be provided by the regional planning agency and/or Caltrans local district offices. For instance, for the I-880 corridor, the Metropolitan Transportation Commissions (MTC) developed a region-wide model that includes a base calibration year and several projection years. For the SR-41 corridor, Caltrans District 6 has the planning model that defines the origins and destinations for the studied corridor.

Land Use

This element provides an overview of current land-use and major changes planned for the future. The data collection for CMPD is focused on land-uses that influence travel patterns such as major office developments, shopping locations, and residential lots. The

primary source of land-use information should be the regional planning agency. In the case of I-880, the information was collected from the Association of Monterey Bay Area Governments (AMBAG). For the SR-41 corridor, the land use data was obtained directly from Caltrans District 6 planning staff.

Transit and other Inter-modal Facilities

Transit information provides a summary of complementary transportation modes along the corridor. All forms of transit should be considered, including local and express bus service, light-rail, heavy rail/subway as well as long-distance passenger rail service. For the I-880 corridor, this will include at a minimum, the Bay Area Rapid Transit (BART) and AC Transit. For each transit operator the data that collected should include information on daily ridership, frequency of service, major origins and destinations served, and major stops.

Other inter-modal facilities consist mainly of seaports, airports, and freight rail and transshipment facilities. This type of facilities turns out to be more relevant for the I-880 corridor than SR-41 since the former is physically adjacent to both passenger facilities (such as the Oakland Airport) and freight facilities (such as the Port of Oakland and rail transshipment sites). For the Port of Oakland, the information that is collected includes:

- The type of ships served (container versus cargo)
- Annual tonnage
- Most typical commodities carried
- Major trading destinations

- Primary access modes and routes

For the Oakland airport, the collected data includes:

- The extent of passenger and freight service
- Annual enplanements
- Access modes, especially the extent to which the corridor and certain interchanges are used.

Appendix A of this report provides more detailed transit and inter-modal facility data related to the I-880 corridor.

Environmental Scan

This element summarizes the potential environmentally sensitive issues along the corridor, including locations of wetlands, sensitive habitats, hazardous waste sites, and general air quality. The purpose is to provide a background about issues that may need to be considered when developing system management strategies for addressing corridor mobility problems. It is not, however, intended to identify previously unknown environmental problems. The environmental scan data was collected from Caltrans GIS layers. Refer to Appendix A for more detailed data on environmental scan data for the I-880 corridor.

Planned and Programmed Improvement Strategies

The strategies provided are a list of planned and programmed improvement projects that are related to the studied corridor. They are obtained from Caltrans and local and regional

transportation management authorities. This information is crucial to developing base year and future year improvement scenarios that can be evaluated through micro-simulations.

3.1.2 Traffic Description Data

Traffic description data provides basic parameters for describing traffic conditions and states. Traffic performance measures, e.g. delay, reliability, and productivity, can all be derived from these basic traffic description data. Except for OD matrices and vehicle types, traffic description data was collected from Tuesdays to Thursdays to capture the traffic conditions during “typical” weekdays. In particular, basic traffic description data includes:

Origin-Destination Demand Matrix

The OD demand matrix (the most critical input to the simulation model) represents the number of trips from a given origin to a destination. This could be static, representing the average trip pattern between the OD pair, or dynamic, capturing the detailed time-dependent (e.g. in each 15-minute interval) demand for the given OD.

For micro-simulations, a dynamic OD matrix is normally needed. Without a reasonably correct OD matrix, micro-simulations tend to produce erroneous results that can not be resolved easily by later calibration steps. In practice, the OD matrix (either static or dynamic) is not directly observable. Usually, static OD is available from traditional corridor planning using travel demand models. On the other hand, dynamic OD needs to be estimated from static planning OD, traffic flow, counts, and turning volume data. This

requires data with much finer level of detail, especially in the temporal domain. For example, 5 or 15-minute link volume data is usually needed for entire rush hours in order to produce a reasonably correct dynamic OD matrix.

Vehicle Type Mix

Vehicle type mix provides the types of vehicles and their percentages in the studied corridor. Particularly for micro-simulations, vehicle type mix is an important input since different types of vehicles (e.g. passenger cars and trucks) tend to have varied characteristics and behaviors such as accelerations and decelerations and gap acceptance for lane changing, etc. This will in turn greatly impact the overall traffic flow characteristics. For a Paramics simulation, vehicle type and percentage need to be integrated with OD demand matrix. In the I-880 study, vehicle type mix data was derived from data collected at Weight-In-Motion stations (WIM), based on the Federal Highway Administration (FHWA)² definition of vehicle categories. Detailed data processing procedure is provided in Section 5. For the SR-41 corridor, the vehicle type data was provided by District 6 staff.

Besides vehicle type mix data, micro-simulations also require vehicle performance data such as maximum acceleration and deceleration. However, this kind of data is difficult to collect in practice, therefore the default values provided in Paramics were used.

Traffic Volume, Occupancy, Speed

² FHWA, Manual for Vehicle Classification

Traffic volume is the most basic parameter describing the state of freeway traffic. Traffic volume data should be collected at identified mainline and ramp locations. The volume data is critical for corridor performance evaluations and micro-simulations. However, these two applications normally require volume data at different levels of granularity. For performance evaluation, 30-minute data works reasonably well; while for simulation (e.g. dynamic OD estimation purpose) 5- or 15-minute volume data is more preferable.

Occupancy and speed data are normally collected at specific locations along the freeway mainline. They can serve as input data for micro-simulation calibrations. For example, speed data can be used as the primary data type for building speed contour maps in order to identify possible bottlenecks along the corridor. Occupancy data can also be used for simulation calibration and bottleneck analysis. Generally speaking, occupancy and speed data can be collected in a 5- or 15- minute interval.

A major source for collecting statewide traffic volume, occupancy and speed data in California is via the Performance Measurement Systems (PeMS)³ which archives loop detector data from eight districts (see Section 3.2). The data provided by PeMS includes 30-second raw data and 5-minute, 15-minute, and hourly aggregated data. For dual loops, speed data is measured; for single loops, speeds are estimated using updated vehicle length⁴.

³ <http://pems.eecs.berkeley.edu/Public/>

⁴ Kwon, J. Joint estimation of the traffic speed and mean vehicle length from single-loop detector data. In *Proceedings of the 82nd Annual Meeting of the Transportation Research Board (CD-ROM)*, Washington, DC.

For the I-880 corridor, on and off ramp volume data was obtained through two sources: hourly census data from Caltrans District 4 and 30-second data from the Traffic Management Center (TMC). For SR-41, all traffic volume, occupancy and speed data were collected by District 6 staff at 11 count locations since PeMS was only archiving a limited amount of detector data for the SR-41 corridor during the study period.

Traffic Counts and Turning Volumes

Traffic counts and turning volumes are mainly used with arterial streets. Traffic counts are collected for arterial roadway links while turning volumes are for intersections. This data is usually collected in a 15-minute or at least 30-minute interval, which are important inputs for simulation calibration and dynamic OD estimations. In case of the I-880 study, traffic counts and turning volumes were obtained from local and regional transportation agencies. For the SR-41 corridor, historically collected data was available and additional field data collections were also conducted to reflect the most up-to-date traffic conditions along the corridor.

Travel Time

Travel time is one of the major criteria for assessing the mobility performance of the studied corridor, for both freeways and arterials. It is also one of the most important forms of traveler information that is currently provided to the driving public by various means (such as CMS). Besides performance evaluations, travel times can be used for simulation calibration purposes in Paramics. The travel time data was collected through

Tach runs⁵ by the districts staff and made available to the project team. Other data sources (such as 511 travel time in the Bay Area) also provide link-based or route-based travel times that can be used in CMPD.

Traffic Incidents

The number and types of traffic incidents are important measurements for evaluating corridor safety performances. In California, traffic incident data is readily available through the California Highway Patrol (CHP) database. For traffic accidents, Traffic Accident Surveillance and Analysis System (TASAS) provides detailed records on accidents that are State highway related.

3.2 Data Sharing and Field Collection

Given the massive data requirements for conducting CMPD as indicated in Section 3.1, it would be too time and resource consuming if all data were collected from scratch. Fortunately, most of the data needed by CMPD are available through various agencies and other freely accessible and dedicated data sources. Under certain circumstances, however, extra data was needed for specific purposes (e.g. dynamic OD estimations). In these cases, additional field data collection efforts were made.

⁵ Caltrans, District 4, *Congestion Monitoring Procedures and Guidelines*, September, 1996.

3.2.1 Data Sharing

Much of the data needed for the CMPD is readily available from various public agencies, including Caltrans (the Headquarters and local Districts), regional transportation planning agencies, cities and counties, and other transportation management authorities (e.g., Port of Oakland). Most of these public agencies are corridor stakeholders, therefore data needs and sharing can be addressed via stakeholder meetings and other means of stakeholder involvement (see Section 2.1). Table 3.1 summarizes the major information providers and their available data.

Table 3.1 Major Data Providers and Available Data

Data Provider		Available Data
Caltrans	GIS Layers	Endangered species, wetlands, vegetation, air quality Political boundaries
	Photolog	Detailed geometry and number of lanes of highway sections
	Traffic Operations	Number and location of TMS elements Metering strategy and detailed control algorithm, if any
	Local Districts	Extra traffic description data, if any, including ramp volume, arterial link counts and/or turning volumes Tach run travel time data
Regional planning agencies		Land use Major origins and destinations and planning OD demand matrices Travel desire lines Mode shares
Cities and counties		Signal timing plans Arterial geometry Link counts and turning volumes, if any
Transit agencies		Description of routes and services Ridership
Airport and seaport authorities (I-880)		Description of facilities Annual enplanements, tonnage and/or use Available access modes and mode split Major access roads
Project reports and environmental study documents		Description of existing Caltrans facility and state-of-practice Environmental indicators
TMS baseline inventory		Number of existing and planned TMS field elements by districts

Other data (such as majority of the traffic description data) can be provided by some dedicated data sources, including PeMS, CHP incident database, and Caltrans Accident Surveillance and Analysis System (TASAS) reports.

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PeMS archives loop detector data from eight districts of Caltrans, primarily volumes, occupancies and speeds. CHP incident database contains information related to incidents on State highways in California. The information includes time and location, as well as type of the incident. Real-time CHP data can be obtained via the Internet⁶ and archived CHP data can be downloaded directly from the PeMS website. Figure 3.1 shows the incident report at CHP website for the Bay Area at a given day.

No	Time	Type	Location	Area
1093	2:27PM	Disabled Vehicle	WB 580 JEO LAKE CHABOT	Castro Valley
1089	2:25PM	Traffic Collision - No Details	SIR FRANCIS DRAKE BLVD AT LA CUESTA DR	Marin
1081	2:21PM	Disabled Vehicle	NB I680 ON EB COLEMAN AV OFR	San Jose
1070	2:19PM	Disabled Vehicle	NB US101 JNO EB SR92	Redwood City
1068	2:18PM	Defective Traffic Signals	SR121 JNO WOODEN VALLEY RD	Napa
1062	2:16PM	Traffic Collision - Property Damage	NB SR29 JSO TRANCAS ST	Napa
1060	2:16PM	Traffic Hazard - Vehicle in Center Divider	SB I680 JNO RUDDGEAR RD	Contra Costa
1044	2:09PM	Traffic Collision - Property Damage	EB I80 JEO HIDDENBROOKE PKWY	Solano
1042	2:08PM	Traffic Collision - Property Damage	SB US101 JNO MANUEL T FREITAS PKWY	Marin
1034	2:03PM	Provide Traffic Control	NB ARNOLD DR AT BONNEAU RD	Napa
1028	2:01PM	Traffic Hazard - Loose Animal	NB I280 JSO NB SR87	San Jose
1024	1:59PM	Traffic Collision - Property Damage	SB I680 JNO ARTHUR RD	Contra Costa
1007	1:50PM	Disabled Vehicle	SR1 JSO STEWARTS POINT	Santa Rosa
1006	1:49PM	Disabled Vehicle	WB SR4 JEO LOVERIDGE RD	Contra Costa
0994	1:40PM	Traffic Hazard - Debris/Objects	NB I680 AT SUNOL BLVD	Dublin
0983	1:31PM	Traffic Collision - Ambulance Responding	EB SR237 JWO N 1ST ST	San Jose
0934	1:10PM	Road Closure	NB US101 AT VISTA PT	Marin
0921	1:05PM	Traffic Collision - Property Damage	NELLIGAN RD AT NUNS CANYON RD	Santa Rosa
0910	12:59PM	Traffic Collision - Property Damage	35680 PALOMARES RD	Castro Valley

Figure 3.1 Snapshot of Incident Report in the Bay Area (CHP)

The TASAS accident database contains specific data for accidents that are State highway related. Each accident record is a location specific to a ramp, intersection or highway postmile address. The master file contains records for 10 years plus the current year. The individual records in the TASAS accident database contain general accident information including:

- o Location
- o Date and time

⁶ <http://cad.chp.ca.gov/default.asp>

- o Severity
- o Primary collision factor
- o Environmental items
- o Roadway conditions
- o Type of collision
- o Number of vehicles involved

3.2.2 Field Data Collection

Besides data obtained from public agencies and other dedicated data sources, extra data is sometimes needed (e.g., ramp volumes, arterial link counts and turning volumes). Often field inspections are desirable as well to observe the real-world traffic states and verify bottleneck analysis results. All these require additional field data collection efforts. Generally, extra field data collections will be made if any of the following four conditions is met:

- Data Coverage is not sufficient (e.g., for the I-880 study, ramp data was not available from PeMS);
- Collected data is out-of-date (e.g., for the SR-41 study, data collection was conducted in 1998);
- Level of detail is not sufficient (e.g., only hourly data is available while finer dataset is more desirable);
- Field inspections for bottleneck evaluations. (e.g., this was conducted for the I-880 study to verify results of bottleneck analysis).

Field Data Collection for I-880 Corridor

The most challenging field data collection issue for the I-880 study was related to ramp data. Since PeMS did not archive ramp data for the I-880 corridor, 30-second raw

detector data was obtained from Caltrans District 4. However, due to detector configuration problems (i.e., how to interpret the 30-second data) and data processing (e.g., aggregating 30-second data to 15-minute), the complete set of ramp data for the I-880 study was not available until early 2006. This resulted in study delays as ramp data is critical to the dynamic OD estimation and simulation model development.

Other field data collection efforts for I-880 mainly focused on field inspections. The major purpose was for calibrating micro-simulations or to verify bottleneck analysis results. They also helped to identify causes of bottlenecks and develop potential improvement strategies. Field inspections are usually qualitative, using visual assessments. In certain cases, field data collection is conducted (e.g. ramp volume counts). Figure 3.2 depicts the field inspection results for the I-880/SR-84 interchange. In this effort, visual assessment was conducted to estimate the queue lengths of on and off ramps for the interchange. The estimated queue length is used by the simulation team to verify the calibration results.



Figure 3.2 Field inspection Results for I-880 vs. SR-84 Interchange

Field Data Collection for SR-41 Corridor

Due to the fact that the available traffic description data for SR-41 corridor was limited and largely obsolete, intensive field data collection efforts were conducted for this study. The traffic data of SR41 network was collected in 1998, which does not reflect current traffic conditions. In addition, the demand information (counts) and traffic performance data had not been collected on the same day, posing difficulties for data processing and analysis. The newly collected data for SR-41 includes:

Freeway loop detectors count data

Freeway traffic volume data, including those of mainline, on/off ramps and freeway interchange, were collected by the loop detector from 11 count locations. Figure 3.3 demonstrates the count stations along SR-41 corridor. Data for three consecutive days was collected from Tuesday to Thursday (November 16 – 18, 2004) to present the typical traffic conditions. The collecting period was five minutes. Since the congestion in this corridor was mainly in the freeway system, the freeway volume data is the most important to match in the calibration.

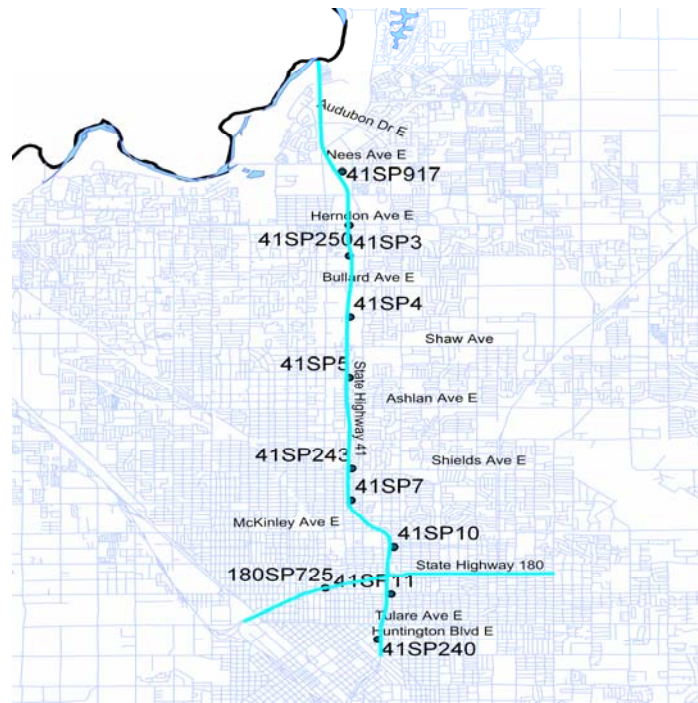


Figure 3.3 SR-41 Freeway Volume Data Collection Locations

Arterials traffic data

Previously there were some historical arterials turning count data for most of the signalized intersections. However, most of them were outdated and were only collected by hour. As a result, they cannot fit the calibration requirement. New count data

collection was conducted from Tuesday to Thursday which can reflect the typical week day traffic pattern. Nine locations were selected for collecting traffic counts and intersection turning volumes, as shown in Table 3.2.

Table 3.2 Locations for Link Counts and Turning Volumes for SR-41 Corridor

	Intersections turning	Cordon link
Locations	Blackston & Herndon	Nees west of Blackston street
	Fresno & Herndon	Nees east of Fresno street
	Blackston & Shaw	Bullard west of Blackston street
	Fresno & Shaw	Bullard east of Fresno street
	Blackston & Shields	Ashlan west of Blackston street
	Fresno & Shields	Ashlan east of Fresno street
	Blackston & Mckinley	Belmont west of Blackston street
	First & Mckinley	Belmont east of First street
	First & Tulare	Tulare between T and U street

Tach run data

Vehicles equipped with GPS devices were sent out to traverse the study area (SR41 freeway, and two parallel arterials) to collect travel time data. The vehicle location was recorded every second. At the end of the trip, all records were output to a text file and processed by specialized software. Travel time and speed data between sections were then generated. They are called the “Tach run” data⁷. With archives of multiple days and multiple vehicle runs, the travel time data can be used in calibration. In this study, we conducted Tach runs on SR41, Blackstone Ave, and Fresno Ave. Figure 3.5 depicts the check point locations for the Tach runs conducted for SR-41 corridor.

⁷ Caltrans, District 4, Congestion Monitoring Procedures and Guidelines, September 1996.

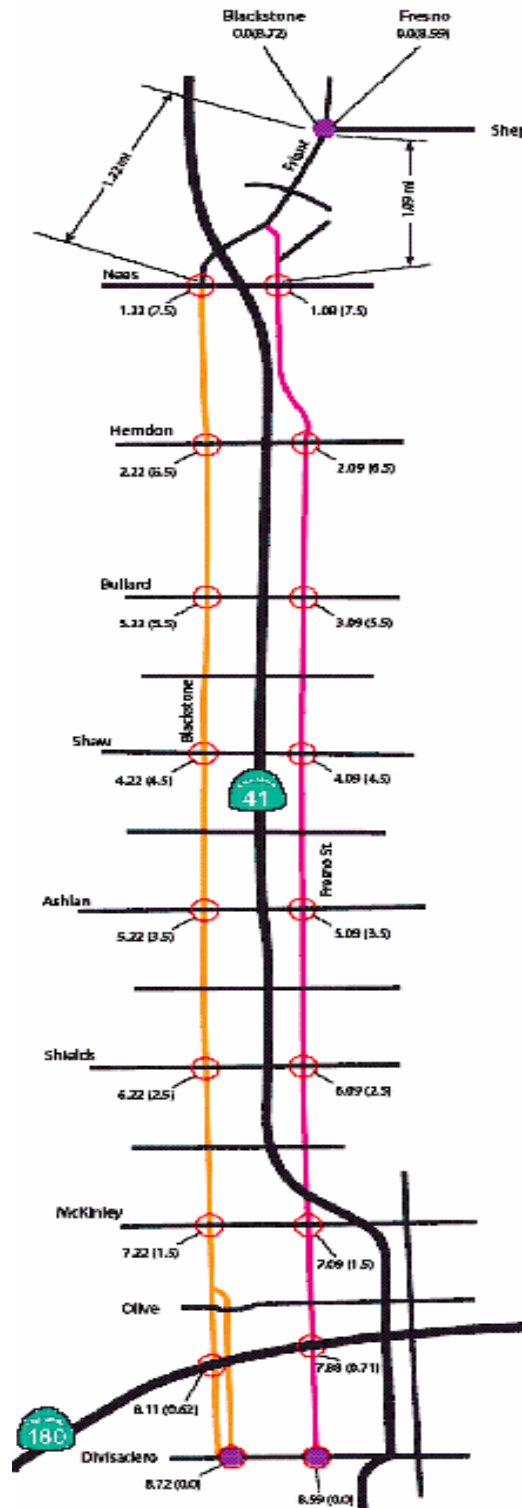


Figure 3.4 Tach run Check Point Locations for SR-41 Corridor

3.3 Performance Evaluation Data

System performance evaluation is the basis upon which corridor management plan strategies are developed. In general, system performance evaluation includes base performance measurements related to current or recent conditions, and future performance measurements related to projections derived from the models. This report focuses on performance evaluations on the State Highway System. For arterials, performance evaluation is much harder to conduct due to the complexity of computing performance measurements for arterials, e.g., delays. This report focuses on the travel times of arterials only.

In CMPD, various measurements have been used to evaluate the system performance, including delay, travel time, productivity, safety, and reliability (see Section 4). Generally, these performance measurements indicate, at a relatively high-level, how the system performs (base case) or will perform (future case). Therefore, data required for performance evaluation is mainly to compute these measurements in an aggregated manner. In most cases, less detailed data could suffice compared with data needs for micro-simulation. For example, 15-minute or 30-minute or even hourly is often adequate to compute performance measures, while much finer data is usually required for micro-simulation calibrations and dynamic OD estimations. Performance evaluations basically need traffic description data. Table 3.3 summarizes the data needs, possible sources, and level of details for computing different performance measurements.

Table 3.3 Data Needs for Performance Evaluation

Data Needs	Level of Details	Measurements	Sources
Volume, Occupancy,	15- or 30-minute	VTM, Delay, speed,	PeMS

Speeds		productivity, bottleneck analysis	
Travel time	15 or 30-minute interval	Travel time, reliability	PeMS, Tach run, 511
Truck Volume	15 or 30-minute interval	Truck VMT	PeMS
Incident/Accident reports	/	Safety	TASAS, CHP, PeMS

3.4 Simulation Model Data

The general steps and data requirements for conducting micro-simulations can be found in the California Department of Transportation’s *Guidelines for Applying Traffic Microsimulation Modeling Software*⁸ and FHWA’s *Traffic Analysis Toolbox, Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software*⁹.

For CMPD, the data requirements for micro-simulation model development are divided into three categories: network coding, OD matrix estimations and simulation calibrations, and improvement scenario evaluations. The following three sub-sections will discuss each in more detail.

3.4.1 Network Coding Data Needs

Network coding is the first step to develop a micro-simulation model. The data needed is primarily the corridor description data, including freeway and arterial geometry, ramp

⁸ Dowling Associates. *Guidelines for Applying Traffic Microsimulation Modeling Software*, Caltrans Report, September 2002.

⁹ Federal Highway Administration, *Traffic Analysis Toolbox, Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software*, Publication No. FHWA-HRT-04-040, June 2004.

metering locations and control plans, signal timing plans and coordination, etc. Table 3.4 summarizes data needs for network coding.

Table 3.4 Data Needs for Network Coding

Data Needs	Descriptions	Sources
Photolog	Number of lanes, locations of on/off ramps, signs, and lane drops	Caltrans
Aerial photo	Curbs, number of lanes	Teraserver.com
Geometry map for each arterial intersection	Intersection geometry, number of lanes, lane assignment	Cities and counties;
Traffic signal	Type of signal, signal timing planning and coordination	Cities and counties
Ramp metering	Type of ramp meter, metering control plans	Caltrans local districts

Due to the inter-regional nature of many corridors, collecting intersection signal timing plans imposes the most challenging part of the overall data collection effort. For the I-880 study, the project team has developed the following sequential data requesting and collection steps that proven to be effective to reduce the overall efforts required:

- Develop a master list of all signalized intersections to be included in the simulation model.
- Send the master list to the Caltrans District 4 Division of Operations as the starting point.
- Once the team receives the data from Caltrans, divide the remaining intersections by cities and send city-specific requests.
- For those intersections that are not covered by Caltrans or the cities, contact the Counties for data.

3.4.2 OD Matrices Estimation and Simulation Calibration

OD estimation and simulation calibration require primarily traffic description data (e.g., freeway mainline and ramp volumes, arterial link counts, and intersection turning volumes). For calibration purposes, 15-minute data may be adequate; while for dynamic OD estimations 5-minute data is sometimes needed. For OD estimations, definitions of OD pairs and the planning OD demand matrix are also important input data, which can be obtained from regional or county travel demand models. Table 3.5 summarizes the data needs for OD estimations and simulation calibrations.

Table 3.5 Data Needs for OD Estimation and Simulation Calibration

Locations		Data Needs	Time Resolution	Source
Freeway	On/off ramps	volumes	5- or 15- minute	PeMS; Caltrans (Census hourly); TMC (30-second);
	Mainline loop stations	Volume, occupancy, speed	5- or 15-minute	PeMS; Caltrans ATMS
	Selected segments	Travel times	15- or 30-minute	PeMS; Tach run; 511
Arterials	Major links	Link counts	15-minute	Caltrans; cities; field data collection
	Major intersections	Turning volume	15-minute	
	Selected routes	Travel times	15- or 30-minute	Tach run

The actual locations and coverage of freeway, arterial and travel time data collections for SR-41 corridor are shown in Figure 3.3, Table 3.2 and Figure 3.4, respectively. For I-880 corridor, 65 NB loop detector locations and 73 SB loop locations, as defined at PeMS, were chosen to collect mainline data. And 44 locations were selected for collecting on/off ramp data. Table 3.6 and 3.7 further list the selected arterial links and intersections for northbound and southbound I-880 corridor respectively. Figure 3.5 shows the selected freeway segments for computing and comparing travel time performances.

Table 3.6 Arterial Data Collection for Northbound of I-880 Corridor

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Type	Screenline	Intersections / Links
Inter-sections	Downtown Oakland	(1) Broadway /14 th (2) Embarcadero/Webster
	Doolittle / 66th Screenline	(3) Dolittle/Island Dr (4) 66th/San Leandro (5) 66th/14 th
	Davis Screenline	(6) Davis/Dolittle (7) Davis/San Leandro (8) Davis/14 th
	SR-238 Screenline	(9) Lewelling/Hesperian
	A street Screenline	(10) A street/Hesperian (11) A street/14th (Mission)
	Control intersection	(12) Tennyson/Hesperian
Links	Airport	(1) Link on Airport Dr between Dolittle and Sally Ride Way (2) Link on Oakport between Lesser St. and 66 th (3) Link on SR-92 between Hesperian and Industrial Blvd

Table 3.7 Arterial Data Collection for Northbound of I-880 Corridor

Type	Screenline	Intersections / Links
Inter-sections	Control intersection	(1) Tennyson/Hesperian
	Tennyson Screenline	(2) Tennyson/Huntwood (3) Tennyson/Mission
	Decoto Screenline	(4) Decoto/Fremont (5) Decoto/Alvarado Niles (6) Decoto/Misson
	Auto Mall Screenline	(7) Automall/Boyce (8) Automall/Grimmer (9) Automall/Osgood (10) Automall / Fremont Blvd
	City of Fremont	(11) Stevenson/Fremont (12) Mowry/Blacow
Links	Important links	(1) Link on Newalk Blvd between Decoto and Jarvis Ave (2) Link on Mission Blvd (SR-262) Between Warm Spring Blvd and Kato Rd



Figure 3.5 I-880 Freeway Segments for Travel Time Collections

3.4.3 Scenario Evaluation

To evaluate base year or future year improvement strategies, the planned or programmed corridor improvements from Caltrans are the most critical dataset. Figure 3.6 depicted the improvement projects at D6 for the SR-41 corridor. This report only covers the generation of the improvement scenarios for the SR-41 corridor. Detailed scenario

evaluations are not yet available for any of the study corridors, and will be provided in a separate report as part of CCIT TO 1015.

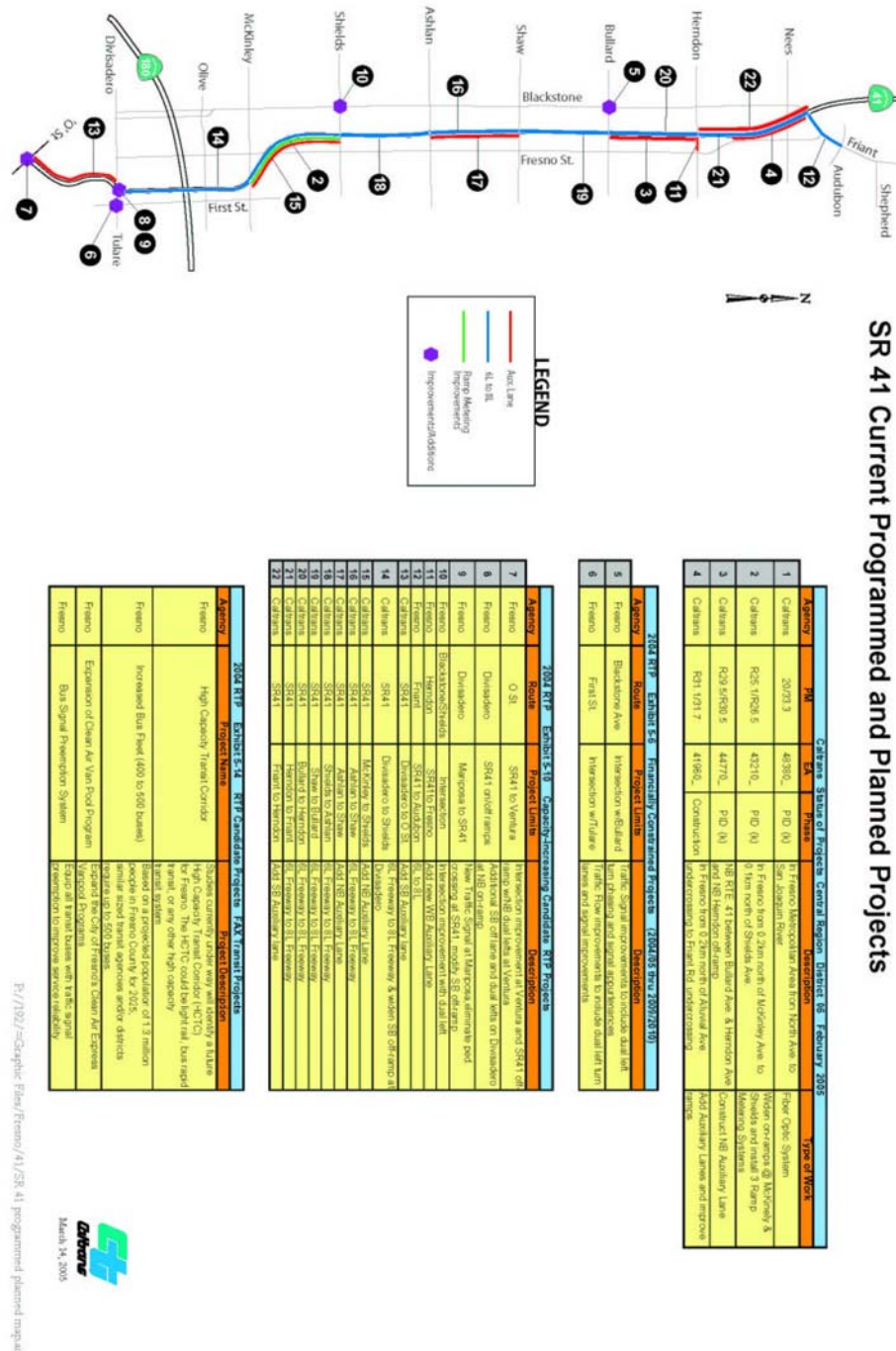


Figure 3.6 Planned and Programmed Improvement Strategies for SR-41 Corridor

3.5 Data Cleaning and Processing

Some of the collected data, especially the traffic count/volume data, may have discrepancies with each other since they may have been collected during different days. As a result, more data cleaning and processing are necessary. Three methods have been applied in CMPD for this purpose. The first approach is to use a tool built in the Paramics Estimator, called “Validate Data”, which can detect count discrepancies automatically.

A second approach is to use an Excel template developed by Caltrans engineers to locate the discrepancy data. One example is provided in Figure 3.7 which is to check the data consistency for a given arterial intersection for the SR-41 study.

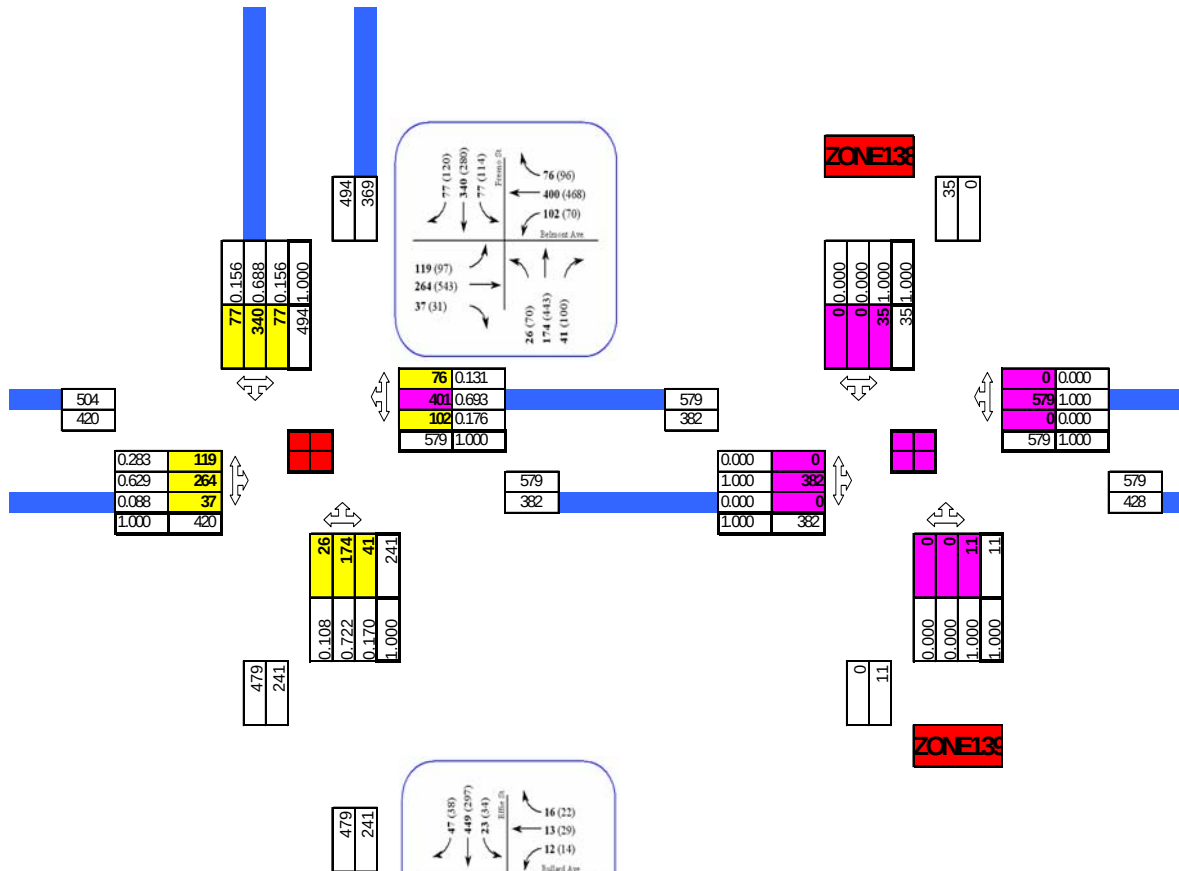


Figure 3.7 Excel Template for Data Consistency Checking

A third method, used in the I-880 study, is to simultaneously process the ramp and mainline traffic volume data to make them consistent with each other. The method assumes the ramp data is perfectly accurate, and the mainline volume is adjusted accordingly. The process starts from the upstream end of the highway, where its data is regarded to be more accurate, and proceeds until the downstream end of highway is reached. However, if this method is used directly, the data set will be very sensitive to errors. As one example, if there is an error at the starting point of count adjustment, all counts points on the downstream will be impacted by the error. To prevent this kind of error propagation, the adopted method should have multiple reference points (i.e., one point every 2-3 miles). A reference point corresponds to a mainline loop detector station

whose data is considered to be 100% accurate. To select a reliable reference point, original data was compared with count data provided by the PEMS website. If count data for a point has a big difference among three surveyed days or it has poor consistency with other reference points, it cannot be used as a reference point. Moreover, if the observation rate of the point is less than 100%, it cannot be used as a reference point either.

Usually, count adjustments are started from the point to the next reference point. For a mainline detector station between two adjacent reference points, although PeMS may report data for this location, its data is actually estimated based on data on reference points and ramps.

Figure 3.8 provides an example of using the third method. In this figure, rows between two reference detectors are separated, so errors in a detector cannot influence beyond the isolated segment. In consistency checking, one-hour counts were used because it is assumed that only ramp census counts are reliable. If an upstream count and a downstream count have inconsistency, it is distributed to all detected points between the two reference points. More details on this data processing method are provided in Section 5 of this report.

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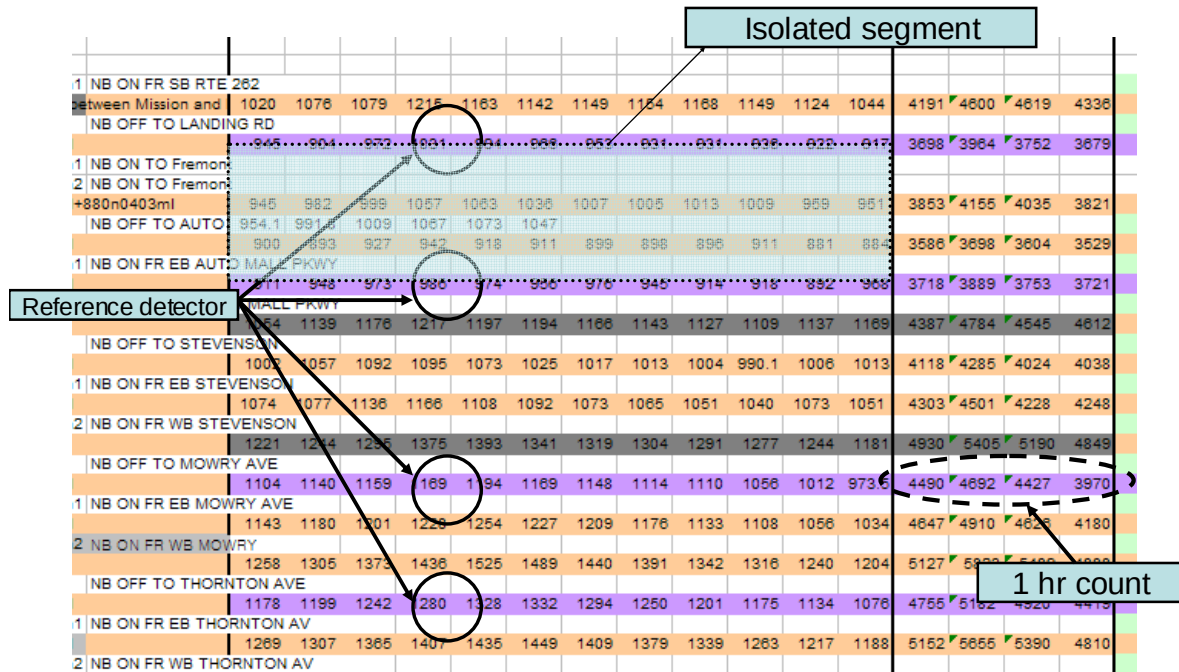


Figure 3.8 Method for Data Consistency

4. Corridor Performance Evaluation

As discussed in Section 3.3 and also shown in Figure 1.1, system performance evaluation is the basis for developing corridor management planning strategies. It can help both traffic engineers and decision makers identify problems within the study area. This is normally the starting point for developing new management strategies. Generally, performance evaluation can be conducted for freeway systems, arterials, and transit. This report only focuses on performance evaluations on the freeway systems. The evaluation includes base performance measurements related to current and recent conditions, and future performance measurements related to projections derived from the models. This report only covers current performance measurements and separate reports will be developed for future performance measurements. In particular, this section mainly focuses on the definitions of the performance measures used in CMPD; detailed corridor performance assessment results can be found in the appendices of the report.

4.1 Performance Measures

Performance measures define quantitatively how the corridor system performs at current or projected future situations. In CMPD, several popularly used measures have been adopted, including various mobility, safety, reliability, and productivity measures. These measures can be computed using collected data (refer to Section 3 for more detail on data collection), although some are readily available from data providers such as PeMS.

4.1.1 Mobility Measures

As the primary objective of transportation system is to transport people and goods, mobility measures are crucial for corridor system performance evaluations. In CMPD, the mobility measures used include vehicle miles traveled (VMT), truck VMT, delay, speed, and travel time.

Vehicle Miles Traveled (VMT)

For a given unit of time and a given section of the freeway, VMT is defined as the sum of freeway miles driven by each vehicle. For a section of fixed length (denoted as L), the number of freeway miles driven is simply the flow for a period of time multiplied by the length L ¹⁰. VMT can be readily obtained from PeMS. Figure 4.1 below is an example of the VMT plot computed by PeMS for NB I-880 on a particular day (March 1, 2005). It shows the expected variation of VMT with more VMT in the daytime compared with night time. Also the two peaks appear during AM and PM rush hours.

¹⁰ <http://pems.eecs.berkeley.edu/Help/index.phtml?content=calculations>

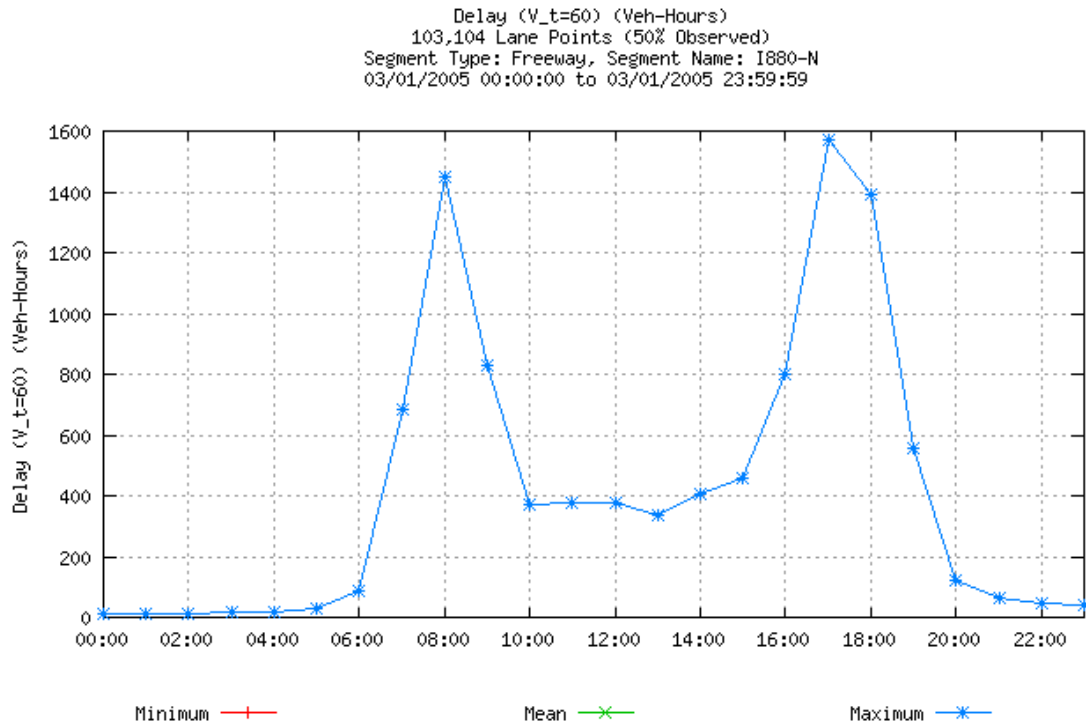


Figure 4.1 VMT for NB I-880 on March 1, 2005

Truck VMT

Truck VMT is the VMT measured and computed particularly for truck flows. This can also be obtained directly from PeMS. Figure 4.2 below is the truck VMT for NB I-880 for March 1, 2005. Note the different trend of truck VMT compared with that for entire traffic flow for the same day in Figure 4.1.

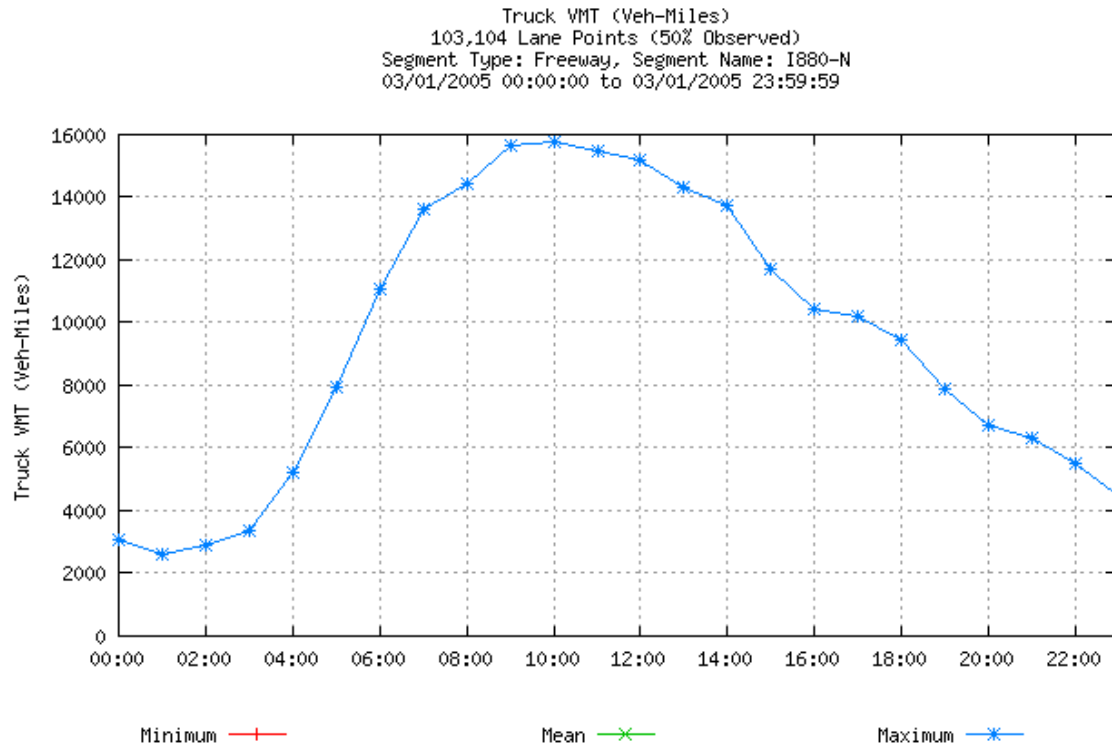


Figure 4.2 Truck VMT for NB I-880 on March 1, 2005

Delay

Delay is defined as the amount of additional time spent by the vehicles on a section of road due to congestion. This is the difference between the travel time at a non-congestion speed and the current speed. Various congestion, or threshold, speeds can be used. In CMPD, **60MPH** was selected for computing the total delay and **35MPH** for severe delay. Delay can be defined mathematically as $D = F * (TT - TT_t) = F * (L/V - L/V_t)$. In these formulas, TT is the travel time at current speed, TT_t is the travel time at the threshold speed, F is the flow, and L is the length of the segment, and V and V_t are the current speed and threshold speed (i.e. 60 MPH), respectively. By this definition, delay can never be negative. Again, delay can be readily obtained from PeMS. Figure 4.3 depicts the total

delay computed by PeMS for NB I-880 on March 1, 2005. The curve contains the typical AM and PM peaks.

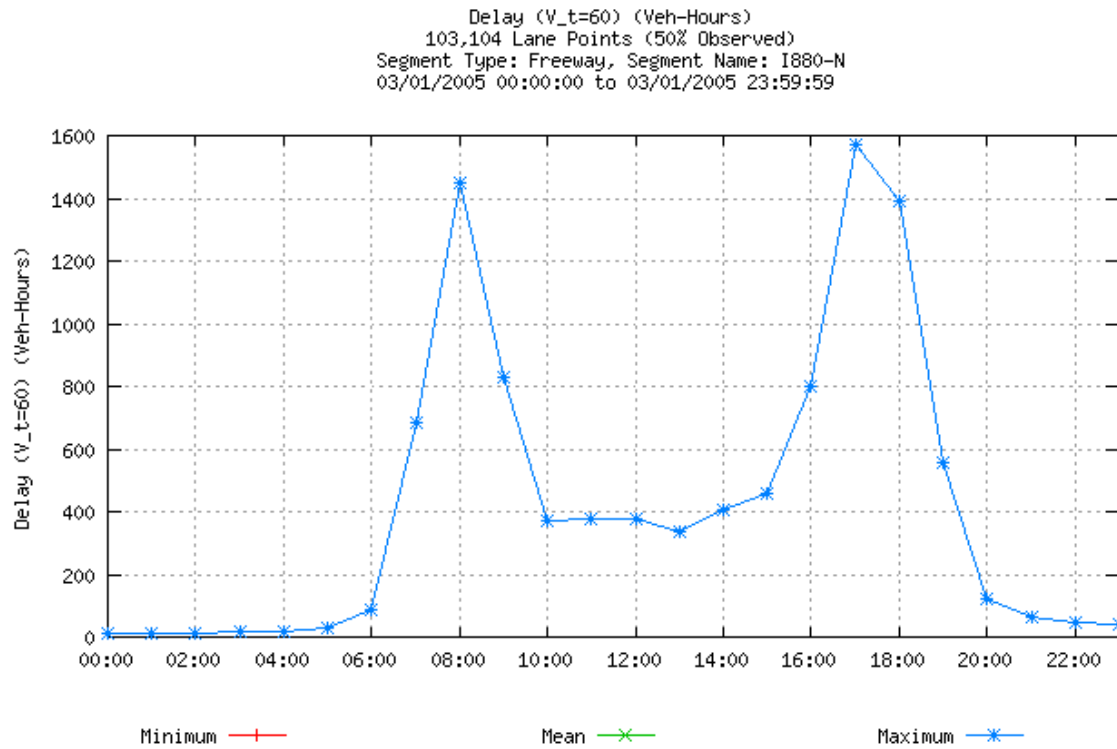


Figure 4.3 Delay for NB I-880 on March 1, 2005

Travel Time

Travel time is the most direct measure for mobility, measuring the time needed for traveling from a given origin to a destination. In CMPD, travel time is collected from Tach runs and some dedicated data sources such as 511. Table 4.1 lists the time-dependent (in 15 minutes) travel times collected for NB SR-41 from O St to Friant Ave.

Table 4.1 SR-41 NB Travel Times

Route	Periods	Average Tach run Travel Time (sec)
Northbound SR-41 from	16:00-16:15	559
	16:15-16:30	553

O St to Friant Ave.	16:30-16:45	549
	16:45-17:00	562
	17:00-17:15	609
	17:15-17:30	723
	17:30-17:45	574

Speed

Speed is another important mobility measure of the corridor system, which is available from PeMS. Note that PeMS archives measured speeds for dual loop detectors, and estimated speeds will be computed and used if detectors are single loops. Figure 4.4 below depicts the variation of lane by lane speed for NB I-880 at 4:00 PM on March 1, 2005. Speeds can also be used to generate speed contour maps that can be used for simulation calibrations and bottleneck analysis, as discussed in detail in Section 4.2.

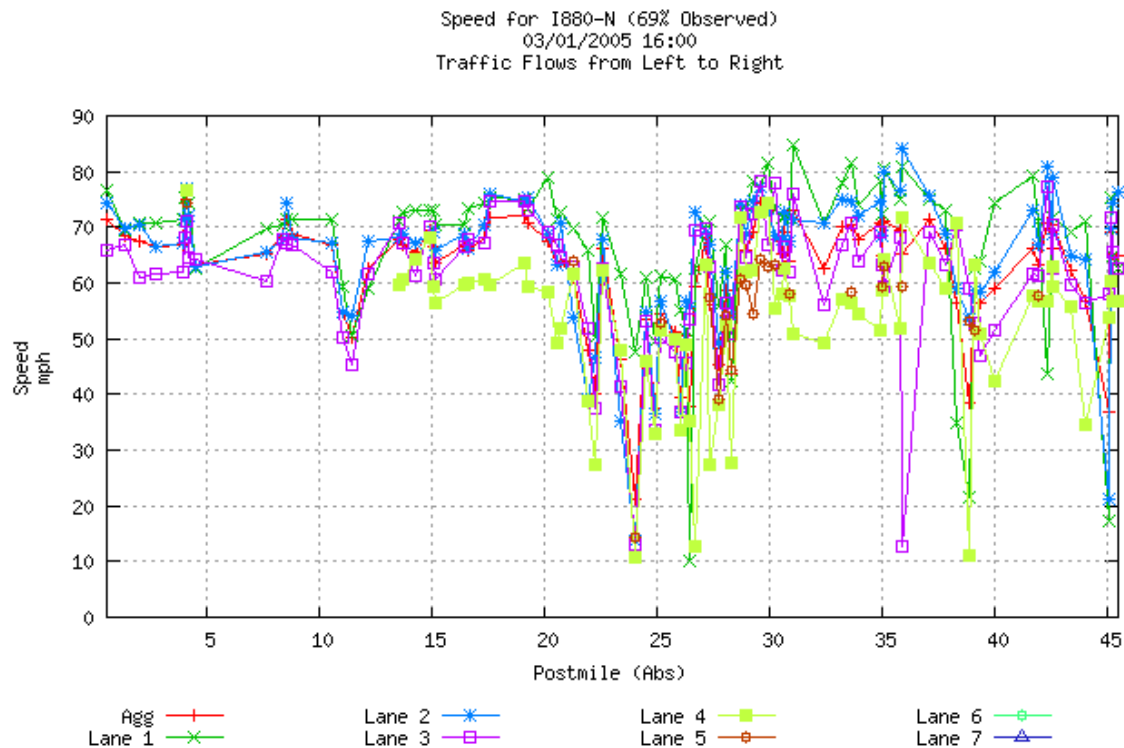


Figure 4.4 Speed Variation for NB I-880 at 4:00 PM on March 1, 2005

4.1.2 Safety Measures

Mobility and safety are two major objectives of transportation systems. In particular, safety has been an increasing concern by both transportation management agencies and the public. In CMPD, two safety measures have been adopted: incidents and accidents. They are available from two data sources, CHP and TASAS.

Incidents

Traffic incidents can be defined as “an unplanned randomly occurring traffic event that adversely effects normal traffic operations.”¹¹ This definition of incidents is very broad and may contain accidents (car crashes), debris on roadway, stalled vehicles, etc. Figure 4.5 plots the incidents occurred along NB I-880 averaged for March 1 – 10 of 2005.

¹¹ Traffic Management Data Dictionary (TMDD) and Message Sets for External Traffic Management Center Communications (MS/ETMCC) Website. Institute of Transportation Engineers. (<http://www.ite.org/tmdd>)

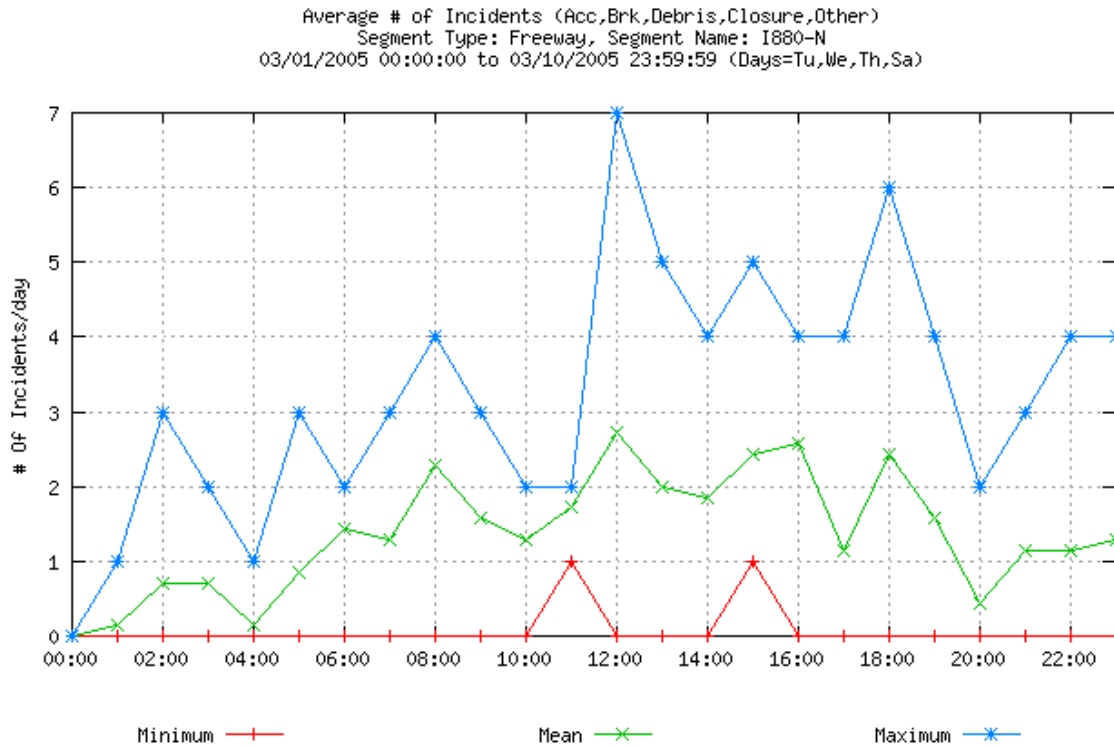


Figure 4.5 Incidents on NB I-880 for March of 2005

Accidents

Accidents are specifically defined as vehicle crashes on the roadway. Therefore, accidents can be treated as one type of traffic incident. Figure 4.6 depicts the average daily number of accidents occurred for both directions of I-880. The data was obtained from the TASAS database and averaged for each month from 1999 to the end of 2004.

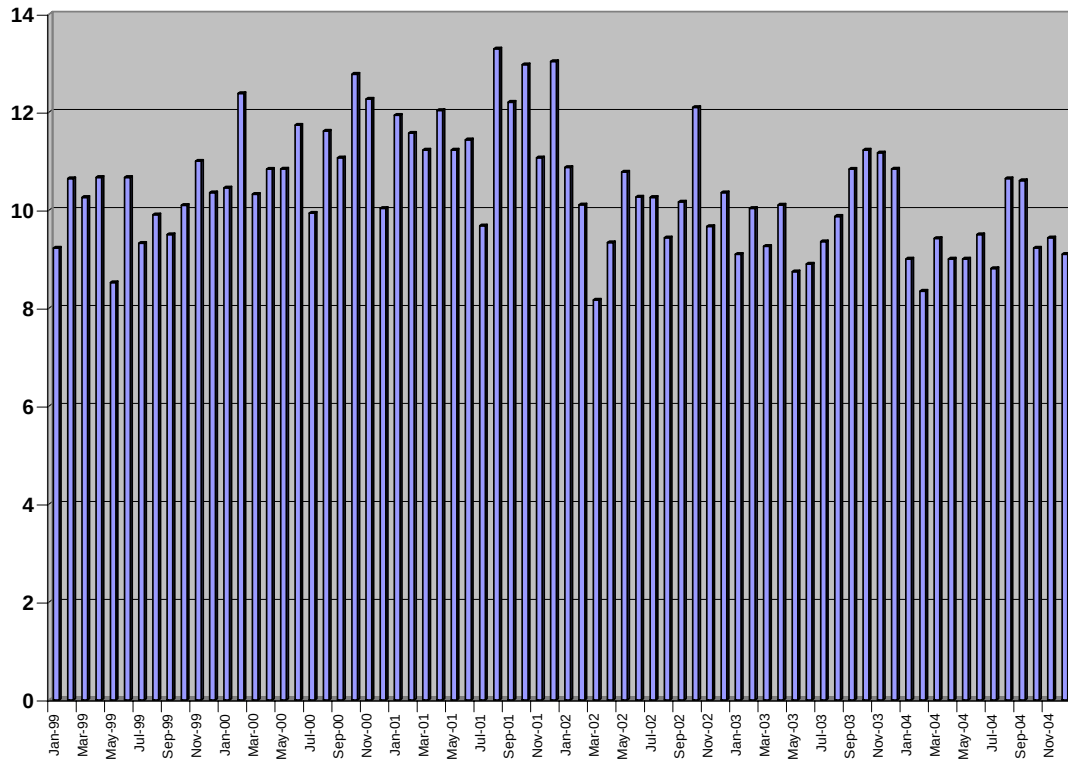


Figure 4.6 Average Daily Accidents for I-880 (Both Directions)

4.1.3 Reliability Measure

The reliability measure adopted for CMPD is “travel time reliability”, which describes the variation of travel times for the studied corridor. One example is provided in Figure 4.7 which depicts the mean and variation of travel times for I-880 NB.

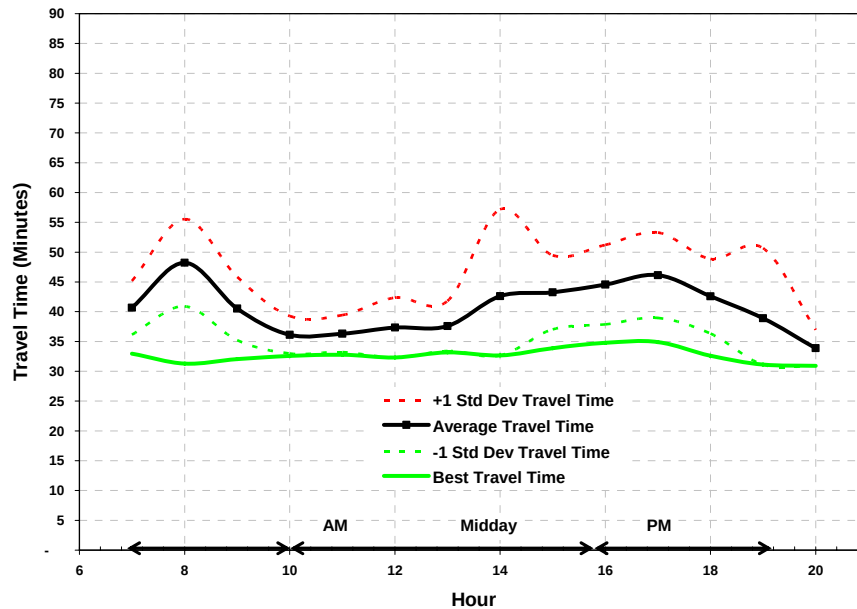


Figure 4.7 Travel Time Reliability for I-880 NB

From Figure 4.7, it is clear that the larger the range between +1 standard deviation and -1 standard deviation, the worse the travel time reliability is. The worst cases normally occur during the AM or PM peak hours.

4.1.4 Productivity Measure

Productivity is the number of lane-mile-hours on the freeway lost due to congested conditions instead of under free-flow conditions. Thus it is also referred to as “Lost Productivity” or “Lost Lane-Miles”. When the freeway is in congestion (i.e., the speed is below **60MPH** in CMPD studies), we find the ratio between the measured flow and the capacity for this location. This drop in capacity is due to the fact that the freeway is operating in congested conditions instead of free-flow. Multiplying one minus this ratio by the length of the segment can produce the value of lost productivity. Figure 4.8 shows one example of the lost productivity for I-880 NB on June 15, 2006. The plot was

generated by PeMS, and presents two obvious peaks during the AM and PM rush hours. Also we can observe the obvious similarity between this lost productivity curve and the delay curve in Figure 4.3.

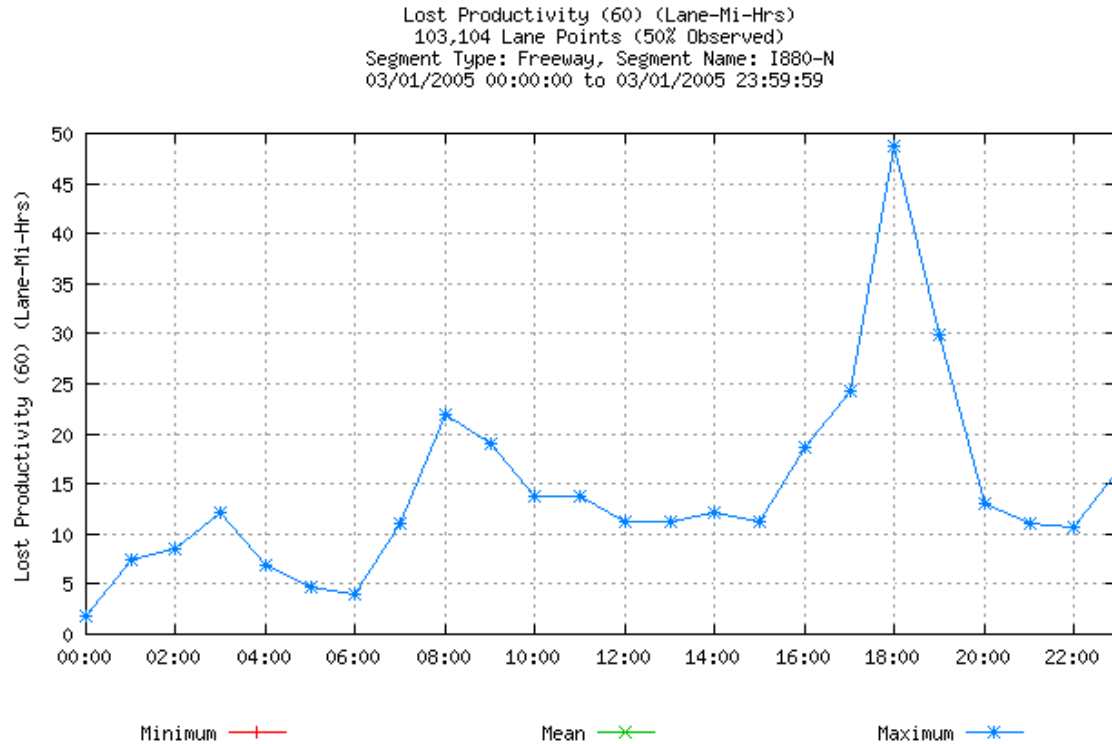


Figure 4.8 Lost Productivity for I-880 NB on March 1, 2005

4.2 Corridor Bottleneck Analysis and Verification

Bottlenecks are sections of the freeway that either have capacities less than or demand greater than other sections. These are the locations that will probably be the first to experience congested conditions as traffic grows. Due to the dynamic nature of traffic flow, bottlenecks are not only location specific, but also time-dependent. Therefore, identifying the exact time durations and spatial extents of bottlenecks along the studied

freeway is of great importance for system performance evaluation, simulation calibration, and development of improvement strategies. Because of the temporal-spatial characteristics of bottlenecks, in CMPD we use two-dimensional (time and space) speed contour maps to identify bottlenecks. Sometimes, two-dimensional volume and occupancy plots can also serve for the bottleneck analysis. As one example, Figure 4.9 depicts the bottleneck plot for I-880 NB for AM peak hours (here we use 6:00 am – 10: am) for a single day (March 1, 2005).

From the speed map, bottlenecks can be visually identified. For example, from the plot in Figure 4.9 we can observe that for that particular day, three major bottlenecks occurred. The one on the most south was located from Whipple Rd and Tennyson Rd with its duration roughly from 7:45 am to 9:10 am.

For a highly congested corridor (e.g. I-880), using one-day speed data is questionable since there is almost no “typical” day for the corridor. In this case, speeds from multiple days need to be analyzed to make the bottleneck analysis results more reliable. Depending on the purposes, average speeds or certain percentile plots may be used for bottleneck analysis. Figure 4.10 below is the average speed plot for 20 days (Jan. 24 – Mar. 9 of 2005, for only Tuesdays, Wednesdays and Thursdays). Apparently, two bottlenecks are significant in this average speed plot.

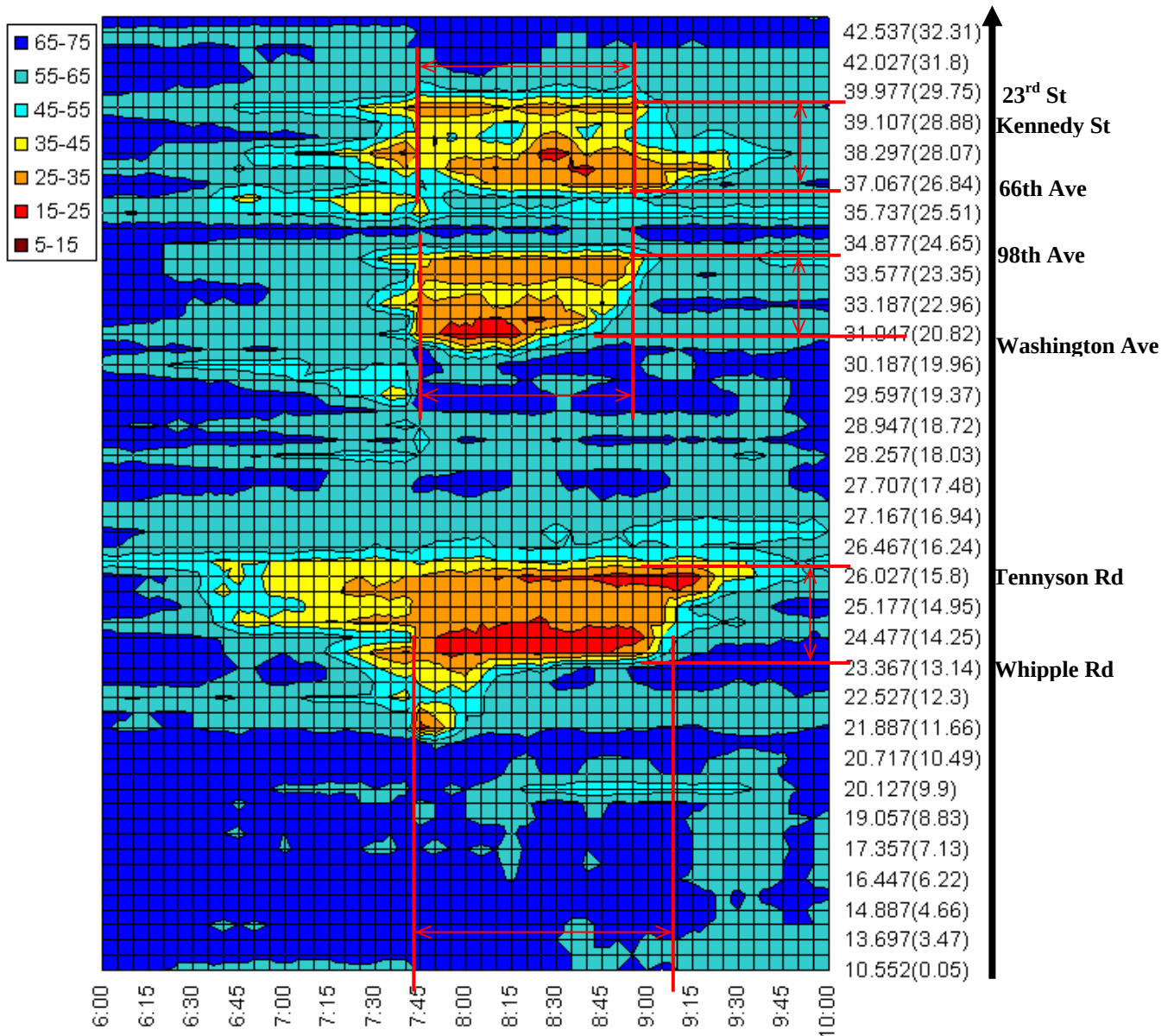


Figure 4.9 Bottleneck Plot for I-880 NB

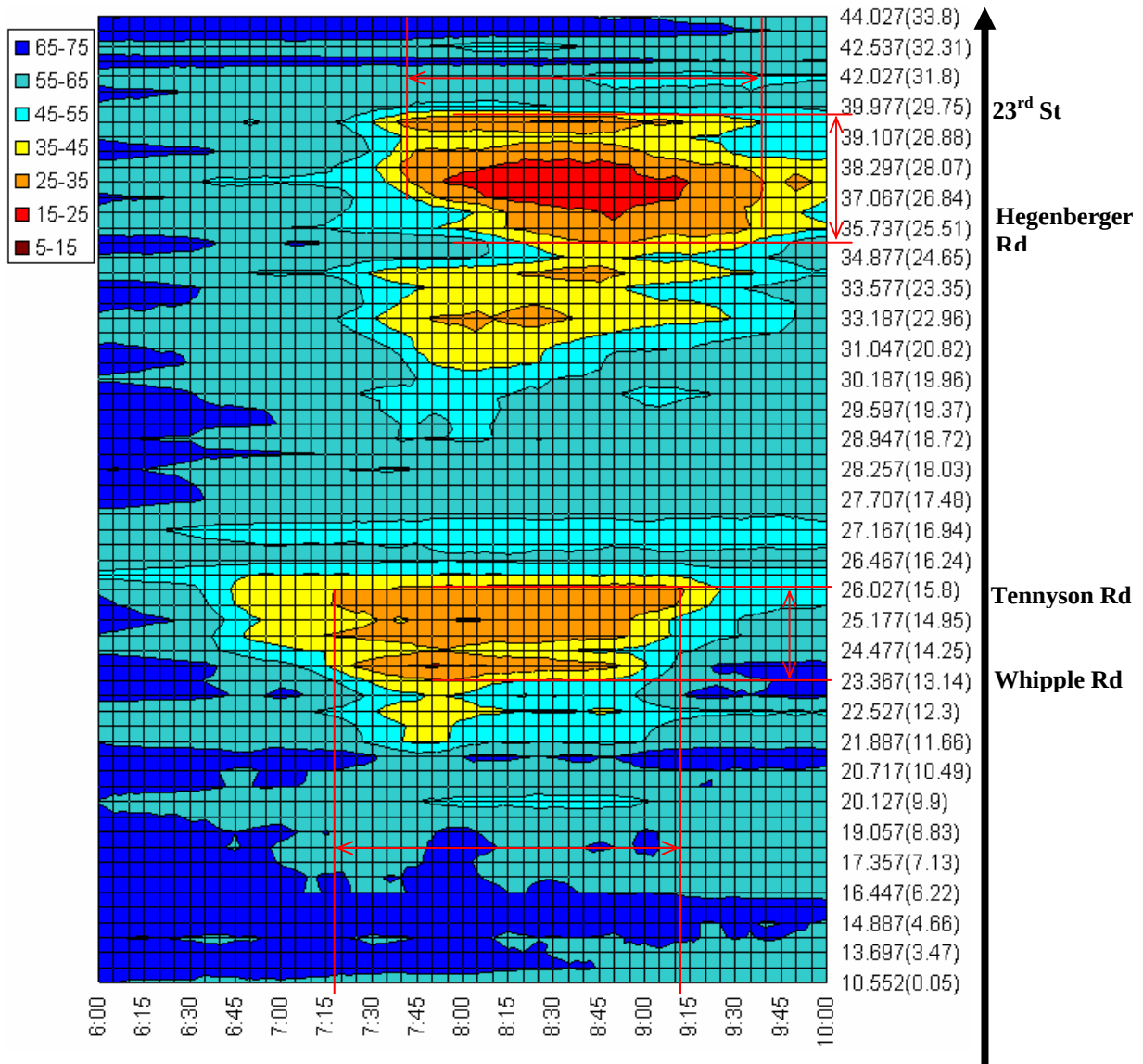


Figure 4.10 Average Speed Bottleneck Plot

4.3 Current Performance

This section briefly discusses current performance of I-880 and SR-41 corridors. Detailed performance assessment results can be found in Appendices A and B, respectively, for the I-880 and SR-41 corridors.

Generally speaking, the I-880 corridor is experiencing heavy congestion during AM and PM peak periods for both northbound and southbound directions. Table 4.2 lists the delay information, in vehicle-hours, based on the time-of-the-day for both directions from 2003 to 2005. The heavy delays shown in Table 4.2 can also be confirmed by the speed contour plots in Figure 4.9 and Figure 4.10.

Table 4.2 Delay of I-880 Corridor

Northbound Direction					
Year	AM Peak	Mid Day	Evening and Early AM	PM Peak	Total Daily
2003	1,499	1,237	552	2,547	5,835
2004	1,124	1,067	360	2,317	4,867
2005	1,331	1,434	285	2,351	5,402
Southbound Direction					
Year	AM Peak	Mid Day	Evening and Early AM	PM Peak	Total Daily
2003	1,924	1,397	276	2,249	5,846
2004	1,728	1,796	291	2,677	6,491
2005	1,678	2,196	232	2,885	6,991

The I-880 corridor is also incident-prone. As depicted in Figure 4.6, there have been at least 8 collisions daily for the corridor (both directions) from Jan. 1999 to Nov. 2004. Therefore, we can conclude that the I-880 corridor is a heavily congested and incident-prone urban corridor for which short- and medium-term operational improvements are needed to solve corridor level traffic congestion and safety problems.

For the SR-41 corridor, only light congestion has been experienced. Figure 4.12 and Figure 4.13 show, respectively, the speed contour maps for PM peak periods for the two directions based on Tach run data. In these figures, each cell of the time-space diagram represents the average speed over multiple Tach runs for a specific mainline freeway subsection. Thus speeds in the figure are shown over time (row summary) and over space

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(column summary). Three levels of speeds are represented by different levels of shading: below 49 mph, between 50 and 59 mph, and over 60 mph.

NB	O ST	DIVISADERO	OLIVE	MCKINLEY	SHIELDS	ASHLAN	SHAW	BULLARD	HERNDON	FRIANT	AUDOBO
	22.949	23.763	24.749	25.266	26.461	27.471	28.463	29.463	30.447	31.683	32.165
4:00:00 PM	65	61	61	63	61	65	61	60	60	62	65
4:05:00 PM	63	66	62	25	40	59	63	66	66	64	66
4:10:00 PM	58	68	61	60	28	57	65	66	63	66	62
4:15:00 PM	61	66	62	50	37	54	60	64	64	63	
4:20:00 PM	64	64	63	40	47	51	55	61	65	60	
4:25:00 PM	61	57	62	57	54	49	57	63	64	61	
4:30:00 PM	61	62	62	64	63	54	62	61	62	63	66
4:35:00 PM	64	62	63	60	49	59	60	62	62	63	65
4:40:00 PM	61	61	61	57	46	56	51	64	61	62	64
4:45:00 PM	63	62	61	51	50	49	54	63	62	61	
4:50:00 PM	64	62	61	46	54	42	57	62	62	60	
4:55:00 PM	61	60	49	41	47	59	38	57	60	64	
5:00:00 PM	61	62	62	64	63	64	61	61	62	63	66
5:05:00 PM	65	62	65	60	40	51	58	61	62	55	59
5:10:00 PM	59	60	58	22	36	39	49	59	60	56	64
5:15:00 PM	62	60	24	27	34	34	44	54	61	59	
5:20:00 PM	63	59	37	29	38	58	56	55	56	62	
5:25:00 PM	59	63	33	17	47	36	41	59	61	56	
5:30:00 PM	61	60	54	33	33	54	63	62	61	61	70
5:35:00 PM	61	60	56	64	60	57	60	60	59	45	65

Figure 4.12 Speed Contour for SR-41 for PM Peak (NB)

SB	FRIANT	HERNDON	BULLARD	SHAW	ASHLAN	SHIELDS	MCKINLEY	OLIVE	DIVISADERO	O ST	RTE 41/99	JENSEN
	31.683	30.447	29.463	28.463	27.471	26.461	25.266	24.749	23.763	22.949	21.798	21.113
4:00:00 PM	64	65	65	65	65	65	63	65	65	62	64	63
4:05:00 PM	60	63	63	59	62	61	61	64	66	63	62	64
4:10:00 PM	65	64	63	62	62	62	60	63	61	60	60	62
4:15:00 PM	66	65	63	62	62	62	61	63	64	62	62	64
4:20:00 PM	67	67	64	61	62	63	62	63	68	64	64	66
4:25:00 PM	59	60	65	65	64	61	61	58	64	63	63	65
4:30:00 PM	61	62	66	65	65	60	60	61	65	63	63	62
4:35:00 PM	63	65	66	66	66	59	58	64	66	64	63	59
4:40:00 PM	67	66	67	63	61	60	63	65	63	60	57	62
4:45:00 PM	69	64	63	65	65	65	66	65	68	65	66	68
4:50:00 PM	64	64	64	63	64	61	62	65	68	63	50	67
4:55:00 PM	69	68	68	67	67	63	67	67	69	67	68	69
5:00:00 PM	62	59	62	62	54	59	61	61	65	63	25	
5:05:00 PM	69	66	64	62	59	58	59	65	66	51	53	61
5:10:00 PM	66	64	62	62	60	61	61	64	64	62	62	62
5:15:00 PM	63	63	63	61	58	57	60	62	62	63	58	63
5:20:00 PM	64	64	66	65	62	60	60	62	65	63	39	61
5:25:00 PM	68	68	68	64	64	67	64	65	70	65	62	69
5:30:00 PM	67	65	71	55	43	36	61	67	46	44	61	
5:35:00 PM	64	64	52	50	58	60	60	63	63	63	63	65

Figure 4.13 Speed Contour for SR-41 for PM Peak (SB)

We can see from the figures that PM congestion mainly appears on NB of the freeway from 4:00 PM to 5:30 PM. The most congested areas are the McKinley Ave., Shields Ave., and Friant Ave. However, for SB, there is almost no congestion. Therefore, the focus of the SR-41 study is long-term improvements with the purpose of accommodating regionally forecast travel demand in the future (25 to 30 years timeframe).

5. Baseline Simulation Model Development

This section provides a detailed procedure for developing the simulation model for the I-880 study using the Paramics microsimulation tool. For the SR-41 simulation model development, please refer to Appendix B.

5.1 Introduction

Before the development of a microscopic simulation model, project scoping is required, which has been explained in Section 2 of the report. Based on project scoping, the microscopic simulation model can be further developed, which involves network coding, data collection and preparation, origin-destination (OD) demand estimation, and model calibration. Usually, OD demand estimation is treated as one step of the model calibration process.

5.2 Microscopic Simulation Network Coding

A microscopic simulation network needs to be built based on a wide range of input data, including data of network geometry, driver behavior, vehicle characteristics, transportation analysis zones, travel demands, and traffic control systems and traffic detection systems (see Section 3). The procedure that may need to be followed is suggested as follows:

- (1) Determine the configuration of the most basic inputs to the model;
- (2) Code the skeleton network;

(3) Code traffic control;

(4) Add zones and demands;

5.2.1 Determine the Configuration of the Most Basic Inputs

The following basic configurations of the model need to be determined first.

5.2.1.1 Link definition

As a basic input to a Paramics simulation model, the “categories” file includes the definition of all available link types within the study network. Each link category includes information that is required for simulation modeling. An example of a freeway link category is as follows:

```
category 1 lanes 1 speed 65 mph width 12.0 ft colour 0x000000ff type highway  
major  
median width 0.0 ft  
headway factor 1.000 curve speed factor 0.0 toll 0.000 cost factor 0.800  
signpost 820.2 ft,3.3 ft
```

The most important thing to consider at this step is to have a certain network road hierarchy. The purpose to define a suitable road hierarchy is to maintain stability of route choice between OD pairs in a Paramics model. This is achieved by defining a set of base categories with suitable category costs factors. A hierarchy suggested by Quadstone¹² is defined as follows:

(1) Major Primary Link Cost Factor 0.8

(2) Major Secondary Link Cost Factor 1.0

¹² Quadstone Limited, Quadstone Paramics V5.1 Modeler Reference Manual, Aug. 16, 2004

(3) Major Primary Link Cost Factor 0.8

(4) Minor Secondary Link Cost Factor 1.0

According to Quadstone, “the hierarchy of a network can be obtained from many sources; ordnance survey maps that have major and minor routes defined, assessment of traffic flow data and of course local knowledge, the latter being invaluable during the calibration process. The creation of a suitable categories file incorporating your chosen cost hierarchy is the primary task in the network building process; this should be undertaken before any network coding (links/nodes etc.) is undertaken. ”

In addition, it is better for the same type of links to use the same color for the link auditing purpose. For our network, all freeway links have the same color; arterials with the same traveling speed have the same color; ramp links have the same color. Using the link auditing tool, the above-mentioned link color settings will help find link coding conflicts easily.

5.2.1.2 Vehicle definition

Paramics regards each vehicle in the simulation as a Driver Vehicle Unit (DVU). The “vehicles” file is another basic input to a Paramics simulation model. It includes the attribute data and demand proportions of all available vehicle types and their associated drivers’ behavior data. The attribute data include vehicles’ physical size, color, weight, characteristics, and etc. The drivers’ behavior data include settings for drivers’ perturbation and familiarity. An example of a vehicle type is as follows:

*type 1 car length 15.42 ft width 6.23 ft height 4.59 ft
acc 11.81 fpss dec -12.80 fpss crawl speed 5.00 mph horsepower 50.00*

*colour 0x00ffffff name "car"
matrix 1 proportion 19.500 perturbation 2.0 familiarity 5.00*

Each vehicle model could have its own vehicle type in Paramics. For detailed modeling, each year and even each color of the same vehicle model can have its own vehicle definition. To decide how many vehicle types are required for a simulation model, the following factors need to be considered:

- (1) How many demand matrices will the simulation model have? For example, there may be one for HOV, one for SOV, and one for trucks.
- (2) What level of detail will the simulation model provide?

A practical simulation model usually simplifies the “vehicles” file by defining limited numbers of vehicle types. The basic vehicle types can include:

- (1) four-door sedan;
- (2) sports car;
- (3) SUV;
- (4) pickup;
- (5) min-Van;
- (6) bus;
- (7) loaded class 5-8 truck;
- (8) empty class 5-8 truck;

- (9) loaded class 9-14 truck; and
- (10) empty class 9-14 truck.

The proportion of each vehicle type in its associated demand matrix needs to be calibrated based on data of the target network. Here, we introduce a two-step method to establish the “vehicles” file for a simulation model. The first step is to determine vehicle groups based on the vehicle classifications by FHWA. The groups are also dependent upon the actual network, especially the number of demand matrices that are used by the simulation. Each of the vehicle groups can be further divided to represent multiple vehicle types in the second step. The vehicle type file can then be created accordingly.

(1) Vehicle Group Determination

Based on the analysis of vehicles in the I-880 network, two demand matrices are used for the simulation, defined as matrix1 and matrix2 respectively. Vehicles that circulate within the network are represented by matrix1, and matrix2 is for those passing through the network. By further investigating the vehicle definition of FHWA, it is determined that vehicle classes 1-8 correspond to matrix1 and classes 9-13 and 15 correspond to matrix2. Classes 1-8 are further categorized to distinguish different vehicle groups. The vehicle groups can be finally defined in Table 5.1.

Table 5.1 Vehicle Group Definition and Percentage

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	matrix1				matrix2
	FHWA class 1-2 (motorcycles or cars)	FHWA class 3 (minivans or pickups)	FHWA class 4 (buses)	FHWA class 5-8 (trucks with 3-5 axles)	FHWA class >=9 (trucks with >= 6 axles)
Total	73%	22.88%	0.12%	4%	100%
HOV (20%)	58.4%	18.3%	NA	NA	NA
Regular (80%)	14.60%	4.58%	NA	NA	NA

The percentage of each category was estimated as follows.

Total percentage of each class of vehicles was derived from the Weigh-In-Motion (WIM) data.

The HOV percentage for class 1-3 was estimated from two sources. The first source is the 1-hour aggregated volume data from PeMS which provides lane by lane volume (the left most lane is the HOV lane). The second source is the HOV report for D4 for 2004. The detailed estimation results are depicted in Table 5.2. From this table, it is evident that **20%** is a good estimate for both directions and both morning and afternoon peak periods.

Table 5.2 HOV Percentage Estimation

	PeMS 1-hour data		D4 HOV report for 2004	
	AM	PM	AM	PM
I880 NB	19%	20%	25%	20%
I880 SB	21%	20%	21%	21%

(2) Vehicle Type Determination

Each of the cells in Table 1 can be further classified into different vehicle types in line with the requirement of Paramics. Currently, the following vehicle types are applied:

Classes 1-2 include “Mustang”, "Crown Victoria", and "Focus Sedan".

Classes 3 include "F-150 Pick up", "Windstar Mini-Van", and "Ford Explorer".

Classes 4 do not include multiple vehicle types.

Classes 4-8 include both “empty” and “loaded” types.

Classes >=9 include both “empty” and “loaded” types.

Note that according to the specific network, vehicle types in each vehicle group may be varied; but the summation of their percentage must agree with the total percentage for that particular group. In addition, due to the lack of actual data, the percentage for each vehicle type within a group is estimated by roughly splitting the total percentage evenly.

3. Final vehicles file

Finally, the vehicle type file for I-880 can be listed as follows.

vehicle types

*type 1 car length 15.42 ft width 6.23 ft height 4.59 ft
acc 11.81 fpss dec -12.80 fpss colour 0x00ffffff draw style pmx model
name "Mustang"
matrix 1 proportion 19.5 perturbation 5.0 familiarity 95.00*

*type 2 car length 17.72 ft width 6.56 ft height 4.59 ft
acc 7.87 fpss dec -12.47 fpss colour 0x00ffffff draw style pmx model
name "Crown Victoria"
matrix 1 proportion 19.5 perturbation 5.0 familiarity 95.00*

*type 3 car length 14.44 ft width 5.58 ft height 4.59 ft
acc 7.55 fpss dec -13.45 fpss colour 0x00ffffff draw style pmx model
name "Focus Sedan"
matrix 1 proportion 19.4 perturbation 5.0 familiarity 95.00*

*type 4 car length 17.39 ft width 6.56 ft height 5.91 ft
acc 7.55 fpss dec -12.14 fpss colour 0x00ffffff draw style pmx model
name "F-150 Pick up"*

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matrix 1 proportion 6.3 perturbation 5.0 familiarity 95.00

type 5 car length 16.73 ft width 6.23 ft height 5.58 ft
acc 7.55 fpss dec -10.17 fpss colour 0x00ffffff draw style pmx model
name "Windstar Mini-Van"
matrix 1 proportion 6 perturbation 5.0 familiarity 95.00

type 6 car length 15.75 ft width 5.91 ft height 5.91 ft
acc 7.87 fpss dec -11.15 fpss colour 0x00ffffff draw style pmx model
name "Ford Explorer"
matrix 1 proportion 6 perturbation 5.0 familiarity 95.00

type 7 car length 15.42 ft width 6.23 ft height 4.59 ft
acc 11.81 fpss dec -12.80 fpss colour 0x000000ff
name "Mustang HOV"
matrix 1 proportion 5.0 perturbation 5.0 familiarity 95.00

type 8 car length 17.72 ft width 6.56 ft height 4.59 ft
acc 7.87 fpss dec -12.47 fpss colour 0x000000ff
name "Crown Victoria HOV"
matrix 1 proportion 5.0 perturbation 5.0 familiarity 95.00

type 9 car length 14.44 ft width 5.58 ft height 4.59 ft
acc 7.55 fpss dec -13.45 fpss colour 0x000000ff
name "Focus Sedan HOV"
matrix 1 proportion 4.6 perturbation 5.0 familiarity 95.00

type 10 car length 17.39 ft width 6.56 ft height 5.91 ft
acc 7.55 fpss dec -12.14 fpss colour 0x000000ff
name "F-150 Pick up HOV"
matrix 1 proportion 1.5 perturbation 5.0 familiarity 95.00

type 11 car length 16.73 ft width 6.23 ft height 5.58 ft
acc 7.55 fpss dec -10.17 fpss colour 0x000000ff
name "Windstar Mini-Van HOV"
matrix 1 proportion 1.500 perturbation 5.0 familiarity 95.00

type 12 car length 15.75 ft width 5.91 ft height 5.91 ft
acc 7.87 fpss dec -11.15 fpss colour 0x000000ff
name "Ford Explorer HOV"
matrix 1 proportion 1.58 perturbation 5.0 familiarity 95.00

type 13 car length 14.44 ft width 5.58 ft height 4.59 ft weight 0.79 ton
top speed 100.00 mph acc 7.55 fpss dec -13.45 fpss crawl speed 50.00 mph
horsepower 100.00 colour 0x00ffffff
name "Buses"
matrix 1 proportion 0.12 perturbation 0.0 familiarity 85.00

type 14 OGV1 length 40.03 ft width 8.53 ft height 13.45 ft weight 3.88 ton
acc 5.58 fpss dec -12.14 fpss crawl speed 55.00 mph horsepower 200.00
colour 0x00ff0000 draw style pmx model group 4
name "Truck - Class 5-8, empty"
matrix 1 proportion 2 perturbation 0.0 familiarity 85.00

type 15 OGV1 length 40.03 ft width 8.53 ft height 13.45 ft weight 7.09 ton
acc 5.58 fpss dec -12.14 fpss crawl speed 42.00 mph horsepower 200.00

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colour 0x00ff0000 draw style pmx model group 4
name "Truck - Class 5-8, loaded"
matrix 1 proportion 2 perturbation 0.0 familiarity 85.00

type 16 OGV2 length 64.96 ft width 8.53 ft height 13.45 ft weight 12.50 ton
top speed 65.00 mph dec -11.48 fpss crawl speed 42.00 mph horsepower
267.00 acc profile 4 dec profile 8 colour 0x0000758b shape 2
name "Truck - Class 9-14, empty"
trailer count 1
(
trailer 1 length 52.99 ft
colour 0x001a2d8b
model type 0
)
matrix 2 proportion 50 perturbation 0.0 familiarity 85.00

type 17 OGV2 length 64.96 ft width 8.53 ft height 13.45 ft weight 23.00 ton
top speed 65.00 mph dec -11.48 fpss crawl speed 28.00 mph horsepower
267.00 acc profile 4 dec profile 8 colour 0x00008b00 shape 2
name "Truck - Class 9-14, loaded"
trailer count 1
(
trailer 1 length 52.99 ft
colour 0x00142c8b
model type 0
)
matrix 2 proportion 50 perturbation 0.0 familiarity 85.00

5.2.1.3 Demand structures

Choosing the demands structure relates to the initial assignment method, the composition of the vehicles types file, and the number of OD matrices to be used during assignment. The determination of demands structure needs to be based on features of the target network.

For the I-880 network, there are many trucks due to the proximity to the Port of Oakland port. As a result, it was determined to have a separate demand matrix (i.e., *matrix2*) for big trucks with FHWA class 9-14. For those trucks with FHWA class 5-8, they are regarded as part of the demand matrix for other vehicles (i.e., *matrix1*). In addition, the study network has HOV lanes, which are operated during peak periods (i.e. 5-9 am and 3-7 pm). Although the ACCMA (Alameda County Congestion Management Agency)

planning model has specific HOV demand models, it will be costly to estimate the HOV demand matrix since HOV flow data is hard to observe and collect. As a result, the I-880 network has two matrices. One is for FHWA class 9-14 trucks and the other is for all other vehicles, including SOV, HOV and FHWA class 5-8 trucks.

5.2.2 Code the Skeleton Network

5.2.2.1 Background images

A simulation network is generally coded based on background images. For the network coding purpose, it is desirable for background images to have a resolution equal or smaller than 1 meter per pixel. Background images can be CAD drawing files (dxf format) that can be obtained from Caltrans and/or cities or aerial photos (in the JPG or BMP format) that can be obtained from the following sources:

- (1) Caltrans Digital Highway Inventory Photography Program (DHIPP):
<http://svhqdhipp:8080/dhipp/view.html>, which only has aerial photos for freeways and areas close to freeways with known resolution information.
- (2) <http://www.terraserver-usa.com>
- (3) <http://mapper.acme.com>
- (4) <http://maps.google.com/>
- (5) <http://local.live.com/>
- (6) <http://www.terraserver.com>

Among them, <http://www.terraserver-usa.com> is one of the best sites for obtaining aerial photos since it is free and also provides users with resolution information. Another excellent site is <http://mapper.acme.com>, which is a Google Map application. Google map provides high-resolution of aerial photos. The first zooming level's resolution is 0.25 meter per pixel resolution. The second level's resolution is 0.5 meter per pixel and the third level's resolution is 1 meter per pixel¹³.

In addition, Google Earth could be used as a source, but how to use it needs to be further investigated.

5.2.2.2 Other road geometry data

The data that may be needed for road geometry coding are summarized in the table below.

Table 5.3 Geometry Data for Network Coding

	Data Type	Data	Sources
Freeway Data	As-built map	Number of lanes, locations of detectors, on-ramps, off-ramps and lane drops	Caltrans
	Photolog	number of lanes, locations of on-ramps, off-ramps, signs, and lane drops	Caltrans http://video.dot.ca.gov/photolog/
	Aerial photos	Curbs, number of lanes	See 5.2.2.1
Arterial Data	As-built map	Number of lanes, , lane assignment, locations of detectors	Cities
	Aerial photos	Curbs, number of lanes	See 5.2.2.1

Background images are the most common data source for details of road network. But, if there is anything unclear on the background images, other geometric data sources shown from the above table are required. If the available sources can not provide details of the

¹³ Due to the terms of Google Map, <http://mapper.acme.com> does not allow users to download map but users can obtain it by printing screen.

network, researchers need to go to the field and write down the geometric details on hand drawing maps.

5.2.2.3 Node naming convention

Before network coding can be started, there may be a need to have a node naming convention. Paramics provides a node with a name automatically. However, a good naming convention may provide additional information to modelers. For example, the node naming convention for the I-880 network is as follows:

- (1) Names of all nodes along the Northbound I-880 start with “8”.
- (2) Names of all nodes along the Southbound I-880 start with “6”.
- (3) Node names have at least four numbers, e.g, 8230, 8230a. For node “8230”, “230” has its own meaning as well, which tells modelers that the node is located at postmile 23.0.

In order to have the above node naming convention, three steps were performed:

- (1) Modelers added nodes with their default names provided by Paramics first;
- (2) A plugin developed by the research team was used to calculate the postmile information for all nodes along the freeway based on a reference point. As a result, a node name lookup table was prepared.
- (3) Node names along freeways were changed to their new names based on the lookup table through Paramics GUI.

5.2.2.4 Geometry coding

The process of road geometry coding involves adding nodes and links, modifying stoplines and Curbs, and allocating lanes to various vehicle movements at intersections based on background images and other geometric data.

1. Nodes

Nodes are usually placed at locations where there is a physical change in road geometry. Typical changes include (1) change in number of lanes; (2) intersection; (3) at the start or the end of a curve link, usually at the tangent point where the straight section begins to curve; (4) change in the use of lanes, such as the start and the end of a HOV lane. It is noted that the number of nodes need to be kept to a minimum because too many nodes provide additional burden for routing cost table calculation.

2. Links

Links are used to connect two nodes. One needs to pay attention to the following items:

- (1) Curve links are encouraged to be used since it is a way to keep the number of nodes to be minimized.
- (2) When coding a link, all attributes of the selected link category will be applied to the link and thus the new link's attribute may need to be changed if necessary.
- (3) When one way link is coded, the link direction (which should be from the purple node to the green node direction) needs to be checked for accuracy.

- (4) If one lane of a multiple lane link is restricted to a specific group of vehicles, the lane restriction feature is used.

3. Curbs and Stoplines

The default positions of curbs (“Kerbs” in Paramics notation) and stoplines are determined by Paramics when associated node and links are coded. Curbs determine where the Curb lines are drawn and the locations of stoplines. Stoplines determine the paths vehicles take as they travel from link to link.

Curbs and stoplines should be coded so that Paramics network can match well with overlay images. It is noted that the start Curb of the downstream link and the end Curb of upstream link cannot be overlapped. Start stoplines of the downstream link and the start stoplines of the upstream link need to be aligned well; otherwise, vehicles may move unrealistically. When stoplines of a link is changed, moving of associated nodes of the link does not change the layout of the link.

4. Junction and nextlanes (Lane allocation)

Editing the attributes of a node is necessary in order to finish the geometric coding of an intersection or node connecting two links with different number of lanes. Paramics has two files associated with lane allocation. One is the “junctions” file, which is used to store lane range information. The junction feature needs to be set for off-ramp junctions and intersections with more than two links. Another is the “nextlanes” file, which is used to specify the detailed vehicular movement rules (e.g. vehicle on lane 4 of the upstream

link will travel to lane 3 of the downstream link). It is suggested that the nextlane feature should be used sparingly. The following conditions may need to use nextlane feature:

- (1) on freeway mainline where there is a lane added. For example, one lane is added to rightmost side of mainline at node *aa* and the upstream link of node *aa* is link *bb:aa* that has 4 lanes and the downstream link is link *aa:cc* that has 5 lanes. Node *aa* may need to set nextlane, which needs traffic on lane 1 of link *bb:aa* moves to lane 2 of line *aa:cc*.
- (2) on arterials where there is a left turn bay for left turn vehicles. For example, there are one lane added to leftmost side of the road at node *aa* and the upstream link of node *aa* is link *bb:aa* that has 3 lanes and the downstream link is link *aa:cc* that has 4 lanes. Node *aa* may need to set nextlane, which needs traffic on lane 3 of link *bb:aa* moves to lane 3 of line *aa:cc*. For vehicles making left turns, they will first select lane 3 of link *aa:cc* and gradually reach lane 4 if needed..

5. Zones

Zones are where vehicles are released and attracted in simulation. Each vehicle usually has an origin zone and a destination zone. A zone can include one link (or more than one links). In order to associate a zone with a link, the majority of a zone's placement must physically cover at least half of the link; otherwise vehicles cannot be released from it.

When adding zones, Paramics automatically assign a zone name and zone number to it. For example, the first zone's name is "zone 001" and its number is 1. When users add zones in sequence, the number included in the zone name is its zone number. It is noted

that zone number may not be the same as the number in zone name if users delete a zone after adding it. Under this situation, there is a lookup table shown in the beginning of the “zones” file in order to associate a zone with its zone number. The reason for the above description is that zone numbers are actually used by OD matrix but users cannot see zone numbers but zone names directly from Paramics GUI. For example, an OD table shows there are 20 vehicles from zone number 3 to zone number 5 but it may not mean there are 20 vehicles from zone name 3 to zone name 5. In order to avoid getting confused, it is recommend adding zones in sequence to the simulation network or editing the “zones” file if manually zone lookup table exists.

5.2.3 Code Traffic Control

5.2.3.1 Intersection control

The intersection control in Paramics can be divided into three types: stop or yield control, fixed timed control, and actuated control. For the first two types of control, they can be added to an intersection by editing priorities of movements associated with a node through Paramics GUI. The actuated signal control is implemented in Paramics using the “plan language” in Paramics or the actuated signal plugin developed by California ATMS testbed at University of California Irvine¹⁴.

Signal control in Paramics is realized using priority concept. There are three priority levels in Paramics, minor, medium, and major. The stop sign control is modeled by the

¹⁴ Liu, X., Chu, L., Recker, W. (2001) Paramics API Development Document for Actuated Signal, Signal Coordination and Ramp Control, PATH working paper UCB-ITS-PWP-2001-11

minor priority. The yield control is modeled by the combination of the use of the medium and major priorities on two opposing movements. For a signalized intersection, three different priority levels may be applied to different movements of the intersection.

The signal coding needs to be based on signal timing charts from traffic agencies. Usually, freeway agencies such as Caltrans control signalized intersections connecting with ramps and cities control signals along local streets.

5.2.3.2 Ramp metering

Ramp metering is a major freeway control method. Through Paramics GUI, users can code fixed-time metering control. However, local adaptive ramp metering control is actually applied in the real world. California ATMS testbed at University of California Irvine has developed several metering algorithms that are applied in California. The coding of a ramp meter needs to be based on the requirement of the selected metering algorithm¹⁵.

5.2.4 I-880 Network Coding

The study area, presented in Figure 5.1 (also in Figure 2.1), is located east bay of the Bay area. The study network comprises of a 34-mile segment of the Interstate 880 (I-880) between Oakland and Milpitas, CA, and some adjacent highways and surface streets. I-880 is a major truck route and a highly congested freeway. The surface streets were selected based on the following: (1) the streets can be used for diverting vehicles; (2) the

¹⁵ Chu, L., Liu X., McNally, M. and Recker, W. (2005) Development of the Capability-Enhanced PARAMICS Simulation Environment, California PATH Research Report UCB-ITS-PRR-2005-12.

streets are major routes in the target area; (3) Stakeholders' request. The major arterials in the simulation network include:

(1) City of Oakland

- Madison
- Oak
- 7th
- E. 8th
- E. 12th
- San Leandro
- Oakport
- Hegenberger
- Fruitvale
- High
- Airport access Road
- 98th

(2) City of Hayward

- Hesperian
- A St.
- Tennyson
- Industrial

(3) City of Fremont

- Blacow
- Grimmer
- Mowry
- Stevenson

(4) City of San Leandro

- San Leandro
- Washington Ave
- Lewelling

(5) City of San Lorenzo (signals are controlled by Alameda County)

- Hesperian
- Lewelling

Based on procedure described in last subsection, the study network was built in PARAMICS, as shown in Figure 5.2 (also in Figure 2.2). The network includes a total of 168 zones. Loop detector stations, actuated signals, and time-dependent ramp meters are

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modeled according to detection and control data provided by Caltrans and cities. There are 157 actuated signal intersections, 25 fixed-time signal intersections and 143 metered lanes at 56 metering locations.

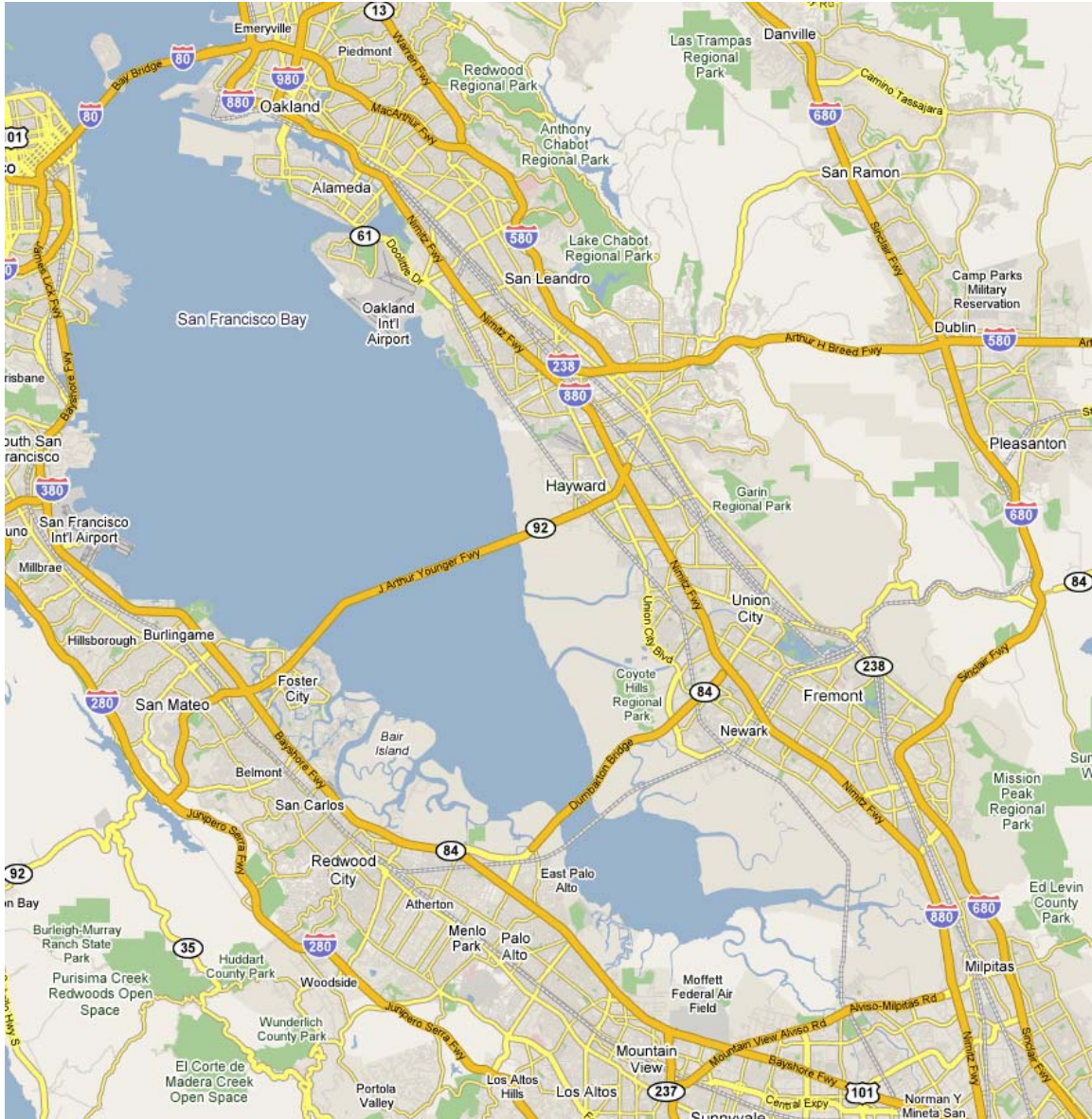


Figure 5.1 The Study Network

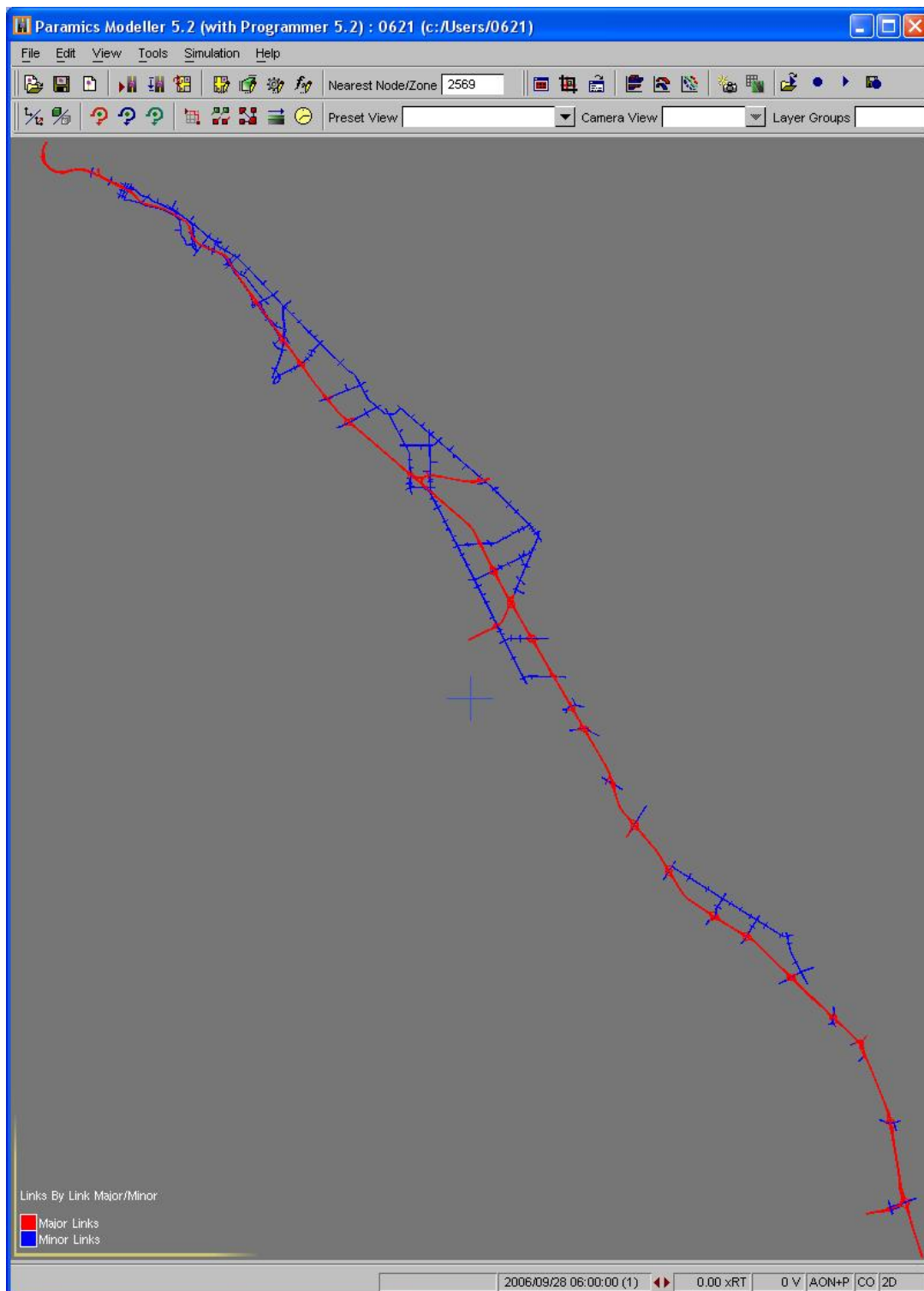


Figure 5.2 Paramics Network

5.3 Calibration data preparation

5.3.1 Existing Data

Data for model calibration, used in this study, includes time-dependent freeway traffic counts, time-dependent section travel times (based on probe vehicles), intersection turning counts, and arterial traffic counts. Data processing was necessary due to missing data, and data inconsistencies. Section 3 briefly discussed data processing issues; detail explanations of data processing for ramp and mainline data are given in this section.

The mainline counts were collected at March 1st, 2nd, and 8th, 2005 through PeMS. The averages of counts from these three days are used as the observed mainline traffic counts. Ramp count data comes from two different sources: Traffic Management Center (TMC), and the census data from Caltrans. Table 5.4 gives the characteristics of the data from these two sources.

Using the detectors installed in the field, TMC can collect ramp (also mainline) data every day with 30-sec format. It is an excellent source of data to use for model calibration. However, the TMC data suffers from missing data due to detector and communication failures. Currently, PeMS can fill in missing records using historical data of the same detector or neighboring detectors. Since it is expected that PeMS will have ramp data for D4 in the future, we suggest using ramp data from PeMS to support micro-simulation studies in the future. For this purpose, Caltrans should improve current detector coverage; especially detectors that monitor freeway to freeway traffic flows need to be installed. For example, traffic flows from SR-92 and I-980 to I-880 have important influence on the traffic condition along 880. However, there is currently no detector to collect traffic flows passing these locations. Although we may be able to estimate their

flows based on mainline detector data, these important locations should have their own detection coverage. In this case, we can use data from the TMC and Caltrans census in a complementary way.

Table 5.4 General Description of Two Ramp Data Sources

	Who collects data	How many days' data	Time interval of data	Cons and pros
Census data source	Caltrans District 4	Usually more than 7 days, covering from Mon through Saturday	Hourly data	(1) Collected once a year but data are massaged data and may thus have higher accuracy; (2) Have a better coverage of counting locations. The number of locations for 2005 dataset is 86. (3)The dataset we used was collected between Nov 2004 and Mar 2005.
TMC data source	loop detectors installed in the field	everyday	30-sec data	(1) Have data everyday but data for a certain time interval may be missing due to communication or detector problems. (2) Although Caltrans installed ramp detectors to most locations with meters, only 44 locations have data. Since there is no meter for freeway to freeway connectors, no data for these important locations.

There are two issues that need to be considered.

(1) Data consistency

Mainline data and ramp data comes from different sources respectively, so they have poor consistency with each other. An inconsistency means that the downstream counts are not matched with its estimated count from the upstream count minus off-ramp counts and plus on-ramp counts. The reason of the inconsistency might be (1) detection error in two datasets; (2) flow fluctuation; and (3) traffic congestion.

The poor inconsistency of data causes errors in OD estimation. Generally, ramp counts are smaller than mainline counts. If the amount of inconsistency is larger than ramp counts, we cannot get accurate estimation for ramp volume. The influence of inconsistency is more serious in early stages of OD estimation, during which the accuracy

of estimated OD table is low. Moreover, this inconsistency might cause OD estimation to a wrong solution which could not be possibly resolved in later steps. To prevent the error propagation, the original data set should be adjusted.

(2) Counting interval for Ramp data

In OD estimation for the I-880 network, we set the time interval length for OD table as 5 minutes and for counting data as 15 minutes. However, census data for the ramp detectors are 1 hour-based, so it should be converted into 15-minute counts.

5.3.2 Preparation of Ramp Data

For ramps, we combined both TMC and census datasets to obtain the “observed” ramp data for model calibration. Below is a description on how ramp data were obtained.

5.3.2.1 Process census data

Census data include data of at least seven days, covering Monday to Sunday. The data of Tuesday, Wednesday and Thursday data are used for model calibration.

For some locations, there are data for more than seven days. In this case, it is possible to have two or more data records for a single day (e.g., for Tuesday). The method to select which Tuesday, Wednesday and Thursday’s data to use is based on whether the three days are consecutive. For example, Tennyson on-ramp to NB 880 has data from 1/19/2005 (Wednesday) to 1/27/2005 (Thursday). Based on the above rule, we used data of 1/25, 1/26 and 1/27 to calculate the average of ramp data. Data of 1/19 and 1/20 were ignored.

5.3.2.2 Process ramp data from TMC

Due to missing data in the TMC dataset, we processed the TMC data using the following method:

(1) Count the number of available data records, say n , for an aggregation interval (15 minutes or 1 hour in our study) from the TMC data. The sum of flows of all these records are the total observed counts v .

(2) The value of n should be 30 for a 15 minute interval (or 120 for 1 hour interval).

However, due to the possibility of missing data, n is normally smaller than these values. We thus use the formula below to estimate the total flow during an interval based on available TMC data:

$$vv = N/n*v$$

Here N is 30 for 15-minute interval and 120 for 1-hour interval.

5.3.2.3 Obtain 1-hr ramp data based on TMC and census datasets

Data from the TMC have 30-sec interval, which are appropriate for simulation model development. However, we found they are not completely satisfactory due to the following reasons:

(1) Census data were collected at the time close to when we collected data from the field, which is March 1st, 2nd, 8th and 9th, 2005. While TMC data we obtained are for Nov 28th, Nov 29th and Nov 30th, 2005 after Siemens fixed D4's detector configuration. We were told that data before that had been permanently lost.

- (2) TMC data had many missing records and we did not have a good method or enough historical data to massage ramp data from the TMC. Therefore, we felt that census data may be more reliable.
- (3) TMC data only covers 44 locations, but census data covers 86 locations.

It was decided to place more emphasis on census data, which has an interval of 1 hour. The 1-hr TMC data and census data of all ramp locations were checked for their consistency. We found that they had same patterns for most locations. For those locations that have a large difference, the census data was used.

5.3.2.4 Estimate 15-min ramp data

We emphasized the use of census data which has 1-hr detecting time interval. However, we prefer to have 15 minute-based counts for OD estimation and model calibration.

Therefore, we used the 15 minute-based count of TMC data to make a time-dependent count pattern. After calculating proportions for each 15-min time interval based on TMC data, we applied these proportions to 1-hr Census data to make 15-min traffic counts.

In some cases, there is no TMC proportion although we have census data. In the case, we chose the nearest ramp of the same type (on-ramp or off-ramp), and applied its 15 minute pattern to 1-hr census data.

5.3.2.5 Important ramp locations without data

Although data from both datasets have good coverage of most ramp locations, there are still some locations (like NB 880 to NB 980) that have no data. Under this situation, we

estimated 15-min ramp data based on data of one immediate upstream and immediate downstream mainline loop detectors from PeMS.

5.3.3 Preparation of Mainline Data

To adjust the mainline counts for consistencies, it is first assumed that the ramp data that we have just processed contains no errors. One common method from practitioners is to hold a value of flow at a single reliable point, usually located at far upstream of the freeway, and continue the adjustment through downstream based on ramp data. Although convenient, this approach inevitably causes error propagation. In this study, we propose the use of multiple reference points, i.e. one reference every 2-3 miles along the freeway. To select reliable reference points, we compared original data with count data obtained from the PEMS website. If any one of the following three conditions is met, the candidate point can not be used as a reference point:

- (1) Count data for the location has large discrepancy among three observation days;
- (2) Count data for the location has poor consistency with other reference points;
- (3) The observation rate of data at the location is less than 90%,

Mainline counts are then adjusted to be consistent with the 1-hr census data based on data on reference points and ramps.

As shown in the Figure 5.3 (also in Figure 3.8), the highlighted rows are used as the reference points that create isolated sections. They can prevent error propagation. The hourly ramp counts from census data are then used in checking the flow consistencies at

every junction points within such isolated sections. Once an inconsistency is found, the discrepancy is distributed over all detection points between the two reference points.

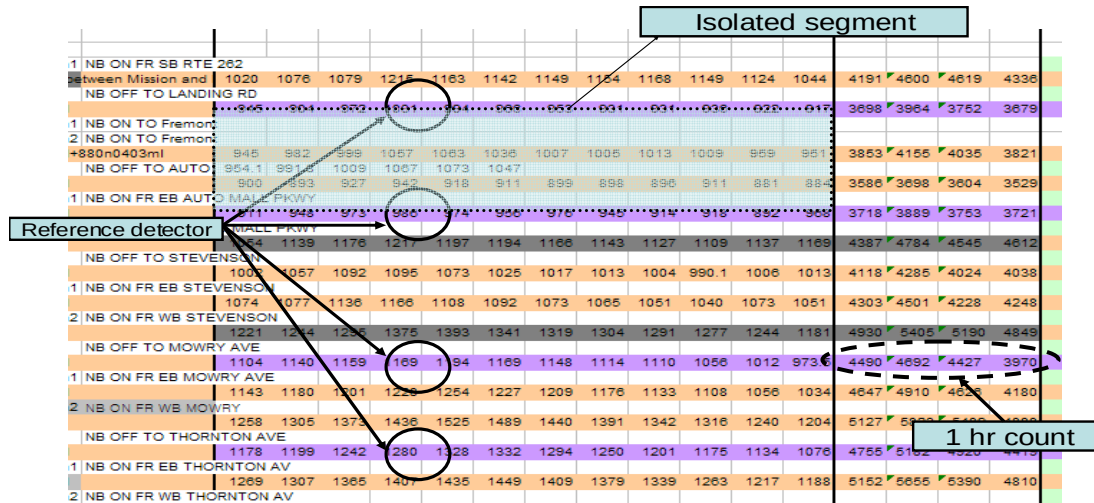


Figure 5.3 Mainline Data Adjustment

5.4 Model Calibration

5.4.1 Methodology

When the simulation network is coded and data prepared, the next step is to calibrate the simulation model. A procedure to calibrate a PARAMICS simulation network is illustrated in Figure 5.4. The following four steps are the most critical issues when performing the model calibration:

- (1) Calibration of driving behavior models
- (2) Initial calibration of route choice model
- (3) Dynamic OD demand estimation
- (4) Network performance calibration and validation

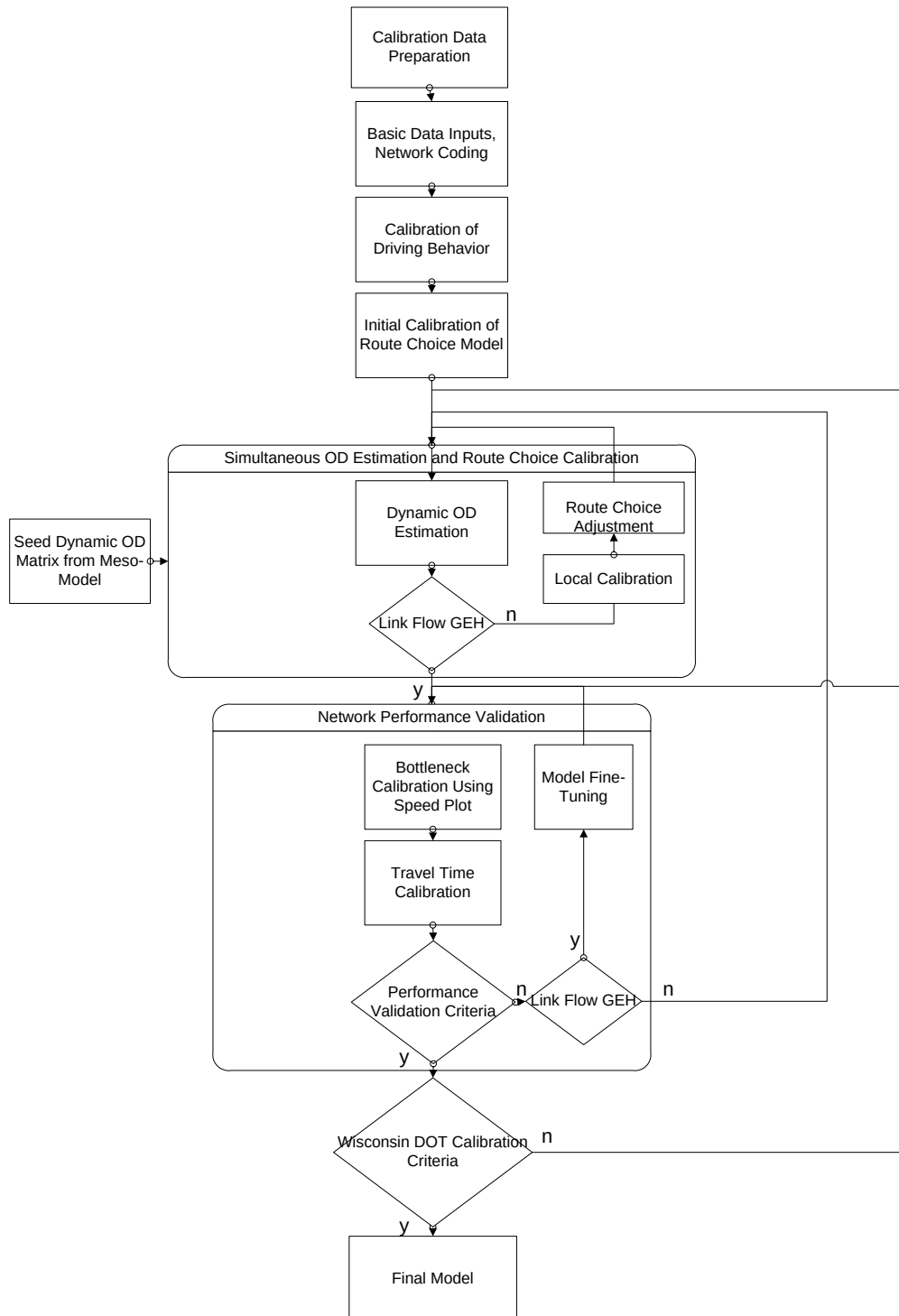


Figure 5.4 Model Calibration

Inappropriate network coding is a major source of abnormal vehicular movements that greatly impacts performance of the model and the OD demand estimation. Such errors can be found at any time during the calibration process. Accordingly, error checking and

network refinement is an important task throughout the whole calibration process, and must be done carefully.

5.4.2 Calibration of Driving Behavior Models

There are four global variables that affect DVU (Driver-Vehicle Unit) behavior: mean target headway, mean reaction time, time-step, and speed memory. Mean target headway and reaction time are two major parameters for Paramics' car-following model. Simulation time-step determines how detailed the simulation is. A certain value of speed memory is required to ensure the following vehicle to respond to the activities of the leading vehicle appropriately. Although PARAMICS provides a set of default values for these variables, the calibration of a simulation model usually requires them to be refined.

1. Mean target headway

Based on mean target headway, each DVU is assigned a target headway when it is released to the network. During simulation, when the DVU moves to a link, the DVU's actual target headway on the link is equal to its own target headway multiplied by headway factor of the link (a local parameter of the link). The target headway on a link is the minimum headway which a following vehicle attempts to maintain behind its leading vehicle. If, for instance, a vehicle's target headway on a link is 1.0, it will attempt to stay at least one second behind its leading vehicle.

The mean target headway also plays a major role in lane-changing model such that a vehicle desiring to merge into an adjacent lane will attempt to maintain its target headway.

For this reason, an unreasonable high value of mean target headway can lead to lower freeway capacity which, in turn, causes unrealistic congestion.

2. Mean Reaction Time

Based on the mean target headway, each DVU is assigned a reaction time when it is released to the network. During simulation, when the DVU moves to a link, the DVU's actual reaction time on the link is equal to its own reaction time multiplied by reaction time factor of the link (another local parameter of the link). The DVU's reaction time is the time used for the DVU to take to respond to the behaviors of the leading vehicle.

Based on experiments performed on the I-405 network, lower mean reaction times were associated with higher freeway capacities and higher critical occupancies. With other variables being fixed, mean reaction time values in the range of 0.8 and 1.2 was found to yield reasonable volume-occupancy plots.

3. Time-step

PARAMICS updates positions and speeds of vehicles in a stepwise manner. The time-step variable indicates the number of times in one second that PARAMICS updates the simulation. Two issues must be resolved when deciding an appropriate time-step value: stepwise spatial resolution and computational efficiency.

The simulation updates the position of the vehicle i by multiplying its speed by the time Δt between updates (time-step interval). Setting too small time-step (large time step interval) leads to the situation that vehicles being displaced by large distances in each step. For example, a vehicle traveling on a freeway with a speed of 65 mph displaces by

approximately 30 meters per second. If the time-step is 2, this vehicle will travel 15 meters per update. Such a large displacement directly impacts the stability of the model.

The second issue is computational efficiency. That is, the numerical effort required to maintain a high number of updates per second can tax a computer's processing resources, which can significantly retard the simulation speed. In addition, a high time-step value shall require a high speed memory, expending a computer's memory and memory access resources.

Based on experiments performed on the I-405 network, we found that the value of 4 for the time-step which yields approximately 7.5 meters per update is reasonable in term of both model stability and computational efficiency.

4. Speed Memory

Fundamentally, speed memory is the number of previous speed values preserved in memory for each vehicle. Since 2.0 seconds seems to be a reasonable upper bound for vehicle reaction time, a speed memory of 8 (when the time-step value is 4) allows PARAMICS to keep 2 seconds of speed data for each DVU. This prediction is supported by a series of trials on the I-405 network using a time-step value of 4.

Having mentioned the characteristics of each parameter, we now present the criteria for choosing a subnetwork to be used as a representative network for the global calibration procedure explained above. Observed data from the field corresponding to the subnetwork must meet certain requirements:

- (1) The flow-occupancy plot from traffic data from the section that has experienced various traffic conditions, from free-flow to heavy congestion, must be obtainable. At the same time, the location should be free from traffic incidents, which would artificially inflate congestion. We note here that such location can be found by examining congestion speed or occupancy contour plots.
- (2) High-fidelity data must be available from locations immediately upstream and immediately downstream. “Immediately” means that there should be no intervening off-ramps or interchanges, which would alter flows in the mainline links.

It was found that the following parameter values generate the best results based on sample sub-networks of I-880:

- (1) Mean target headway: 0.9
- (2) Mean Reaction Time: 0.8
- (3) Timestep: 5
- (4) Speed memory: 6

Note that these parameters can be adjusted locally in the step of model fine-tuning to fit the average driving behavior which is greatly dependent on the geometry of the freeway. For example, we use Caltrans photo log files to investigate the merging pattern at some ramps and freeway interchanges. Then, the adjustment is performed to match the simulation result with the observed congestion patterns.

5.4.3 Initial Calibration of Route Choice Model

There are three steps to calibrate the route choice model in Paramics.

- (1) Definition of generalized cost function
- (2) Selection of route choice model
- (3) Calibration of core parameters of the selected route choice model

1. Generalized cost function

Travel cost is represented by a combination of factors that drivers take into account when choosing routes. In Paramics, the base cost for links is calculated using the following generalised cost equation:

$$cost = a*T + b*D + c*P$$

where:

- a is time coefficient in minutes per minute (default 1.0)
- b is distance coefficient in minutes per kilometre (default 0.0)
- c is toll coefficient in minutes per monetary cost (default 0.0)
- T is free-flow travel time in minutes
- D is the length of the link in kilometres
- P is the price of the toll in monetary cost units

The most important parameters are a and b , i.e. parameters associated with time and distance, respectively. In addition, tolls can also be considered where a monetary value is charged for the use of specific sections of road and thus can be used to model a drivers’

willingness to pay. By default, Paramics favors travel time, however, users may need to investigate various combinations based on the study network.

A traditional method to determine parameter values of the generalized cost function is sensitivity analysis of routes between major OD pairs of the target simulation network. For example, parameter settings of the I-880 simulation network are: $a = 0.75$; $b = 0.25$, $c = 1$. The reason to have the parameter for toll is because it was found that some long-trip vehicles may not stick to the freeway mainline until the exit close to their destination zone. Due to specific geometric features at an interchange and /or traffic congestion, it may bring more time-saving if drivers exit at the off-ramp of an interchange and then go back to freeway mainline through the on-ramp at the same interchange. However, in reality, this never happens. To overcome this unrealistic behaviour in simulation, a two minutes toll was applied to all on-ramps and off-ramps in order to avoid the above-mentioned behaviour.

2. Selection of route choice model

Paramics has three route choice models, which are all based on the generalized cost function described above. They are: all-or-nothing assignment, stochastic assignment, and dynamic feedback assignment.

- (1) All-or-nothing assignment assumes that there is only one path from an origin to a destination and the path has the lowest cost. The familiarity settings for each type of vehicles are indirect parameters of the method. The definition of generalized cost function is the key to the method.

- (2) Stochastic assignment in PARAMICS assumes that different drivers perceive different costs from a decision node to the destination. The perceived cost is calculated based on the given perturbation factor with a random number assigned to the vehicle, and the shortest perceived route is chosen at the decision node. Parameter of the method includes perturbation of each vehicle type. The familiarity settings for each type of vehicles are indirect parameters of the method.
- (3) Dynamic feedback assignment routing method assumes travelers select route based on instantaneous traffic information. It has two parameters—feedback period and compliance rate (i.e. familiarity). The dynamic feedback routing method updates link costs at a certain feedback period and a certain percentage of travelers determined by the compliance rate are regarded as familiar drivers and can change paths when en-route.

The selection of route choice model is based on features of the target network and the scope of the project. The use of appropriate route choices becomes critical especially when both freeways and parallel streets are included in the study network. Usually, the combination of two or three routing methods is applied to a complicated simulation model (a simple simulation model may include only one active routing method), in which:

- (1) Different types of vehicles may use different route choice models.
- (2) Part of a certain type of vehicles may use different route choice models.

For example, the I-880 simulation model includes all three routing models. Familiar drivers for all vehicle types use dynamic feedback assignment; trucks use all-or-nothing assignment; other vehicles use stochastic assignment.

3. Initial calibration of core parameters of the selected route choice mode

Fundamentally, the calibration of the route choice behavior model is conducted on a network level. Core parameters of the route choice model can be calibrated using either aggregated data or individual data obtained from driver surveys.

For the I-880 network, all three routing methods are applied and thus there are three routing parameters: (1) perturbation; (2) familiarity; (3) feedback cycle. For the first two parameters, they are vehicle type specific. For the latter one, it is a global parameter. Their initial settings can be obtained from either a similar network that has been calibrated, or from sensitivity analysis of routes between major OD pairs of the target simulation network. The initial settings for these parameters are as follows: (1) perturbation = 2%; (2) familiarity = 5%; (3) feedback cycle = 2 minutes. These parameters are subject to change in the following model calibration process.

5.4.4 Dynamic OD demand estimation

Static traffic assignment based on the well known user equilibrium assumption has been extensively used in urban transportation planning analysis. Under this approach, all vehicles in the transportation network are assumed to be in the steady-state equilibrium flow. Namely, under this approach, it is assumed that the vehicular flow (demand) and transportation system (supply) are time-invariant and thus time-varying congestion (such

as queue spill back effects) is ignored. The assigned flows only provide a static average view of the transportation network. This is usually enough for planning decisions especially when focusing on capacity expansion. However, in terms of system management approaches to transportation planning, the information regarding time varying traffic flows (which cannot be forecasted or analyzed with the static tool) is critical. Therefore, there is a strong need for analysis tools that are able to estimate dynamic OD demands.

The I-880 study team investigated the advantages of microscopic traffic simulation in the transportation system management context and developed a new analysis methodology by combining a traffic assignment tool, mesoscopic simulation model, and microscopic traffic simulator.

The Methodology

To be able to evaluate the performance of the transportation system in a more comprehensive way, the study team developed a new hybrid scheme that has the advantages of different transportation analysis models: planning model, meso-scopic traffic simulation, and microscopic simulation model (see Figure 5.5).

The planning model with the least detailed descriptions is applicable to large networks; while the microscopic simulation model, which has the greatest detail, is limited to small to medium-size networks due to the overwhelming burdens on computation and coding efforts.

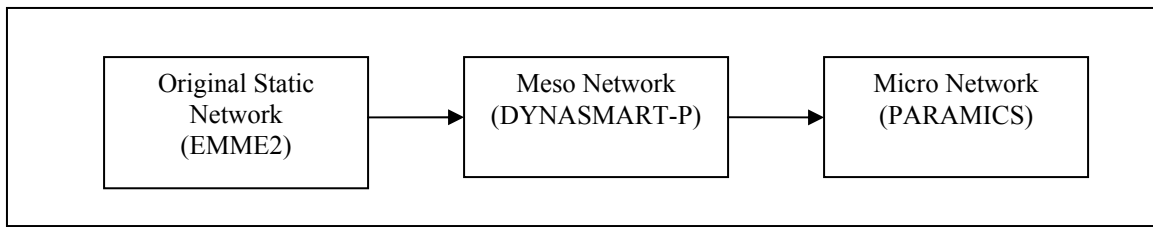


Figure 5.5 Incorporating Traffic Simulations into Conventional Planning Procedure

The key point is that the mesoscopic model (whose characteristics are between the two aforementioned models) can be used as the bridge to connect them. The mesoscopic model is used, in this research, as a means to provide dynamic OD demand matrices for the microscopic traffic simulation (which is the heart of any dynamic study). The study explicitly relaxes the assumption commonly adopted in practice when one attempts to estimate the OD demand that vehicles can finish their trip within a single time interval of demand matrix. This assumption might hold for small transportation networks, but most practitioners usually deal with large and congested networks where such assumptions are not valid. The direct use of the OD demand matrix from a static model (or time-slice demand from the static OD matrix) as the input for microscopic traffic simulation may bring about misleading results.

Another premise is to combine advantages from dynamic path flows in the larger network coded in a mesoscopic model with the more realistic and detail models in microscopic traffic simulation. The mesoscopic model provides more paths as users' responses to the time-varying traffic conditions within the regional network. On the other hand, this type of responses cannot be modeled within microscopic simulation alone since the path flows would have already been fixed into the form of entry flows. This scheme suggests the use of a mesoscopic model when the effects of demand and/or supply changes outside the microscopic network are significant.

The proposed methodology can be viewed as the extension of the traditional four-step model with the additional modules as the 5th and 6th steps. The scheme can be explained as follows:

- 1) Sub-area Analysis: Within the original static network (e.g. ACCMA Travel Demand Model), the static traffic assignment is run, and the sub-area analysis is performed. The output from this step is a static OD demand matrix of original zones within the sub-area, as well as new zones along the boundary of the sub-area (external zones).
- 2) Construction of Dynamic Network: The subtracted network is then converted into a dynamic network in a mesoscopic simulation model, DYNASMART-P¹⁶. Note that DYNASMART-P does not use centroids and centroid connectors; rather, it directly generates vehicles on generation links in a zone. Also, the zonal aggregation is need for the dynamic network.
- 3) A Bi-level OD Estimation: we currently use the standard bi-level approach. DYNASMART-P is used as the dynamic traffic assignment model in the lower problem. The objective function is some variation of GLS (General Least Square) of the difference between simulated and observed volumes. The module starts with the seed OD demand matrices from the static network. The outputs from this module are dynamic OD demand matrices for microscopic traffic simulation. These matrices reflect paths and departure times as in the meso-model.

¹⁶ <http://www.dynasmart.umd.edu/dynasmarptp/index.htm>

- 4) Microscopic Traffic Simulation: capacity calibration should first be done for the microscopic traffic simulation. Then, using the estimated dynamic OD demand matrices and observed data from the field, calibration of microscopic traffic simulation can be performed. Note that further OD demand adjustment within the microscopic traffic simulation itself when there is discrepancy between the two models.

Implementation

1). Mesoscopic dynamic network preparation

A dynamic network used for calibrating dynamic OD demand matrices was first built in a mesoscopic simulation model (Dynasmart-P) based on the same set of inputs (lengths free-flow speeds, and link capacities) used in the static model. The conversion from macroscopic to mesoscopic model was done by directly transferring the network input files (both network and OD demand data). In terms of traffic assignment, Dynasmart-P utilizes the modified Greenshield's function¹⁷ while TransCAD uses BPR (Bureau of Public Roads) cost function¹⁸. Due to the lack of data for calibrating parameters for the Greenshield model, the default values of capacity per lane and jam density are used.

The OD estimation process started with extracting the seed OD matrix from sub-area analysis, a standard function in TransCAD, as shown in Figure 5.6. This OD matrix can

¹⁷ Greenshield, B. D. (1935). "A study of traffic capacity." Highway research board proceedings 14, 448–477.

¹⁸ http://en.wikipedia.org/wiki/Routing_protocol

be viewed as the result of the assigned path flows based on the traditional link-based static assignment model.

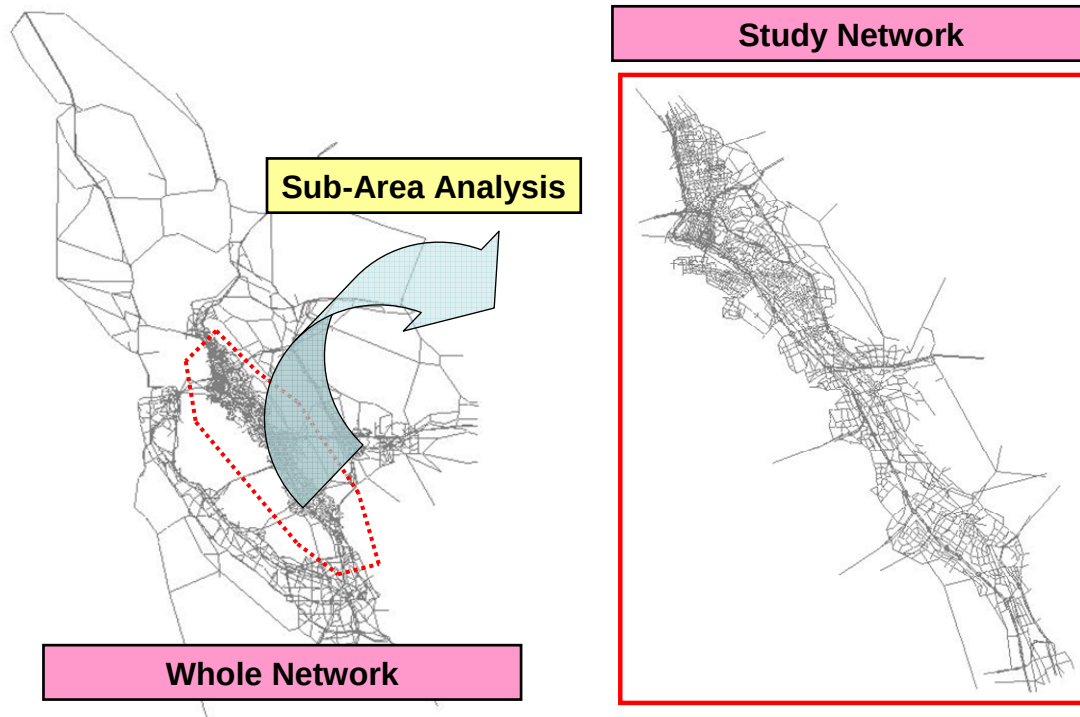


Figure 5.6 Subarea Analysis on A Static Network by TRANS CAD

Due to the discrepancy in zone concepts between the two models, zone aggregation is necessary. Specifically, TransCAD uses the concept of centroid and generates vehicles through centroid connectors, while Dynasmart-P adopts the concept of TAZ (Transportation Analysis Zone) which directly generates vehicles on a set of generation links. For that reason, after converting the network from TransCAD to Dynasmart-P, all centroids and their connectors were deleted and the rates of generation on each generation link were calculated by considering numbers of arrival and departure vehicles. Moreover, in order to keep a reasonable number of zones, some neighboring minor centroids were unified into a single Traffic Analysis Zone (TAZ). Figure 5.7 shows the dynamic network from such network conversion process.

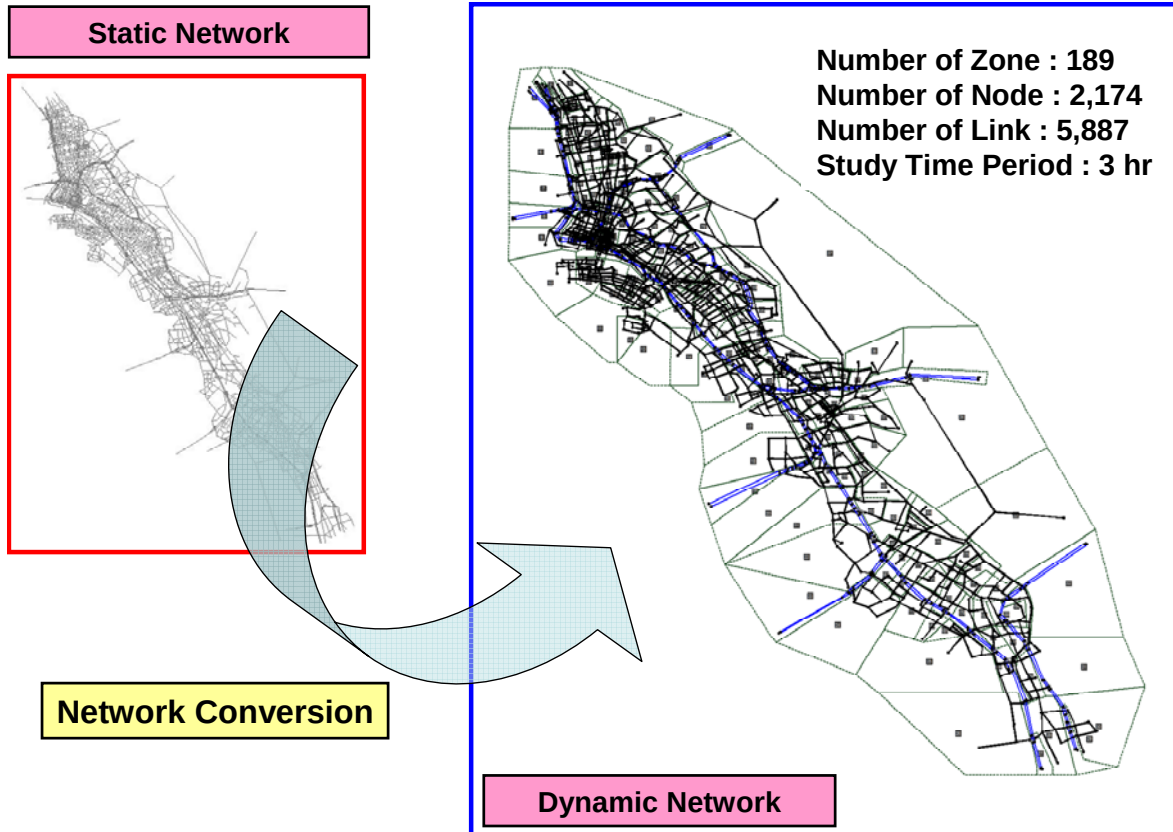


Figure 5.7 Network Data Conversion from Static Network to Dynamic Network

The procedure of the subarea analysis was well explained in Mahmassani et al. (2005)¹⁹. Seed dynamic OD demand matrices (which were not originally available) were needed as the initial inputs into the OD estimator. This study adopted a heuristic approach to convert a static OD demand matrix to dynamic ones. By assuming the average travel time throughout the network as 30 minutes, we projected the static OD demand matrix based upon the observed distribution of link counts over the entire observation period. A warm up time of 30 minutes is necessary to fill the network with the traffic before the OD estimation period.

¹⁹ Mahmassani H, Zhou X., and Erdogan S., Zonal aggregation and network extraction for subarea analysis using a dynamic assignment procedure, 84th TRB Annual Meeting, 2005.

2). Preparation for dynamic micro model

The seed dynamic OD demand matrices obtained from the procedure mentioned above were used as the initial solution into the OD estimator at the mesoscopic level. The team ran a number of iterations until OD matrices were obtained that, when assigned in Dynasmart-P network, generated link counts that reasonably match with observed ones. Such OD matrices were then used as seed for the similar type OD updating procedure but within PARAMICS. The entire framework of the OD demand matrix update is shown in figure 5.8. Figure 5.9 shows the final OD from Dynasmart-P to be used as initial OD for PARAMICS.

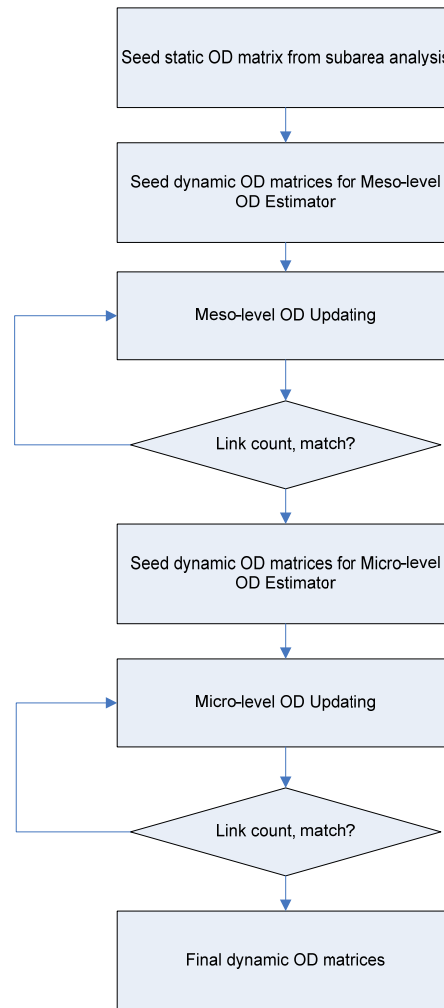


Figure 5.8 Framework for OD Demand Matrix Estimation

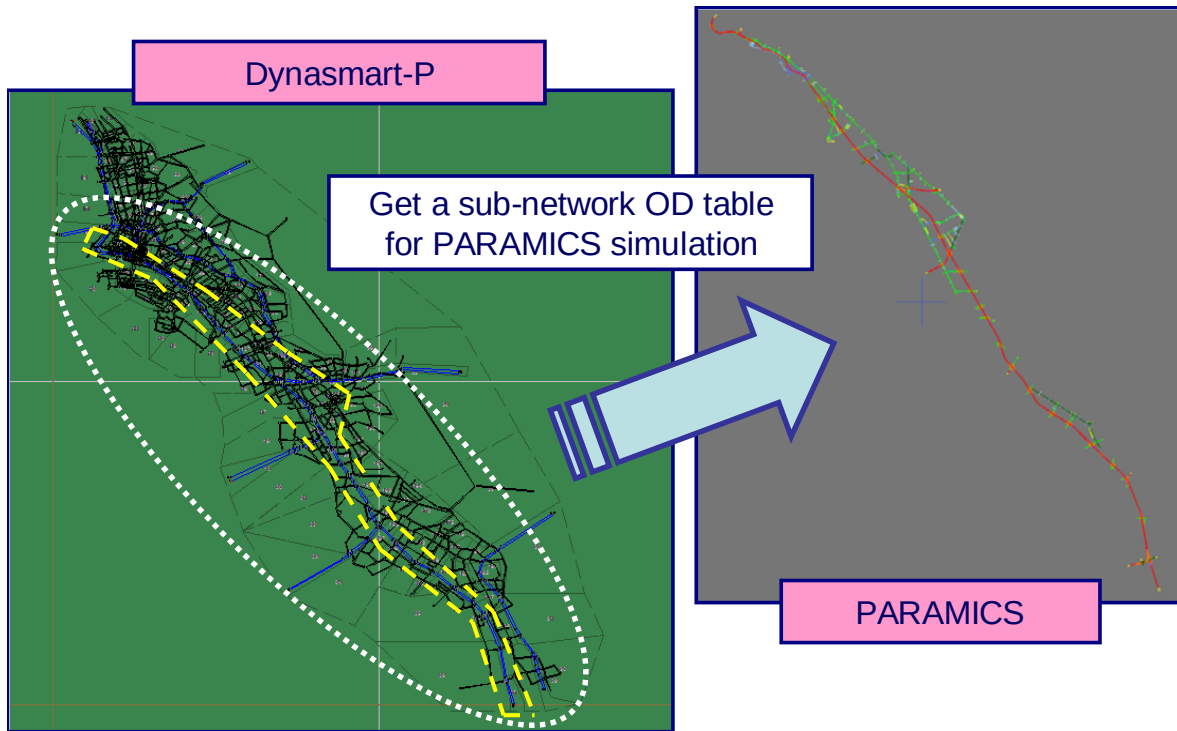


Figure 5.9 PARAMICS seed OD Table Estimation

Dynasmart-P can output the entire travel trajectories of all generated vehicles during a simulation period. Based on vehicle trajectories, we obtained an OD table for a specific inner area in Dynasmart-P network from path flows. Zones in PARAMICS were set, based on vehicle demands, network topology, and other data from both macro and mesoscopic models. The purpose was to capture path flows in the meso model that enter and leave the microsimulation network.

3). Model development

A bi-level generalized least square (GLS) estimator was developed in this study (shown in Figure 5.10). Its objective function in the upper problem was set to minimize the discrepancy between observed counts and simulated counts from the simulation

(Dynasmart-P, or PARAMICS) based on the last updated OD demand matrices in the previous upper problem. This approach uses a simulation model to generate the relationship between estimated OD demand matrices and the link counts through the assignment mapping operation, $R_a^{ij}(t_{dp}, t_{ar})$. Each iteration, the assignment mappings were assumed fixed, implying the assumptions of fixed travel time distribution, and fixed route choice proportions from the last iteration. Such assumptions are scarcely valid as the updated OD demand matrices might be greatly different from those of last iterations. Therefore, theoretically the correlation effect among OD pairs should be explicitly taken into account. Nevertheless, calculating a covariance matrix is practically cumbersome, especially for a large network where such correlation analysis is required for all OD pairs, all link flows, all departure time periods, and all observation time periods. To overcome this problem, a selective adjusting procedure was developed. Namely, the team minimized the number of OD pairs that potentially receive any update from the algorithm and bound the magnitude of changes in order to decrease the correlation effects. This was done instinctively by selecting only links that have current GEH value greater than a specific threshold to be included in the set of observation links when calculating the GLS error. The threshold was set high during early iterations to speed up the algorithm and was set lower progressively in later iterations as the correlation effect becoming more problematic.

Other problems common to all existing OD estimation models were rooted from the model inability in identifying traffic flow condition (i.e., using flows as decision variables in the OD estimation takes no knowledge of traffic conditions into account). For instance, the OD estimator has no knowledge of traffic condition on the link with a single

given information indicating “low flow.” It is either a free-flow condition or extremely congested. In other words, this low flow can be due to either low demand or low speed. Additionally, traffic counts at congested locations might be quite fluctuated which, in turn, makes the OD estimation become unstable. To prevent such instability, traffic counts observed on congested links were disqualified to be included in the observation dataset. Congested links were indirectly indicated by searching for those that have 15-minute averaged speed lower than 35 mile per hour, v^{Jam} . The minimization programming of the upper problem is shown below:

$$\text{Min} \sum_{a \in A^m} \sum_{t_{ar} \in t} \delta_{m,a}^{GEH} \cdot \delta_{m,a}^{Spd} \cdot \{x_a(t_{ar}) - \bar{x}_a(t_{ar})\}^2 + \sum_{a \in A^r} \sum_{t_{ar} \in t} \delta_{r,a}^{GEH} \cdot \{x_a(t_{ar}) - \bar{x}_a(t_{ar})\}^2 \quad (5.1)$$

subject to

$$x_a(t_{ar}) = \sum_{ij \in OD} \sum_{t_{dp} \in t} T^{ij}(t_{dp}) \cdot R_a^{ij}(t_{dp}, t_{ar}) \quad (5.2)$$

where,

$T^{ij}(t_{dp})$: OD demand from i to j during a departure time interval t_{dp} ,

$x_a(t_{ar})$: Link traffic flows at link a during a surveying time interval t_{ar} ,

$R_a^{ij}(t_{dp}, t_{ar})$: Assignment map from an OD demand from i to j departing time interval t_{dp} into link flows at link a during a surveying time interval t_{ar} ,

$\delta_{m,a}^{GEH} = 1$; If $\varepsilon_{m,a}^{GEH}$ is larger than GEH criteria for mainline,

= 0; Otherwise,

$\delta_{m,a}^{Spd} = 1$; If the speed of mainline link a is larger than v^{Jam}

= 0; Otherwise,

$\delta_{r,a}^{GEH} = 1$; If $\varepsilon_{r,a}^{GEH}$ is larger than GEH criteria for ramp,

= 0; Otherwise.

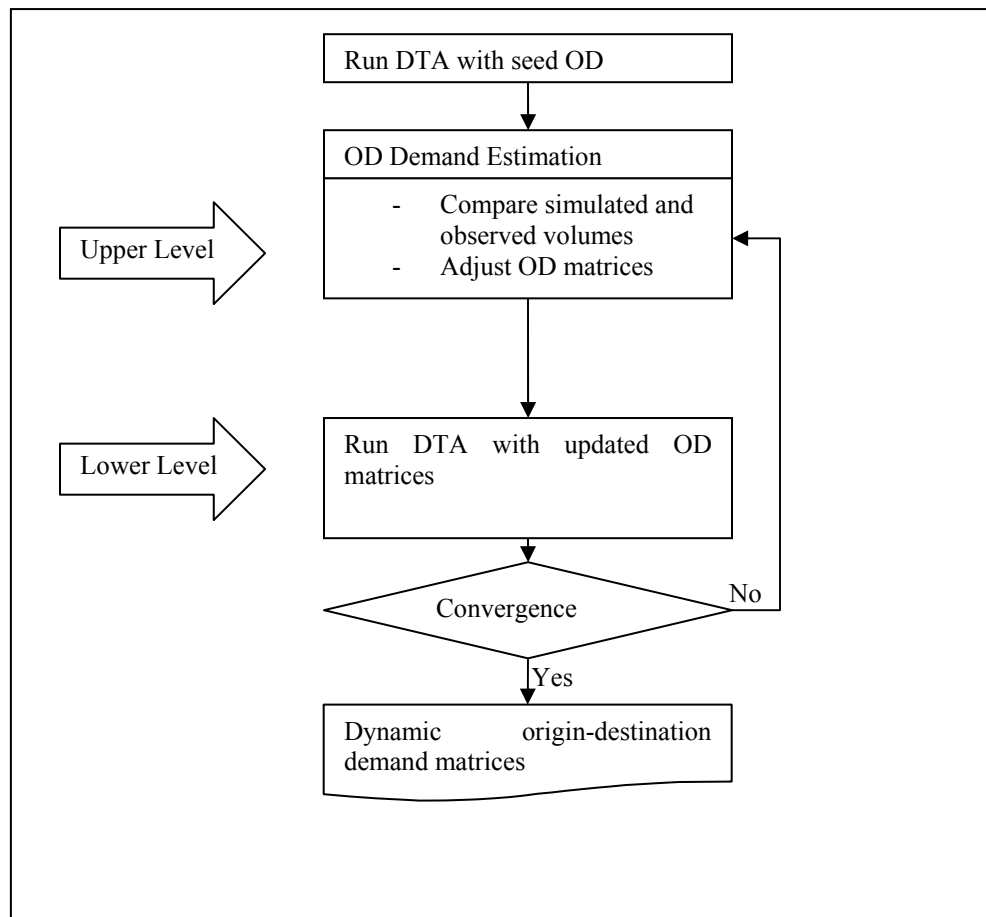


Figure 5.10 Bi-level Dynamic OD Demand Estimation Process

To search for the optimal solution that minimizes the objective function (5.1), this study used the modified gradient method originally proposed by Spiess (1990)²⁰. There are two main advantages of this approach. The first is its capability in performing a large scale optimization. The second is its characteristics of being able to improve solution quality by moving toward an intermediate solution in the vicinity of the initial solution. This is indeed beneficial as the structure of the seed OD demand matrices from the mesoscopic model is preserved. The following equations illustrate how the OD pair gradient is computed:

Insert Eq. (5.2) into Eq. (5.1).

$$Z(T) = \sum_{a \in A^m} \sum_{t_{ar} \in t} \delta_{m,a}^{GEH} \cdot \delta_{m,a}^{Spd} \cdot \left\{ \sum_{ij \in OD} \sum_{t_{dp} \in t} T^{ij}(t_{dp}) \cdot R_a^{ij}(t_{dp}, t_{ar}) - \bar{x}_a(t_{ar}) \right\}^2 +$$

$$\sum_{a \in A^r} \sum_{t_{ar} \in t} \delta_{r,a}^{GEH} \cdot \left\{ \sum_{ij \in OD} \sum_{t_{dp} \in t} T^{ij}(t_{dp}) \cdot R_a^{ij}(t_{dp}, t_{ar}) - \bar{x}_a(t_{ar}) \right\}^2 \quad (5.3)$$

The gradient of OD ij's travel demand from (5.3) can be calculated as:

$$\nabla^{mn}(t_{dp}') = \frac{\partial Z(T)}{\partial T^{mn}(t_{dp}')} = \frac{\partial}{\partial T^{mn}(t_{dp}')} \left[\sum_{a \in A^m} \sum_{t_{ar} \in t} \delta_{m,a}^{GEH} \cdot \delta_{m,a}^{Spd} \cdot \left\{ \sum_{ij \in OD} \sum_{t_{dp} \in t} T^{ij}(t_{dp}) \cdot R_a^{ij}(t_{dp}, t_{ar}) - \bar{x}_a(t_{ar}) \right\}^2 \right.$$

$$\left. + \sum_{a \in A^r} \sum_{t_{ar} \in t} \delta_{r,a}^{GEH} \cdot \left\{ \sum_{ij \in OD} \sum_{t_{dp} \in t} T^{ij}(t_{dp}) \cdot R_a^{ij}(t_{dp}, t_{ar}) - \bar{x}_a(t_{ar}) \right\}^2 \right]$$

$$= 2 \cdot \sum_{a \in A^m} \sum_{t_{ar} \in t} \delta_{m,a}^{GEH} \cdot \delta_{m,a}^{Spd} \left[\left\{ \sum_{ij \in OD} \sum_{t_{dp} \in t} T^{ij}(t_{dp}) \cdot R_a^{ij}(t_{dp}, t_{ar}) - \bar{x}_a(t_{ar}) \right\} \cdot R_a^{mn}(t_{dp}', t_{ar}) \right] +$$

²⁰ Spiess H. (1990). A gradient approach for the O-D Matrix Adjustment Problem. Publication 693, Centre de recherche sur les transports, Université de Montréal.

$$\begin{aligned}
 & 2 \cdot \sum_{a \in A^r} \sum_{t_{ar} \in t} \delta_{r,a}^{GEH} \left[\left\{ \sum_{ij \in OD} \sum_{t_{dp} \in t} T^{ij}(t_{dp}) \cdot R_a^{ij}(t_{dp}, t_{ar}) - \bar{x}_a(t_{ar}) \right\} \cdot R_a^{mn}(t_{dp}', t_{ar}) \right] \\
 & = 2 \cdot \left(\sum_{a \in A^m} \sum_{t_{ar} \in t} \delta_{m,a}^{GEH} \cdot \delta_{m,a}^{Spd} \cdot [\{x_a(t_{ar}) - \bar{x}_a(t_{ar})\} \cdot R_a^{mn}(t_{dp}', t_{ar})] + \right. \\
 & \quad \left. \sum_{a \in A^r} \sum_{t_{ar} \in t} \delta_{r,a}^{GEH} \cdot [\{x_a(t_{ar}) - \bar{x}_a(t_{ar})\} \cdot R_a^{mn}(t_{dp}', t_{ar})] \right) \quad (5.4)
 \end{aligned}$$

By introducing a new term as in Eq. (5.5), Eq. (5.4) becomes Eq. (5.6)

$$\varepsilon_a(t_{ar}) = x_a(t_{ar}) - \bar{x}_a(t_{ar}) \quad (5.5)$$

$$\nabla^{mn}(t_{dp}') = 2 \cdot \left\{ \sum_{a \in A^m} \sum_{t_{ar} \in t} \delta_{m,a}^{GEH} \cdot \delta_{m,a}^{Spd} \cdot \varepsilon_a(t_{ar}) \cdot R_a^{mn}(t_{dp}', t_{ar}) + \sum_{a \in A^r} \sum_{t_{ar} \in t} \delta_{r,a}^{GEH} \cdot \varepsilon_a(t_{ar}) \cdot R_a^{mn}(t_{dp}', t_{ar}) \right\} \quad (5.6)$$

With the gradient of each OD pair calculated using Eq. (5.6), a new OD table can be updated using Eq. (5.7).

$$T_{n+1}^{ij}(t_{dp}) = T_n^{ij}(t_{dp}) \cdot \left\{ 1 - \lambda \cdot \nabla_n^{ij}(t_{dp}) \right\} \quad (5.7)$$

subject to

$$\lambda \cdot \nabla_n^{ij}(t_{dp}) \leq 1 \quad \forall ij, t_{dp}.$$

To update $T_n^{ij}(t_{dp})$, an optimal λ value is needed. The value can be determined as follow.

At first, Eq. (5.7) is plugged into Eq. (5.3). Then we have Eq. (5.8).

$$Z_n = \sum_{a \in A^m} \sum_{t_{ar} \in t} \delta_{m,a}^{GEH} \cdot \delta_{m,a}^{Spd} \cdot \left[\sum_{ij \in OD} \sum_{t_{dp} \in t} T_n^{ij}(t_{dp}) \cdot \left\{ 1 - \lambda \cdot \nabla_n^{ij}(t_{dp}) \right\} \cdot R_{n,a}^{ij}(t_{dp}, t_{ar}) - \bar{x}_a(t_{ar}) \right]^2$$

$$+ \sum_{a \in A^r} \sum_{t_{ar} \in t} \delta_{r,a}^{GEH} \cdot \left[\sum_{ij \in OD} \sum_{t_{dp} \in t} T_n^{ij}(t_{dp}) \cdot \left\{ 1 - \lambda \cdot \nabla_n^{ij}(t_{dp}) \right\} \cdot R_{n,a}^{ij}(t_{dp}, t_{ar}) - \bar{x}_a(t_{ar}) \right]^2 \quad (5.8)$$

Using Eq. (5.5), the above equation is simplified as Eq. (5.9).

$$Z_n = \sum_{a \in A^m} \sum_{t_{ar} \in t} \delta_{m,a}^{GEH} \cdot \delta_{m,a}^{Spd} \cdot \left[\varepsilon_a(t_{ar}) - \lambda \cdot \sum_{ij \in OD} \sum_{t_{dp} \in t} T_n^{ij}(t_{dp}) \cdot R_{n,a}^{ij}(t_{dp}, t_{ar}) \cdot \nabla_n^{ij}(t_{dp}) \right]^2$$

$$+ \sum_{a \in A^r} \sum_{t_{ar} \in t} \delta_{r,a}^{GEH} \cdot \left[\varepsilon_a(t_{ar}) - \lambda \cdot \sum_{ij \in OD} \sum_{t_{dp} \in t} T_n^{ij}(t_{dp}) \cdot R_{n,a}^{ij}(t_{dp}, t_{ar}) \cdot \nabla_n^{ij}(t_{dp}) \right]^2 \quad (5.9)$$

To represent above equation simply, let define A as follow:

$$A = \sum_{ij \in OD} \sum_{t_{dp} \in t} T_n^{ij}(t_{dp}) \cdot R_{n,a}^{ij}(t_{dp}, t_{ar}) \cdot \nabla_n^{ij}(t_{dp})$$

$$\frac{\partial Z}{\partial \lambda} = 2 \cdot \sum_{a \in A^m} \sum_{t_{ar} \in t} \delta_{m,a}^{GEH} \cdot \delta_{m,a}^{Spd} \cdot [\varepsilon_a(t_{ar}) - \lambda \cdot A] \cdot (-A) + 2 \cdot \sum_{a \in A^r} \sum_{t_{ar} \in t} \delta_{r,a}^{GEH} \cdot [\varepsilon_a(t_{ar}) - \lambda \cdot A] \cdot (-A) \quad (5.10)$$

At optimum λ , $\partial Z / \partial \lambda = 0$.

$$- \sum_{a \in A^m} \sum_{t_{ar} \in t} \delta_{m,a}^{GEH} \cdot \delta_{m,a}^{Spd} \cdot \varepsilon_a(t_{ar}) \cdot A - \sum_{a \in A^r} \sum_{t_{ar} \in t} \delta_{r,a}^{GEH} \cdot \varepsilon_a(t_{ar}) \cdot A$$

$$+ \lambda \cdot \sum_{a \in A^m} \sum_{t_{ar} \in t} \delta_{m,a}^{GEH} \cdot \delta_{m,a}^{Spd} \cdot A^2 + \lambda \cdot \sum_{a \in A^r} \sum_{t_{ar} \in t} \delta_{r,a}^{GEH} \cdot A^2 = 0$$

Therefore,

$$\lambda^* = \frac{\sum_{a \in A^m} \sum_{t_{ar} \in t} \delta_{m,a}^{GEH} \cdot \delta_{m,a}^{Spd} \cdot \varepsilon_a(t_{ar}) \cdot A + \sum_{a \in A^r} \sum_{t_{ar} \in t} \delta_{r,a}^{GEH} \cdot \varepsilon_a(t_{ar}) \cdot A}{\sum_{a \in A^m} \sum_{t_{ar} \in t} \delta_{m,a}^{GEH} \cdot \delta_{m,a}^{Spd} \cdot A^2 + \sum_{a \in A^r} \sum_{t_{ar} \in t} \delta_{r,a}^{GEH} \cdot A^2} \quad (5.11)$$

5.4.5 Network Performance Calibration and Validation

Based on estimated dynamic demand tables, the simulation model will be further fine-tuned to match speed plots and travel time data from the real-world and satisfy FHWA's calibration criteria. As shown in Table 5.5, the model calibration criteria of the Wisconsin DOT were suggested by FHWA's microscopic simulation guidelines²¹.

Table 5.5 Wisconsin DOT Freeway Model Calibration Criteria

Criteria and Measures	Calibration Acceptance Targets
Hourly Flows, Model Versus Observed	
Individual Link Flows	
<i>Within 15%, for 700 veh/h < Flow < 2700 veh/h</i>	> 85% of cases
<i>Within 100 veh/h, for Flow < 700 veh/h</i>	> 85% of cases
<i>Within 400 veh/h, for Flow < 700 veh/h</i>	> 85% of cases
Sum of All Link Flows	Within 5% of sum of all link counts
GEH Statistic < 5 for Individual Link Flows	> 85% of cases
GEH Statistic for Sum of All Link Flows	GEH < 4 for sum of all link counts
Travel Times, Model Versus Observed	
Journey Times, Network	
<i>Within 15% (or 1 min, if higher)</i>	> 85% of cases
Visual Audits	
Individual Link Speeds	
<i>Visually Acceptable Speed-Flow Relationship</i>	To analyst's satisfaction
Bottlenecks	
<i>Visually Acceptable Queuing</i>	To analyst's satisfaction

The GEH statistic is computed as follows:

$$GEH = \sqrt{\frac{(E - V)^2}{(E + V) / 2}}$$

where :

E =model estimated volume

V =field count

Next, we will explain bottleneck calibration and then methods for model fine-tuning.

²¹ Dowling, R., Skabardonis, A., and Alexiadis, V. (2004) *Traffic Analysis Toolbox Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software*. PUBLICATION NO. FHWA-HRT-04-040, June 2004.

5.4.5.1 Bottleneck calibration

According to the FHWA micro-simulation guidelines, the project team mainly conducted the bottleneck calibration using visual assessment. This was done by visually assessing speed contour maps created by both simulated and observed data to make sure the number and locations of bottlenecks can roughly match. No quantitative criteria can be easily defined for this process since it highly depends on experience and engineering judgment. However, this visual assessment step is very important since it can guarantee that the simulation can generate meaningful results regarding reproducing the real world bottlenecks.

5.4.5.2 Model fine-tuning

Model fine-tuning involves the adjustment of many local parameters of the model and even global parameters in order to satisfy calibration targets. When the simulation model shows a problem (e.g., unnecessary congestion) at a certain location, the following steps may need to be checked in sequence in order to identify reasons of the problem:

1. Link level problem

The details of coding nodes and links and their associated attributes need to be checked.

The following items may need to be checked for errors in sequence:

- (1) Stop lines and Curbs. Stop lines and Curbs are automatically generated when the node and links are coded. In some links, Stop line positions and angles are not properly oriented that create bottlenecks in the network. This is evident when a lane is dropped or added in a link. Stop lines were adjusted properly for smooth

- transition of vehicles from one link to the other. Curbs are edges of the link. Sometimes Curbs of two are not well aligned which generated unexpected behavior of vehicles. This was adjusted as required.
- (2) Nodes. The distance between two adjacent links should be minimized. Otherwise, vehicles will slow down unnecessarily when they move from one link to the other.
 - (3) Curved links. Curved links in Paramics are modeled as part of a circle and the length of the link should be less than half of the circumference of the circle; otherwise speeds of vehicles traveling on the link may be unnecessarily reduced.
 - (4) Next lanes of a node: Next lane is more useful especially in a section where a significant amount of weaving and merging take place. Using next lane it is possible to distribute the traffic among different lanes from an upstream section to the downstream section smoothly.
 - (5) Ramp parameters. In any on-ramp, merging of vehicles is dictated by three factors: ramp headway factor, ramp awareness distance, and ramp minimum time. Smaller values of ramp headway factor and/or minimum ramp time can usually increase the capability of merging area of the mainline. For the I-880 network, ramp headway factor and minimum ramp time was reduced as low as 0.4 and 0 sec respectively. This improved the holding capacity of the on-ramps and ramp vehicles could merge into the freeway more quickly. Ramp awareness distance was changed to 150 ft, 250 ft or 350 ft depending upon the ramp configuration in order to avoid bottlenecks at mainline merging locations. This improved the

merging of vehicles as well as through flow of traffic in the mainline by warning upstream traffic about the merging of on-ramp vehicles.

(6) Signposting and signrange of a link. Signposting and signrange are the locations and location ranges where vehicles start to know the hazards located at the end of the link. The behaviors of drivers after knowing hazards may be lane changing. Improper values of signposting and signrange may cause vehicles to change lanes at last minute, which may generate artificial bottlenecks. In general, a thumb of rule is to increase signposting values and keep signrange as half of the signposting distance. This has been shown to be effective to reduce the irregular driver behaviors at diverging locations.

(7) Link headway factor and reaction time factor. Apart from global mean headway factor (0.9) and reaction time (0.8), each link can be adjusted by local headway and reaction time factors to calibrate the capacity of the link. They affected the car-following and lane changing behaviors occurred on the particular link only. For example, the use of values smaller than 1.0 for link headway factor (or reaction time factor) will cause smaller target headways (or reaction times) applied to vehicles on the link, which makes the link have higher capacity.

(8) Lane Choice: Lane choice was useful to control the lane change behaviors of vehicles, especially at freeway to freeway interchanges and at off-ramp locations.

2. Signal or metering problem

Signal operation is very important for the performance of a simulation model. Some causes for improper operation of a signal are: (1) wrong detectors associated with a signal phase; (2) improper placement of a detector; (3) no signal coordination (i.e. no offset setting); (4) wrong timing data. Some causes for improper operation of ramp metering are (1) the emulation of metering may be different compared to that in the real world; (2) incorrect settings for metering in simulation; (3) wrong detectors associated with a meter; (4) improper placement of a detector; (5) no queue override control, while in the real world, queue override control is enabled.

3. Route level problem

The route level problem means that some vehicles may not select routes appropriately. Since vehicles only select the shortest path in simulation, this problem is usually caused by the condition that the cost for a selected route is lower than the expected one. The causes for this problem could be: (1) a necessary movement at a node is barred; (2) speed limit along the selected route is higher than the expected one. If the routing problem is not caused by coding problems, the following two strategies may be used: (1) applying a link cost factor to a link (instead of the default value, 1); (2) applying tolls to some types of links. The first method is easier to use. The second method is more powerful for a large-size network.

For the I-880 network, we applied a 2 minutes toll to all on-ramps and off-ramps in order to avoid the routing problem.

4. Network level problem.

If the network has lower or higher capacity than the real world at many bottleneck locations or inappropriate routing behaviors, the network's global parameters (such as mean target headway, mean reaction time, perturbation, or familiarity, etc) may need to change.

Under the process of local calibrations, we adjust local parameters (link headway factor, signposting, lane choice, and ramp parameters) from the upstream to downstream to check the consistency with field observation in terms of vehicle movements, section capacity, and shockwave propagation.

5.5 Calibration results

5.5.1 Link flow GEH

The project team had completed simulation calibrations for AM peak periods (7:00 AM – 9:00 AM) for both directions of the I-880 study. The GEH values for the link count matches for NB and SB are shown in the Table 5.6 and Table 5.7, respectively.

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Table 5.6 GEH Statistic for NB

Mainline Detectors			7:00 AM		to	8:00 AM			8:00 AM		to	9:00 AM		
Detector Name	Link	Description	Obs	Sim	% diff	# diff	GEH	Target	Obs	Sim	% diff	# diff	GEH	Target
880n0765ml	7074:7078	NB start	4989	5025	1%	36	0.5	1	5633	5664	1%	31	0.4	1
880n0836ml	7081:7082	Calaveras Blvd	4480	4521	1%	41	0.6	1	4987	4956	-1%	-31	0.4	1
880n0168ml	8007:8020a	Gateway Blvd	4720	4719	0%	-1	0	1	5135	5265	3%	130	1.8	1
880n0328ml	8032:8036	Fremont Blvd	3963	3907	-1%	-56	0.9	1	3751	3894	4%	143	2.3	1
880n0403ml	8040:8041		4155	3914	-6%	-241	3.8	1	4034	4025	0%	-9	0.1	1
880n0466ml	8046:8051	AutoMall Pkwy	3698	3763	2%	65	1.1	1	3604	3709	3%	105	1.7	1
880n0622ml	8061:8065	Stevenson Blvd	4502	4324	-4%	-178	2.7	1	4229	3934	-7%	-295	4.6	1
880n0713ml	8071:8074	Mowry Ave	4691	4874	4%	183	2.6	1	4428	4395	-1%	-33	0.5	1
880n0736ml	8074:8076		4910	4995	2%	85	1.2	1	4626	4509	-3%	-117	1.7	1
880n0883ml	8088:8091	Thornton Ave	5182	5285	2%	103	1.4	1	4920	4951	1%	31	0.4	1
880n0990ml	8095:8100		6441	6585	2%	144	1.8	1	6124	6198	1%	74	0.9	1
880n1028ml	8102:8105	SR-84	4679	4894	5%	215	3.1	1	4635	4428	-4%	-207	3.1	1
880n1049ml	8105:8106		5533	5564	1%	31	0.4	1	5397	5109	-5%	-288	4	1
880n1105ml	8110:8112		5881	5918	1%	37	0.5	1	5715	5387	-6%	-328	4.4	1
880n1166ml	8116:8118	Alvarado Blvd	5951	5613	-6%	-338	4.4	1	5446	5006	-8%	-440	6.1	0
880n1230ml	8119:8127a		6629	6579	-1%	-50	0.6	1	6226	5994	-4%	-232	3	1
880n1314ml	8127a:8132	Alvarado Niles Rd	6075	6190	2%	115	1.5	1	5725	5606	-2%	-119	1.6	1
880n1378ml	8138:8140	Whipple St	5694	5485	-4%	-209	2.8	1	5610	5184	-8%	-426	5.8	0
880n1425ml	8142:8147		5728	5927	3%	199	2.6	1	5730	5701	-1%	-29	0.4	1
880n1495ml	8147:8153	Industrial Pkwy	6311	6517	3%	206	2.6	1	6333	6394	1%	61	0.8	1
880n1554ml	8154:8159		5903	5936	2%	33	1.7	1	5662	5803	2%	141	1.9	1
880n1580ml	8159:8161	Tennyson Rd	5803	5884	1%	81	1.1	1	5662	5847	3%	185	2.4	1
880n1624ml	3700:8164		6840	6727	-2%	-113	1.4	1	6637	6563	-1%	-74	0.9	1
880n1645ml	8165:8171	SR-92	5581	5442	-2%	-139	1.9	1	5443	5238	-4%	-205	2.8	1
880n1711ml	3701:8173		7115	7301	3%	186	2.2	1	6734	6942	3%	208	2.5	1
880n1782ml	3703:8182	Winton St	6951	6970	0%	19	0.2	1	6487	6416	-1%	-71	0.9	1
880n1848ml	8182:8185	A. St	7169	7246	1%	77	0.9	1	6798	6548	-4%	-250	3.1	1
880n1872ml	8185:8188		7778	7798	0%	20	0.2	1	7321	7060	-4%	-261	3.1	1
880n2042ml	8203:8205	I-238 interchange	5476	5594	2%	118	1.6	1	5046	5022	0%	-24	0.3	1
880n2082ml	8207:8210	Washington Ave	5821	5649	-3%	-172	2.3	1	5078	5023	-1%	-55	0.8	1
880n2213ml	8210:8226		7796	7337	-6%	-459	5.3	0	6887	6929	1%	42	0.5	1
880n2296ml	8228:8230	Marina St	6513	6226	-4%	-287	3.6	1	5633	5745	2%	112	1.5	1
880n2369ml	8236:8239	Davis St	6891	6497	-6%	-394	4.8	1	6167	5858	-5%	-309	4	1
880n2465ml	8246:8248	98th Ave	6412	6296	-2%	-116	1.5	1	5804	5602	-3%	-202	2.7	1
880n2484ml	8248:8250		6755	6565	-3%	-190	2.3	1	6215	5870	-6%	-345	4.4	1
880n2552ml	8253:8255	Hegenberger	6695	6405	-4%	-290	3.6	1	6032	5469	-9%	-563	7.4	0
880n2684ml	8260:8269	66th Ave	7059	6721	-5%	-338	4.1	1	6156	5720	-7%	-436	5.7	0
880n2865ml	8285:8287	Fruitvale Ave	7276	6909	-5%	-367	4.4	1	6898	6258	-9%	-640	7.9	0
880n2888ml	8287:8288		7231	6856	-5%	-375	4.5	1	6806	6299	-7%	-507	6.3	0
880n2975ml	8297:8299	14th Ave	8562	8241	-4%	-321	3.5	1	8295	7913	-5%	-382	4.2	1
880n3166ml	8314:8317	Broadway	7869	7509	-5%	-360	4.1	1	7467	7245	-3%	-222	2.6	1
880n3315ml	8331:8335	NB end	5333	4880	-8%	-453	6.3	0	5169	4815	-7%	-354	5	1

Ramp Detectors			7:00 AM		to	8:00 AM			8:00 AM		to	9:00 AM		
Detector Name	Link	Description	Obs	Sim	% diff	# diff	GEH	Target	Obs	Sim	% diff	# diff	GEH	Target
880n0836r1	2005:2014	Calaveras Blvd	619	473	-24%	-146	6.2	0	848	722	-15%	-126	4.5	1
880n0836r1m1	2019:2020		174	145	-17%	-29	2.3	1	177	149	-16%	-28	2.2	1
880n0836r2	2936:2937		348	329	-5%	-19	1	1	326	258	-21%	-68	4	1
880n0877r1m1	2939:2938		202	253	25%	51	3.4	1	238	290	22%	52	3.2	1
880n0005r1	2030:2032	Dixon Landing Rd	807	837	4%	30	1	1	842	761	-10%	-81	2.9	1
880n0005r1m1	1622:3208		415	360	-13%	-55	2.8	1	398	349	-12%	-49	2.5	1
880n0224r1	8021:606	Mission Blvd	1118	1072	-4%	-46	1.4	1	1223	1229	0%	6	0.2	1
880n0224r2	8023:829		369	361	-2%	-8	0.4	1	692	689	0%	-3	0.1	1
880n0224r1m1	609:8025		1373	1287	-6%	-86	2.4	1	1363	1317	-3%	-46	1.3	1
880n0328r1	1339:1340	Fremont Blvd	675	574	-15%	-101	4	0	886	825	-7%	-61	2.1	1
880n0328r1m1	3212:1356		209	178	-15%	-31	2.2	1	206	215	4%	9	0.6	1
880n0328r2	1359:625		263	265	1%	2	0.1	1	252	279	11%	27	1.7	1
880n0466r1	851:1410	AutoMall Pkwy	622	563	-9%	-59	2.4	1	672	691	3%	19	0.7	1
880n0466r1m1	3214:1377		134	131	-2%	-3	0.3	1	130	101	-22%	-29	2.7	1
880n0466r2	3216:867		982	844	-14%	-138	4.6	1	777	646	-17%	-131	4.9	0
880n0622r1	1378:877	Stevenson Blvd	502	437	-13%	-65	3	1	625	539	-14%	-86	3.6	1
880n0622r1m1	882:1387		215	167	-22%	-48	3.5	1	189	168	-11%	-21	1.6	1
880n0622r2	908:1388		957	933	-3%	-24	0.8	1	932	926	-1%	-6	0.2	1
880n0713r1	1390:911	Mowry Ave	574	526	-8%	-48	2	1	657	676	3%	19	0.7	1
880n0713r1m1	3219:1297		222	124	-44%	-98	7.5	1	189	113	-40%	-76	6.2	1
880n0713r2	3374:1301		899	903	0%	4	0.1	1	861	901	5%	40	1.3	1
880n0883r1	942:943	Thornton Ave	613	568	-7%	-45	1.9	1	586	530	-10%	-56	2.4	1
880n0883r1m1	3221:1498		508	509	0%	1	0	1	438	490	12%	52	2.4	1
880n0883r2	3223:1305		897	861	-4%	-36	1.2	1	753	678	-10%	-75	2.8	1
880n1028r1	1311:972	SR-84	1729	1660	-4%	-69	1.7	1	1835	1777	-3%	-58	1.4	1
880n1028r1m1	978:1312		695	677	-3%	-18	0.7	1	710	677	-5%	-33	1.3	1
880n1028r2	983:8106		297	359	21%	62	3.4	1	317	273	-14%	-44	2.6	1
880n1166r1	1004:1005	Alvarado Blvd	298	345	16%	47	2.6	1	364	346	-5%	-18	1	1
880n1166r1m1	3225:1315		1043	963	-8%	-80	2.5	1	990	987	0%	-3	0.1	1

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Table 5.7 GEH Statistic for SB

Mainline Detectors			7:00 AM				to	8:00 AM				8:00 AM				to	9:00 AM			
Detector Name			Obs	Sim	% diff	# diff	GEH	Target	Obs	Sim	% diff	# diff	GEH	Target	Obs	Sim	% diff	# diff	GEH	Target
880s3380ml	6340:6336	SB start	4018	4118	2%	100	1.6	1	3767	3977	6%	210	3.4	1	3767	3977	6%	210	3.4	1
880s3231ml	6326:6324		3862	3865	0%	3	0	1	3712	3587	-3%	-125	2.1	1	3712	3587	-3%	-125	2.1	1
880s3131ml	6314:6311	Oak St	6028	5893	-2%	-135	1.7	1	5845	5612	-4%	-233	3.1	1	5845	5612	-4%	-233	3.1	1
880s2975ml	6298:6296		6516	6950	7%	434	5.3	0	6214	6539	5%	325	4.1	1	6214	6539	5%	325	4.1	1
880s2888ml	6290b:6289	23rd Ave	6306	6292	0%	-14	0.2	1	5766	5992	4%	226	2.9	1	5766	5992	4%	226	2.9	1
880s2865ml	6289:6288	29th Ave	6691	6802	2%	111	1.4	1	6201	6481	5%	280	3.5	1	6201	6481	5%	280	3.5	1
880s2807ml	6281:6277	High St	6151	6241	1%	90	1.1	1	5718	5742	0%	24	0.3	1	5718	5742	0%	24	0.3	1
880s2633ml	6266:6260	66th Ave	6433	6682	4%	249	3.1	1	6048	6600	9%	552	6.9	0	6048	6600	9%	552	6.9	0
880s2547ml	6257:6253	Hegenberger	4991	5248	5%	257	3.6	1	4676	5188	11%	512	7.3	0	4676	5188	11%	512	7.3	0
880s2460ml	6248:6246	98th Ave	6042	6165	2%	123	1.6	1	5943	5739	-3%	-204	2.7	1	5943	5739	-3%	-204	2.7	1
880s2353ml	6241:6237	Davis St	5934	5883	-1%	-51	0.7	1	5668	5443	-4%	-225	3	1	5668	5443	-4%	-225	3	1
880s2335ml	6233:6232		7140	6970	-2%	-170	2	1	6811	6658	-2%	-153	1.9	1	6811	6658	-2%	-153	1.9	1
880s2272ml	6231:6227	Marina St	6120	6093	0%	-27	0.3	1	5799	5588	-4%	-211	2.8	1	5799	5588	-4%	-211	2.8	1
880s2213ml	6227:6213		7067	7011	-1%	-56	0.7	1	6734	6703	0%	-31	0.4	1	6734	6703	0%	-31	0.4	1
880s2065ml	6212:6207	I-238 interchange	5516	5297	-4%	-219	3	1	5012	5019	0%	7	0.1	1	5012	5019	0%	7	0.1	1
880s2033ml	6206:6202	Hesperian	5782	5520	-5%	-262	3.5	1	5418	5192	-4%	-226	3.1	1	5418	5192	-4%	-226	3.1	1
880s1996ml	6199:6197		7513	6936	-8%	-577	6.8	0	7016	6669	-5%	-347	4.2	1	7016	6669	-5%	-347	4.2	1
880s1937ml	6194:6191		7951	7795	-2%	-156	1.8	1	7737	7502	-3%	-235	2.7	1	7737	7502	-3%	-235	2.7	1
880s1825ml	6188:6179	A. St	7481	7231	-3%	-250	2.9	1	7100	6978	-2%	-122	1.5	1	7100	6978	-2%	-122	1.5	1
880s1782ml	6178:6174	Winton St	7169	7018	-2%	-151	1.8	1	6510	6665	2%	155	1.9	1	6510	6665	2%	155	1.9	1
880s1711ml	6171:6170		7669	7571	-1%	-98	1.1	1	7736	7208	-7%	-528	6.1	0	7736	7208	-7%	-528	6.1	0
880s1681ml	6170:6164	SR-92	5321	5206	-2%	-115	1.6	1	5372	4940	-8%	-432	6	0	5372	4940	-8%	-432	6	0
880s1624ml	6169:6160a		6542	6329	-3%	-213	2.7	1	6515	6170	-5%	-345	4.3	1	6515	6170	-5%	-345	4.3	1
880s1550ml	6160a:6154	Tennyson Rd	6224	5826	-6%	-398	5.1	1	5976	5563	-7%	-413	5.4	0	5976	5563	-7%	-413	5.4	0
880s1495ml	6154:6149		6744	6691	-1%	-53	0.6	1	6696	6401	-4%	-295	3.6	1	6696	6401	-4%	-295	3.6	1
880s1469ml	6149:6145	Industrial Pkwy	5783	6018	4%	235	3.1	1	5710	5641	-1%	-69	0.9	1	5710	5641	-1%	-69	0.9	1
880s1425ml	6144:6139		6514	6677	3%	163	2	1	6380	6163	-3%	-217	2.7	1	6380	6163	-3%	-217	2.7	1
880s1354ml	6139:6135	Whipple St	5732	5925	3%	193	2.5	1	5576	5425	-3%	-151	2	1	5576	5425	-3%	-151	2	1
880s1310ml	6132:6129	Alvarado Niles Rd	5604	5766	3%	162	2.1	1	5468	5183	-5%	-285	3.9	1	5468	5183	-5%	-285	3.9	1
880s1294ml	6129:6127		5967	6110	2%	143	1.8	1	5743	5467	-5%	-276	3.7	1	5743	5467	-5%	-276	3.7	1
880s1159ml	6116:6114	Alvarado Blvd	5781	5672	-2%	-109	1.4	1	5472	5436	-1%	-36	0.5	1	5472	5436	-1%	-36	0.5	1
880s1105ml	6112:6110a		6812	6646	-2%	-166	2	1	6665	6707	1%	42	0.5	1	6665	6707	1%	42	0.5	1
880s1032ml	6104:6102	SR-84	5389	5108	-5%	-281	3.9	1	5092	5210	2%	118	1.6	1	5092	5210	2%	118	1.6	1
880s0990ml	6099:6095		6324	6339	0%	15	0.2	1	6172	6422	4%	250	3.2	1	6172	6422	4%	250	3.2	1
880s0887ml	6090:6087	Thornton Ave	5772	5770	0%	-2	0	1	5547	5752	4%	205	2.7	1	5547	5752	4%	205	2.7	1
880s0868ml	6087:6085		6189	6188	0%	-1	0	1	6077	6126	1%	49	0.6	1	6077	6126	1%	49	0.6	1
880s0711ml	6071:6068	Mowry Ave	6402	6377	0%	-25	0.3	1	5815	6205	7%	390	5	1	5815	6205	7%	390	5	1
880s0629ml	6065:6062	Stevenson Blvd	6006	5909	-2%	-97	1.3	1	5563	5660	2%	97	1.3	1	5563	5660	2%	97	1.3	1
880s0610ml	6062:6059		6326	6249	-1%	-77	1	1	6036	6072	1%	36	0.5	1	6036	6072	1%	36	0.5	1
880s0478ml	6050:6046	AutoMall Pkwy	5541	5345	-4%	-196	2.7	1	5328	5070	-5%	-258	3.6	1	5328	5070	-5%	-258	3.6	1
880s0403ml	6041:6038		6078	5477	-10%	-601	7.9	0	5637	5271	-6%	-366	5	1	5637	5271	-6%	-366	5	1
880s0324ml	6035:6033	Fremont Blvd	5470	5226	-4%	-244	3.3	1	4721	4915	4%	194	2.8	1	4721	4915	4%	194	2.8	1
880s0305ml	6033:6030		5681	5548	-2%	-133	1.8	1	4994	5290	6%	296	4.1	1	4994	5290	6%	296	4.1	1
880s0243ml	6027:6026	Mission Blvd	4813	4765	-1%	-48	0.7	1	4380	4635	6%	255	3.8	1	4380	4635	6%	255	3.8	1
880s0168ml	6018:6015	Gateway Blvd	6108	6203	2%	95	1.2	1	5757	6037	5%	280	3.6	1	5757	6037	5%	280	3.6	1
880s1021ml	5103:5101	Dixon Landing Rd	5890	5866	0%	-24	0.3	1	5747	5731	0%	-16	0.2	1	5747	5731	0%	-16	0.2	1
880s0753ml	5081:5078	South of 237	5059	5217	3%	158	2.2	1	5102	5285	4%	183	2.5	1	5102	5285	4%	183	2.5	1
Ramp Detectors			7:00 AM				to	8:00 AM				8:00 AM				to	9:00 AM			
Detector Name			Obs	Sim	% diff	# diff	GEH	Target	Obs	Sim	% diff	# diff	GEH	Target	Obs	Sim	% diff	# diff	GEH	Target
880s3278rm1	2053:6333	7th ST On Ramp	502	552	10%	50	2.2	1	577	584	1%	7	0.3	1	577	584	1%	7	0.3	1
880s3278rf1	6330:2058	Union ST Off Ramp	772	807	5%	35	1.2	1	885	973	10%	88	2.9	1	885	973	10%	88	2.9	1
880s3180rm1	1900:1899	5th ST On Ramp	232	237	2%	5	0.3	1	338	322	-5%	-16	0.9	1	338	322	-5%	-16	0.9	1
880s3166rf1	1884:1885	5th ST Off Ramp	554	489	-12%	-65	2.8	1	634	593	-6%	-41	1.7	1	634	593	-6%	-41	1.7	1
880s3166rm1	1881:1886	1980 On Ramp	1532	1540	1%	8	0.2	1	1440	1421	-1%	-19	0.5	1	1440	1421	-1%	-19	0.5	1
880s3163rm1	1880:1890	Jackson ST On Ramp	229	252	10%	23	1.5	1	301	286	-5%	-15	0.9	1	301	286	-5%	-15	0.9	1
880s3096rm1	3276:1891	Oak St	808	851	5%	43	1.5	1	839	776	-8%	-63	2.2	1	839	776	-8%	-63	2.2	1
880s3020rm1	1819:1818	Embarcadero	307	336	9%	29	1.6	1	302	346	15%	44	2.4	1	302	346	15%	44	2.4	1
880s2975rf1	1814:1815		274	128	-53%	-146	10.3	0	323	159	-51%	-164	10.6	0	323	159	-51%	-164	10.6	0
880s2910rf1	1808:1807	23rd Ave	661	655	-1%	-6	0.2	1	618	550	-11%	-68	2.8	1	618	550	-11%	-68	2.8	1
880s2888rm1	1762:1761		489	512	5%	23	1	1	518	495	-4%	-23	1	1	518	495	-4%	-23	1	1
880s2865rm1	1765:6288	29th Ave	591	545	-8%	-46	1.9	1	538	482	-10%	-56	2.5	1	538	482	-10%	-56	2.5	1
880s2865rf1	6287a:1772	Fruitvale	376	381	1%	5	0.3	1	401	417	4%	16	0.8	1	401	417	4%	16	0.8	1
880s2807rf1	6283:3601	to 42th total	758	648	-15%	-110	4.1	1	782	714	-9%	-68	2.5	1	782	714	-9%	-68	2.5	1
880s2807rf2	1726:1724	42th Ave to Oakport	509	403	-21%	-106	5	0	508	404	-20%	-104	4.9	0	508	404	-20%	-104	4.9	0
880s2807rf3	1726:1727	880S 42th to Ave	249	246	-1%	-3	0.2	1	275	308	12%	33	1.9	1	275	308	12%	33	1.9	1
880s2807rm1	1735:1724	42th to 880S	551	528	-4%	-23	1	1	550	440	-20%	-110	4.9	0	550	440	-20%	-110	4.9	0
880s2753rm1	1786:1781	High St	1178	1200	2%	22	0.6	1	1120	1057	-6%	-63	1.9	1	1120	1057	-6%	-63	1.9	1
880s2684rf1	1681:1682		538	491	-9%	-47	2.1	1	596	503	-16%	-93	4	1	596	503	-16%	-93	4	1
880s2633rm2	1686:1687	66th Ave East	14	4	-71%	-10	3.3	1	30	3	-90%	-27	6.6	1	30	3	-90%	-27	6.6	1
880s2633rm1	3371:1687	66th Ave West	255	219	-14%	-36	2.3	1	325	295	-9%	-30	1.7	1	325	295	-9%	-30	1.7	1
880s2633rm3	1691:1692	66th Ave total	269	221	-18%	-48	3.1	1	355	301										

5.5.2 Time-Dependent Section Travel Time

Table 5.8 and table 5.9 show the comparison of the time dependent section travel times for NB and SB, respectively.

Table 5.8 Section Travel Times for NB

	Start	End	StartPostmile	EndPostmile	obs	sim	diff	%diff	P/N
SB-1	N.end	29th	3315ml	2888ml	294	307.3	13.3	4.52%	TRUE
SB-2	29th	98th	2888ml	2475ml	249	239.8	-9.2	-3.69%	TRUE
SB-3	98th	I238	2475ml	2065ml	486	302	-184	-37.86%	FALSE
SB-4	I238	SR-92	2065ml	1645ml	444	517.8	73.8	16.62%	FALSE
SB-5	SR-92	SR-84	1645ml	1032ml	418	481.3	63.3	15.14%	FALSE
SB-6	SR-84	Automall	1032ml	0478ml	415	382.2	-32.8	-7.90%	TRUE
TOTAL	N.end	Automall	3315ml	0478ml	2306	2230.4	-75.6	-3.28%	TRUE

Table 5.9 Section Travel Times for SB

	Start	End	StartPostmile	EndPostmile	obs	sim	diff	%diff	P/N
NB-8	S.end	Automall	SCL-0765ml	0466ml	381	424.8	43.8	11.50%	TRUE
NB-9	Automall	SR-84	0466ml	1028ml	307	340.5	33.5	10.91%	TRUE
NB-10	SR-84	SR-92	1028ml	1645ml	676	528.5	-147.5	-21.82%	FALSE
NB-11	SR-92	I238	1645ml	2042ml	234	187.2	-46.8	-20.00%	TRUE
NB-12	I238	98th	2042ml	2465ml	387	353.7	-33.3	-8.60%	TRUE
NB-13	98th	29th	2465ml	2888ml	322	266.6	-55.4	-17.20%	TRUE
NB-14	29th	N.end	2888ml	3315ml	327	349.5	22.5	6.88%	TRUE
TOTAL	S.end	N.end	SCL-0765ml	3315ml	2634	2450.8	-183.2	-6.96%	TRUE

Table 5.10 below is a summary of the calibration results based on Table 5.6 – Table 5.9.

In this table, the percentage in each cell indicate the percentage that the AM simulation results satisfy the FHWA simulation calibration criteria in Table 5.5. The percentages in parenthesis are for results from 8:00 AM- 9:00 AM.

Table 5.10 Summary of AM Simulation Calibration Results

	Mainline vol. %	Mainline vol. GEH	Ramp vol. %	Ramp vol. GEH	Seg. Travel Time	Total Trip Travel Time
NB	100% (100%)	95.2% (85.7%)	75.9% (79.3%)	93.1% (96.6%)	57.1%	Satisfied
SB	100% (100%)	91.5% (93.6%)	83.3% (79.2%)	95.8% (91.7%)	85.6%	Satisfied

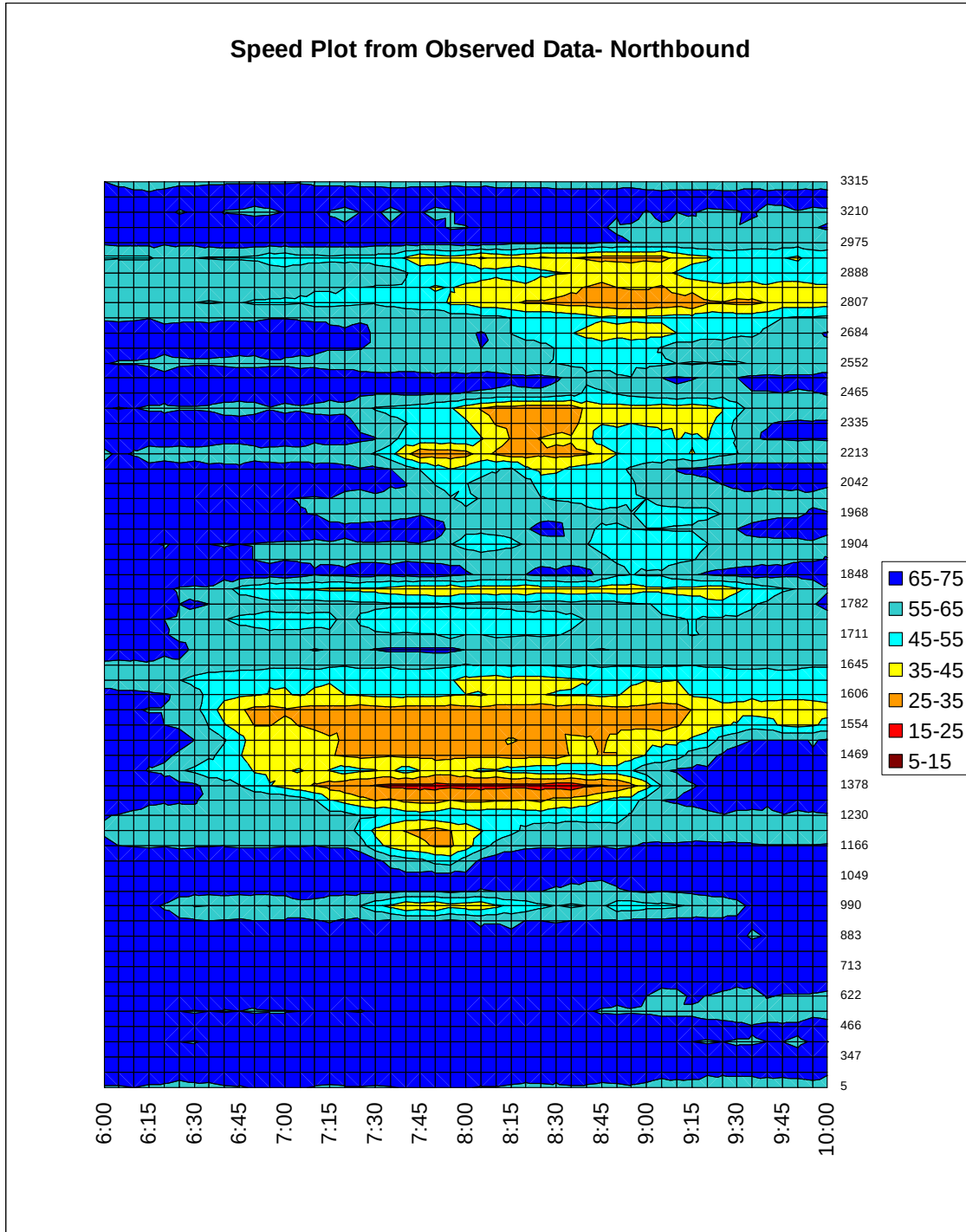
Table 5.10 shows that mainline volumes satisfy the criteria for both percentage and GEH.

Ramp volumes were more difficult to match due to the ramp data quality and coverage.

The calibration results still show a relatively reasonable match between the observed and simulation data for ramps. For travel times, the total trip travel times for both directions can be satisfied. However, a relatively large error is found for NB segment-based travel times. Further investigation is needed to resolve this issue.

5.5.3 Bottleneck Calibration Results

Figure 5.11 and figure 5.12 show the contour map plots of speeds from observed data and simulation results of the NB, respectively. Similarly, figure 5.13 and figure 5.14 show the speed contour maps from observed data and simulation results of the SB, respectively. From these four figures, we can find a general match of bottlenecks in observed data and that from the simulation. However, discrepancies still exist which requires further calibration efforts.



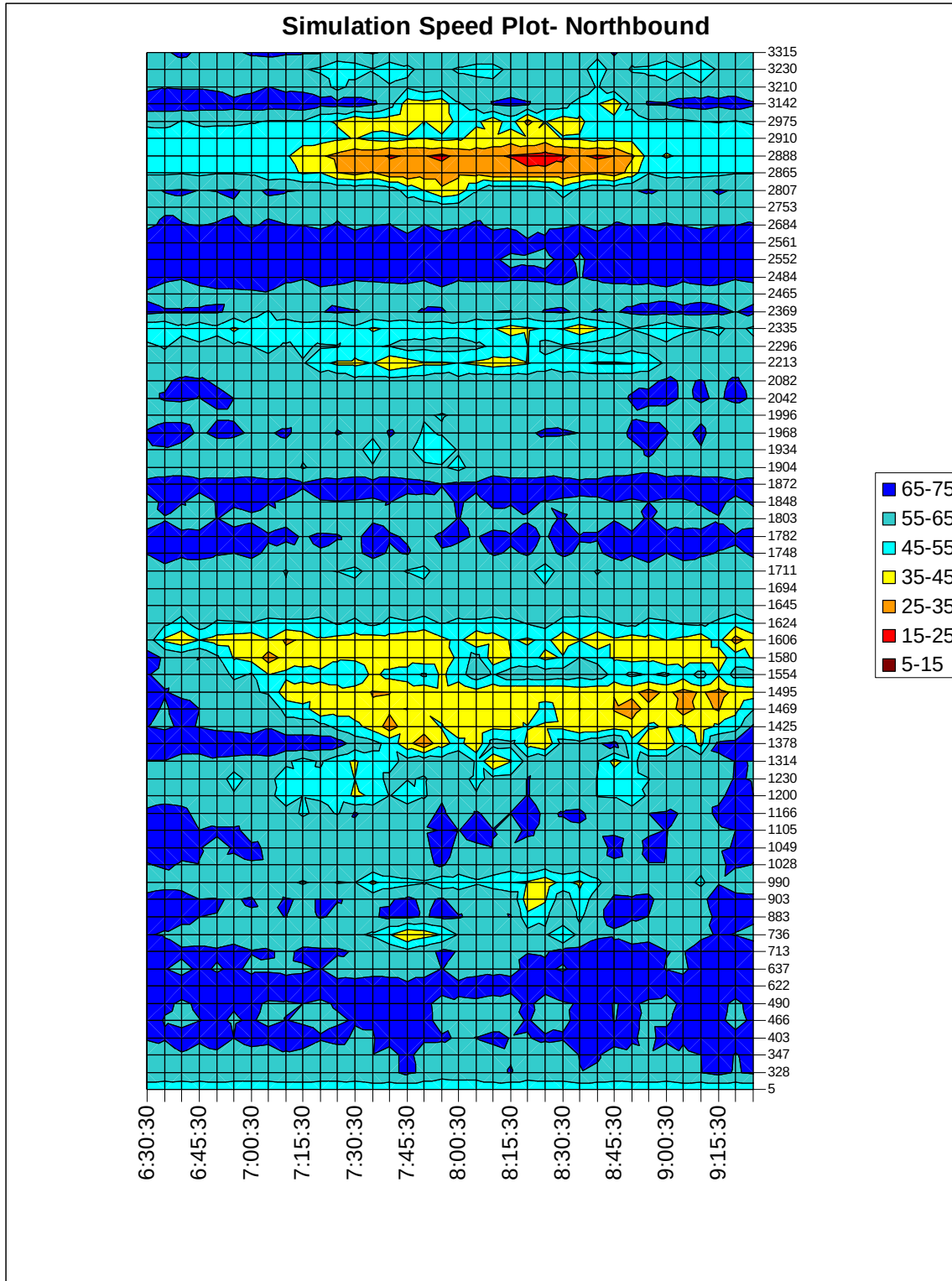
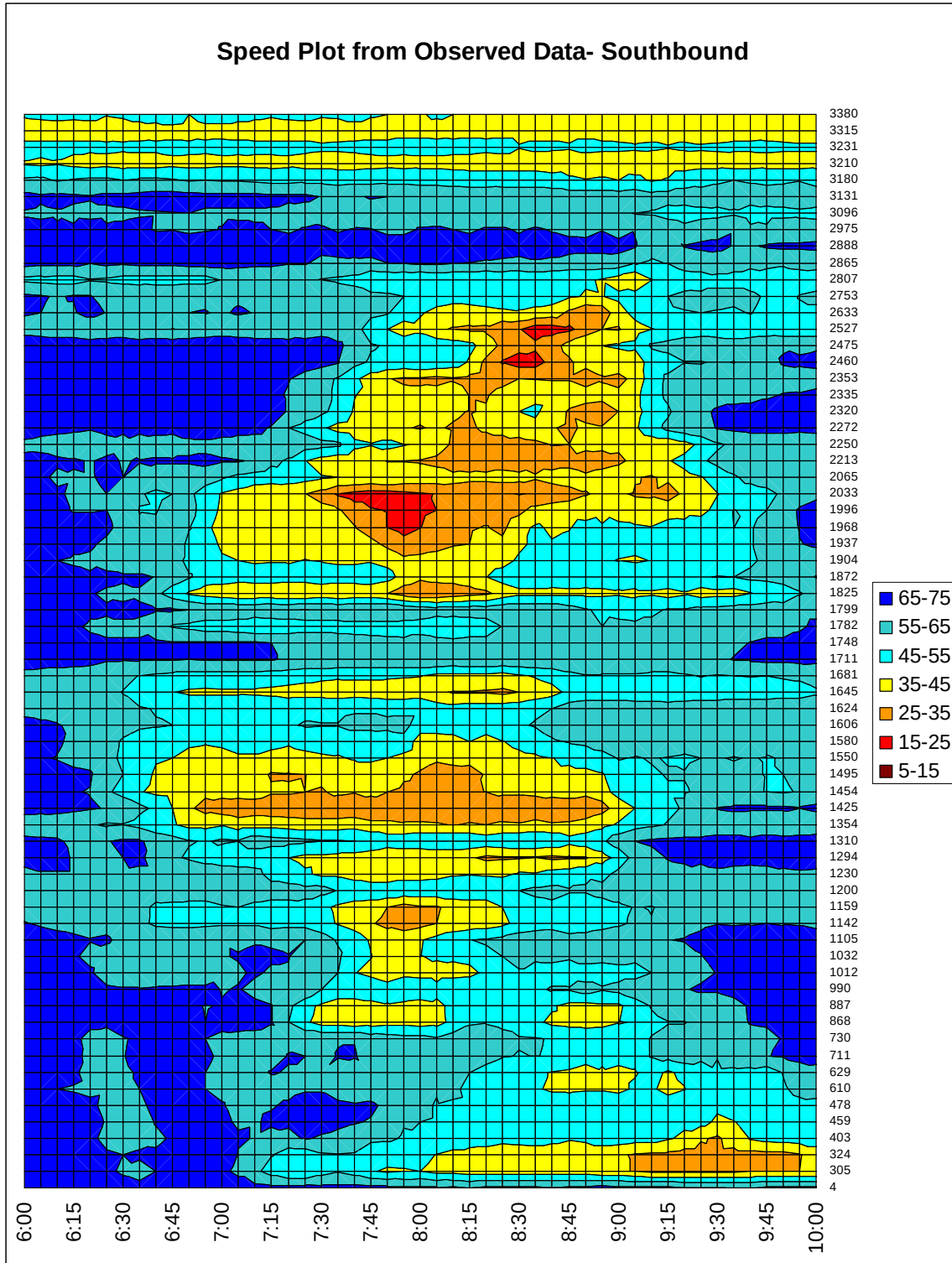


Figure 5.12 Speed Plot from Simulation Results (NB)



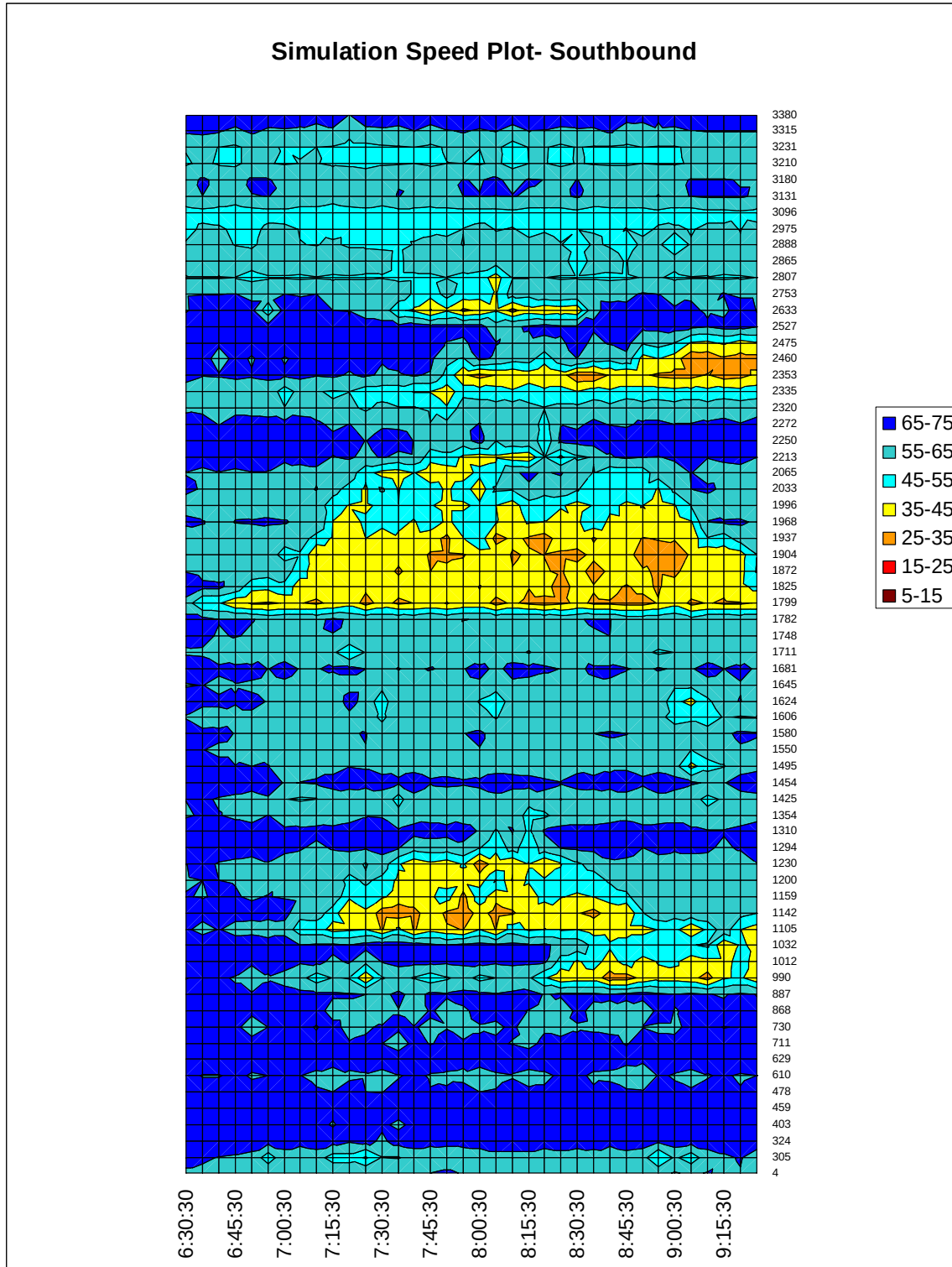


Figure 5.14 Speed Plot from Simulation Results (SB)

5.6 Challenges of Micro-Simulation Model Development

The two simulation studies in CMPD, especially the I-880 study, possibly represent the largest micro-simulation study that has been conducted to date. Developing such models imposed challenges in terms of dynamic OD estimation and model calibration.

First, to estimate dynamic OD matrices of large-size simulation networks such as I-880, the project team devised a new bi-level optimization method by combining the meso- and micro-level models with traditional travel demand models (Section 5.4.4). Extensive research efforts have been conducted by the project team to derive algorithms for the bi-level model so that accurate and reliability OD matrices can be estimated. Since solving the bi-level model requires multiple simulation runs, the algorithm is itself computationally intense. As a result, the dynamic OD estimation task took longer to complete than expected.

Second, the simulation model has deficiencies to capture some traffic phenomena. For example, the ramp-merging behavior in micro-simulation did not match well with real-world observations. This was especially true for the Tennyson interchange of the I-880 study. In fact, the simulation team spent a significant amount of extra time to calibrate the ramp merging model for the Tennyson interchange.

In addition, the calibration of large-scale micro-simulation models is typically difficult and time-consuming. Since to date no standard method is perfectly reliable, manual adjustment of model parameters is frequently required. As a result, model calibration is an iterative process, with more iterations are necessary as the simulation network

becomes larger. Given the scope of the corridor-level microsimulation attempted for these studies, many more manual iterations were required than expected.

In summary, the difficulty of simulation model development, together with challenges of data collection and addressing stakeholders' needs (e.g., arterial coverage) are among the major challenges for corridor-level microsimulation efforts.

6. Improvement Scenarios

Time and resource limits allowed the project team to generate improvement scenarios only with the SR-41 corridor in District 6. These scenarios include short-, medium, and long-term operational improvements. Evaluation of improvement scenarios had not been completed for the other corridor studies by the end of Task Order 3 (i.e., June 30, 2006). Instead, this will be conducted in the continuation task order (Task Order 1015) and the evaluation results will be presented in the subsequent Task Order 1015 report. As a result, this chapter will only summarize the improvement scenarios that were developed for SR-41 and will be evaluated further in Task Order 1015. Section 6.1 lists the scenarios for the SR-41.

6.1 Improvement Scenarios for SR-41

The improvement scenarios for the SR-41 corridor were generated from the planned and programmed projects in District 6, as depicted in Figure 3.7. In particular, Figures 6.1 - 6.3 illustrate the short-, medium-, and long-term improvement strategies, respectively. These strategies were initially identified by the project team and agreed by corresponding District 6 staff with some modifications. In these three figures, the numbers indicate the planned or programmed projects in District 6. Arrows indicate which projects were selected as improvement strategies in the SR-41 study.

- Construct auxiliary lane
 - SR41 NB @ Bullard-Herndon 3
 - SR41 NB @ Herndon-Friant 21
- Improve the ramp geometry
 - SR41 NB off @ Friant 12
- Dual left turn lanes and signal improvements
 - Bullard @ Blackstone 5
 - Tulare @ First 6
- Change priority and signal control
 - Shaw @ Fresno NEW
 - Friant @ Fresno NEW

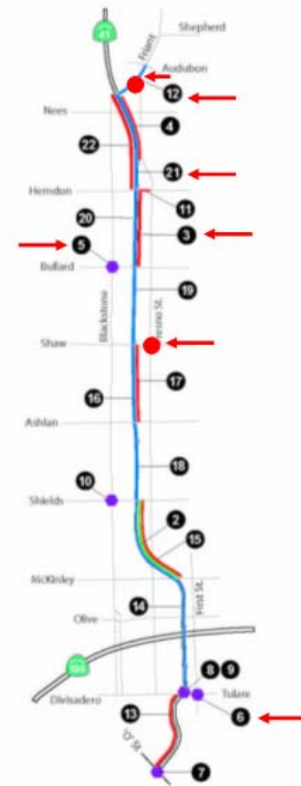


Figure 6.1 Short-Term Improvement Strategies for the SR-41 Corridor

- Dual left turn lane
 - SR41 NB @ Divisadero 8
 - Shields @ Blackstone 10
- New auxiliary lane
 - Herndon Ave. WB 11
- Intersections signalized
 - SR41 SB off @ O ST 7
 - Mariposa @ Divisadero 9



Figure 6.2 Medium-Term Improvement Strategies for the SR-41 Corridor

- **Auxiliary lane**
 - Friant Ave 12
 - SR41 SB @ Tulare to O St. 13
 - SR41 NB @ Shields to Ashlan 18
 - SR41 SB @ Friant to Herndon 22
- **Additional lane**
 - SR41 SB @ Friant to Divisadero New
 - SR41 NB @ Divisadero to Friant New
- **HOV lane**
 - SR41 SB @ Friant to Divisadero New
 - SR41 NB @ Divisadero to Friant New

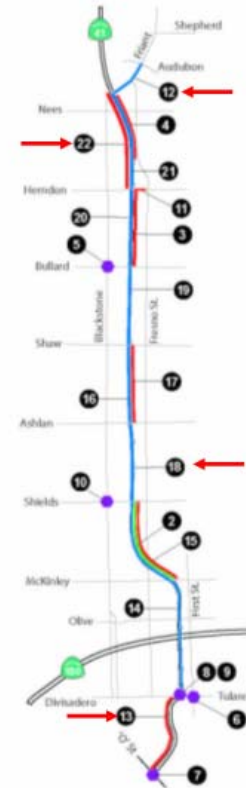


Figure 6.3 Long-Term Improvement Strategies for the SR-41 Corridor

7. Next Steps

7.1 Lessons Learned

A comprehensive documentation of lessons learned from the CMPD process will be completed as part of the continuation Task Order 1015, to be developed upon completion of the three demonstration corridor studies. These lessons learned will further identify and describe the challenges in development of the CMP template and corridor-level microsimulation models, as well as the application of these tools to system management practice at Caltrans.

7.2 Recommendations for Future Study

As noted in previous sections, Task Order 3 was not able to fully complete its planned activities as a result of a variety of factors. However, CCIT and its subcontractors plans to continue to assist Caltrans in refining, presenting, and developing consensus on findings and conclusions related to corridor management planning. The team recommends continuing to develop these studies as a means to help local Caltrans Districts implement corridor management strategies and make sound investment decisions. In order to achieve these goals, the team will continue to pursue stakeholders' involvement and update current performance measurements. The final product will be a set of tools and templates for Caltrans to conduct effective and efficient corridor management planning in the future. In particular, next steps will include the following tasks:

7.2.1 Stakeholder Involvement

During the course of the CMPD project, all stakeholder groups, including those in Caltrans District 4, District 6, District 12, and other stakeholders (e.g., Department of Finance (DOF), Legislative Analyst's Office (LAO), and Business, Transportation & Housing Agency (BT&H)) have been briefed on the status of CMPD. However, in order to maintain momentum, additional presentations need to be provided at the request of stakeholders. For this purpose, the project team will continue to present the interim and final findings and conclusions to different local and State stakeholder groups as needed.

7.2.2 Finalizing the Three Simulation Studies

This task will finalize the three simulation studies currently under development. By the end of CCIT TO 3, the team completed the majority of the SR-41 study and had made significant progress on I-880 and I-5. In Task Order 1015, the team will complete the simulations and evaluations, as well as update performance measures and fill data gaps. This will make the final conclusions of the project more current and accurate.

For the I-5 corridor, we will finalize the simulation model development and scenario evaluations. This will require more data collections for arterials (such as turning volumes and signal timing of intersections, etc.), additional simulation calibrations and validations (such as truck OD estimations, etc.), and more scenario evaluations.

7.2.3 Developing the Template for Corridor Management Plans

During the CMPD project, the team has gained much experience on how to conduct corridor management plan studies. We also delivered various presentations and reports

regarding performance measurement evaluations and bottleneck analysis. For example, the SR-41 team has developed detailed simulation calibration procedures and OD estimation tools. The team has also been closely working with D6 engineers to apply the research findings and tools developed to conduct simulation study on AM peak period. Based on these experiences, the project team developed a template for I-880 corridor as an attachment of this report.

The SR-41 and I-880 studies represent, respectively, a mid-size and large corridor management study at a detail level that has never been performed before. Therefore, it may be meaningful to further verify the methodologies developed during these two studies on another corridor such as I-5. As a result, it would be beneficial to develop a more comprehensive template at the completion of the extended I-5 study by integrating experiences and lessons learned from all three studies.

The template to be delivered will serve to demonstrate and document procedures that Caltrans staff can use to conduct similar corridor management studies in the future. It will include the guidelines to develop a study work scope based on the target network, available resources and time frame, as well as procedures and tools to set up the microscopic traffic simulation framework and compute corridor performance measurements. It will also recommend processes to evaluate different corridor management strategies (including ITS strategies and/or operational improvements). The data requirement, collection, processing, and quality control issues for each of the major steps will also be summarized in the template.

7.2.4 Initial Implementation of Corridor Management Plans

The overall goal of the CMPD is to develop a corridor management planning template that analyzes and evaluates investment options within freeway corridors. To achieve this goal, the study team will work closely with the Districts with identified corridors to recommend projects to implement the selected corridor management plans, especially short term (0-5 years) recommendations. In addition, the team will offer development of Action Plans to help secure the funding required to implement the recommendations that yield the highest return on investment. For this purpose, the project team may present research findings, evaluation performances of planned improvement scenarios and recommended actions to various levels of decision makers. This may also require discussions with planning and programming managers and other decision makers to evaluate processes that ensure results of these investments are comparable to their projected benefits.

Appendices

Appendix A: System Metrics Group. Draft I-880 Corridor Management Plan. November 2006.

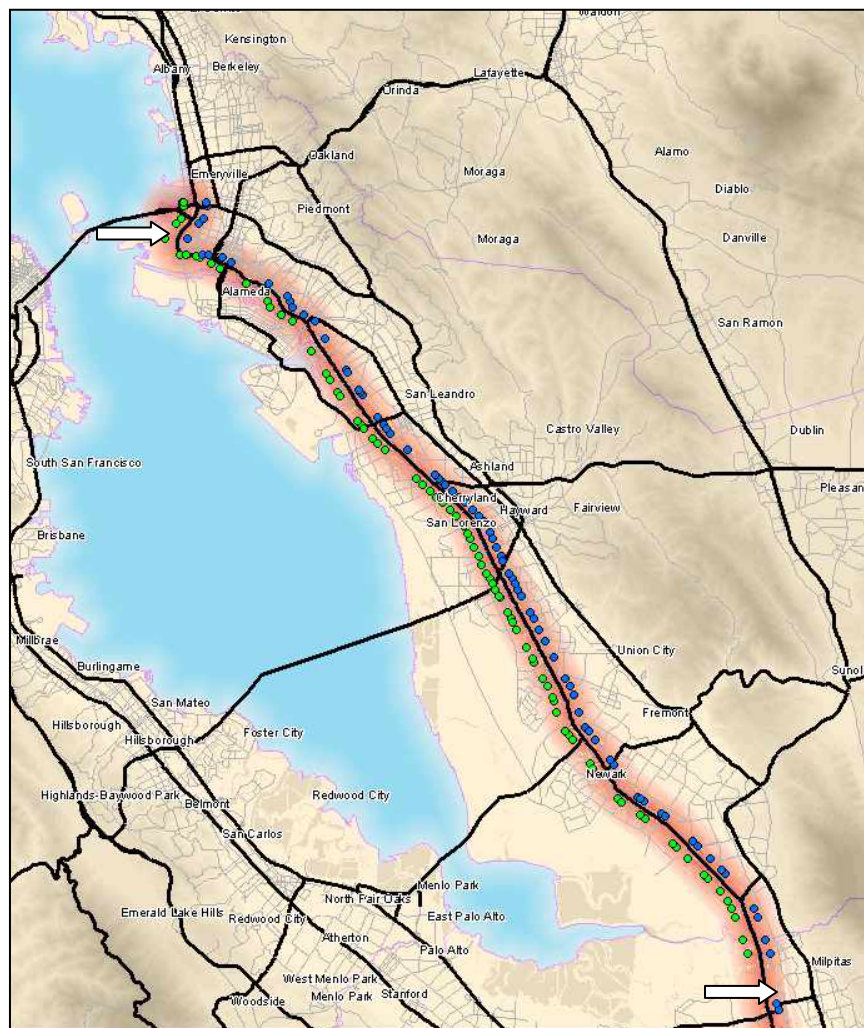
Appendix B: Ding, Liang. California SR-41 Corridor Simulation Study – Calibration Procedures and Results. 2005.

I. INTRODUCTION

This document presents the Model Corridor Management Plan for the Nimitz (I-880) Freeway corridor in the Bay Area from the SR-237 interchange in Fremont to the Grand Street interchange in Oakland. This plan represents the first attempt by the California Department of Transportation (Caltrans) to develop a phased plan that integrates operational analysis with more traditional system planning based on a foundation of comprehensive performance assessment and evaluation.

The corridor was selected by Caltrans District 4 (Bay Area) and its stakeholders, partly based on the availability of detection data needed for the critical performance assessment efforts. Exhibit 1 below shows the corridor boundaries (identified by the arrows) and its detection stations (shown as small blue and green dots).

Exhibit 1 – 880 Corridor Study Area and Detection Stations



What is a Corridor Management Plan?

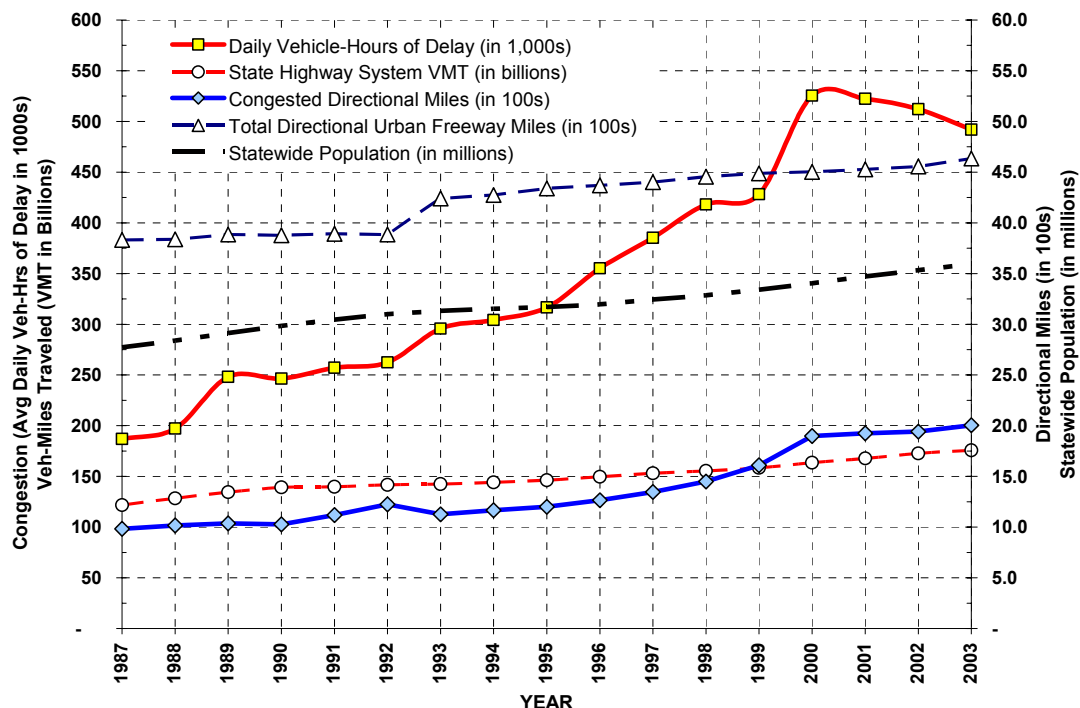
A Corridor Management Plan is a document that identifies the recommended system management strategies for a given State Highway System facility based on comprehensive performance assessment and evaluation. The strategies are phased and include both operational and more traditional longer range capital expansion strategies. The strategies take into account transit usage and projections and interactions with the arterial network.

As such, this corridor management plan serves as a “first cut” template that integrates the overall concept of system management into Caltrans’ planning and decision making processes. Moving away from the traditional approach of identifying localized freeway problem areas and finding solutions that are often expensive capital improvement focus, this project focuses on the corridor management plan approach with greater emphasis on performance assessments and operational strategies that yield higher benefit to cost results.

System Management

With the rising cost and complexity of construction and right of way acquisition, the era of building new facilities is coming to an end. On a “good” year, California, like so many other states in the country, grows its transportation infrastructure by less than two percent. Yet as demand for transportation keeps rising, congestion keeps increasing as well, as indicated in Exhibit 2.

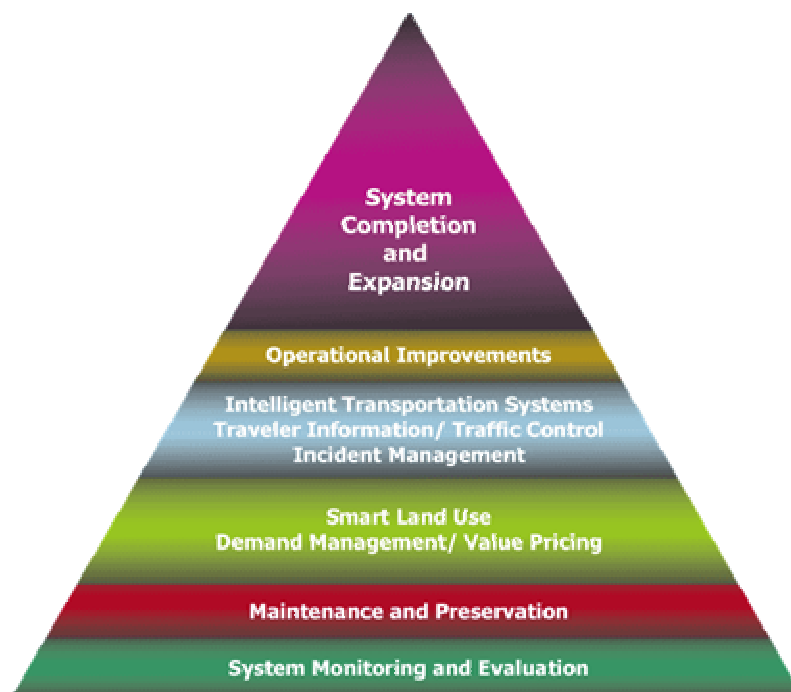
Exhibit 2 - California Freeway Traffic Congestion Growth Last 20 Years



As compared to the growth of population and vehicle miles traveled (VMT), congestion related delay is growing at a much higher rate. Clearly, infrastructure expansion has not kept and is not likely to keep pace with demand. So if conditions are to improve, or at least not deteriorate as fast, a new approach to transportation decision making and investing is needed.

Caltrans recognizes this emerging need as it recently adopted a “One Vision/One Mission” statement to improve mobility across California. It specifies a revised set of goals to help guide the State towards that new approach: productivity, reliability, flexibility, safety, and performance. The first three are new goals that call for improving the efficiency of the transportation system, reducing traveler delays due to incidents and road work, and making transit a more practical travel option. The last two are traditional but critical, ensuring the public’s safety and delivering the projects efficiently. This mission and its goals are consistent with the System Management pyramid shown in Exhibit 3.

Exhibit 3 – System Management Pyramid



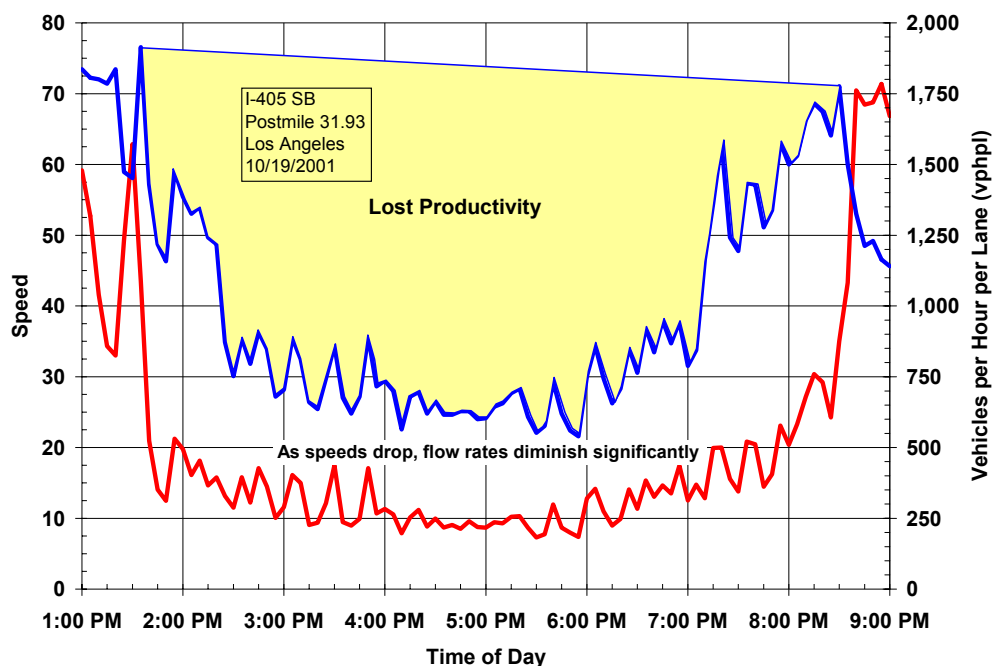
System Management (SM) is the wave of the future and is being touted at the federal, state, regional and local levels. SM addresses both transportation demand and supply to get the best system performance possible. Ideally, Caltrans and its regional partners would develop a regional system management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

Successful SM practices require a much closer coordination between planning and operations functions. Caltrans has recognized the need for such coordination and has embarked on an initiative to address it.

The foundation of system management is system monitoring and evaluation (the base of the pyramid) through comprehensive performance assessment and evaluation. Understanding how a corridor performs and why it performs the way it does is critical to crafting the appropriate strategies. An entire section of this document (Section IV) is dedicated to performance assessment. A relatively new measure merits a discussion here since it explains the increased emphasis on operational strategies. This measure is productivity.

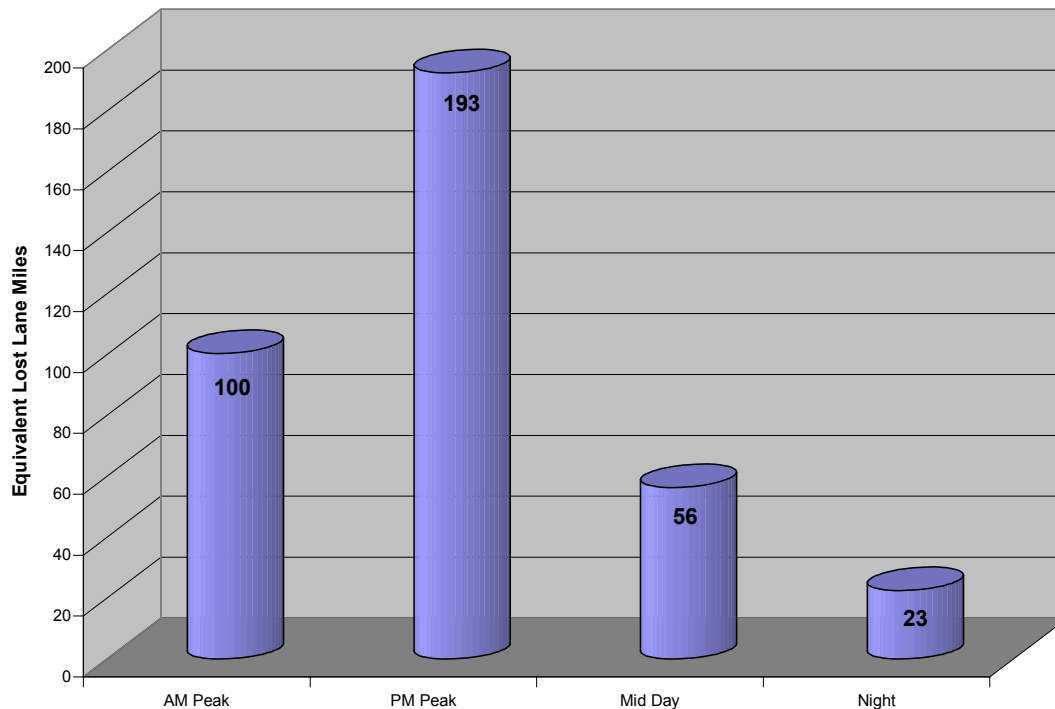
A critical goal of System Management is to “get the most out” of the existing system, or maximize system productivity. One would think that a given freeway is most productive during peak commute times. This is true for freeways not experiencing congestion. However, for California’s urban freeways that have been experiencing growing congestion, the opposite is true. Exhibit 4 illustrates how congestion leads to lost productivity. The exhibit represents speeds in red and flow rates in blue on one section of the 405 freeway in Los Angeles. It shows that once severe congestion starts (at around 2 pm) and speeds dip to 20 miles an hour, flow rates (the number of vehicles passing through the segment per hour) dips to below 750 per lane per hour. Given that design capacities for freeways are around 2,000 vehicles per hour per lane, actual flow rates during the congested period can represent a loss of more than 50 percent of this capacity. This loss, shown as the shaded area in the exhibit, is referred to as lost productivity and can be presented in terms of “Lost Lane Miles”.

Exhibit 4 – Productivity Loss During Severe Congestion



As shown in Exhibit 5, lost productivity, aggregated for Los Angeles County, was estimated to be equivalent to almost 200 lane miles during the afternoon peak commute periods. Stated differently, just when the region needed the most capacity, its freeways performed in least productive manner. This is a major cost of congestion that is rarely discussed or understood.

Exhibit 5 – 2003 Lost Productivity in Los Angeles County



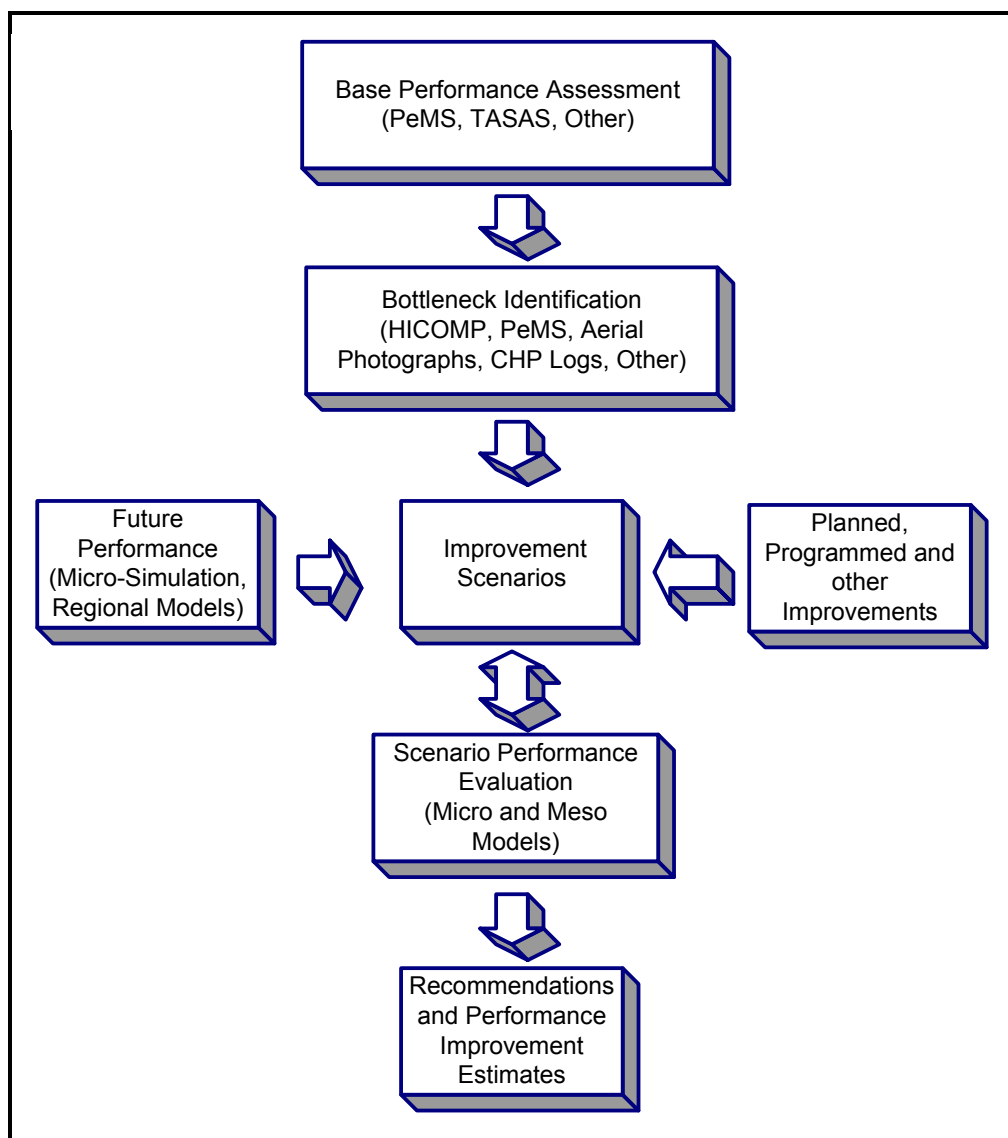
Losing almost 200 lane miles in the afternoon peak periods effectively means that approximately \$6 billion of our previous investments in the region were idled when demand is at its highest. The equivalent total for the entire State surpasses \$20 billion. Clearly, the State, if at all possible, must leverage these past investments to the extent possible and this can be done in large part by operational strategies.

Infrastructure expansion, although still an important strategy, cannot be the only strategy for addressing the mobility needs of Californians. System management is needed to get the most out of the current system and must be an important consideration as we evaluate the need for facility expansion investments. Simply stated, the system management philosophy begins by defining how the system is performing, understanding why it is performing that way, and then evaluating different strategies, including operations centric strategies, to address deficiencies. These strategies can then be evaluated using different tools to allow for estimation of the benefits and an evaluation of whether the benefits are worthy of the associated strategy costs.

Study Approach

The study approach and steps is shown on Exhibit 6 and includes the important data sources or tools used for each task (data needs and sources are discussed in the appendix section). Note that the base performance assessment relied on the Performance Measurement System (PeMS) developed by Caltrans and the Traffic Accident and Surveillance Analysis System (TASAS), also developed and maintained by Caltrans. These systems are invaluable for mobility, reliability, productivity, and safety analysis. Also note that throughout the study, stakeholders from all jurisdictions were involved to ensure acceptance of the final recommendations.

Exhibit 6 – Study Approach



The remainder of this document describes all the individual steps presented in Exhibit 6 except for the micro simulation activities which are addressed in a separate report developed by the University of California, Irvine (UCI). UCI was responsible for all micro simulation work during this project.

It is also important to note that different types of corridors require different approaches to developing corridor management plans. A highly urban and congested corridor (e.g., I-880, Freeway in the San Francisco Bay Area) requires more analysis and modeling to evaluate operations-centric strategies. A less urban and less congested corridor may require less modeling and more emphasis on safety and preservation issues. The “Lessons Learned” section of the appendix elaborates on these differences. The remainder of this document is organized as follows:

- Section II - Stakeholder Participation – which summarizes the efforts to involve stakeholders throughout the study
- Section III - Corridor Description – which describes the multi-modal corridor and the major facilities it serves.
- Section IV - Current Performance – which presents the results of the comprehensive performance measurement and evaluation efforts
- Section V - Expected Future Performance – which discusses expected future performance based on the micro simulation models
- Section VI - Recommended Improvements – which describes the projects and scenarios that were evaluated and recommends a phased implementation of the most promising set of strategies.
- Appendix
 - A – Data Needs for Corridor Management Plans
 - B – Lessons Learned

II. STAKEHOLDER PARTICIPATION

Corridor management plan require close participation of all critical stakeholders. Any strategies recommended for a major urban corridor will undoubtedly impact a number of different constituents and will therefore require their acceptance before implementation.

This is especially true for operational strategies on the State Highway System. For these strategies have the potential to impact the local arterial system, the transit agencies that use the corridor, and the planning agencies that have studied the corridor in the past.

In the case of the 880, the stakeholders that were invited to participate from the beginning of the study include:

- Cities along the corridor, including:
 - Hayward
 - San Leandro
 - Union City
 - Fremont
- The Alameda County Congestion Management Agency (ACCMA)
- The Metropolitan Transportation Commission (MTC)
- The Port of Oakland
- Alameda-Contra Costa Transit (AC Transit)
- The Association of Bay Area Governments (ABAG)
- Caltrans (headquarters and District 4)

The stakeholders are not only critical for overall study acceptance. In fact, they provided much of the non-freeway data to the UCI modeling team. The data provided included:

- The MTC travel demand model
- The ACCMA travel demand model
- Arterials to include in the simulation modeling effort
- Signal timing data for the arterials selected
- Project listings either programmed, planned, or under consideration
- Land use data from ABAG

It is therefore strongly recommended that every effort is made to include the relevant stakeholders for any similar study and to leverage their existing data to the extent possible.

More than 12 formal meetings and 20 presentations were conducted as part of the stakeholder participation efforts to date.

The presentations were more for decision makers for all these agencies, including:

- The ACCMA Board
- The California Transportation Commission,
- The Secretary of Business, Transportation, and Housing,
- The Caltrans District Directors,
- The MTC Deputy Director for Operations,
- The Department of Finance (DOF)
- The Legislative Analyst Office (LAO).
-

These presentations received a very good response and Caltrans was commended for this new approach to planning and decision making.

III. CORRIDOR DESCRIPTION

Within the Caltrans District 4 area and the Northern California Bay Area region, the I-880 East Shore South corridor from the Grant Avenue to SR-237 was selected for this study based on a number of criteria:

- Serve significant inter-regional travel
- Multi-modal in nature
- Congestion is high and projected to grow
- High potential for benefits and B/C ratios
- Good detection infrastructure and data
- Serve the goods movement industry

Note that other corridors, especially the I-580 and the I-80 were originally preferred by the stakeholders. However, due to the lack of detection on these corridors and the need for the detection for a comprehensive performance assessment, the I-880 was selected instead.

Freeway

The I-880 corridor selected for this study begins from the SR-237 interchange in Fremont to the Oakland to Grant Avenue. SR-237 runs in an east-west direction with connectors to the northbound and southbound segments of the I-880. The eastbound SR-237 to northbound I-880 connector has three travel lanes with two metered single occupancy vehicle (SOV) lanes and one high occupancy vehicle (HOV). The right-most lane drops approximately 560 feet north of the merge providing a total of five travel lanes for northbound traffic.

Southbound traffic at this interchange provides three through lanes and two exit lanes to eastbound SR-237. Outside shoulders are approximately 8-feet wide while inside shoulders range from approximately 18- to 25-feet wide. A concrete median divides the freeway. North of the California Circle interchange, both the northbound and southbound directions are reduced to three through travel lanes.

A peak hour HOV lane begins at the SR-262 interchange with an auxiliary lane that extends from SR-262 to the Fremont Boulevard interchange. In this segment, the freeway has three through travel lanes, one peak-hour HOV lane in each direction, and intermittent auxiliary lanes to facilitate merging and diverging traffic.

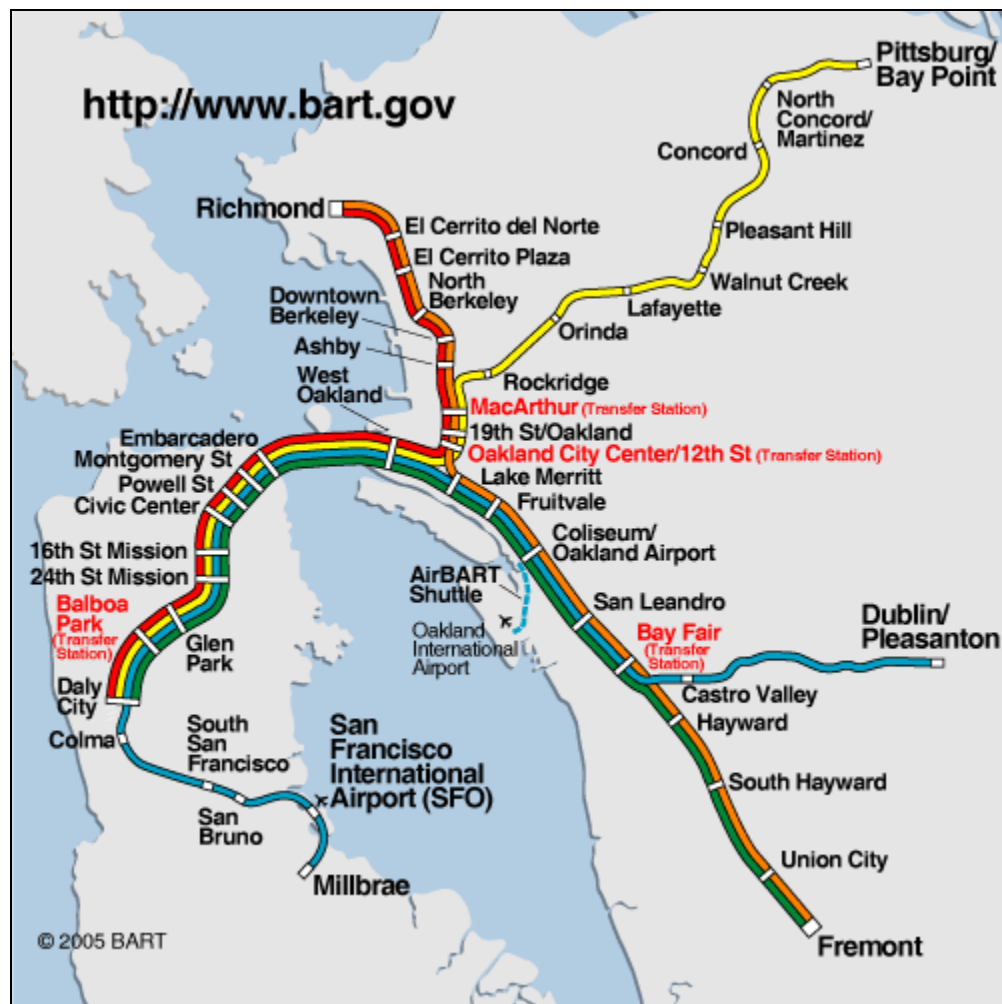
From the SR-92 to the I-238 interchange, both northbound and southbound lanes have four through travel lanes and one peak-hour HOV lane. From the I-238 interchange to the I-980 interchange, the number of total travel lanes varies from four to five in each direction. The peak-hour HOV lanes end north of the I-980 with three to four travel lanes in each direction. Major interchanges in this study corridor include the SR-237, SR-238, SR-84 (Dumbarton Bridge), and SR-92 (San Mateo-Hayward Bridge).

The I-880 corridor is a Surface Transportation Assistance Act (STAA) route and therefore large trucks are allowed to operate on it. The segment just south of the I-980 interchange to Alameda is a California Legal Advisory route. According to the 2004 Annual Average Daily Truck Traffic on the California State Highway System published by Caltrans in August 2005, this segment of the study corridor's 2004 daily truck traffic ranges from 4.4% to 10.7% of the total daily traffic.

Transit

Major transit operators within this regional corridor are the Bay Area Rapid Transit (BART) and the Alameda-Contra Costa Transit (AC Transit). Intercity rail service from Amtrak also offers service from Sacramento to the Bay Area region. The Fremont line, shown as part of the BART map on Exhibit 7 below, serves an almost parallel route to the I-880 corridor under study.

Exhibit 7 – Bay Area Rapid Transit Map



BART service operates on Mondays through Fridays from 4 a.m. to midnight, on Saturdays from 6 a.m. to midnight, and on Sundays from 8 a.m. to midnight. In many cases, service extends beyond midnight depending upon the station coordination of the last running train. Based on the BART Station Profile Study conducted by San Francisco Bay Area Rapid Transit District in 1999, BART surveys show an average daily ridership of more than 300,000. Several million Bay Area residents take BART each year, often for occasional travel to events, shopping, or visiting friends and family.

On a typical weekday however, most of BART's customers are regular riders who use BART to commute to work. With regional population growth expected to grow to 7.8 million in 2020, a 22% increase from 1995, and the elderly population expected to also nearly double during this period, forecasts show that the BART ridership could potentially be affected by the growing population and changes in more flexible work schedules.

The BART Fremont service lines serve the I-880 corridor by providing connectivity to three end points:

- The Fremont to Richmond line provides connectivity between Fremont to Oakland, Berkeley, and Richmond.
- The Fremontline also allows transfers at the Oakland City Center/12 Street and MacArthur to provide a connection to the Pittsburg/Bay Point terminus
- The Fremont to Daly City line starts from Fremont with transfer stations at Bay Fair and Balboa Park where the connection provides access to San Francisco International Airport and Millbrae.

The BART Strategic Plan was adopted in 1999 and updated in 2003. The BART's system capacity goal is to create capacity for the BART core system to carry 500,000 average weekday riders by 2025. Subject to funding, the BART may be extended south of the Fremont terminal to Warm Springs, providing additional access to handle future increased ridership along the I-880 corridor.

The Alameda-Contra Costa Transit District (AC Transit) serves more than 100 local lines within the East Bay and more than 27 Transbay to San Francisco and the Peninsula. As the third largest all-bus system in California, AC Transit provides connection to 21 BART stations. AC Transit's strategic vision anticipates that ridership will be increased to approximately 100 million per year by 2010. A new Transbay Terminal in downtown San Francisco is expected to begin construction in 2008 and completed within five years. This rebuilt structure will be a modern and multimodal facility that would serve more than 100,000 passengers a day on Transbay buses, Muni, intercity buses and Caltrain and ultimately California High Speed Rail services.

AC Transit Line S West Hayward runs parallel to I-880 from Oliver Eden Shores Park to the San Francisco Transbay Terminal via the I-880 with no stops. This line operates

during the weekday directional commuting peak hours from 5:16 a.m. to 8:45 a.m. in the westbound direction and from 4:10 p.m. to 7:10 p.m. in the eastbound direction with frequencies ranging from 30 to 45 minutes. The Line SA Washington Manor runs south of I-880 starting from the San Lorenzo Village station to the San Francisco Transbay Terminal via the I-880 with no stops. This line also operates during the weekday directly commuting peak hours from 5:20 a.m. to 8:45 a.m. in the westbound direction and from 4:00 p.m. to 7:45 p.m. with frequencies ranging from 20 to 45 minutes. The Line SB Newark runs south of I-880 from the Cedar Boulevard & Stevenson Boulevard intersection to the San Francisco Transbay Terminal also via the I-880 with no stops. This line also operates during the weekday directional commuting peak hours from 5:17 a.m. to 8:40 a.m. in the westbound direction and from 4 p.m. to 9:15 p.m. in the eastbound direction with frequencies from 20 to 45 minutes.

The Line OX runs along the freeway from Park Street in Oakland to the San Francisco Transbay Terminal. This line operates during the weekday directional commuting peak hours from 5:30 a.m. to 9:00 a.m. in the westbound direction and from 4:10 p.m. to 8:39 p.m. in the eastbound direction with frequencies from 10 to 20 minutes. The Line O also runs along the freeway from the Posey and Webster Tube in Oakland to the San Francisco Transbay Terminal. Line O operates daily with frequencies from 10 to 45 minutes. In the westbound direction during the weekdays, it operates from 5:26 a.m. to 12:10 a.m. In the eastbound direction during the weekdays, it operates from 6:22 a.m. to 12:41 a.m. During the Saturdays, Sundays, and holidays, the westbound line operates from 6:01 a.m. to 11:29 a.m. and the eastbound line operates from 6:25 a.m. to 12:51 a.m.

The Line W runs along the freeway from the Oakland Posey and Webster Tube along the freeway to the San Francisco Transbay Terminal. This line operates during the weekday directional commuting peak hours from 5:46 a.m. to 9:00 a.m. in the westbound direction and from 4 p.m. to 8:49 p.m. in the eastbound direction with frequencies of 20 minutes.

The Amtrak Capitol Corridor (Auburn-Sacramento-Emeryville[San Francisco]-Oakland-San Jose) provides service between the Sacramento region and the Bay Area with many stops in between. It starts at Auburn, runs southwest to Emeryville and terminates south at the San Jose transfer station to Caltrain and motorcoach service lines south of San Jose. A station is available just south of the SR-237 and I- 880 interchange in Santa Clara and the line runs adjacent to I- 880 to north of Oakland and Sacramento.

Intermodal Facilities

The Port of Oakland is a major seaport facility that is growing and planning to capture a larger share of west coast maritime activities. The Port currently processes almost 1.7 Twenty-foot Equivalent Units (TEUs) annually. As such, the Port is a major origin and destination of significant truck trips. An aerial of the Port is shown in Exhibit 8.

Exhibit 8 – Port of Oakland Aerial



Ten Container terminals and two intermodal rail facilities serve the Oakland waterfront. The Union Pacific and the Burlington Northern and Santa Fe Railway Company (BNSF) railroad facilities are located adjacent to the marine terminal area to provide a reliable and efficient movement of cargo between the marine terminals or transload facilities and the intermodal rail facilities.

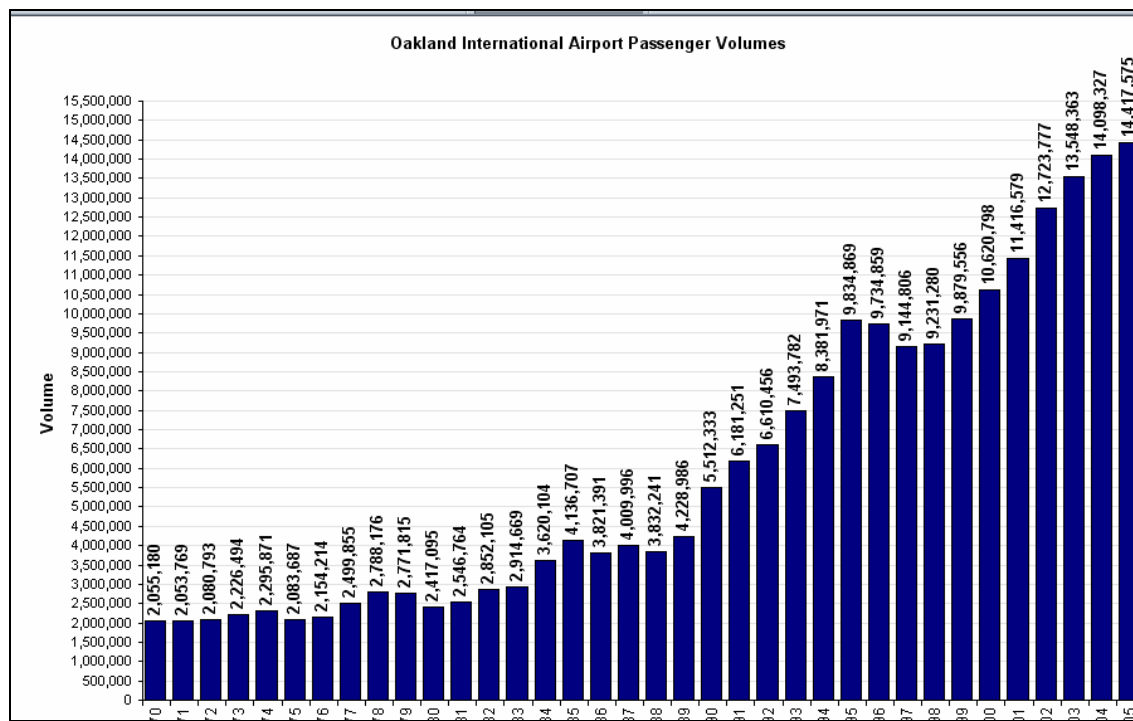
Through its Vision 2000 Maritime Development Program, the BNSF and Port of Oakland reached an agreement in 2002 for BNSF to operate the Port's Joint Intermodal Terminal, known as Oakland International Gateway. BNSF will also be able to provide service to other third parties for this facility, which will also benefit the community by taking more than 20,000 truck moves a year off Interstate 80. Oakland International Gateway ties into BNSF's rail network by way of trackage rights and specific access conditions approved by the Surface Transportation Board (STB) to BNSF as part of the 1995 Union Pacific/Southern Pacific Merger Settlement Agreement.

The 880 also serves the Oakland Airport, which grew even after the 9/11. Exhibit 9 below summarizes some demand related statistics of the airport and Exhibit 10 shows the overall trend for passenger volumes over time. Note that in 2005, the airport passenger volumes exceeded 14 million, therefore representing significant demand on the 880 corridor.

Exhibit 9 – Oakland Airport Passenger and Cargo Statistics

Passengers:	2004	2005	Difference From 2004	Percent Annual Increase/Decrease
Enplaned:	7,066,037	7,215,905	149,868	2.12%
Deplaned:	7,032,290	7,201,670	169,380	2.41%
Total:	14,098,327	14,417,575	319,248	2.26%
Air Cargo: (metric tons)	2004	2005	Difference From 2004	Percent Annual Increase/Decrease
<i>Freight</i>				
Inbound:	324,051	318,438	-5,613	-1.73%
Outbound:	341,729	347,879	6,150	1.80%
Total:	665,780	666,317	537	0.08%
<i>Mail</i>				
Inbound:	2,999	2,829	-170	-5.66%
Outbound:	2,377	2,199	-178	-7.50%
Total:	5,376	5,028	-348	-6.47%
Total Air Cargo: (freight + mail)	671,156	671,345	189	0.03%
	2004	2005	Difference From 2004	Percent Annual Increase/Decrease
Landed Weight (000): (in pounds)	12,534,134	12,776,710	242,576	1.94%
Commercial Operations:	186,550	187,693	1,143	0.61%

Exhibit 10 – Oakland Airport Passenger Volume Trends



Special Event Facilities

The 880 Corridor also serves the McAfee Coliseum, which is the home stadium for Major League's Baseball's Oakland Athletics and the National Football League's Oakland Raiders. Right next to it is the enclosed Sports Arena which is the home of the National Basketball Association's Golden State Warriors. Between these three professional franchises, there are more than 130 events that impact the mobility on the 880. Other events such as concerts also contribute to the transportation demand on the 880 corridor. An aerial of the McAfee Coliseum and the Sports Arena is shown on Exhibit 11 below.

Exhibit 11 – McAfee Coliseum and Adjacent Sports Arena Aerial



Land Use

The Association of Bay Area Governments (ABAG) is a regional land use planning agency responsible for describing existing conditions, forecasting changes to the population and economy, and assisting local governments to identify policies that address a changing environment.

The traditional focus of ABAG's research and analysis has been its biennial long run forecast of the region known as Projections. The next forecast, Projections 2007, is expected to be issued at the end of 2006. Projections 2007 will describe the changes in population, housing and employment within the region over the next 25 years.

ABAG also produces a short term forecast which identifies economic changes for the coming two years. This short term forecast is released each January at a special conference. The conference information includes a state-level forecast, regional retail sales forecast information and information on the regional housing situation.

The ABAG Projections 2005 forecasted population, housing, jobs, and income for the nine-county San Francisco Bay Region to year 2030. Comparing Projections 2005 to Projections 2002 extended to 2030, the newer forecast predicts 121,970 more housing units.

The additional housing would mean that almost 330,000 additional residents will live in the region by 2030. The additional housing is also expected to provide a home for approximately 180,000 more employed residents than forecasted by the Projections 2002 base-case forecast. The increase in employed residents is significant, when compared to the number of jobs in the region, because it gives a rough estimate of the net interregional commute.

Projections 2005 forecasts over 46,000 fewer jobs than Projections 2002. This is a result of the slow pace of job growth in the Bay Area during the early part of the forecast. With the forecasted increase in residents by 2030, the Construction and goods and services sector jobs are expected to increase while jobs in other economic sectors are expected to slow due to the slower economy of the last few years.

Projections 2005 also included forecasts based on implementation of Smart Growth policies. It assumes that state, local, or regional policy makers would change land use policies or other types of funding decisions in a way that would change regional development. This in effect results in a higher number of housing units produced than under previous forecasting assumptions. Although ABAG did not adopt the numerical values of the Smart Growth Vision, the Projections 2005 analysis included information from the Smart Growth Vision.

Government Lands

As shown in Exhibit 12, the 880 Corridor includes an array of government-owned lands. Within three miles of the corridor nearly 50 square miles are owned by federal, state, or local governments. Most of the land consists of recreational areas and abandoned military bases, including:

- Oakland Army Terminal, which was closed as part of a 1993 government base closure program. The Oakland Base Reuse Authority approved plans for conversion to civilian use, involving creation of an industrial park and job-training center, with much of the waterfront being placed under control of the Port of Oakland.

- *Alameda Naval Station*, which was the headquarters for Fleet Air Pacific, but closed as part of a 1993 government base closure program
- *Coast Guard Island*, which is the Northern California Headquarters for the US Coast Guard
- *Knowland Park*, which includes the Oakland Zoo
- *Garin Regional Park*, a recreation area built on former ranch lands containing a blacksmith shop and exhibits about ranching history
- *Ardenwood Regional Preserve*, which is part of the East Bay Regional Park District and includes the Patterson Ranch mansion and gardens as well as a working demonstration farm
- *San Francisco Bay National Wildlife Refuge*, which encompasses over 18,000 acres of estuarine habitat, including uplands, open water, mudflats, salt ponds, and salt marshes

Exhibit 12: Government-Owned Land

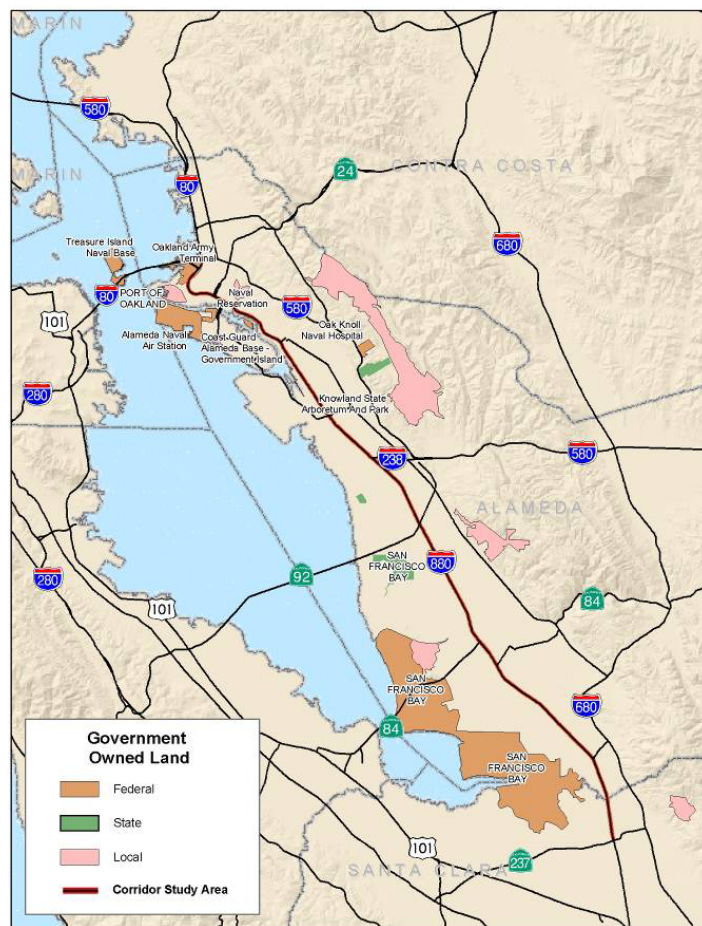


Exhibit 13 shows the location of 18 recreational area along the 880 Corridor. Extensive recreational opportunities are available and a number of these are part of the East Bay Regional Park District. There are no public or private golf courses within three miles of the corridor.

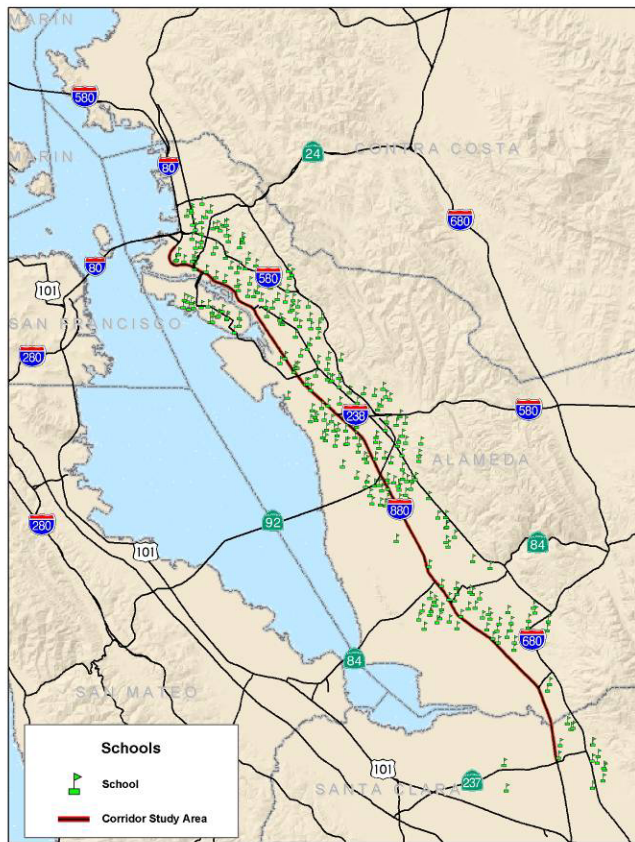
This map illustrates the San Francisco Bay Area, highlighting parks and a designated corridor study area. The map includes major highways (Interstates 580, 80, 880, 680, 280, 101, 205, 237, 24, 92, 84) and geographical features like the San Francisco Bay, San Francisco Peninsula, and various regional parks. A red line indicates the Corridor Study Area, which runs from the San Francisco Peninsula through the East Bay and into the South Bay. A legend in the bottom left corner identifies the symbols used.

Parks

- Parks
- Corridor Study Area

The 880 corridor includes over 275 public and private elementary schools, middle schools, high schools, and public academies. Exhibit 14 shows the location of these educational facilities. These schools impact the traffic on the I-880 corridor both in the morning and afternoon.

Exhibit 14: Educational Facilities



Hazardous Material Sites

According to the hazardous waste sites database provided by Caltrans District 4, there are more than 44,000 sites within three miles of the corridor. These include sites identified by the State and the United States Environmental Protection Agency (US EPA) under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Resource Conservation and Recovery Act (RCRA). There are sites on the state priority list and two sites are on the national priority list (NPL).

Exhibit 15 shows the location of the seven largest sites:

- Site 1 (the former Alameda Naval Air Station) includes underground leaking storage tanks and is on the RCRA large generators list and the state priority list.
- Site 2 is on the Department of Toxic Substances Control Hazardous Waste and Substances Sites (Cortese) List
- Site 3 is on the state list of underground storage facilities.
- Site 4 is on the state CERCLIS list.

- ## ***Wetlands***

- Marine – open ocean overlying the continental shelf and coastline exposed to the open ocean

- Since the 880 corridor parallels the San Francisco Bay coastline, much of the adjacent land west of the corridor consists of estuarine wetlands (approximately 47,000 acres), as shown in Exhibit 16. Most of the other wetlands are lacustrine (approximately 20,000 acres) or palustrine (less than 7,000 acres).

IV. CURRENT PERFORMANCE

Comprehensive performance measurement and evaluation is the foundation for implementing the system management philosophy. Without understanding how any corridor performs and why it performs the way it does, it is impossible to truly practice system management. For the I-880 corridor, the performance assessment efforts included three critical steps as follows:

- Compute and evaluate corridor-wide performance and trends thereof
- Identify key bottlenecks
- Understand the relative contributions of each bottleneck to overall corridor performance

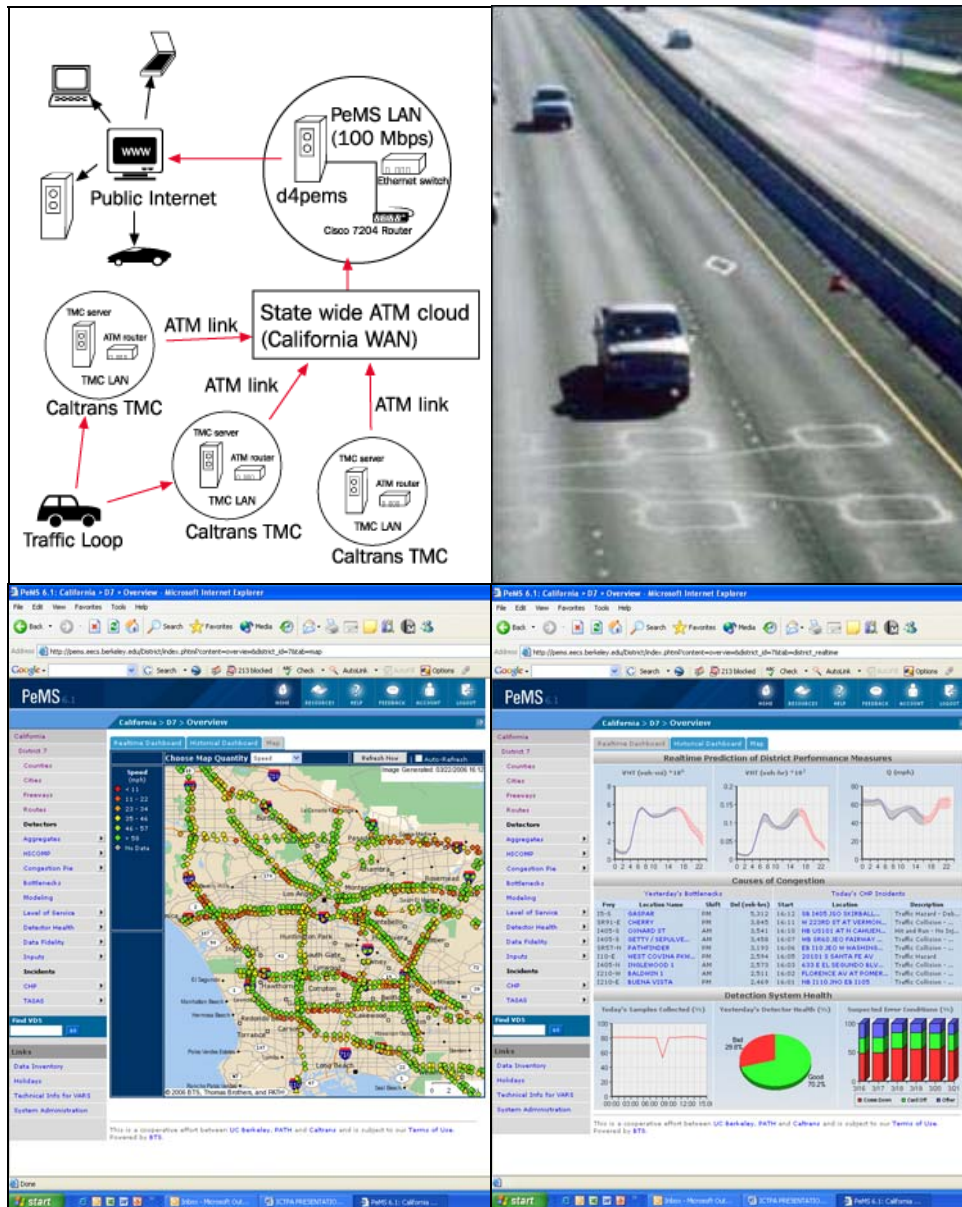
For this project, freeway performance was measured using the Performance Measurement System (PeMS), a software tool designed at UC Berkeley to host, process, retrieve and analyze road traffic conditions information. The PeMS database logs data from California freeway traffic detectors, as well as incident-related data from the California Highway Patrol (CHP) and weather data. PeMS features a web-based Graphical User Interface (GUI) that provides the ability to extract various representations of the data.

PeMS is a joint effort by Caltrans, the University of California, Berkeley, and PATH, the Partnership for Advanced Technology on the Highways, and is a traffic data collection, processing and analysis tool to assist traffic engineers in assessing the performance of the freeway system. PeMS extracts information from real-time and historical data and presents this information in various forms to assist managers, traffic engineers, planners, freeway users, researchers, and traveler information service providers. PeMS obtains 30-second loop detector data in real-time from each Caltrans District Transportation Management Center (TMC). The data are transferred through the Caltrans wide area network (WAN) to which all districts are connected. The 30-second data received by PeMS consist of counts (number of vehicles crossing the loop), and occupancy (the average fraction of time a vehicle is present over the loop). Exhibit 17 presents PeMS connectivity with the TMCs and two of its GUI screens.

PeMS processes the data in real-time and performs the following steps:

- Performs diagnostics on the data to determine if the loop detector is faulty;
- Aggregates 30-second values of counts and occupancy to lane-by-lane, 5-minute values
- Calculates the speed for each lane based on individual g-factors (which represent the average vehicle length) for each loop detector in the system
- Aggregates the lane-by-lane value of flow, occupancy, and speed across all lanes at each detector station (one station typically serves the detectors in all the lanes at one location)
- Computes performance measures
- Aggregates across geographical boundaries.

Exhibit 17 – PeMS Connectivity to TMCs and Example Screens



Corridor-wide Performance Measures and Trends

Corridor-wide performance measures were computed for three years (2003 through 2005) with the exception of safety performance results, which were computed using the Caltrans TASAS database from January 1999 through June, 2003. The measures computed include:

- Mobility Measures – Delay, travel time
- Reliability Measures – Variability of travel time

- Safety Measures – Number of collisions, number of incidents
- Productivity – Lost Lane miles

Corridor-Wide Mobility Results - Delay

Delay was computed for four time periods: AM peak (from 6 am to 9 am), mid day (9 am to 3 pm), PM peak (3 pm to 7 pm), and evening/early am (from 7pm to 6 am). Delay is computed as the difference in travel time between actual congested conditions and freeway conditions (assumed to reflect speeds of 60 miles per hour).

Exhibits 19 and 20 on the next page show the three-year trend in overall weekday delay (i.e., excluding weekends and holidays) for the three years analyzed for the northbound and southbound directions respectively. Note that the PM peak period generally has the highest delays, followed by the AM peak period. Looking at the two exhibits together, it is evident that the southbound travel experiences higher delays overall than the northbound direction. Finally, it is evident that delay varies significantly from day to day, week to week, and month to month. All the spikes on both exhibits show that using one or two days of data can lead to less than defensible conclusions. In 2005 for instance, some days experienced less than 4,000 hours of total delay, and others as much as 8,000 hours or more. Clearly, to truly compute “average delays”, the sample size of days must be quite large. For comparison purposes, we averaged delays for each year using the same data that was used to develop the charts. The results are shown below in Exhibit 18.

Exhibit 18 – I-880 Study Area Average Daily Delay by Time Period

Northbound Direction					
Year	AM Peak	Mid Day	Evening and Early AM	PM Peak	Total Daily
2003	1,499	1,237	552	2,547	5,835
2004	1,124	1,067	360	2,317	4,867
2005	1,331	1,434	285	2,351	5,402
Southbound Direction					
Year	AM Peak	Mid Day	Evening and Early AM	PM Peak	Total Daily
2003	1,924	1,397	276	2,249	5,846
2004	1,728	1,427	291	2,375	5,821
2005	1,678	1,848	232	2,444	6,202
Total Corridor					
Year	AM Peak	Mid Day	Evening and Early AM	PM Peak	Total Daily
2003	3,423	2,634	828	4,796	11,682
2004	2,852	2,494	651	4,691	10,688
2005	3,009	3,282	517	4,795	11,604

Interestingly, based on the data, 2004 showed reductions in delay northbound for every time period compared to 2003, while the southbound delays increased in all periods except for the AM Peak. 2005 showed more consistent delay increases for both directions. Average total daily delay (both directions) was almost 12,400 hours in 2005.

Exhibit 19 – Northbound Average Daily Delay by Time Period

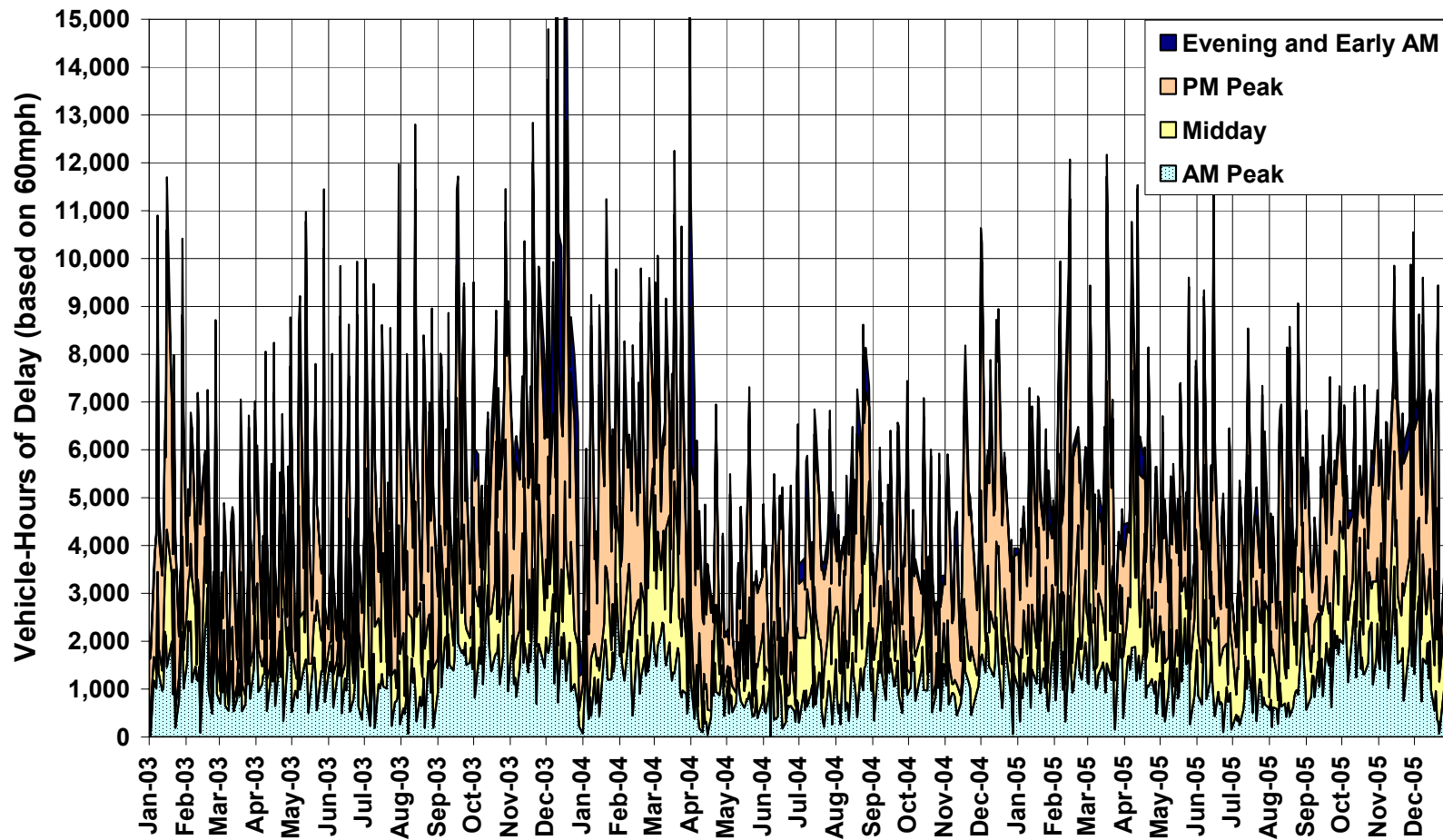
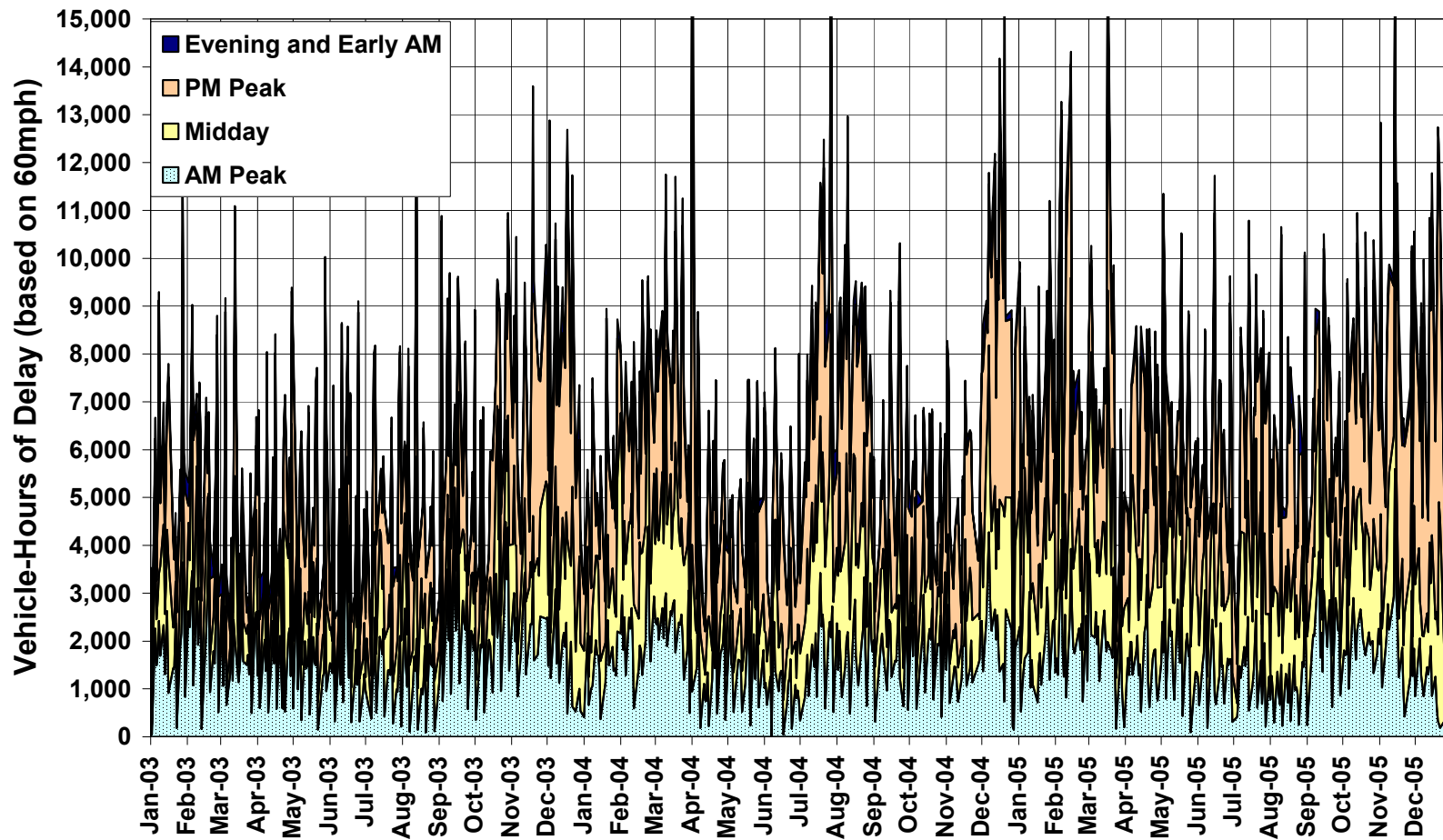


Exhibit 20 – Southbound Average Daily Delay by Time Period



The next set of exhibits enables further understanding of delay characteristics and trends. Exhibits 21 and 22 below show the average daily delay by month for the northbound and southbound by time period respectively.

Exhibit 21 – Northbound Average Monthly Daily Delay by Time Period

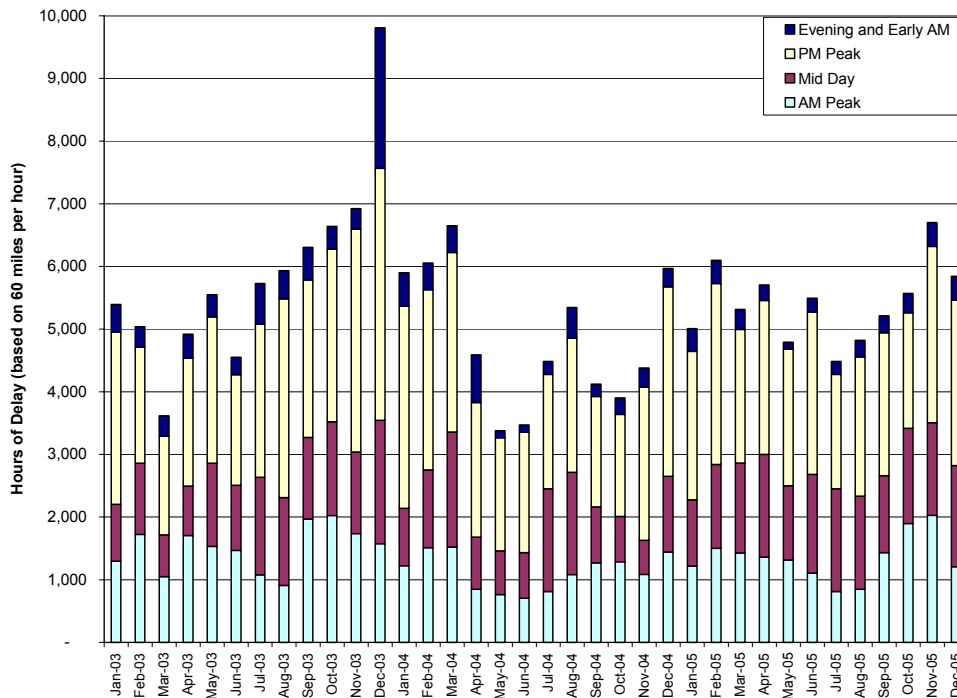
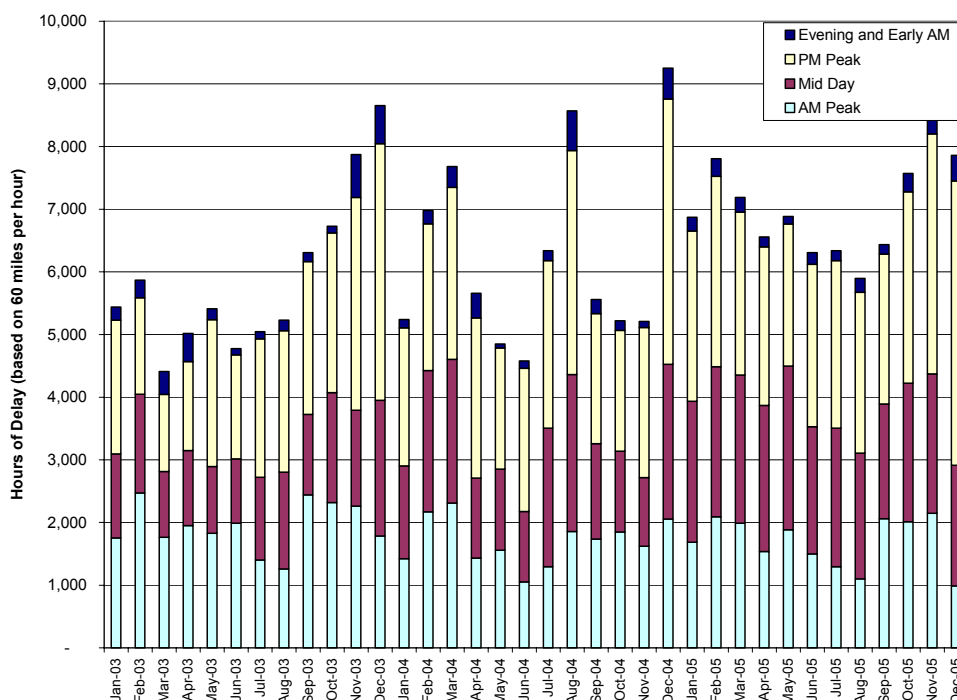


Exhibit 22 – Southbound Average Monthly Daily Delay by Time Period



These two exhibits better reflect the higher PM peak delays, the trend of increasing delays in 2005, and the fact that southbound delays are higher than northbound delays. They also show the seasonality of delay during the year. At this point, the outlier for evening/early morning delays in the northbound direction in December, 2003 has not been explained. It may be related to construction and/or maintenance activities that were undertaken at night.

As mentioned earlier, delays presented to this point represent the different in travel time between actual conditions and free flow conditions at 60 miles per hour. This delay can be segmented into two components:

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

Severe delay represents breakdown conditions and is generally the focus of congestion mitigation strategies. On the other hand, “other” delay represents conditions approaching the breakdown congestion, leaving the breakdown conditions, or areas that do not cause wide-spread breakdowns, but cause at least temporary slowdowns. Although combating congestion requires the focus on severe congestion, it is important to review “other” congestion and understand its trends. This could allow for pro-active intervention before the “other” congestion turns into severe congestion.

Exhibit 23 shows the severe congestion related delay averages by year for both the northbound and southbound directions. Exhibit 24 presents the information for the non-severe or “other” congestion related delay.

Note that severe congestion in the northbound direction increased on Mondays, Tuesdays, and Wednesdays in 2005 compared to 2004, whereas congestion decreased slightly on Thursdays and Fridays. For the southbound direction, every weekday, except for Thursday, shows increases in severe congestion.

Yet, non-severe, other congestion, increased more significantly than non-severe congestion. So whereas total weekday congestion increased by 9 percent in 2005 compared to 2004, severe congestion only increased by 7 percent and non-severe, other congestion increased by 20 percent. Why non-severe congestion grew by this large percentage is not totally clear, but during the field visits conducted for this study, it was observed that some bottlenecks were close to each other. So as drivers exited one bottleneck, there was not sufficient distance and time to fully accelerate before arriving at the queue related to the next bottleneck (more on that later). If this is the primary reason for the increase in non-severe delay, then it can be expected that as the bottleneck related queues extend back further, some of the non-severe congestion will transition into severe congestion (assuming demand continues to increase).

Exhibit 23 – Average Severe Congestion by Day of Week

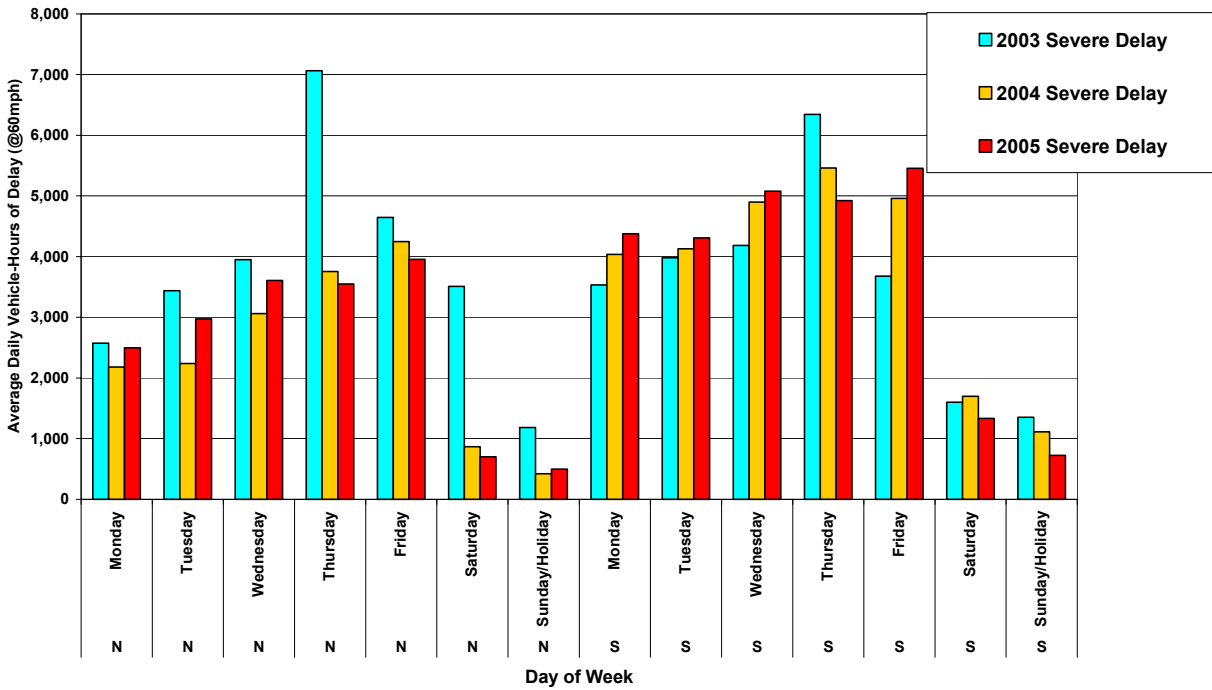
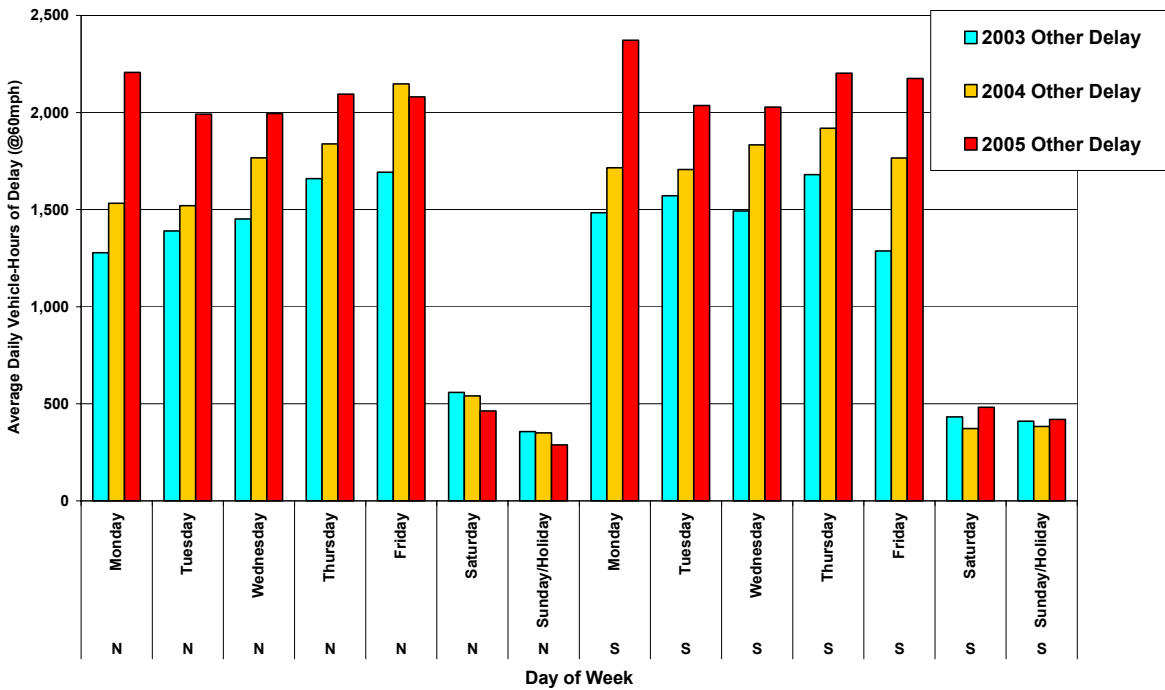


Exhibit 24 – Average Non-Severe, Other Congestion by Day of Week



Another way to understand the characteristics of congestion and related delays is shown on Exhibits 25 and 26, which summarize average weekday hourly delay for the three years analyzed.

Exhibit 25 – Average Northbound Weekday Hourly Delay

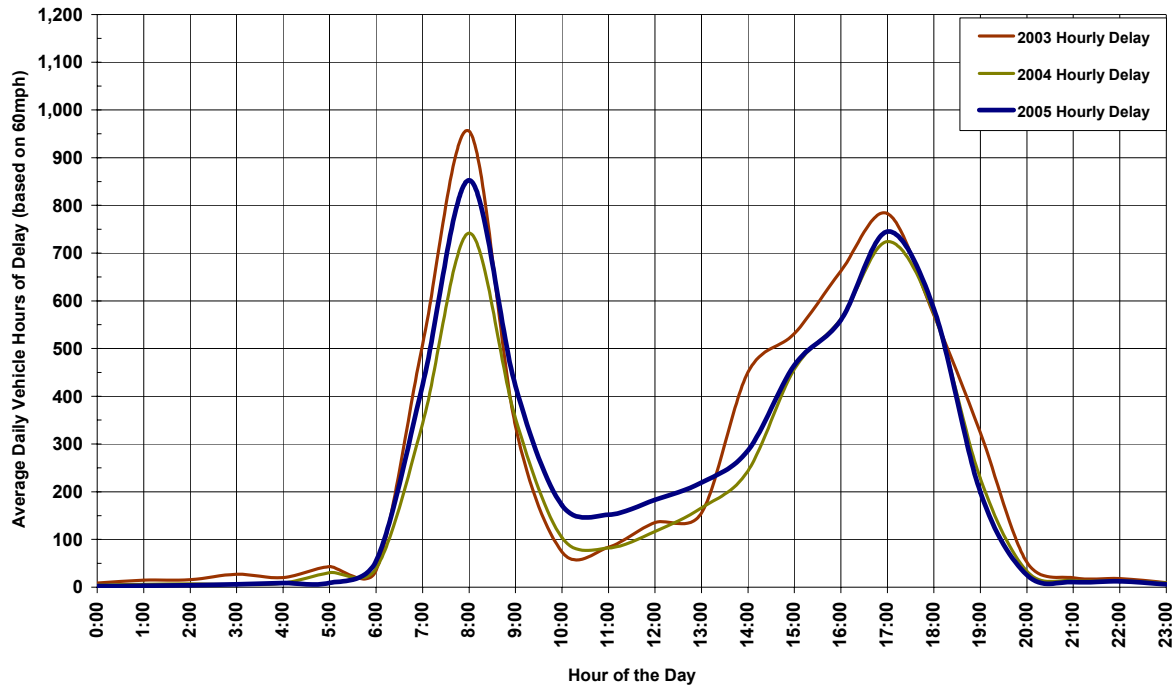
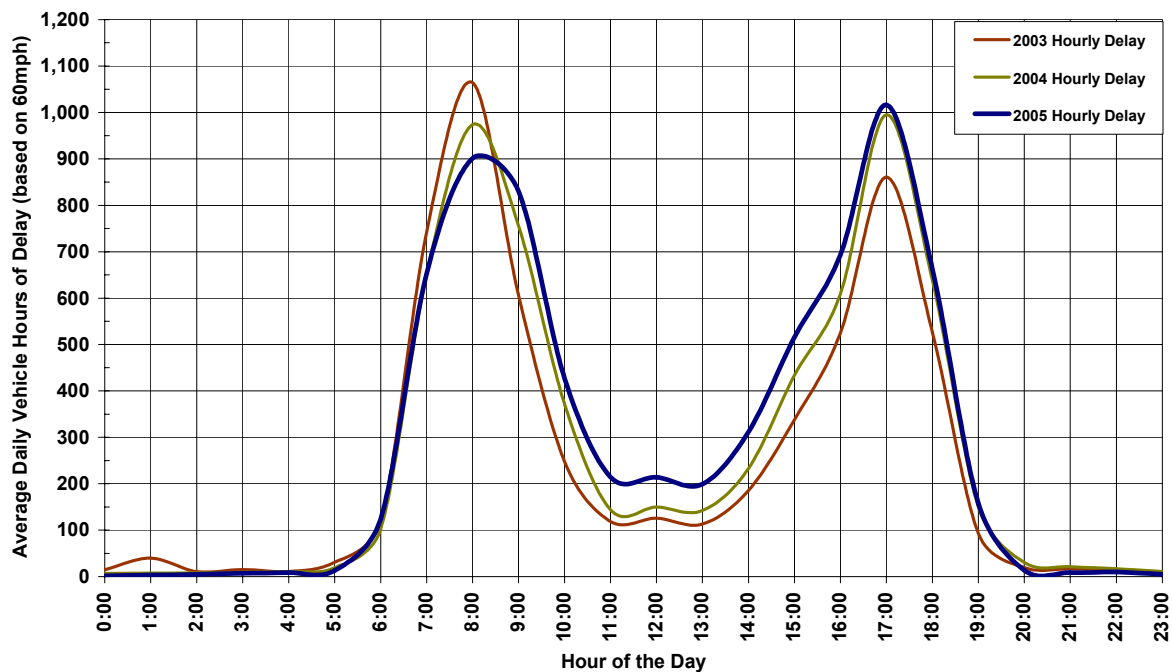


Exhibit 26 – Average Southbound Weekday Hourly Delay



These two exhibits help identify the peak hour for congestion both in the AM and PM peak periods (8 to 9 am in the morning, and 5 to 6 pm in the afternoon). They also help review “peak spreading” trends, which reflect the extent to which congestion spreads (or compresses) during the peak commute periods. Note that for the northbound direction, the PM peak in fact compressed in 2004 and 2005 compared to 2003. For the southbound direction, the afternoon congestion actually spread compared to 2003 and 2004.

Corridor-Wide Mobility Results – Travel Time and Reliability of Travel Time

In addition to understanding delay characteristics and trends, it is useful to understand the impacts of congestion on the traveler. The best mobility result the traveler relates to is travel time. How long does it take a driver to get from point A to point B?

For the purposes of the I-880 corridor study area, the entire corridor delineates points A and B. Travel time statistics provided represent either an entire southbound trip (from Grand Avenue to SR-237) or an entire northbound trip (SR-237 to Grand Avenue).

Obviously, these travel times differ by time of day. Exhibits 27 and 28 show the average weekday travel times by time of day for the three years analyzed for the northbound and southbound directions respectively. Note that the hourly travel time trends are consistent with the hourly delay trends in Exhibits 25 and 26 (which is to be expected).

Exhibit 27 – Average Northbound Travel Times by Hour

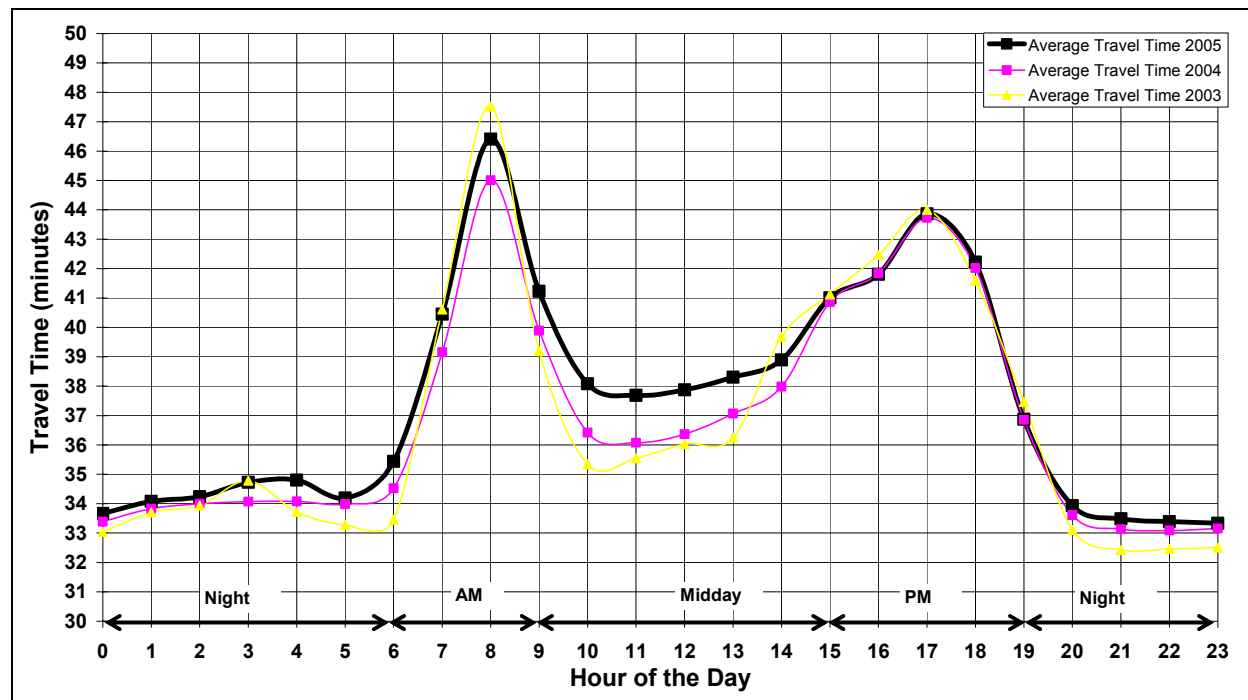
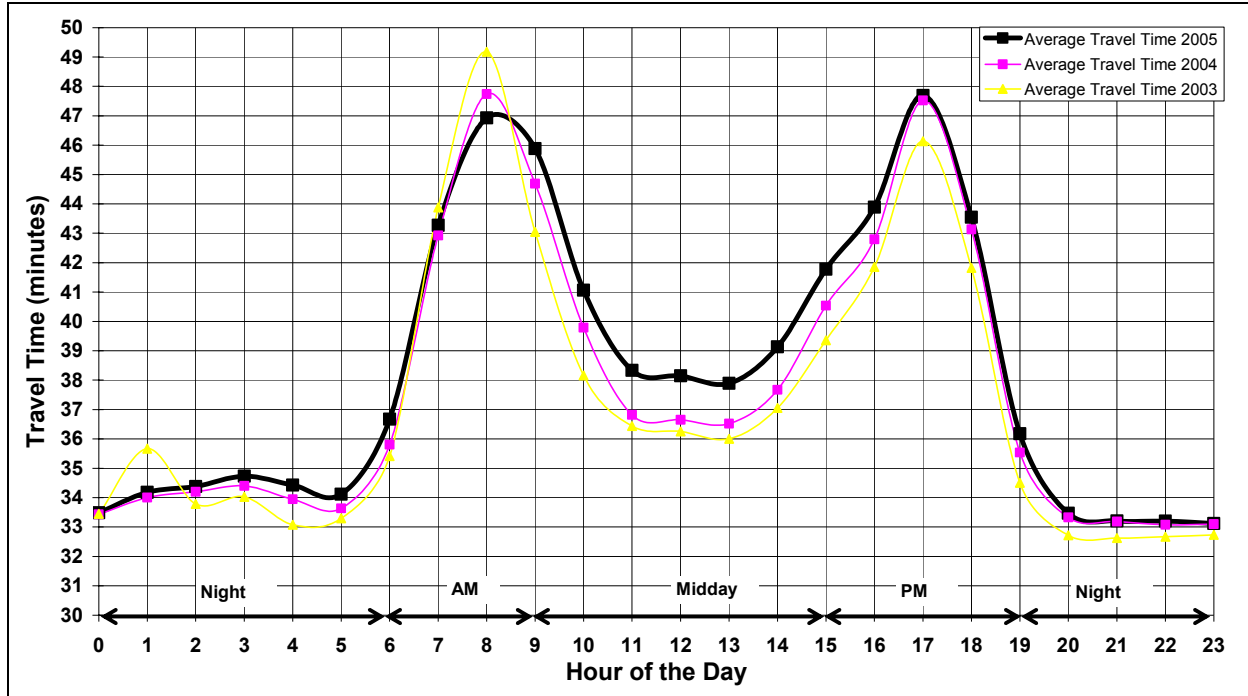


Exhibit 28 – Average Southbound Travel Times by Hour



Despite the consistencies between delay and travel times, it is critical to understand that significant delay changes often mean small travel time changes. For instance, using the data from Exhibit 18, the most dramatic change in delay occurred in the AM peak period in the northbound direction from 2003 to 2004. Delay was reduced from 1,499 hours to 1,124 hours representing a decline of almost 25 percent. During that same time, the maximum reduction in average travel time was less than 3 minutes. The reason this is critical to understand is that decision makers seem to be often disappointed when improvement strategies are predicted to reduce travel time by a “meager” two or three minutes. But, as shown, two to three minutes can mean a reduction of 25 percent of congestion. Moreover, as these two to three minutes accumulate over time (as demand increases), stakeholders are surprised by the compounded increase in congestion. Stated differently, small reductions in overall average travel times often relate to significant reductions in delay.

In addition to understanding the trends of delay and average travel time, it is important to understand the variation of travel time, perhaps the single most frustrating aspect for the traveling public. Even though average travel times at 8 am in the northbound direction are shown to be around 46 minutes in 2005 (as shown in Exhibit 27), few travelers experience the exact average travel time on a day to day basis. In fact, commuters experience a large variation in travel times due to seasonality, accidents, special events, road closures, and small changes in demand (among others). Understanding these variations are important to address the customers’ frustrations and evaluate strategies meant to reduce these variations and thereby increasing the overall reliability of the trip. The next few exhibits illustrate this point.

Exhibit 29 – 2003 NB Travel Time Variability

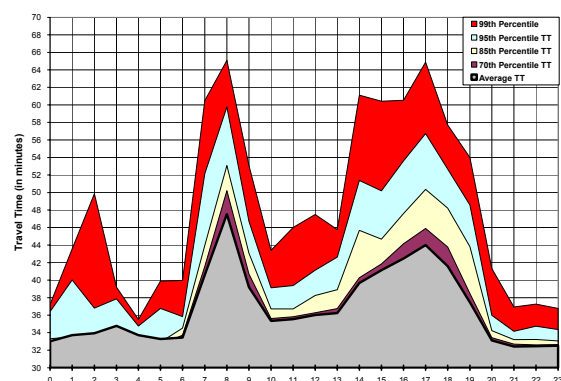


Exhibit 31 – 2004 NB Travel Time Variability

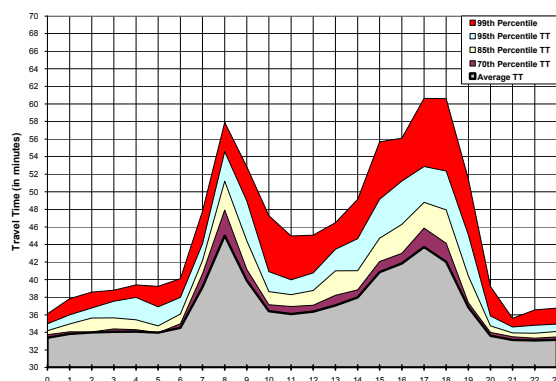


Exhibit 33 – 2005 NB Travel Time Variability

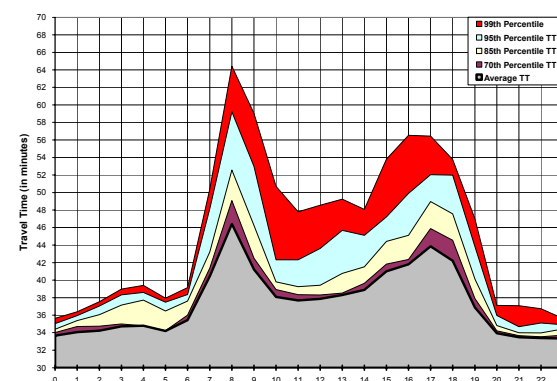


Exhibit 30 – 2003 SB Travel Time Variability

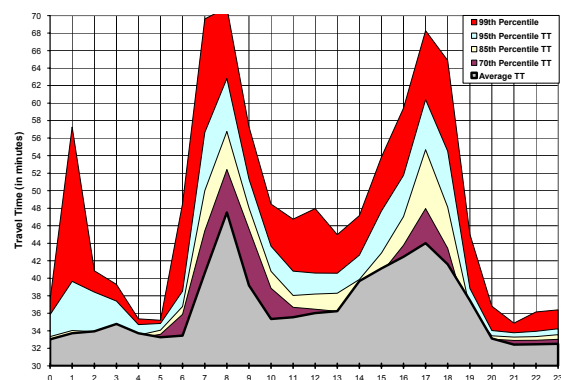


Exhibit 32 – 2004 SB Travel Time Variability

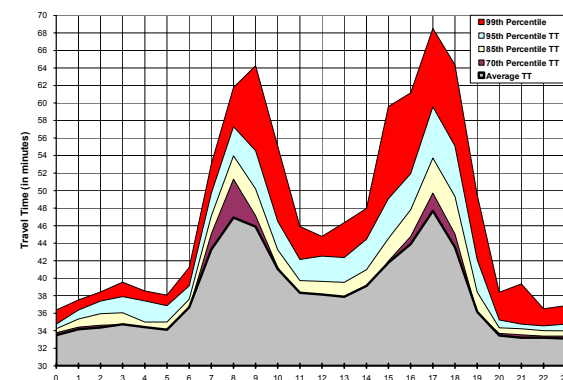
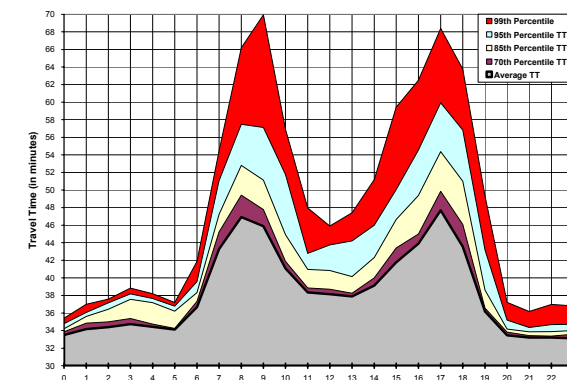


Exhibit 34 – 2005 SB Travel Time Variability



Notes:

- 2005 variability worsened in 2005 compared to 2004 in both directions during the AM peak period and stayed more or less the same during the PM peak period.
- In 2005, a northbound traveler needs to add approximately 12 minutes to the average travel time to be 95 percent confident to arrive at the destination on time
- In 2005, a southbound traveler needs to add approximately 20 minutes to the average travel time to be 95 percent confident to arrive at the destination on time

Corridor-Wide Productivity Results

Productivity, defined as throughput during peak congestion conditions, can be represented by the “lost lane miles” measure discussed in the introduction section. As congestion occurs, flow rates on the freeway diminish due to merging, weaving, and queuing. Exhibits 35 and 36 summarize the productivity losses on the I-880 for the three years analyzed for the northbound and southbound travel direction respectively. Similar to congestion related delay results, productivity decreased the most from 2004 to 2005, with lost lane miles increasing the most in the southbound direction during the afternoon peak commute period (from 3.3 to 5.4 equivalent lane miles lost).

Exhibit 35 – Average Northbound Lost Lane Miles

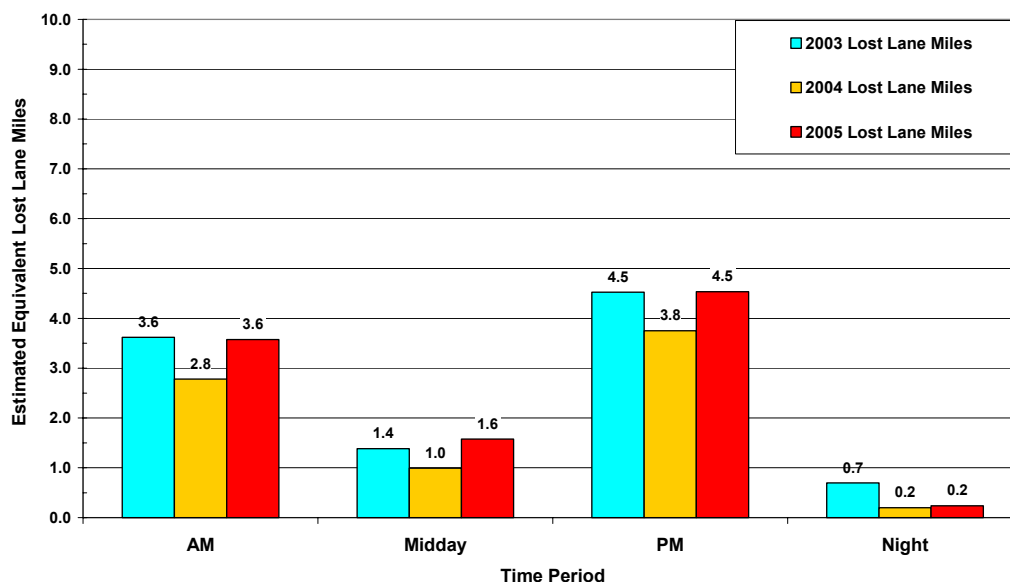
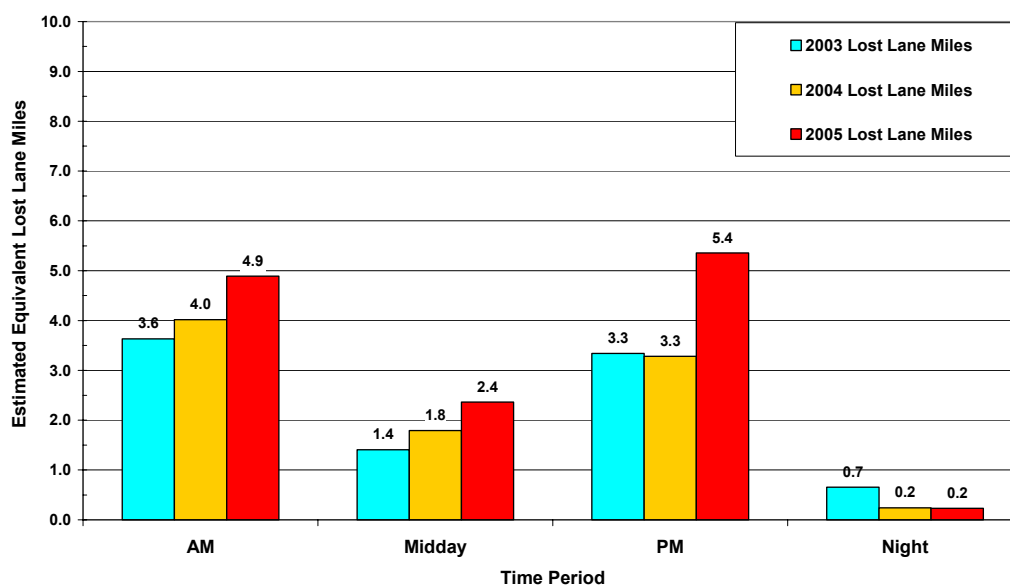


Exhibit 36 – Average Southbound Lost Lane Miles



Strategies to combat such productivity losses are primarily related to operations and include building new or extending auxiliary lanes, developing more aggressive ramp metering strategies without negatively impacting the arterial network, improvements in incident clearance times. These types of improvements will be tested using the micro simulation models to identify the most promising and cost effective strategies.

Corridor-Wide Safety Results

Safety results are based on the TASAS database, which Caltrans maintains. It contains all collisions on the State Highway System. In addition, incident data (which includes collisions and other incidents) was collected from the California Highway Patrol (CHP) for a week to understand the relationship between incidents and collisions (e.g., how many non-collision incidents occur compared to collisions).

Exhibit 37 shows the results of synthesizing the incident data from CHP. The graph depicts daily number of incidents reported. Surprisingly, the number of incidents exceeded 100 every day analyzed. Next, incidents were discarded if their descriptions did not suggest a likely impact on congestion (e.g., changeable message sign malfunction). The remaining incidents that were likely to impact congestion were then divided by time period for the entire week. Exhibit 38 shows the results of this second step. These show that at least for the week analyzed, the highest number of incidents occurs between 3 pm and 6 pm (over 100 incidents during the week or over 15 per day) and between 6 pm and 9 pm (more than 90 incidents or 13 per day).

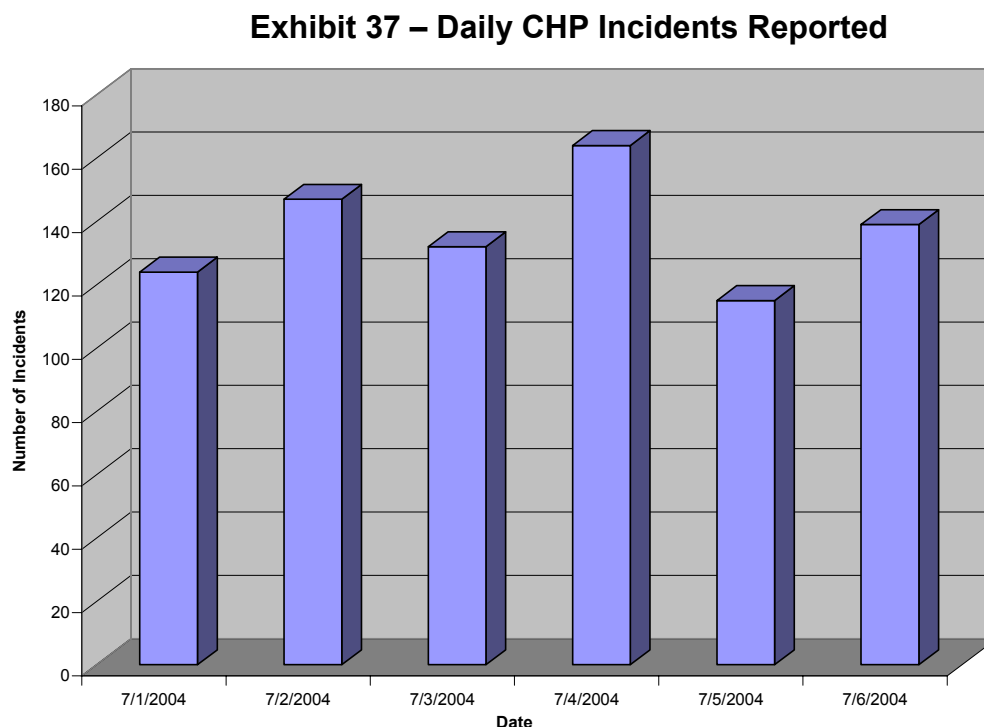
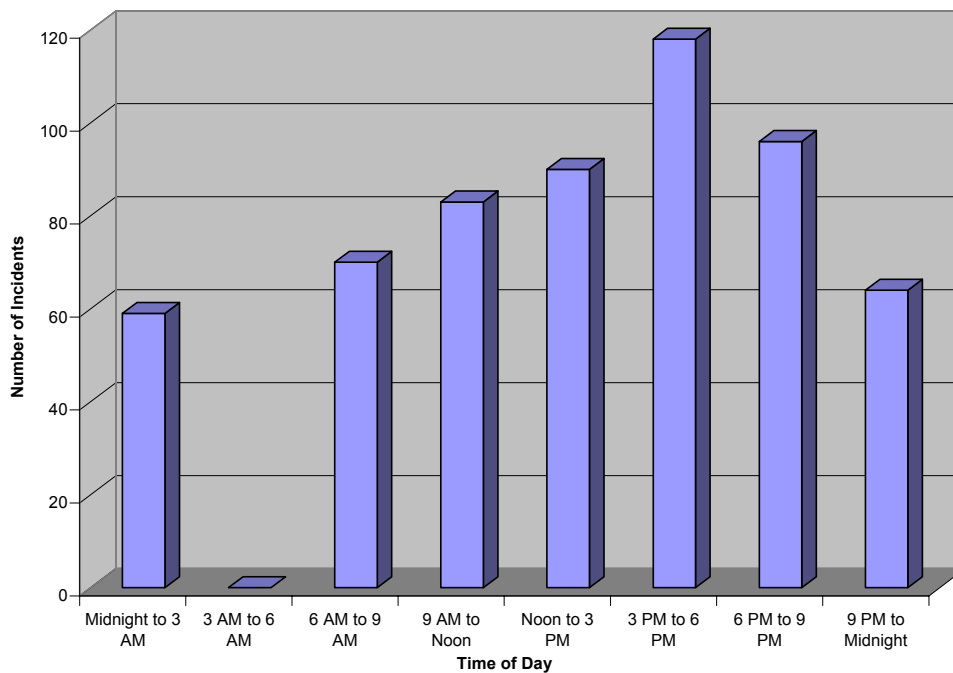


Exhibit 38 – Week Total CHP Incidents Likely to Impact Congestion By Time Period



The results of the collision analysis are summarized in Exhibits 39 and 40. The first shows a daily count of collisions for the more than five years analyzed. The second shows average number of daily collisions by month to better understand the overall trend. Note that on a daily basis, the number of collisions generally ranges between 5 and 15. Obviously, these collisions add to the daily congestion, especially when they occur during peak commute periods.

Also note that starting around the beginning of 2002, a downward trend in average number of collisions is established. Around that same time, Caltrans started metering the corridor after working with the local stakeholders to agree on the ramp metering approach. Although the data does not conclusively prove that metering caused the reduction in the number of collisions, it is consistent with federal and state studies that imply that such a correlation in fact exists.

Comparing the number of incidents to the number of collisions, one can deduce a rule of thumb that we have approximately five to six incidents for each collision. Of course, incidents in general do not contribute to congestion as much as collisions do. In subsequent discussions regarding bottlenecks, collisions will be discussed again to better understand where and when collisions do occur and how they relate to the major bottlenecks on the study corridor.

To properly understand congestion and resulting delay, it is imperative to understand its causes. Until recently, even with the detection data, it was impossible to divide congestion into components, each relating to a specific cause.

Exhibit 39 – Daily CHP Collisions Reported

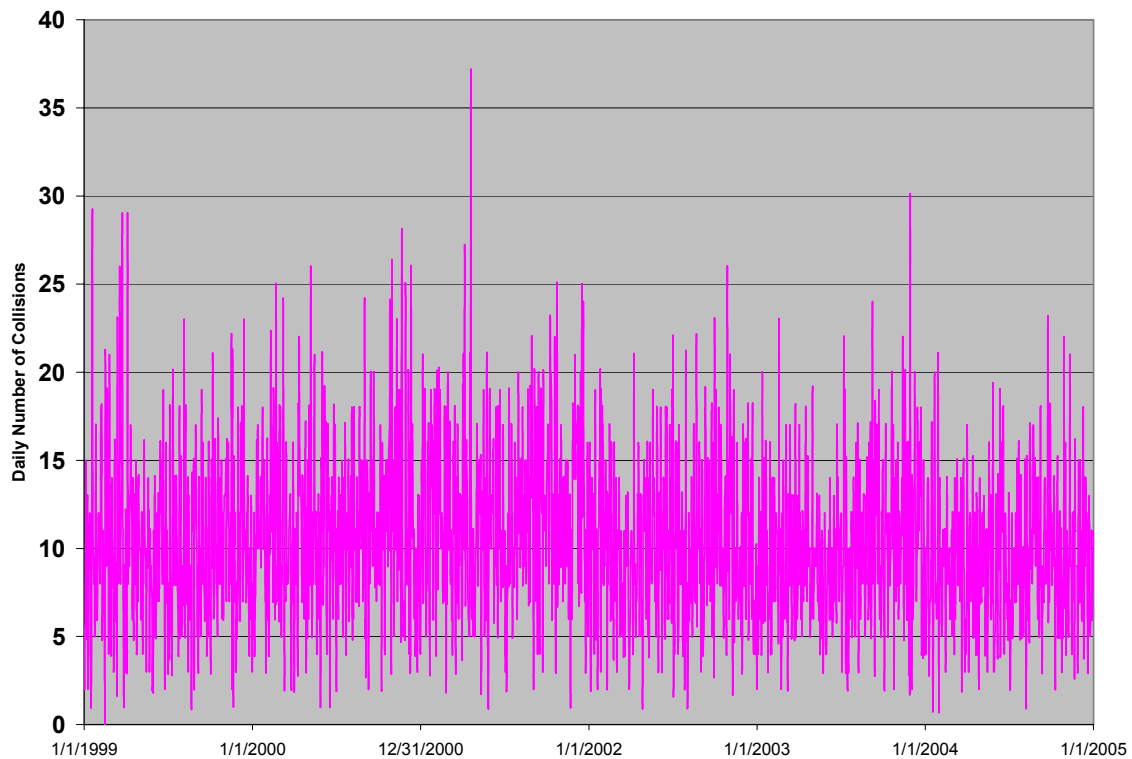
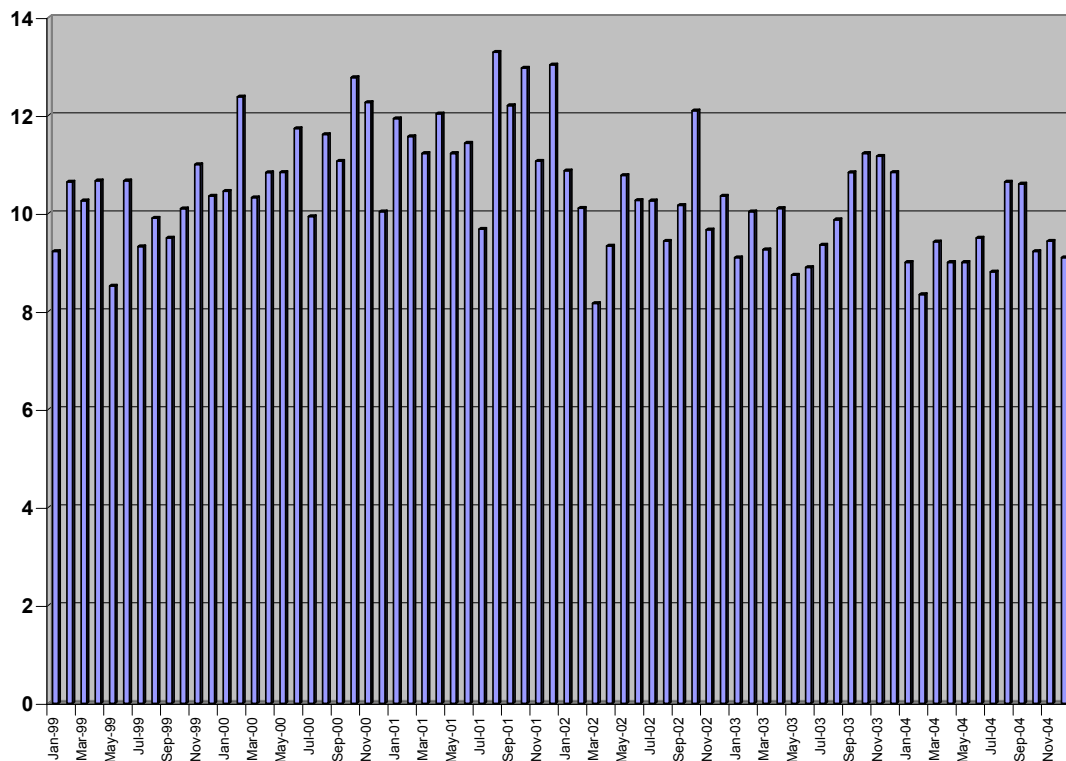


Exhibit 40 – Average Daily CHP Collisions Reported by Month



Recently, Caltrans and UC Berkeley developed an algorithm that estimates the congestion by cause. Even though these algorithms are new and do not identify each cause, they present an approach to estimate the contributions of major causes of congestion. Exhibits 41 and 42 illustrate the results of these algorithms. They divide overall congestion into three components: collisions, excess demand, and potential reduction.

The first two categories are self-explanatory. The third, “potential reduction”, reflects the potential reduction in delay if it were possible to optimize operational strategies. Of course, it is almost impossible to fully optimize operational strategies. However, focusing on these strategies in conjunction with reducing collisions and/or removing them faster will have significant congestion-relief benefits.

Exhibit 41 – AM Congestion Breakdown Estimates by Cause

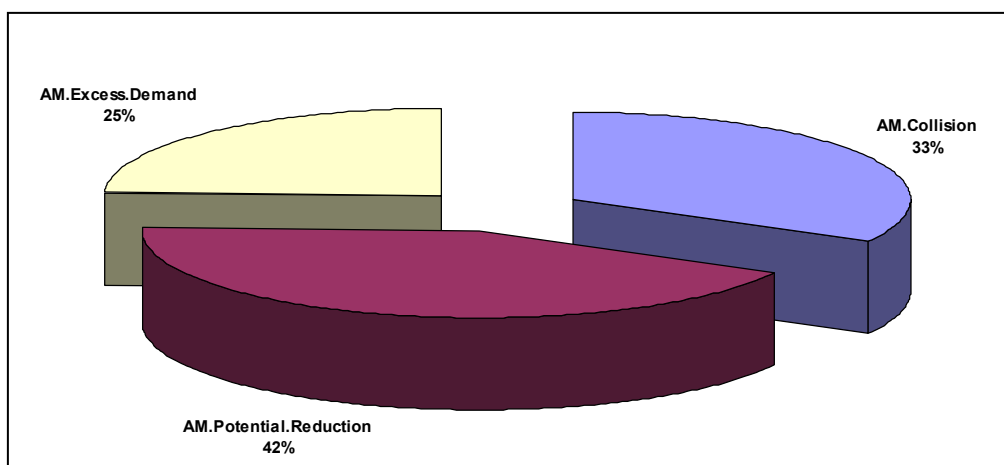
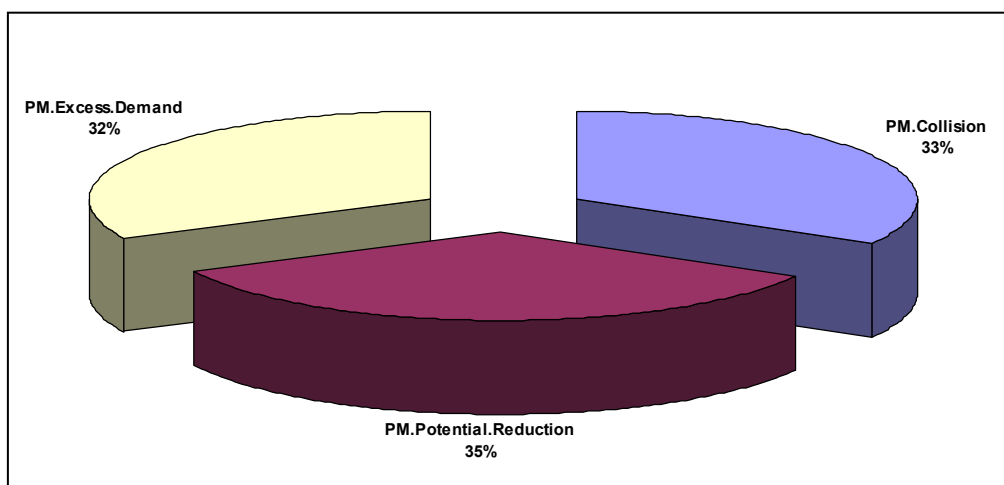


Exhibit 42 – PM Congestion Breakdown Estimates by Cause



Bottleneck Analysis

The previous discussions focused on corridor-wide performance results and trends, as well as a corridor-wide causality analysis (i.e., the congestion pie). At this point, the aforementioned results established the following:

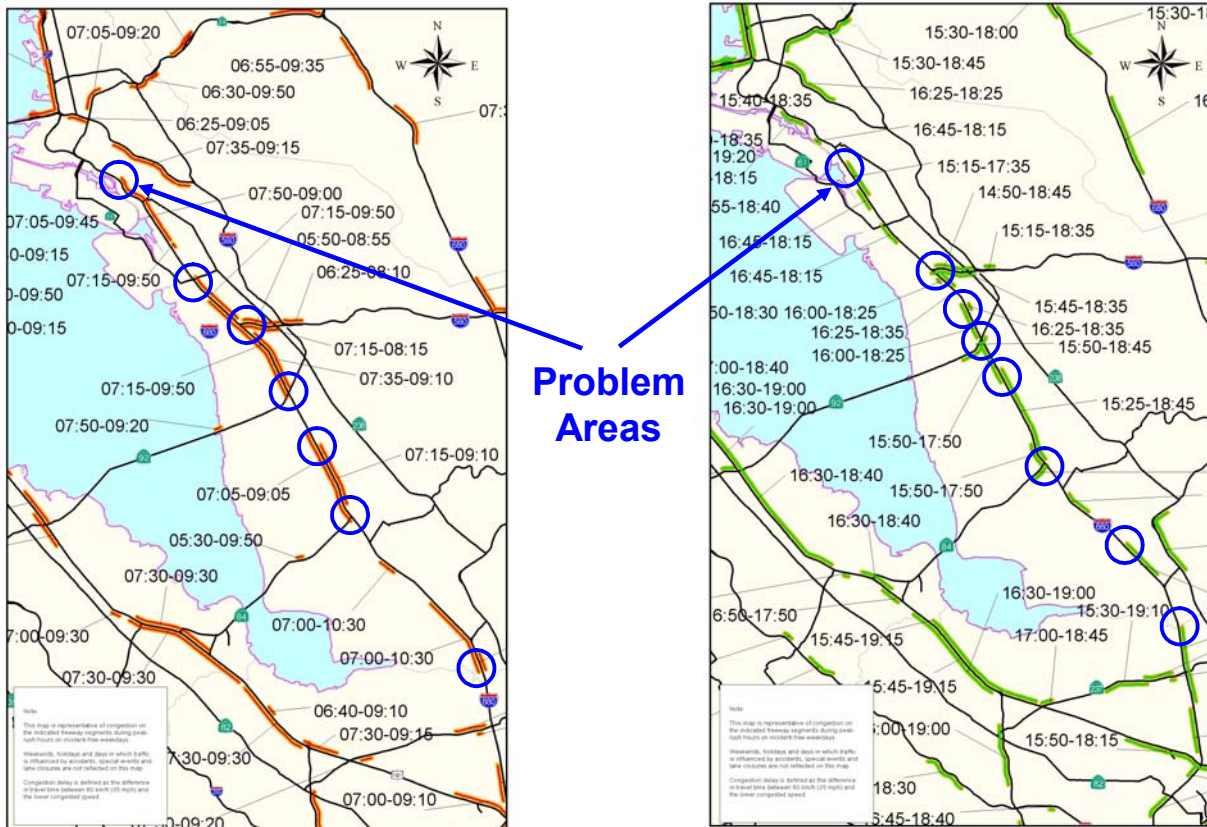
- Corridor delays increased in 2005 compared to 2004, but have not reached the 2003 delay numbers. Non-severe delays, representing the delays associated for speeds above 35 miles per hour, spiked in 2005. This may be a prelude for increased severe delays in the future. Overall, daily delays on the 880 averaged approximately 12,400 hours.
- Overall, PM peak delays are larger than AM peak delays and PM peak congestion lasts longer. PM peak congestion lasts approximately four hours whereas AM peak congestion lasts around two hours. Overall, AM and PM daily delays averaged around 3,000 and 5,250 hours respectively.
- Travel times trends are similar to congestion delay figures. However, travel time variability spiked in 2005 during the AM peak period. So whereas the average travel time saw a small increase in 2005, reliability declined considerably.
- Safety data was only available through 2004. Therefore, it is difficult to compare safety statistics and the decrease in reliability in 2005. However, safety collisions through 2004 showed a continuation of the decline that started in 2002, starting approximately after ramp metering was initiated.
- Total delay can be roughly attributed equally to three factors (in 2004): collisions, excess demand, and lack of optimal corridor management. The latter represents the maximum potential improvements if the corridor can be managed optimally.

Although these findings are important, they do not lend themselves to identifying potential location-specific improvements. They do lend themselves to corridor-wide strategies, such as increased freeway service patrol during the PM peak period. But more is needed to start developing projects for addressing congestion.

Therefore, the second major step in performance measurement requires location specific analysis to identify bottlenecks that create the congestion in the first place. As a first step in this effort, it is useful to analyze the HICOMP report developed by Caltrans District 4 in coordination with MTC. The report includes maps identifying the locations and durations of severe congestion. The 2003 HICOMP report maps for the study corridor are shown on Exhibit 43 on the next page.

Note that these are useful in identifying the possible problem areas in both directions. Whenever there is a stretch of freeway experiencing severe congestion, the end point of the congested segment (e.g., the north end of a congested segment in the northbound direction) is a possible or likely bottleneck.

Exhibit 43 – 2003 HICOMP Report Maps

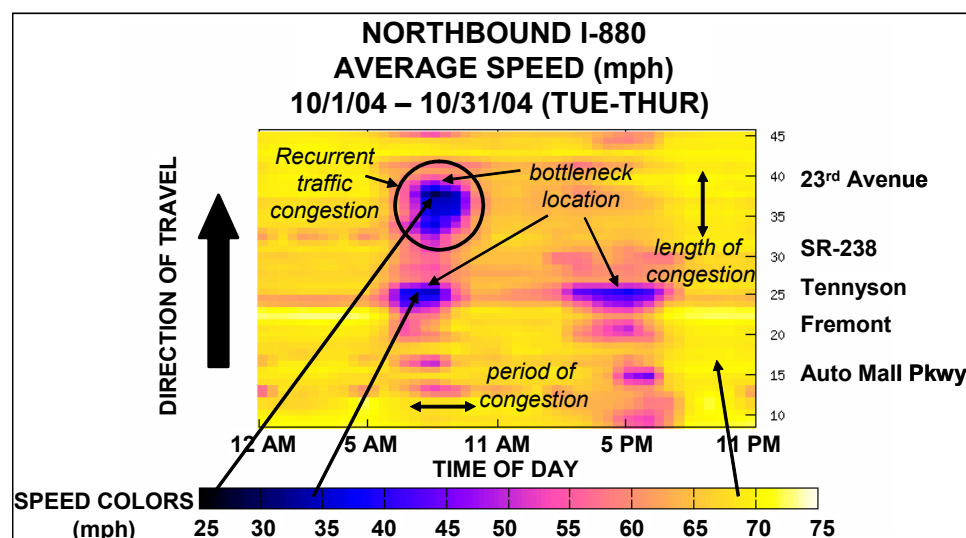


As indicated in the map, there are four locations during the AM peak hours and six locations during the PM peak hours in the northbound direction (i.e., shaded segments on the right side of the 880 in either map denoting northbound travel) that could potentially be bottleneck areas. In the southbound direction, there are 3 locations during the AM peak hours and five locations during the PM peak hours that could potentially be bottleneck areas (i.e., shaded segments on the left side of the 880). However, further analysis is needed to identify all bottlenecks and understand the associated causes.

In addition to HICOMP maps, the study team relied on speed contour plots that can be accessed using the PeMS web site. Exhibit 44 illustrates a typical speed contour plot generated by PeMS. It illustrates the average speed contour plot for the I-880 freeway corridor in the northbound direction in the month of October 2004. It represents the average speeds by time of day for mid-week days (Tuesdays through Thursday) from October 1, 2004 to October 31, 2004. Along the horizontal axis is the time period from 12 AM to 11 PM. Along the vertical axis is the corridor segment from milepost 10 to milepost 45. The various colors represent the average speeds corresponding to the color speed chart shown below the diagram. As shown, the dark blue blotches represent congested areas where speeds are reduced. The tops of each dark blotch

represent bottleneck areas. The vertical length of each blotch represents the length of the congested segment. The horizontal length represents the duration of congestion.

Exhibit 44 – Example Speed Contour Plot



As indicated, the congestion occurs at different locations anywhere from approximately 6 AM to 10 AM during the morning commute hours and from 3 PM to 7 PM during the evening commute hours.

Northbound Bottlenecks

The preliminary identified major bottleneck areas are at the 23rd Avenue interchange and at Tennyson Road interchange. Smaller bottlenecks may also be present at SR-238 interchange, Fremont Boulevard interchange, and Auto Mall Parkway interchange. The highest congestion appears at the 23rd Avenue interchange with typical queues extending as long as 6 miles during the AM peak hours. However, the queues could be related to multiple bottlenecks. The congestion at the Tennyson Road interchange appears to be the second largest with congestion during both the AM and PM peak hours and with the queues extending to about 3 miles back. All of these preliminary findings were consistent with the HICOMP report.

More detailed analysis is required to “pin down” the locations of the bottlenecks and compare 2003 through 2005 bottlenecks. This detailed analysis focuses first on bottleneck trends and then adds precision to the speed contour plots by focusing on each major bottleneck separately. Following this analysis, it is imperative to conduct field observations to check on the findings and understand the reasons for the bottlenecks.

The northbound bottleneck trends are shown on the next page on Exhibits 45, 46, and 47 for the month of October in years 2003, 2004, and 2005 respectively.

Exhibit 45 – October 2003 NB Speed Contour Plot

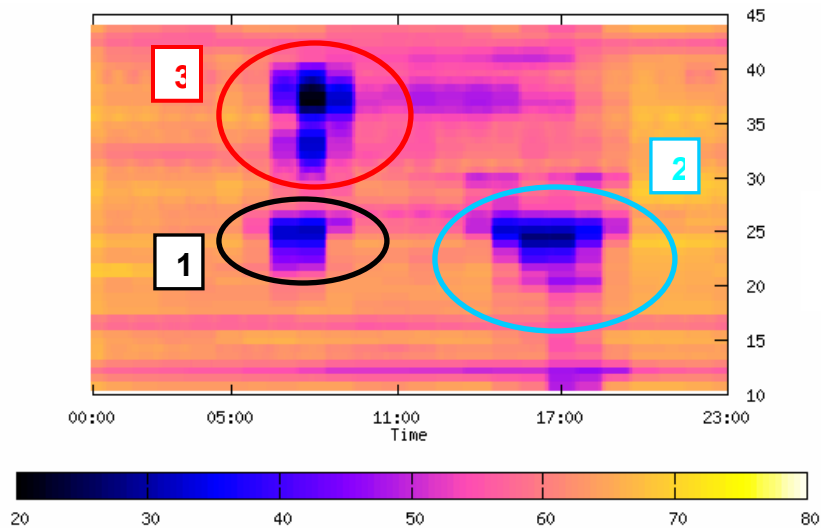


Exhibit 46 – October 2004 NB Speed Contour Plot

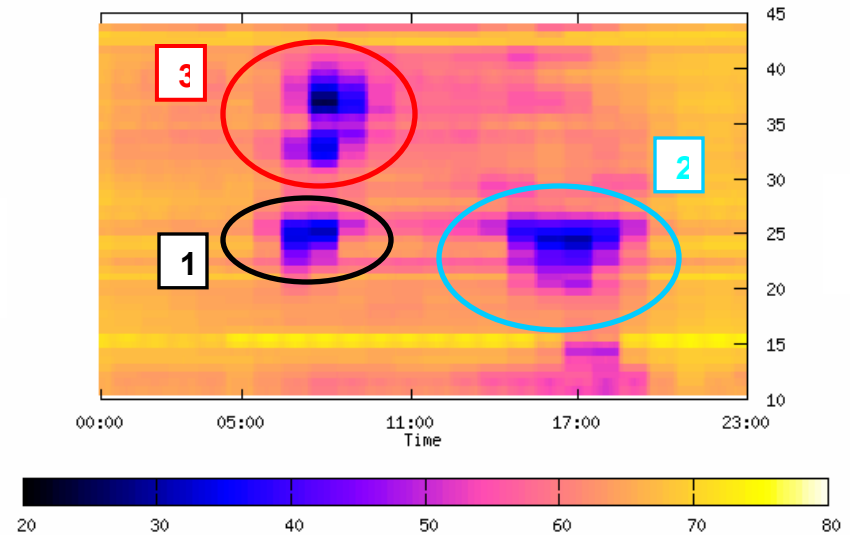
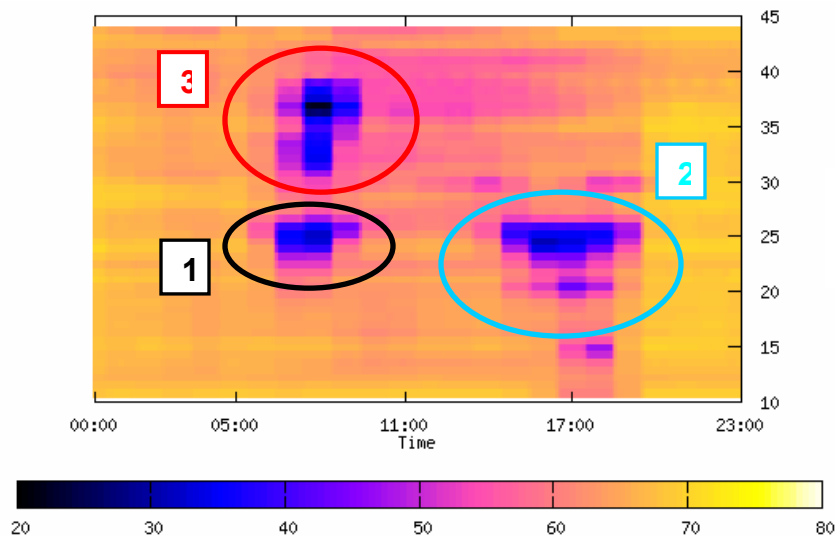


Exhibit 47 – October 2005 NB Speed Contour Plot



- All three speed contour plots represent the monthly weekday averages for northbound direction.
- Areas denoted with **1** and **2** represent the aforementioned Tennyson bottleneck both in the AM and the PM peak periods
- Area denoted with **3** represents the aforementioned preliminary 23rd Avenue bottleneck.

A few notes on these three exhibits:

- The 2003 northbound direction shows significantly slower speeds and severe congestion for bottleneck area (1). This can be observed by the darkness of the area, which reflects speeds at or below 20 miles per hour.
- The 2004 contour map suggests what was originally viewed as one bottleneck around 23rd Avenue may be two separate bottlenecks. This lightening of the color around post mile 35 shows higher speeds dividing the two slower speed areas.
- Both the 2003 and 2005 contour maps do not show this distinction. This could mean that the bottleneck at 23rd Street in fact extends all the way to the bottleneck upstream.
- The queue behind the 23rd Avenue bottleneck grew in the AM peak period by 1-2 miles in 2005 compared to 2004.
- The Tennyson bottleneck denoted by (2) in the AM peak period grew in duration (i.e., the horizontal length of the dark area) in 2005 compared to 2004.
- The combination of the queue length growth at 23rd Avenue and the congestion duration at Tennyson are probably the main reasons why the AM peak congestion (in terms of hours of delay) increased between 2004 and 2005.

Before addressing the southbound direction, it is important to further analyze the AM peak 23rd Avenue bottleneck area to verify the existence of a second bottleneck and identify its location.

Exhibit 48 through 51 on the next page present daily speed contour plots zoomed to the specific bottleneck area in the AM peak period. Note that on some days (such as on October 17, 2005), it is impossible to distinguish between the two bottlenecks.

However, as different days are selected, a clearer pattern emerges that identifies two distinct bottlenecks:

- one is at 23rd Avenue (around absolute post mile 40)
- the other at Davis (around absolute post mile 34), which in effect is a hidden bottleneck when only analyzing monthly trends

This determination needed to be confirmed with numerous field visits as mentioned before.

Exhibit 48 – October 17, 2005 NB Speed Contour Plot

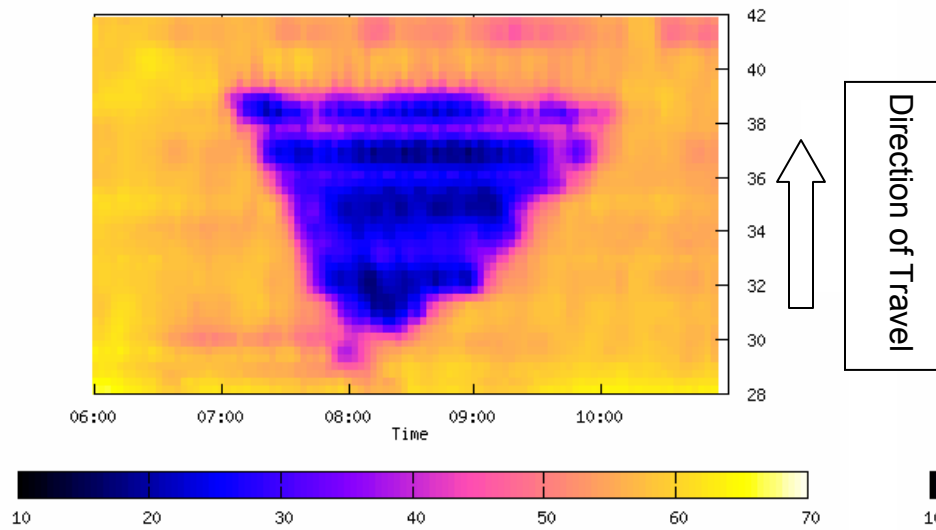


Exhibit 49 – October 7, 2005 NB Speed Contour Plot

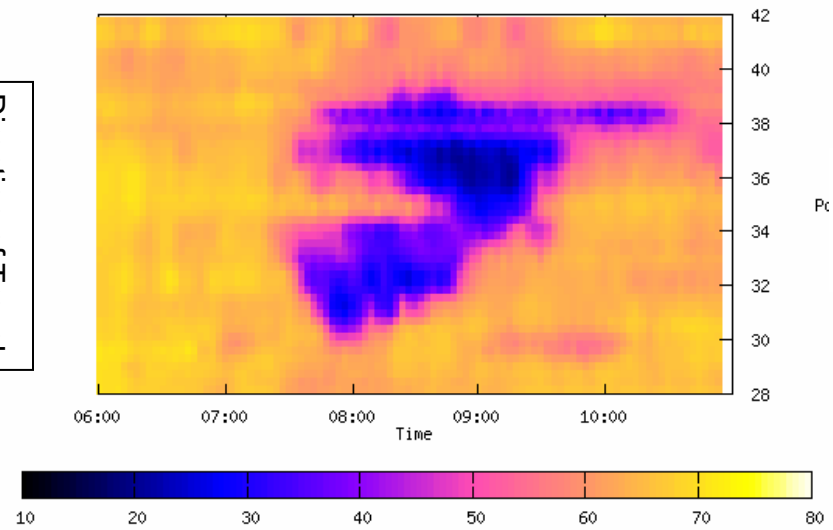


Exhibit 50 – September 19, 2005 NB Speed Contour Plot

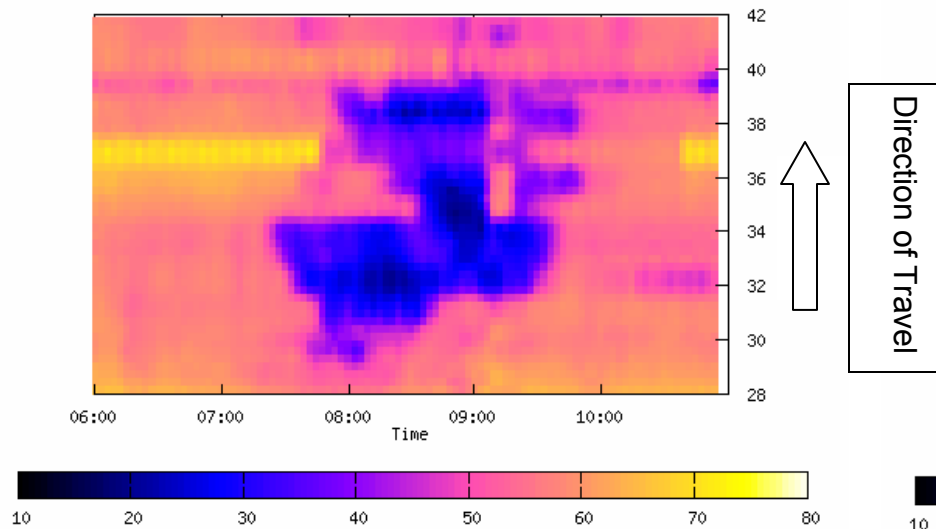
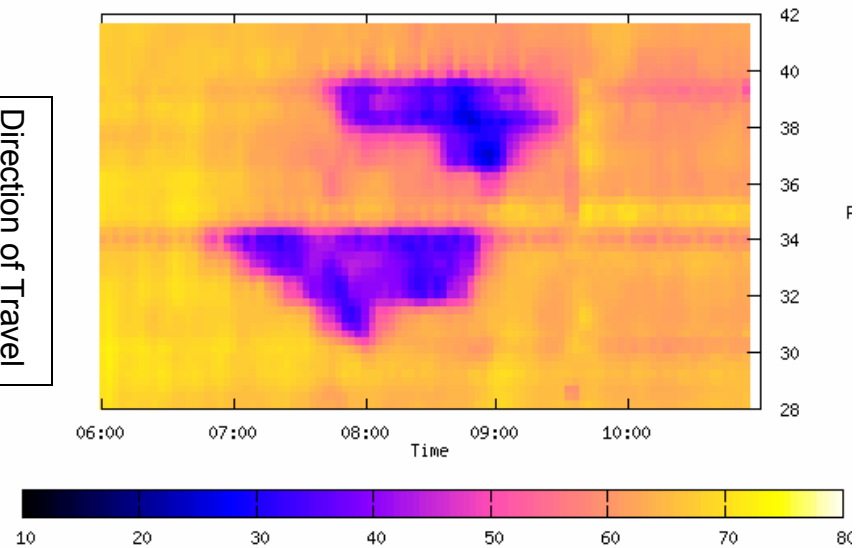


Exhibit 51 – July 18, 2006 NB Speed Contour Plot



The next step is to verify these findings and determine the potential causes of these congested areas and its bottlenecks. By reviewing the aerial photographs of geometric layout and observing field traffic conditions during the congested hours several times, the specific locations of the bottlenecks can be verified and the potential causes can be investigated. Bottlenecks are discussed starting from the southern end of the study corridor and moving northbound.

Tennyson Interchange Bottleneck (Northbound AM and PM Peak around abs post mile 25)

The Tennyson bottleneck occurs both in the AM peak and the PM peak periods. In analyzing the Tennyson Road interchange, we again find two side-by-side on-ramps with high traffic volumes. However, unlike the Davis bottleneck, there is only a short on-ramp merge taper and split ramp metering systems that allows for platoons to occur at the merge. This is shown on Exhibit 52 below showing a photo taken during one of the field observation efforts.

Exhibit 52 – Tennyson Merge Bottleneck



Again, during our field observations, we witnessed the speeds pick up after the merge congestion as shown on Exhibit 53.

Exhibit 53 – Traffic Clearing after Tennyson On-ramps



23rd Avenue Interchange Bottleneck (Northbound AM Peak at around abs post mile 40)

Investigating the 23rd Avenue interchange congestion, the aerial photograph on Exhibit 54 shows that the 23rd Avenue interchange is very “busy” with two closely spaced railroad overpass structures with sharp horizontal curves. The curves likely affect sight distance and the overpass structures tend to slow down truck traffic due to perceived low clearance as shown on Exhibit 55. In addition, there are two very close on-ramps with high volumes during the AM peak period. Caltrans ramp data indicated that about 15,000 vehicles each day enter the freeway at the interchange

Exhibit 54 – Aerial of the 23rd Avenue Interchange

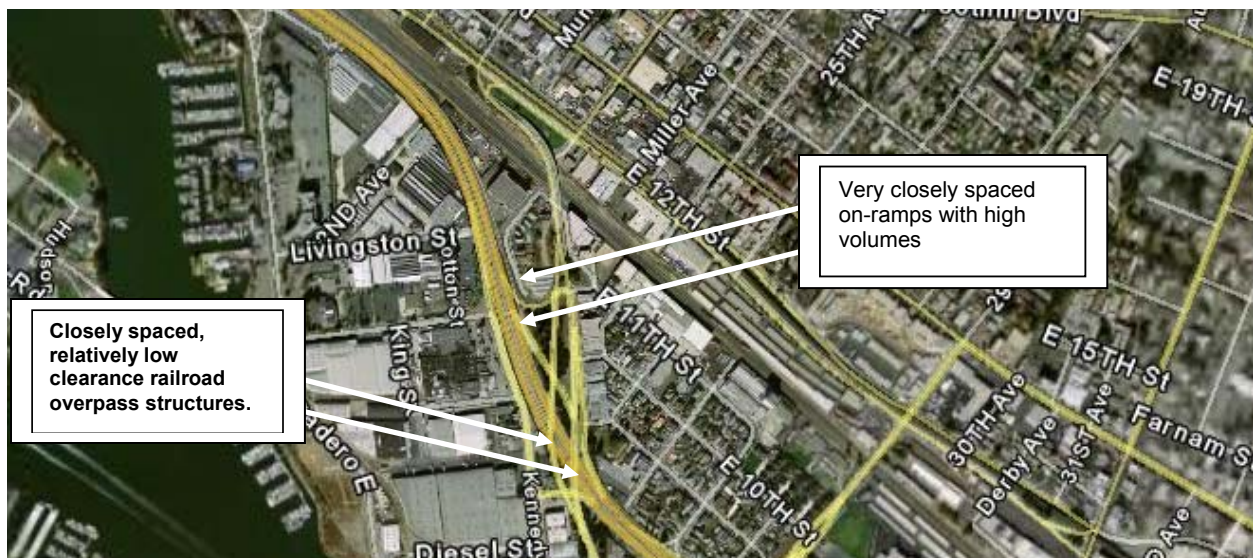


Exhibit 55 – Overpass Structures at 23rd Avenue



Given the high volume of large trucks using the I-880, the above overpasses slow down the traffic before the merges from the on-ramps. Also note the relatively poor pavement conditions at the same location. The combination of the geometric (i.e., low overpasses, curvature), high on-ramp merge traffic, and pavement conditions are the causes of the bottleneck and resulting congestion. In fact, Exhibit 56 is a photo taken during one of the field visits (the same visit used to capture Exhibit 55), shows that the traffic clears right after the on-ramps.

Exhibit 56– Traffic Clearing after 23rd Avenue On-ramps

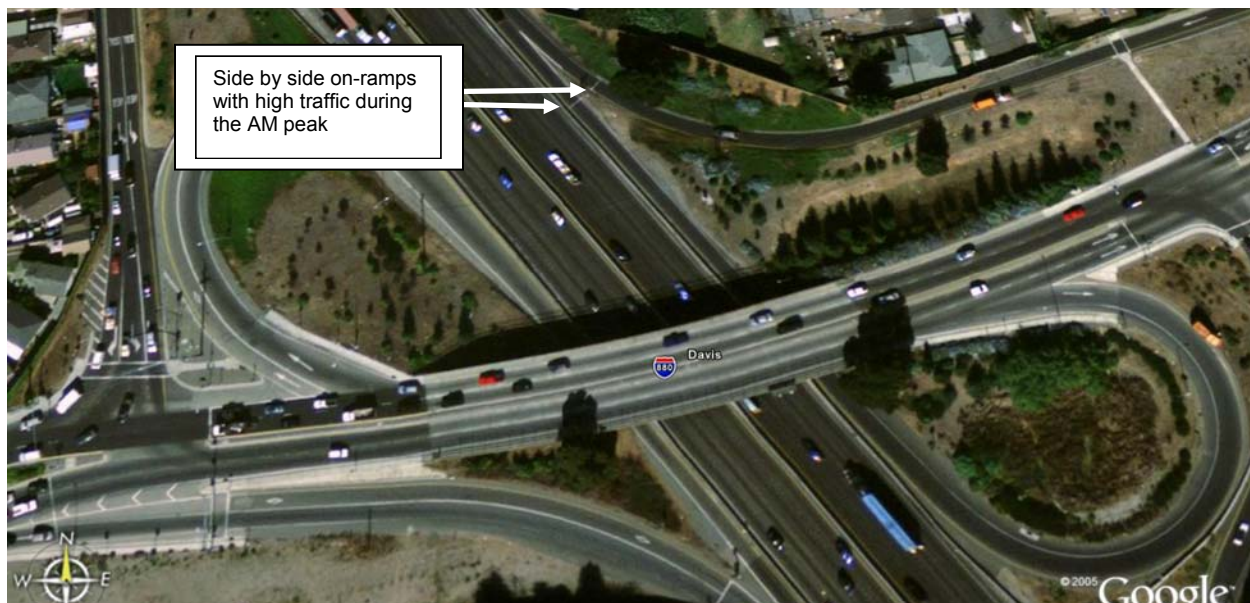


Davis Interchange Bottleneck (Northbound AM Peak at around abs post mile 34)

Identifying the location of this bottleneck was not easy. During several field visits, the 23rd Avenue bottleneck created queues that extended beyond the Davis interchange. As is the case with the some speed contour plots, when one bottleneck's queues extend back to another bottleneck location, the latter becomes "hidden".

After several field visits and reviewing aerials, the bottleneck was identified. The importance of identifying a "hidden" bottleneck must be emphasized. For if only the 23rd Avenue bottleneck were identified and a project were implemented that somehow relieves it, the Davis bottleneck would still cause congestion and become more visible. Exhibit 57 is an aerial of the Davis interchange.

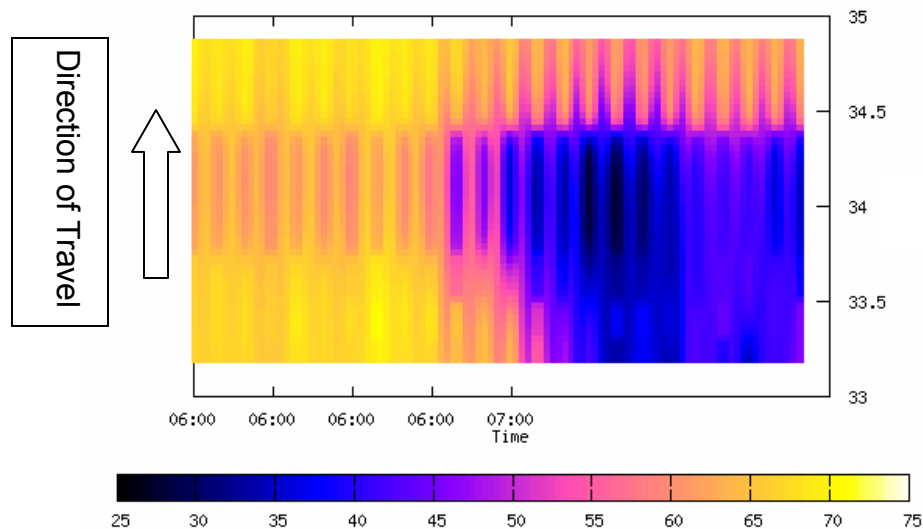
Exhibit 57 – Davis Interchange Bottleneck (Northbound AM Peak)



Note that there are two on-ramps side-by-side at Davis with high traffic during the AM peak period. Generally speaking, one on-ramp with high traffic on a busy corridor can create slowdowns due to merging. With side-by-side on-ramps, despite a relatively long auxiliary lane to space the merging, the additional traffic creates the Davis bottleneck.

To check on the accuracy of our findings, a more detailed speed contour plot is shown below on Exhibit 58. Note that the speeds increase before absolute post mile 34.5. The Davis on-ramps are both at before 34.5. The speeds increase occurs past the auxiliary lane from which the merges occur.

Exhibit 58 – Detailed Speed Contour Plot for Davis Bottleneck



Southbound Bottlenecks

Exhibits 59 through 61 show weekday speed contour plots for the month of November for years 2003, 2004, and 2005 in the southbound direction. From these plots, the preliminary identified major bottleneck areas are at the 98th and the Mission (SR-262) interchanges. A number of smaller bottlenecks are also present between absolute post mile 17 and 33 ending at around Tennyson.

The exhibits also show that the bottlenecks around the 98th and around Mission (SR-262) interchanges intensified in 2005 when compared to 2004 (note increased darkness denoting slower speeds for areas denoted as 1, 4, and 5). On the other hand, the bottlenecks between these two (i.e., the multiple bottlenecks between post mile 17 and 33) did diminish in 2005 compared to 2004 (note reduced dark areas in 2005 at these locations denoted by 2 and 3).

As with the northbound bottlenecks, the southbound direction required further detailed analysis as well as numerous field observations to determine the specific locations of the bottlenecks, identify hidden bottlenecks if they do exist, and determine likely causes for these bottlenecks.

The results of these detailed analyses and field observations are shown following the speed contour plots on the next page starting from the north end of the study corridor and moving south.

Exhibit 59 – November 2003 SB Speed Contour Plot

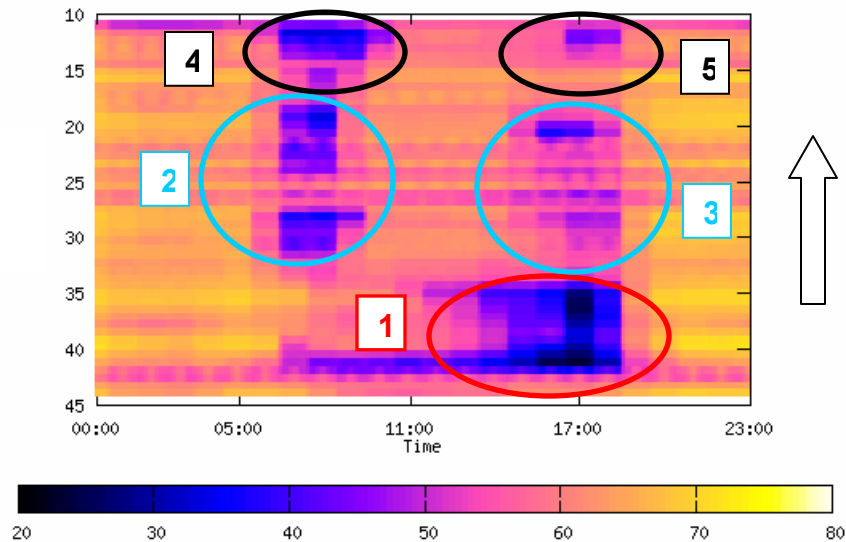


Exhibit 60 – November 2004 SB Speed Contour Plot

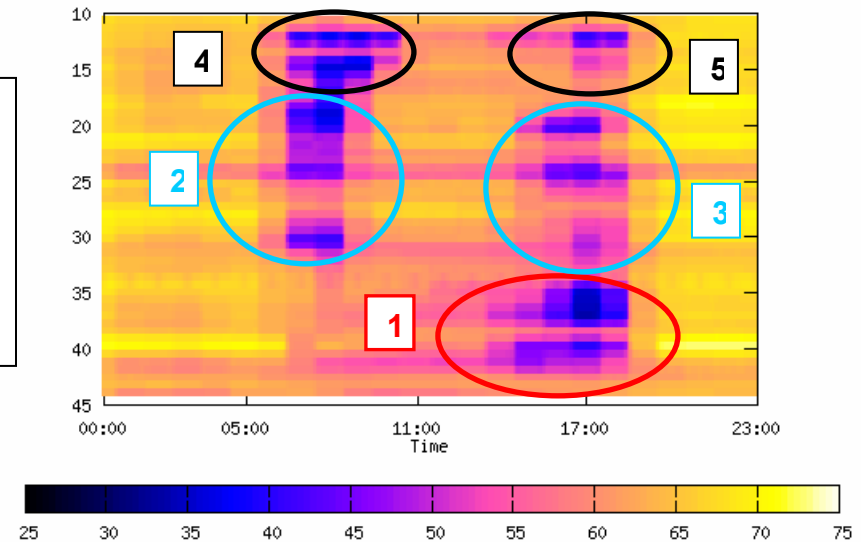
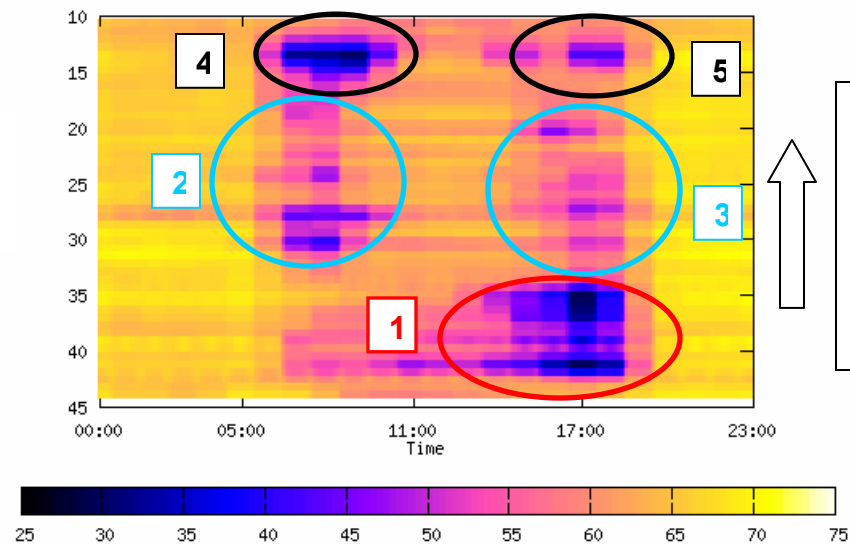


Exhibit 61 – November 2005 SB Speed Contour Plot



- All three speed contour plots represent the monthly weekday averages for southbound direction.
- Areas denoted with **1** represents the preliminary 98th bottleneck in the PM peak period only
- Areas denoted with **2** and **3** represent the multiple smaller bottlenecks ending at Tennyson both in the AM and the PM peak periods
- Areas denoted with **4** and **5** represent the preliminary bottleneck at Mission Blvd – Rte 262

98th Avenue Bottleneck (Southbound PM Peak around abs post mile 34.5)

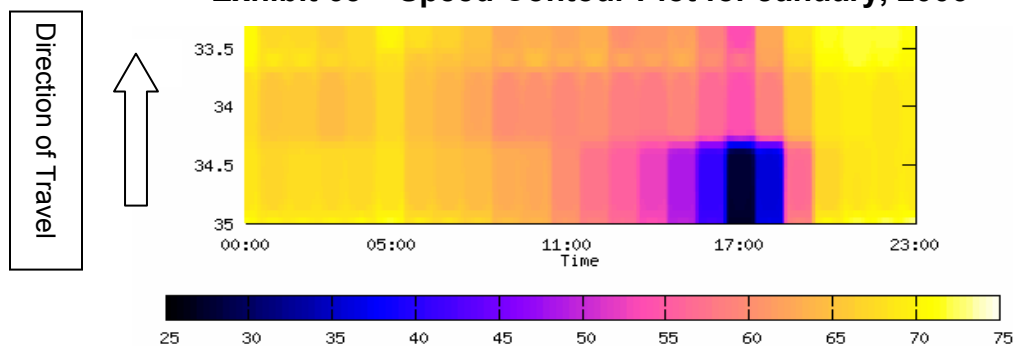
Originally, the study team believed this bottleneck to be at Marina/Davis on-ramps. However, after further review from the speed contour plots as well as field visits, it became evident that the bottleneck is actually at the 98th Avenue on-ramps. One way to ensure that the correct bottleneck has been identified is to look at speed data in 5-minute increments as shown in Exhibit 62 below. Note that the speeds start diminishing at 98th Street, not Davis or Marina (direction of travel is from bottom to top). By the time they get to Davis, speeds have already picked up. Also, note that the percentage of observed data is reasonable (i.e., more than 30 percent). Finally, note two separate speed reduction areas at 29th off-ramp to Fruitvale and at Oak. These locations and others (e.g., at Broadway) are occasional bottlenecks that do not always occur.

Exhibit 62 – Five-Minute Speeds by Detector for January, 2006

Postmile (Abs)	Location	% Observed	15:30	15:35	15:40	15:45	15:50	15:55	16:00
30.187		39.8	54.7	55.1	54.8	54.2	53	52.8	52.3
30.557		80.4	59.2	59.2	59	58.6	57.9	57.1	56.8
30.877		0	59.4	59.3	59.3	58.8	58.1	57.4	57.2
32.357		0	61.7	61.9	61.7	62	62.4	62.5	62.9
32.727		77.5	59.1	59.6	59.7	60.6	60.6	60.6	60.8
32.947	Marina	71.1	57.8	57	56.2	55.4	54.9	54.5	55.8
33.427		77	60.7	60.3	59.2	57.6	56.7	56.3	57.9
33.577	Davis	44.2	61.3	61.6	60.6	59.7	59.6	59.2	60.5
34.827	98th	77.8	48.5	48.4	47.1	42.4	39.2	38	39.1
35.497		61.2	47.2	47.2	45.3	43.1	42	41	40.1
35.697		52.9	49.2	48.7	47	44.8	43.5	41.5	40.2
36.557		80.2	51.2	49.5	47.1	45.2	43	42.2	42.8
37.757		82.8	50.6	50	48.7	46.1	43.8	42.5	42.4
38.297		67.5	51.2	50.2	48.5	47.1	47.9	48	47.5
	29th off-ramp to								
38.877	Fruitvale	91	47.1	47.4	43.9	42.8	42.9	42.7	41.8
39.107		71.1	50.8	50.5	48.1	46	46	44.9	44.1
39.327		35.6	54	53.8	52.5	52	51.8	51.6	51.8
39.977		38.5	59.9	59.9	59.3	59.7	59.8	60.2	60.7
41.187	Oak St	59	48	47.1	45.9	45.3	44.2	42.6	42.6
41.537		82.2	51.4	51	49.4	48.9	47.6	47.8	47.6
41.887		17.2	57.7	57.3	55.9	55.7	56.2	56.2	55.8
42.027		23.3	59.4	59.5	59	58.9	60	59.6	58.8
42.127		67.2	71.9	71.7	71.2	71.9	73.4	73.5	73.5
42.327		37.4	67	66.6	67	67.6	67.3	67.4	67.5

The 98th Street bottleneck can be further verified by the speed contour plot in Exhibit 63 below. Note that the darker areas denoting the slower speeds occur well before post mile 34, which means it cannot be at Davis (which is at around post mile 33.5).

Exhibit 63 – Speed Contour Plot for January, 2006

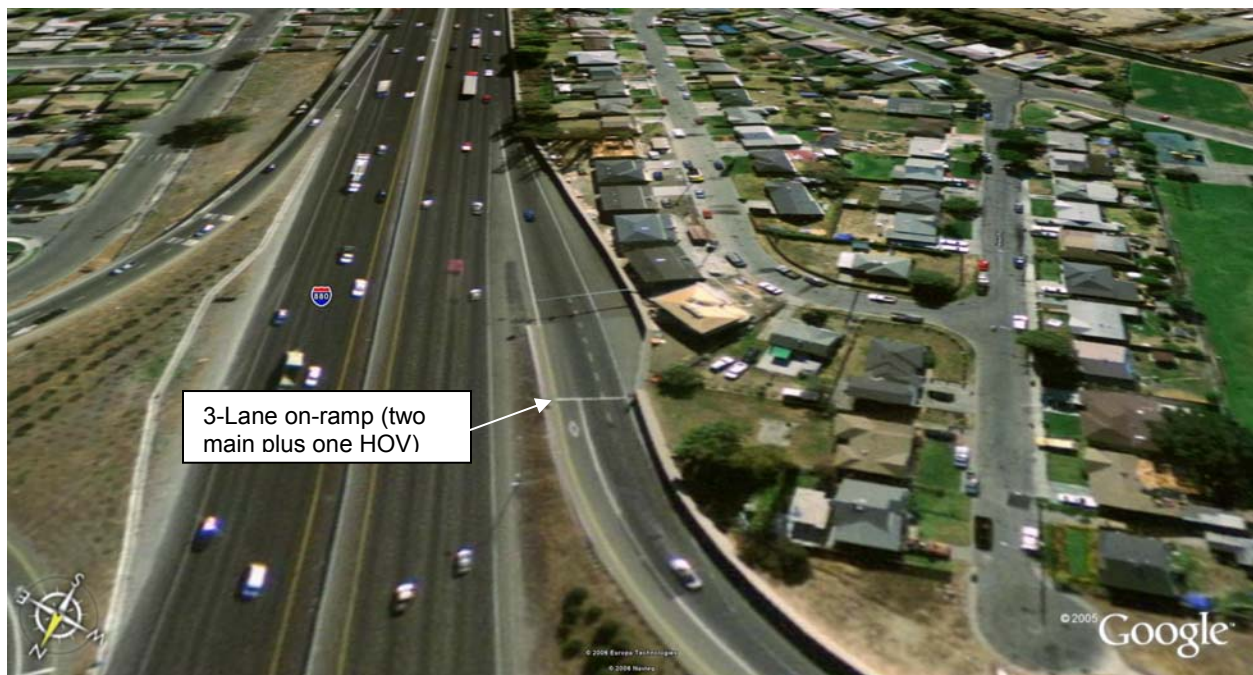


Finally, Exhibits 64 and 65 show the likely cause of the bottleneck at 98th. The on-ramps from the eastbound and westbound directions are close to each other. In addition, the eastbound on-ramp includes two main lanes and one HOV lane. At peak demand, the high merge and weave activities cause the bottleneck.

Exhibit 64 – 98th On-Ramp Bottleneck



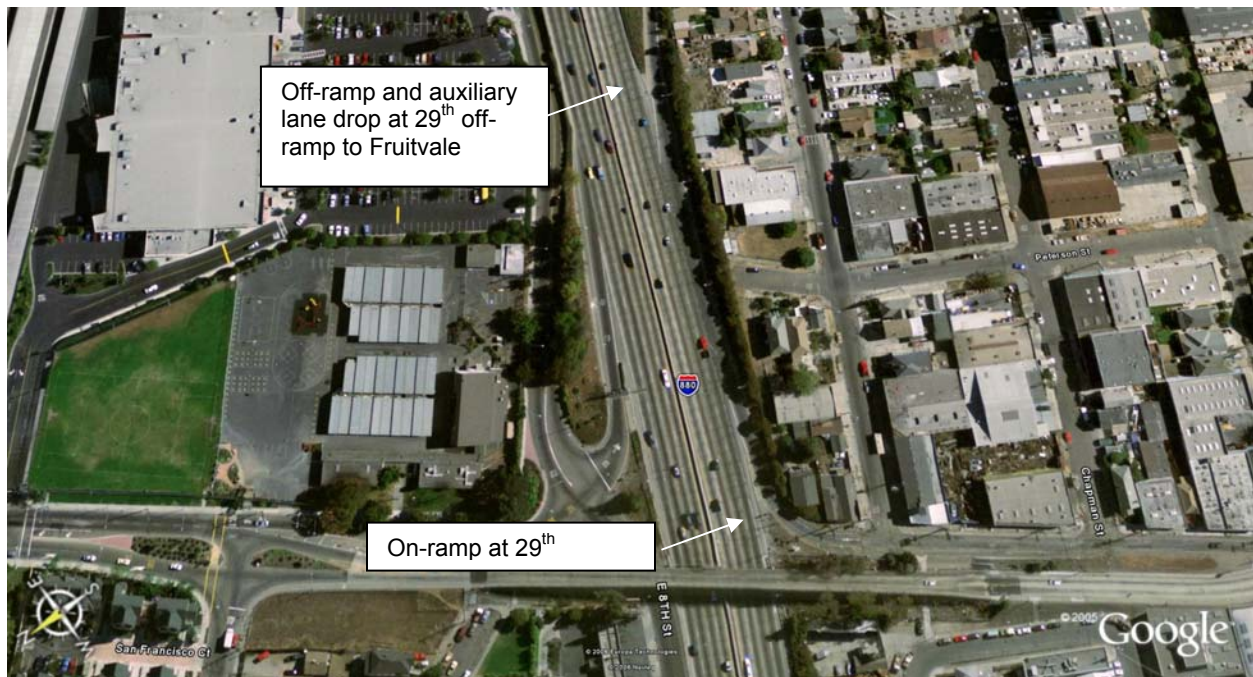
Exhibit 65 – On-Ramp from Eastbound 98th



29th Avenue Off-Ramp Occasional Bottleneck (Southbound PM Peak at around abs post mile 38.8)

This occasional bottleneck is sometimes hidden by the queues from the 98th bottleneck. This off-ramp shown on Exhibit 66 allows travelers to exit the 880 and get to Fruitvale. The off-ramp includes an auxiliary lane drop, which contributes to the bottleneck and backs up traffic on the 880. In addition, the 29th on-ramp just north of the off-ramp forces drivers to merge left while drivers wishing to exit are forced to merge right. The combination and the demand during the peak period occasionally cause the bottleneck.

Exhibit 66 – 29th Off-Ramp Bottleneck



Oak On-Ramp Bottleneck (Southbound PM Peak around abs post mile 41.2)

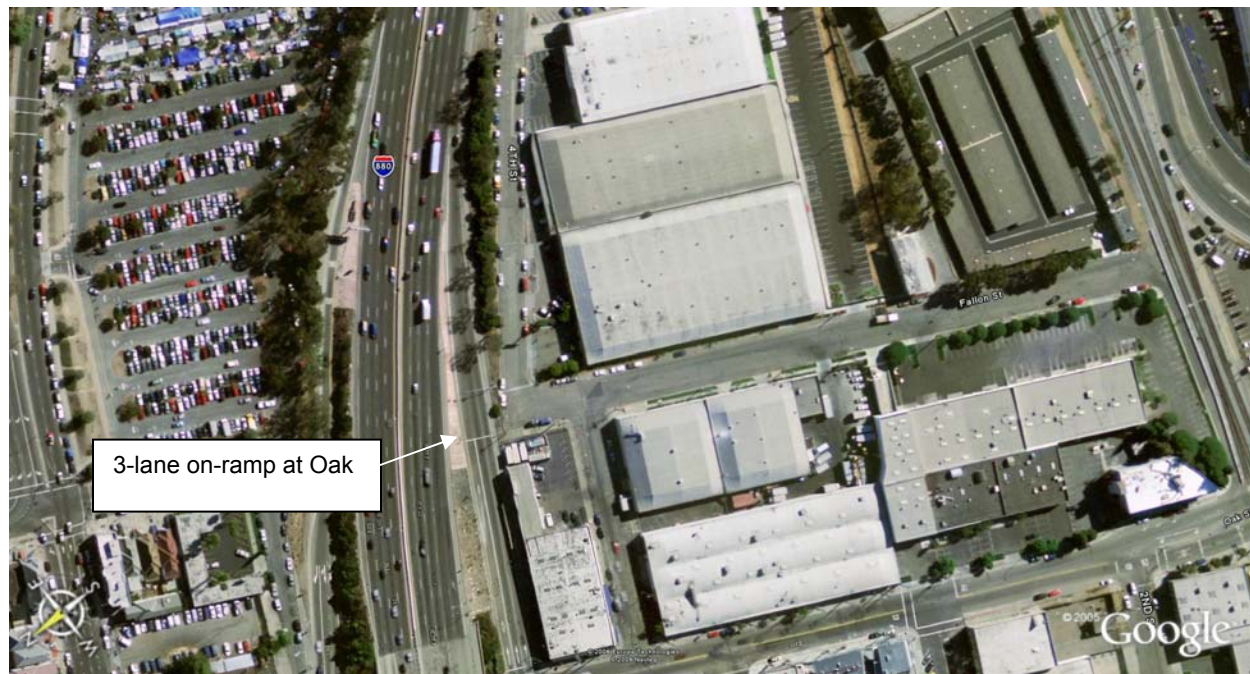
This occasional bottleneck is located is sometimes hidden by the combination of the 98th on-ramp and 29th off-ramp bottleneck queues. Exhibit 67 shows how the speeds drop at Oak and Broadway and the queue forms in the PM peak period.

Exhibit 68 shows the likely reason for this occasional bottleneck. Note the three lane on-ramp that merges into the 880 at Oak. When demand is already high, a three-lane on-ramp in total produces a high volume of vehicles which add merge and weave activities that sometimes produce the bottleneck.

Exhibit 67 – 5-Minute Speeds for Oak On-Ramp Bottleneck

Postmile (Abs)	Postmile (CA)	Location	% Observed	16:00	16:05	16:10	16:15	16:20	16:25	16:30	16:35	16:40	16:45	16:50
		29th off-ramp												
38.877	28.65	to Fruitvale	68.6	40.7	39.8	38.5	38.9	40	39.6	40	41.1	40.6	40	41.3
39.107	28.88		80.4	44.8	44.2	43.1	42	42.6	42	42.1	42.6	42.1	41.1	42.8
39.327	29.1		48.7	42.8	41.9	41.3	40.7	41.1	40.6	40.8	42	41.9	41.1	42.5
39.977	29.75		69.7	62.7	62.5	62.5	62.8	63	63.5	64.1	64.6	64.4	64.8	64.6
41.187	30.96	Oak	59.9	52.8	52.7	51.3	51.1	51.1	50.1	50.2	50.2	50.2	50.1	50.2
42.027	31.8		39.1	47.8	46.5	45.3	44.7	44.6	44.5	44.6	45.5	44.6	43.4	43
42.127	31.9		68.9	50.7	49.1	45.6	44.2	43.6	43.2	42.9	43.5	43.3	42.6	41.2
42.327	32.1		59.1	60.5	60.7	60.2	59.9	57.6	55.8	55.1	55.2	55.3	55.2	54.7

Exhibit 68 – Oak On-Ramp Bottleneck



Multiple smaller bottlenecks ending at Marina (between abs post miles 33 and 17)

The next set of bottlenecks occurs in the morning and to a much lesser degree in the afternoon peak period. None of the bottlenecks is as severe as the previously discussed ones. However, they do occur on a regular basis. Exhibit 69 on the next page shows the 5-minute speeds for January, 2006 for that part of the corridor.

Note that speeds slow down considerably at Winton, West A Street, Hesperian, Tennyson, and up to Mowry. In 2003 and 2004, there were also considerable slowdowns at Whipple and Tennyson. Now only moderate slowdowns occur at Tennyson and Mowry during the AM peak.

These bottlenecks are generally caused by on-ramp traffic merges as shown on Exhibit 70 on the next page. The exhibit shows the Winton on-ramps (from both directions). Note that the eastbound on-ramp auxiliary lane ends and forces traffic to merge left, which causes the bottleneck during peak demand conditions.

Exhibit 69 – Smaller Bottlenecks (Southbound AM)

Postmile (Abs)	Postmile (CA)	Location	% Observed	07:30	07:35	07:40	07:45	07:50	07:55	08:00	08:05	08:10	08:15	08:20	08:25
17.337	7.11	EB Mowry	91.4	56.5	55.4	52.8	50.6	50.3	51.2	51.8	52.2	52.4	52.8	53.4	52.7
17.527	7.3		91.7	57.4	57.3	55.9	53.8	52.8	53.1	53.5	54	54.6	55.3	56.1	55.5
18.907	8.68		79.1	55	52.2	47.7	44.2	43.5	43	43.5	44.9	45	45.1	45.8	45.9
19.097	8.87		78.7	59.1	57.1	51.7	47.6	45.8	45.1	45.7	46.7	45.9	46	46.2	47.1
20.127	9.9		50.4	57.1	56.9	56.7	56.3	53.1	52.6	52.2	52.5	53.3	54.5	53.6	53.7
20.347	10.12		79.8	59.2	59.4	58.9	56.1	50.8	47.9	47.1	47.7	48.7	49.8	49.8	49
20.547	10.32		80.3	61.2	60.9	60.4	58.9	55.9	53.5	52.7	52.9	53.4	54.1	53.6	53.3
21.277	11.05		91.1	62.7	62.3	62.2	61.4	60.9	60.1	59.6	58.8	59.5	59.5	59.5	59.6
21.647	11.42		77.9	55.6	55	55.3	52.6	50.8	48.7	47.8	47	47.7	47.7	47.1	46.7
21.817	11.59		32.6	54.8	54.1	54	52.4	50.5	48.7	48.1	47.2	46.9	46.4	45.1	44.1
22.227	12		5.4	58.9	58.2	58	58.1	56.3	56.8	57.1	57.5	56.9	57.2	56.9	56.4
22.527	12.3		80.3	53.4	51.5	51.8	52.6	51.9	52.1	51.3	51.1	50.6	49.9	50.5	49.5
22.777	12.55		60.3	52.4	51.6	50.1	49.1	48.5	50.3	50.5	49.5	48	47.1	47.9	47.8
23.167	12.94		74.5	58.5	57.7	57.3	55	55.6	56.6	57.4	55.1	53.9	53.2	53.2	53.2
23.327	13.1		80.4	59.7	59	59.4	58.3	59.2	59.5	60.7	59.1	57.4	56.8	55.8	56.3
23.767	13.54		79.8	53.8	53.3	53.7	53.9	54.6	54.7	54.7	54	53.1	52.2	51.4	51.6
24.477	14.25		51.9	52.7	52.3	52.2	51.5	51.6	51.4	51.6	51.6	51.2	51	51.6	51.6
24.767	14.54		84	55	55.4	55.9	55.9	56.3	56.5	56.6	56.7	57.5	57.1	56.6	55.6
25.177	14.95		80.2	58.2	58.5	58.8	58.8	59.2	59.4	59.1	59	59.9	59.7	58.3	57.7
25.727	15.5	Tennyson	61.6	44.8	44.7	44.8	45	44.8	44.3	44.6	44.7	44.6	44.4	43.8	43.1
26.027	15.8		80	60.6	60.9	59.8	60.1	59.4	59.9	59.4	59.6	59.1	59	58.3	58.1
26.287	16.06		59.8	56.5	56.2	55.7	55.6	54.1	54.2	54.8	55.4	55.2	54.6	54.9	55
26.467	16.24		43.1	57.4	57.1	56.8	56.7	54.7	53.3	53.7	54.4	54.1	53.6	54.3	55.2
26.677	16.45		16.1	56.8	56.2	55.5	55.3	54.7	52.9	53.1	53.4	53.4	52.6	53.6	54.5
27.037	16.81	SR92/Jackson	73.3	53.7	54.2	53.3	53.1	53.4	53.4	53.6	53.2	52.9	52.4	52.8	53.3
27.337	17.11	Winton	70.4	38.2	38.4	38.1	38.1	40	41.3	41.6	41.3	40.4	39.6	39.3	39.4
27.707	17.48	Winton	89.9	39.7	38.6	38.5	38.9	40.3	42	42.3	41.5	41.5	41.4	41.2	40.8
28.047	17.82	Winton	71.3	49.8	48.1	48	48.5	49.4	51.1	51.4	51.2	51.2	50.8	51.2	50.9
28.217	17.99		41.2	58.2	57.9	57.4	57.8	57.8	58.1	58	58.1	57.8	56.9	57.6	57.5
28.477	18.25	West A Street	91.2	41.9	40	38.9	37.6	36.6	37.7	40.3	41.1	41.6	42	42.8	43
28.947	18.72		64.3	53.3	52.4	51.2	50.8	49.8	50.4	51.9	54	54.9	54.6	54.4	54.4
29.267	19.04		56.3	50.7	50.5	48.4	48.1	46.4	46.8	48	50.2	50.4	49.7	50.1	50.3
29.597	19.37	Hesperian	78.1	49.7	47.9	46.1	45.7	44.8	45.7	46.6	48.6	49.2	48.9	48.2	48.7
29.907	19.68	Hesperian	63.6	47.4	45.5	44.3	43.3	42.9	42.6	43	44.5	44.9	45.7	44.9	44.3
30.187	19.96	Hesperian	39.8	44	41.8	41.1	39.6	39.4	39.2	39.2	39.5	40	40.8	40	39.5
30.557	20.33		80.4	45.9	44	42.5	41.8	40.3	38.9	39.7	39.7	40.3	40.3	40.3	40.2
32.727	22.5	Marina	77.5	54.1	47.5	43.2	39.6	37.3	35.7	34.7	34.3	36.3	37.6	36.4	40.5
32.947	22.72	Marina	71.1	61.5	60.8	60.5	59.2	58	56.7	56.2	55.6	54.6	53.9	54.1	54.1

Exhibit 70 – Winton On-Ramp Occasional Bottleneck



Mission Blvd - Rte 262 Bottleneck (Southbound AM and PM Peak around abs post mile 12)

In further analyzing this bottleneck it becomes apparent that the darker area with slower speeds represents two separate bottlenecks. The first is indeed at Mission Blvd at the Rte 262 interchange. The second is at the Fremont interchange. Reaching this conclusion was somewhat challenging because of changes in detection data.

The next page explains these challenges and our conclusions, which were also verified with field observations:

- Exhibit 71 on the next page shows 5-minute speeds by detector for the month of October, 2004. For each detector, it also identifies the percentage of “observed” data. This refers to the percent of the data that was actually received from the detector station. So for instance, the detector at post mile 11.402 only had 15.8 percent of the data received from the field. PeMS does estimate the remainder, although when it estimates a high percentage, the results may not be correct. Note how there are two separate sets of detectors that report deteriorating speeds. The first set starts at absolute post mile 11.402. This detector represents the Mission Blvd interchange. The speeds diminish to below 30 miles per hour. However, at post mile 12.657, which has almost 80 percent observed data, speeds pick up again to above 60 miles per hour. Then at post mile 13.277, speeds diminish again. This detector represents the Fremont interchange. Clearly, speeds recover between the two bottlenecks.
- Exhibit 72 shows the same type of data for the month of March, 2005. The same trend is shown with two distinct bottleneck areas and speeds recovering between them.
- However, Exhibit 73 representing October, 2005 no longer shows any detection at post miles 11.402, 12.467, or 12.657. Furthermore, it shows that zero observed values for post mile 12.182. Hence, it appears that there is only one bottleneck since the Mission Blvd interchange no longer produces any data.
- Exhibit 74 further illustrates this point. The exhibit represents March, 2006 data and no longer shows any detection at post mile 12.182.

This analysis underscores the need to verify any detection related conclusions with observed data. If the study team had relied on 2005 and 2006 detection data, it is likely that it would have identified only the Fremont Blvd bottleneck.

But in fact, there are two separate bottlenecks. The Mission Blvd bottleneck queue sometimes (e.g., November 2003 on Exhibit 60) extended beyond the Fremont bottleneck. Also note from the Exhibits 60 through 62 that the bottleneck speeds at Fremont were lower (with darker color) in 2005 compared to 2004. This accounts for some of the delay increases reported as part of the corridor-wide results in this section.

Exhibit 71 – 5-Minute Speeds by Detector Southbound at/near Mission Blvd - October 2004

Postmile (Postmile (VDS	% Observed	06:20	06:25	06:30	06:35	06:40	06:45	06:50	06:55	07:00	07:05	07:10	07:15	07:20	07:25	07:30	07:35	07:40
10.21 10.21 401642	0	64.5	64.1	64.2	63.9	64	64.3	64.4	64.1	64.2	64.1	63.8	63.8	64	63.9	63.7	63.5	63.1
10.542 0.04 401637	0	65.5	65.3	65	64.9	64.9	65	65	65.2	65.1	64.8	64.3	63.8	63.3	62.8	62.3	61.5	60.7
11.052 0.55 401647	0	64.2	64	63.3	62.6	62.5	62.4	62.4	62.5	62.2	62	61.9	61.6	61.4	60.8	60.3	59.7	59
11.402 0.9 401648	15.6	60.7	59.7	57	53.1	50	48	46.6	46.2	44.6	45.2	46	46.2	46.7	46.2	45.8	45.2	45.2
12.182 1.68 400371	84.8	58.7	56.5	53.8	48.9	40.5	35.2	29.6	29	29.1	29.7	29.2	28.9	28.2	27.2	25.9	23.1	22.9
12.467 2.24 400077	0	62.1	61.3	61	60.1	58.2	57.2	55.8	55.5	55.5	55.4	54.9	54.6	54.6	54.2	53.9	53.5	53.7
12.657 2.43 401080	83.7	65.6	64.7	64.7	64.5	65	65.1	65.3	65.7	66.1	65.8	65.3	65.3	65.8	65.3	65.2	65.8	65.3
13.277 3.05 400409	17.7	61.2	59.7	59.4	58.7	57	53.4	52.5	51.3	50.8	50.3	47	45.1	44	43.7	43.1	41.7	41.8
13.467 3.24 400941	28	62	61	60.1	57.6	55.3	51.7	50.5	49.2	48.9	48.4	42.7	39.5	37.1	36.1	35.2	32.5	31
14.257 4.03 400698	53.4	59.6	58.8	58.4	55.5	54.8	53.8	51.8	51.1	49.5	47.8	46.3	44.6	43.5	40.6	40.7	39	37
14.807 4.58 400363	40.9	59.8	58.8	58.1	57.5	56.3	55	54.1	52.4	52.1	50.2	50.4	49.7	44.8	42.3	38.7	36.7	34.9

Exhibit 72 – 5-Minute Speeds by Detector Southbound at/near Mission Blvd - March 2005

Postmile (Postmile (VDS	% Observed	06:20	06:25	06:30	06:35	06:40	06:45	06:50	06:55	07:00	07:05	07:10	07:15	07:20	07:25	07:30	07:35	07:40
10.21 10.21 401642	39.8	78	77.8	77.6	77.7	77.5	76.9	77.5	78	78.3	78.3	78.2	77.9	77.6	77.7	77.7	77.8	78.1
10.542 0.04 401637	0	67.7	67.3	66.8	66.8	66.3	66	66.3	66.8	66.9	66.9	66.6	66.5	66.2	66.1	65.7	65.7	65.5
11.052 0.55 401647	0	62.9	62.1	61.4	60.5	59	58.2	57.2	57.6	57.9	57.8	57.8	58.1	58.7	58.6	57.7	58.2	58.3
11.402 0.9 401648	79.5	63	61.3	59.6	57.1	54.3	51.6	51.1	51.9	52.3	52.2	51.7	52.4	53.7	53.5	51.7	52.5	52.9
12.182 1.68 400371	77.5	60.7	58.2	55.4	51.7	45.8	38.3	32.3	32.4	31.8	30.7	30.7	30.7	30.8	30.4	29.1	27.9	27.8
12.467 2.24 400077	0	63	61.8	61.6	60.7	59.7	57.9	56.3	55.8	55.8	55	54.5	54.2	54.5	54.6	54.7	54.4	54.4
12.657 2.43 401080	79.7	67	66.8	66.8	66.6	67	66.5	67.1	67.4	67.8	67.1	66.6	66.5	66.3	66.3	65.9	65.6	65.6
13.277 3.05 400409	75.7	64.6	63.6	62.3	59.8	58.6	56.2	53.3	51.1	49.6	48.3	46	42.2	38.9	36.3	35.5	32.9	30.4
13.467 3.24 400941	80.5	65.9	64.8	63.6	62	60.1	58.8	57.2	55.4	53.4	51.6	49.2	46	42.7	39.8	37.4	34.3	32
14.257 4.03 400698	78.4	64.8	63.6	61.5	60.3	59.5	59.3	60	60.1	59.5	58.3	57.1	55.4	53.5	52.3	49.2	47	43.7
14.807 4.58 400363	82.1	64.8	63.5	60.9	59.9	58.8	58.4	58.9	59.9	59.6	58.1	57.4	57.4	56.2	54.6	52.1	50.8	49.7

Exhibit 73 – 5-Minute Speeds by Detector Southbound at/near Mission Blvd - October 2005

Postmile (Postmile (VDS	% Observed	06:20	06:25	06:30	06:35	06:40	06:45	06:50	06:55	07:00	07:05	07:10	07:15	07:20	07:25	07:30	07:35	07:40
10.21 10.21 401642	92.7	61.7	61	60.3	60.3	60.4	60.8	60	59.7	58.9	57.9	57.5	57.9	58	57.7	57.7	57.5	57.7
10.542 0.04 401637	0	59.6	59.3	58.8	58.8	58.7	58.9	58.6	58.4	57.9	57.4	57	57.1	56.9	56.6	56.6	56.6	56.7
12.182 1.68 400371	0	63.2	62.8	61.6	58.5	54.7	51.2	48.9	47.9	48.6	48.3	48.5	48.5	49.1	48.2	47.2	44.6	43.5
13.277 3.05 400409	89.2	62.2	61	58.2	50.6	41.2	33.7	27.9	27	27.6	26.6	26.9	27	26.8	25.8	23.6	20.7	18.9
13.467 3.24 400941	87.8	63.9	62.7	60.1	55.2	47.4	40.1	35.2	32.4	32	30.8	30.6	30.5	30.3	28.4	26.4	24.1	22.5
14.257 4.03 400698	91.8	61.2	59.7	56.9	53.2	49.6	45.6	41.4	39.2	37.8	39.7	39	37	35.2	33.6	32.5	32.6	32.3
14.807 4.58 400363	92.9	62	60.2	57.6	55.5	54.1	51.3	48.3	46	46.3	48	49.4	48.4	44.9	42.6	39.9	37.7	36.4

Exhibit 74– 5-Minute Speeds by Detector Southbound at/near Mission Blvd – March 2006

Postmile (Postmile (VDS	% Observed	06:20	06:25	06:30	06:35	06:40	06:45	06:50	06:55	07:00	07:05	07:10	07:15	07:20	07:25	07:30	07:35	07:40
10.21 10.21 401642	86.3	70.7	70.2	70.1	69.7	69.5	69.4	69.6	69.5	68.9	68.3	67.6	67.6	67.5	67.4	67.8	67.2	67.1
10.542 0.04 401637	0	66.1	65.7	65.3	64.5	63.7	63	62.7	62.6	62.4	62.6	62.3	62	60.8	60.1	59.8	59.1	58.8
13.277 3.05 400409	73.6	59.6	58.4	55.7	52.1	47.7	42.7	40.3	41.3	40.5	41.4	41.6	39.2	35.8	33.1	29.8	26.9	25.1
13.467 3.24 400941	88.3	64.1	63.3	60.3	57.7	54	50.2	48.2	47.9	47.4	48.3	48.4	46.5	42.1	39.8	36	32.6	30.1
14.257 4.03 400698	73.3	63	62.3	60.8	59.5	59.2	58.8	56.4	56.7	57.5	58.2	59.1	57.7	54.5	52.1	50.1	48.1	46.3
14.807 4.58 400363	91.5	59.6	58.2	56.8	56	55.2	56	55.2	55.7	55.4	55.4	55.1	54.2	54	53.4	51.8	50.3	48.5

Traveling southbound, a traveler experiences the Fremont interchange first as in Exhibit 75. The on-ramp for this interchange is quite large with 3 lanes (2 SOV, 1 HOV). The merge from this on-ramp leads to the congestion with queues as long as 1-2 miles.

Exhibit 75 – Southbound Bottleneck at the Fremont Interchange



Around one mile after the Fremont interchange, the traveler arrives at the next bottleneck at the Mission/Rte-262 interchange. The reason for this bottleneck can be attributed to the merge activities from the Mission/Rte 262 on-ramp as well as another on-ramp just after it at Gateway Blvd as shown on Exhibit 76 below.

Exhibit 76 – Southbound Bottleneck at the Mission/Rte 262 Interchange

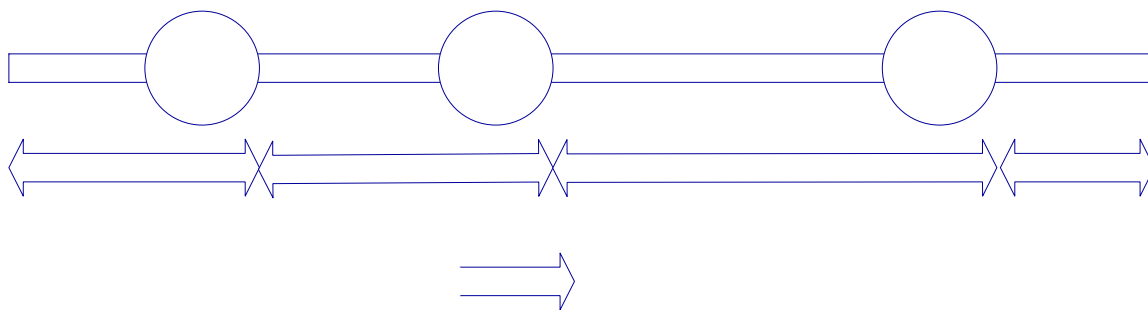


Summary of Bottlenecks

Many of the bottlenecks discussed in this section relate to on-ramp merging traffic. This is not to say that the on-ramps are inadequate. Rather, it is a demand related issue. Obviously, if the demand from these on-ramps were low, the resulting merges would not cause the types of bottlenecks observed. However, there may be ways to manage this high demand (e.g., via more restrictive metering), assist the incoming vehicles to better merge with the freeway traffic (e.g., via extension of auxiliary lanes), and other operational strategies. These will be tested using the micro simulation model being developed.

In order to get a sense of priority among bottlenecks, the study team also re-analyzed the delay and collision data and divided them into “bottleneck areas”. Bottleneck area is a term used here to define a portion of the freeway from one bottleneck to another as depicted in Exhibit 77. Note that occasional bottlenecks (e.g., at Oak) have been included as part of the more severe bottlenecks. Also, the multiple, smaller bottlenecks between absolute post miles 25 and 33 are considered one single bottleneck area. Finally, when two bottlenecks are very close to each other such as the case with Fremont and Mission Blvd southbound in the AM, these were combined into one bottleneck area (since we do want to address them concurrently to the extent possible).

Exhibit 77 – Dividing Corridors into Bottleneck Areas



Based on this approach, the following is a listing of bottleneck areas:

Northbound

From			To			Description	Designation	Bottleneck Period
Abs	CA	County	Abs	CA	County			
8.4	8.4	Santa Clara	26.5	16.3	Alameda	From 237 to Tennyson	Tennyson Bottleneck (N1)	AM and PM Peak
26.5	16.3	Alameda	34.0	23.8	Alameda	From Tennyson to Davis	Davis Bottleneck (N2)	AM only
34.0	23.8	Alameda	40.0	30.0	Alameda	From Davis to 23rd	23rd Bottleneck (N3)	AM only
40.0	30.0	Alameda	44.0	34.0	Alameda	From 23rd to 7th	Not a bottleneck at all (N4)	None

Southbound

From			To			Description	Designation	Bottleneck Period
Abs	CA	County	Abs	CA	County			
44.0	34.0	Alameda	34.8	24.6	Alameda	From 7th to 98th	98th Street Bottleneck Area (S1)	PM Peak Only
34.8	24.6	Alameda	17.0	6.8	Alameda	From 98th to Marina	Multiple Bottleneck Area (S2)	AM and PM Peak
17.0	6.8	Alameda	11.0	0.8	Alameda	From Marina to Dixon Landing (south of Mission/Rte 262)	Fremont and Mission/Rte 262 Bottleneck Area (S3)	AM and PM Peak
11.0	0.8	Alameda	8.4	8.4	Santa Clara	From Automall to SR 237	Not a bottleneck area at all (S4)	None

Using these bottleneck areas, the study team computed delay by bottleneck area as well as collisions by bottleneck area. The results are shown below in Exhibit 79. Note that the collision data only goes through 2004 whereas the delay data includes all of 2005.

California SR41 Corridor Simulation Study

--Calibration Procedure and Results

by

Liang Ding

A master's report submitted in partial fulfillment
of the requirements for the degree
of

MASTER OF SCIENCE

in

Civil and Environmental Engineering

Approved:

Henry Liu
Major Professor

Anthony Chen
Committee Member

William Grenney
Committee Member

UTAH STATE UNIVERSITY
Logan, Utah

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Abstract

This master's report presents the calibration procedure and results for a large scale corridor management simulation study on State Route SR41 in Fresno, California. The corridor management aims to incorporate detailed multi modal performance measurement and operational analysis into the traditional corridor planning efforts. Micro-simulation software Paramics is used to evaluate and test different traffic management strategies for an integrated multi-modal traffic system. Alternative modes of transportation could be microscopically simulated to assess and maximize operational characteristics. A complete streamlined and practical calibration procedure is described in the report, including methods for data collection and analysis, capacity calibration, origin-destination demand estimation and calibration, and calibration and validation. Calibration results are also shown by the proposed calibration procedure.

(74 pages)

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CHAPTER 1: INTRODUCTION

1.1 Project Background

The corridor management aims to incorporate detailed multi modal performance measurement and operational analysis into the traditional corridor planning efforts. The goal of this project is to improve corridor management planning and to develop a standard corridor planning template for use by staff of the California Department of Transportation (Caltrans).

Caltrans has designated certain corridors for aggressive implementation of ITS strategies such as traffic control (freeway ramp metering & arterial signalization), traveler information, and incident management. These strategies will complement other improvements such as transit and rail, maintaining state and local agency roadways, and some highway capacity improvements in order to provide the multi-faceted approach needed for sound system management.

Since not all corridors are ready for aggressive system management, Caltrans will select specific corridors that are appropriate for the development of system management plans which fully incorporate operational strategies, particularly those enabled by intelligent transportation systems.

The concept of the project is to provide computer modeling outputs/results and extensive public involvement process to assist in developing a comprehensive corridor plan.

State Route (SR) 41 is an intensive transportation corridor, which traverses the Fresno urbanized area and southeastern Madera County. The computer modeling tools would provide valuable input into comprehensive corridor planning for SR 41, particularly for the Fresno urbanized area.

The SR41 corridor network is shown in FIGURE 1. The network is about 16 miles long in North-South and four miles wide in East-West. It contains one major freeway (SR41) and two parallel streets with other adjacent surface streets. There are totally 176 TAZs and 89 signalized intersections, and 15 ramp metering controllers. The study area has different congested patterns in AM and PM peak hours. For AM peak hours (6-9AM), the congestion happens in the southbound and northbound for PM peak hours (4-7 PM). In this report, Paramics is used as the tool for simulation study and PM calibration will be conducted as an example of the streamlined procedure.

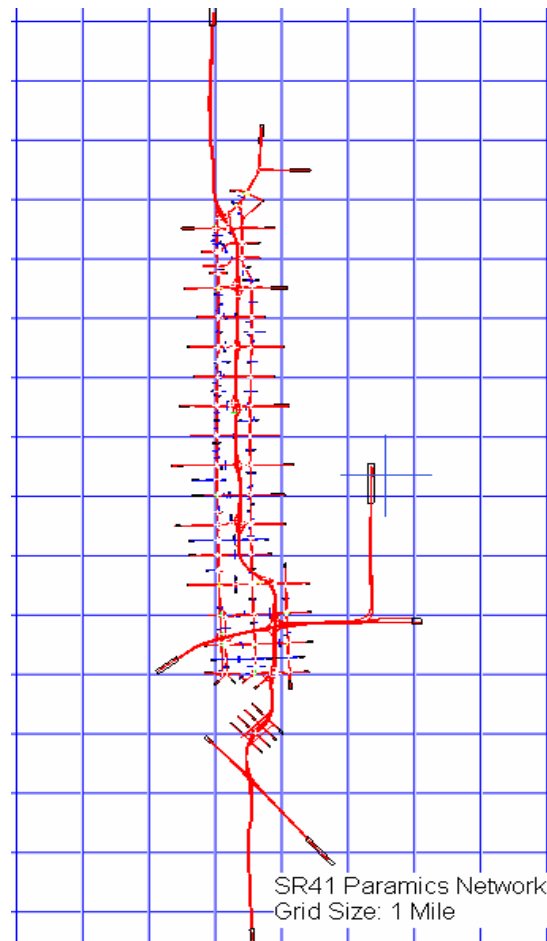


Figure 1 Layout of the Study Network

1.2 Project Scope and Objectives

The report describe the first phase of the ongoing project “California SR41 Corridor Traffic Simulation Study”, it mainly focuses on:

1. Network error coding check, data organization and analysis, and preliminary calibration;
2. Estimate origin-destination demand matrix and calibrate and validate Paramics model for SR41 Corridor network.

Micro simulation becomes more and more popular and effective in solving transportation problems. It provides visualization of traffic flow on the transportation system given current and proposed conditions. In corridor management procedure, micro simulation can serve as an evaluation tool for traffic management strategies over an integrated multi-modal system. In addition, alternative modes of transportation could be micro simulated to assess and maximize operational characteristics. For any micro simulation study, the calibration procedure is always a very crucial step. In particular for large scale networks, the calibration is normally difficult and time-consuming.

The Calibration for a simulation study ultimately requires comparing simulated data with field-observed traffic data. Because field observations vary from day to day due to the stochastic nature of traffic, the calibration objective is to re-construct the typical real world traffic variation in the Paramics simulation. The calibration efforts are focused on the use of aggregated data to calibrate the most critical parameters in Paramics, including OD matrix adjustment, route choice parameters, the mean target headway and driver reaction time, and signposting settings of important freeway links in Paramics.

The traditional process of simulation model calibration relies heavily on the engineering judgment, i.e., to adjust the model parameters (usually demands and network) until reasonable (quantitatively and qualitatively) matches between field data and simulated model results are reached (Gardes *et al*, 2002, 2003). Without a clearly defined streamlined procedure, these adjustments can be very time consuming and tedious. Especially for large scale networks, because the number of parameters is large, the trial-and-error method sometimes cannot get the realistic result. Another

deficiency for this method is, because of the limitations of the human knowledge, for the large scale network with many traffic analysis zones (TAZs), the demands usually can not be handled properly.

Some researchers therefore focus on systematic approaches by formulating the steps of the calibration as an optimization problem. Then the calibration procedure becomes determining a combination of parameter values. By using certain approaches such as gradient and genetic algorithms, the combination of parameters with the best performance is found (Xu, *et al*, 2004; Lee, *et al*, 2001; Cheu, *et al*, 1998). This optimization method has the potential to achieve the global solution of the calibration problem. However most of them can only handle parameters in driving behavior and route choices. For large scale networks, OD demands can not be well represented in the procedure. Further, this method is not easily understood and conducted by practitioners.

In this report, we present a streamlined and practical calibration procedure for large scale corridor network simulation study, namely the California SR41 corridor network simulation study. The procedure includes methods for data collection and analysis, capacity calibration, OD matrix estimation including both hourly and dynamic demands, and calibration and validation. Approaches for demand pattern matrix updating and dynamic OD generation are proposed along with the calibration procedure. Calibration results show that such a procedure can provide reasonably accurate matches with the field data and is easily conducted by traffic engineers.

1.3 Organization of Report

The report consists of four major parts.

Part I is mainly on project introduction, including Chapter 1 project background introduction information for the SR41 corridor network simulation study, and Chapter 2 introduces outlines the overall calibration procedure and objectives of calibration.

Part II includes Chapter 3 and Chapter 4. In Chapter 3, data collection and analysis methods for the simulation study are provided; and in Chapter 4, the preliminary calibration methods, including network coding error checking are provided.

Part III is focused on the Calibration Methodology and Procedure, the procedure for capacity calibration is discussed in Chapter 5. Chapter 6 to Chapter 8 present in detail the methods for OD estimation and calibration, including the pattern matrix updating (Chapter 6), hourly OD estimation in Paramics Estimator (Chapter 7), and dynamic OD matrix generation (Chapter 8). The model final tuning of the calibration is given in Chapter 9.

Finally in PART IV, the calibration and validation results are shown in Chapter 10, followed by conclusions and future research directions in Chapter 11.

CHAPTER 2 CALIBRATION OBJECTIVES AND PROCEDURE

2.1 Streamlined calibration procedure

Comparing and analyzing the traditional calibration methods, a clearly defined streamlined calibration procedure will be described in the paper. It follows the traditional step-by-step calibration framework which can be easily understood and used by traffic engineers. In particular, we put extensive effort on the OD demand estimation and calibration and develop some methods for this purpose. The calibration procedure can be depicted in the flow chart shown in FIGURE 2.

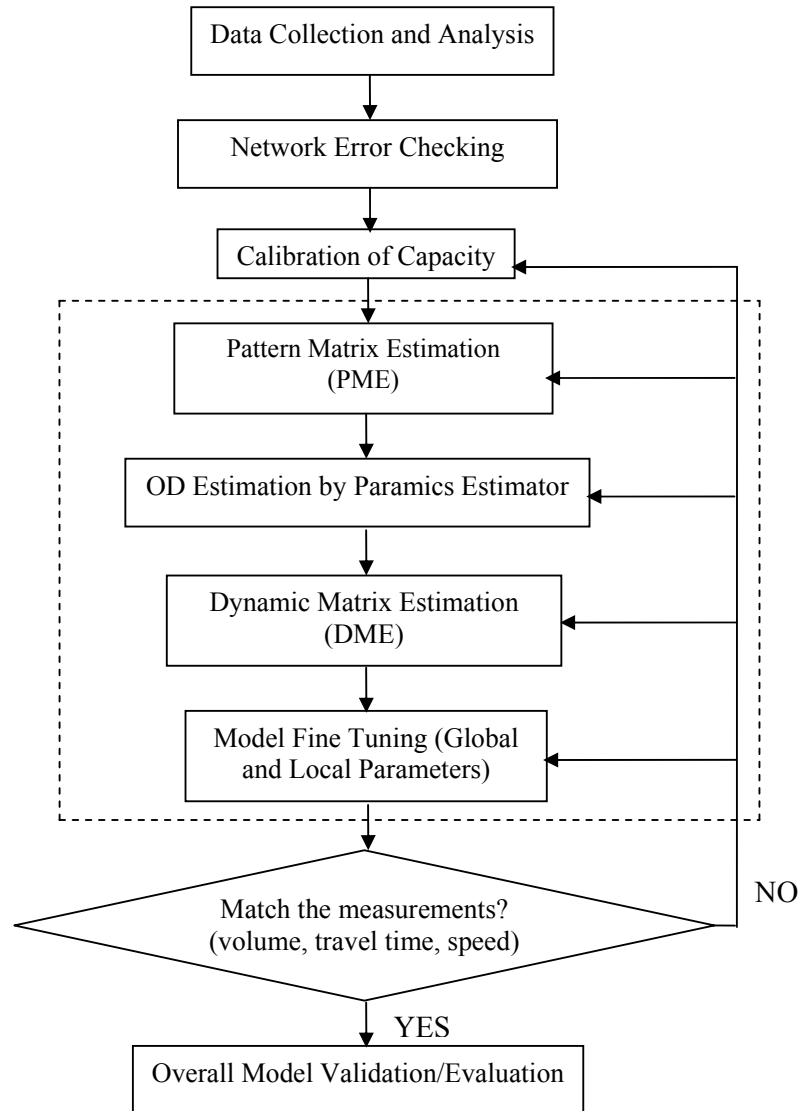


Figure 2 Flow Chart for the Calibration Procedure

The following chapters will further detail the calibration steps in FIGURE 2.

2.2 Objectives of Calibration

The objective of model calibration is to get the best match possible between model performance estimates and field measurements of performance. However, there is a limit to the amount of time and effort anyone can put into eliminating error in the model. There comes a point of diminishing returns where large investments in effort

yield small improvements in accuracy. The analyst needs to know when to stop. The following Table 1 is suggested by Wisconsin Department of Transportation for potential stopping points for calibration. (Dowling, *et al*, 2002)

Table 1 Micro Simulation Model Calibration Criteria

Criteria & Measures	Acceptability Targets
Hourly Flows, Model vs. Observed Individual Link Flows Within 15%, for 700 vph < Flow < 2700 vph Within 100 vph, for Flow < 700 vph Within 400 vph, for Flow > 2700 vph Total Link Flows Within 5% GEH Statistic – Individual Link Flows GEH < 5 GEH Statistic – Total Link Flows GEH < 4	 > 85% of cases > 85% of cases > 85% of cases All Accepting Links > 85% of cases All Accepting Links
Travel Times, Model vs. Observed Journey Times Network Within 15% (or one minute, if higher)	 > 85% of cases
Visual Audits Individual Link Speeds Visually acceptable Speed-Flow relationship Bottlenecks Visually acceptable Queuing	 To analyst's satisfaction To analyst's satisfaction

The GEH statistic is computed as follows:

$$GEH = \sqrt{\frac{(V - C)^2}{(V + C)/2}}$$

GEH = the statistic

V = model estimated directional hourly volume at a location.

C = directional hourly count at a location.

CHAPTER 3: DATA COLLECTION AND ANALYSIS

3.1 Introduction

A reliable and complete dataset is crucial for the simulation calibration study. It should cover not only the demand side (traffic demand information), but also the actual traffic performance data (volume, travel time, speed, and etc.). It is only when a complete set of traffic data is available that a model can be calibrated and validated against real-life traffic conditions.

3.2 Original data set

The traffic data of SR41 network had been collected before. One major issue with the dataset that had been used previously was that the demand information (counts) and traffic performance data had not been collected on the same days. Another problem was that this dataset, dating back to 1998, was outdated and did not reflect current traffic conditions anymore.

- Volume data, including the freeway mainline volume, ramp volume, arterials intersection turning count data, those data were collected from different years.
- Control data, including the signalized intersection timing plan, on-ramp operation data.
- Vehicle data, including performance, characteristics and mix by type.

3.3 Additional Data Collection

Additional new dataset reflecting the most recent traffic conditions on the SR41 peak hours are therefore collected. The new data needs were discussed with Caltrans District 6 staff, who provided most of the resources to gather the new dataset.

(1) Freeway loop detectors count data

Freeway traffic volume data, including mainline, on ramp and freeway interchange data, were collected by the loop detector from count locations. Data for five consecutive days were collected from Tuesday to Friday (November 16 – 18, 2004) to present the typical traffic conditions. The collecting period is five minutes. Since the congestion in this study happens mainly in the freeway system, the freeway volume data is the most important one to match in the calibration.

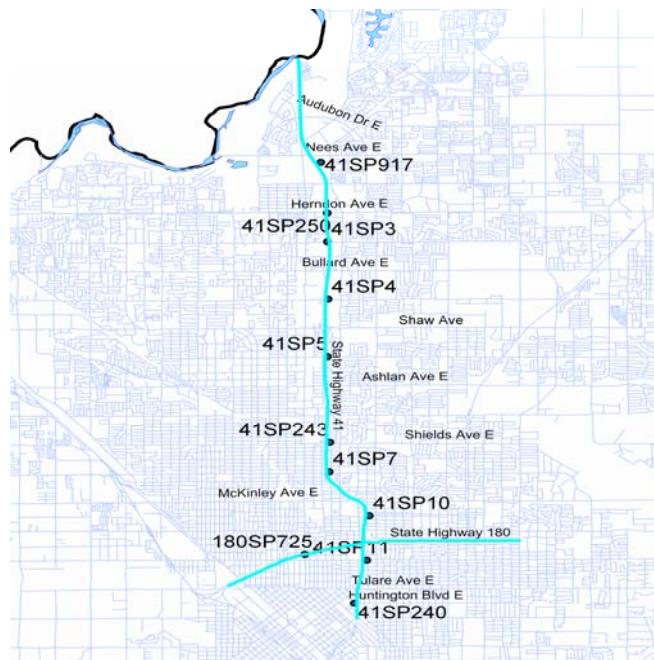


Figure 3 Freeway volume data collection locations

The collected data should at least have the following features:

- o 15 minutes interval

- o 3 hours duration
- o Both AM and PM peak
- o Both lane directions

(2) Arterials traffic data

Previously there are some historical arterials turning count data for most of the signalized intersections. But most of them are outdated and were only collected by hours. So they cannot fit the calibration requirement. New count data collection was conducted from Tuesday to Thursday which can reflect the typical week day traffic pattern. Totally 9 counting locations were selected.

Some of the major arterial cordon link counts also are considered to be the control points, both in the hourly OD estimation and the later time dependent demand matrix reconstruction. So the cordon link counts are collected for 9 locations.

The locations are list below, and they are all at the major intersections of the study area and cover most of the in/out traffic of the corridor.

Table 2 Arterials count locations

	Intersections turning	Cordon link
Locations	Blackston & Herndon	Nees west of Blackston street
	Fresno & Herndon	Nees east of Fresno street
	Blackston & Shaw	Bullard west of Blackston street
	Fresno & Shaw	Bullard east of Fresno street
	Blackston & Shields	Ashlan west of Blackston street
	Fresno & Shields	Ashlan east of Fresno street
	Blackston & Mckinley	Belmont west of Blackston street
	First & Mckinley	Belmont east of First street
	First & Tulare	Tulare between T and U street

(3) Tachrun data

Vehicles with GPS device were sent out to traverse the study roads (SR41 freeway, and two parallel arterials) for travel time data collections. Every second the vehicle location was record. At the end of the trip, all record were output to a text file and processed by the specified software called CLOG. Then travel time and speed data between sections were generated. With multiple days and multiple vehicle running, the travel time data can be used in calibration. In this study, we conducted Tachruns on SR41, Blackstone Ave., and Fresno Ave.

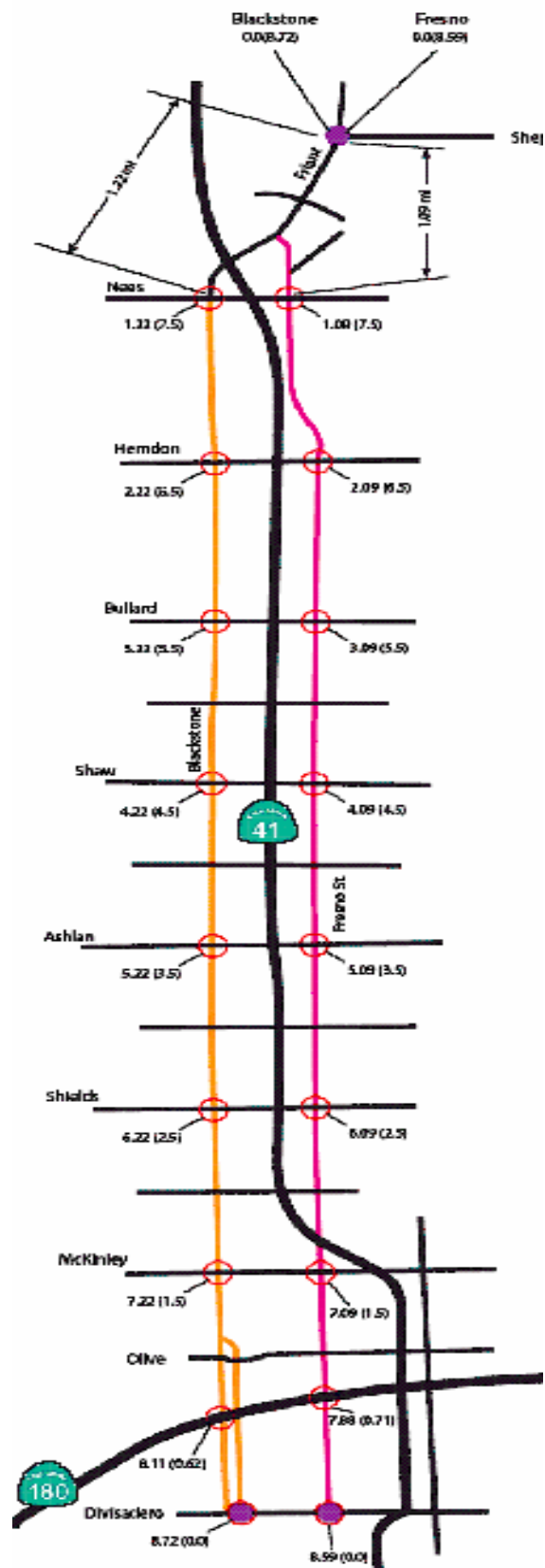


Figure 4 Tachrun check points locations

(4) Reference OD demand

From county travel demand model in TP+ and using the sub-area analysis method, the study area planning demand OD matrix can be retrieved in TP+. These planning demand matrix were mapped into Paramics network by a zonal system matching.

3.4 Count Data Cleaning and Processing

Data come from different sources have different accuracies and confidential levels. For the calibration purpose, they are given different weight as follows

- Freeway mainline data, higher weight (0.90)
- Freeway ramps and connectors, high weight (0.80)
- Arterials new cordon link count, higher weight (0.90)
- Arterials screenline intersections turning count, high weight (0.80)
- Old arterials data, lower weight (0.70)
- Reference OD demands, lower weight (0.70)

Some of data, especially the traffic count data, may have discrepancies with each other since they were collected during multiple days, some of them are very high and these data will effect the OD estimation adversely. They need to be further massaged. Lower weight data will be adjusted according to the higher weight data, i.e. if freeway mainline and freeway on ramp count are not coincide to the adjacent intersections count, the tuning counts will be adjust to match the freeway counts.

Two tools can be applied into this process:

One approach is to use the one of the Paramics Estimator functions, “Validate Data”, which can detect the count discrepancy automatically.

Another approach is to use the Excel template developed by Caltrans engineers to locate the discrepancy data. The sample is shown in Figure 5.

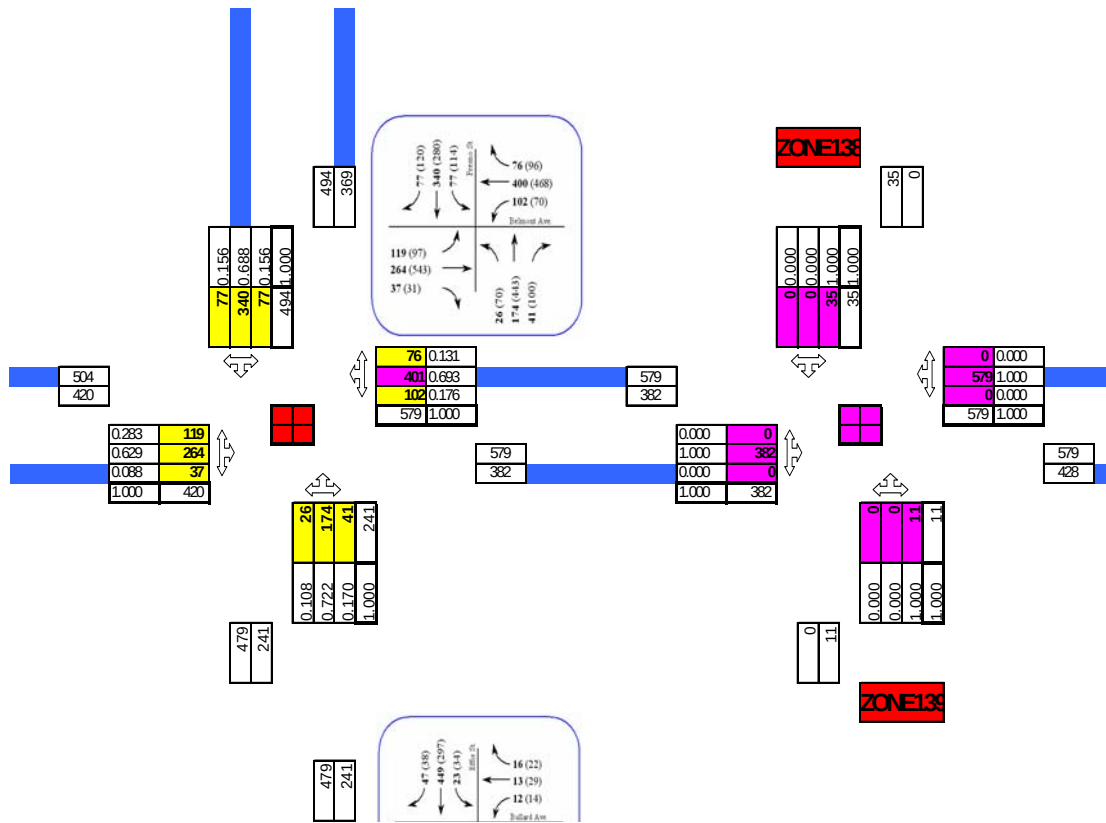


Figure 5 Abstract Excel grid network

3.5 Tachrun Data Processing and Analysis

On the basis of the multiple Tachruns in multiple days, a speed contour map can be created to present the speed change both spatially and temporarily. FIGURE 6 depicts the speed contour map for PM peak hours of the freeway mainline for NB and SB, respectively. In the figures, each cell of the time-space diagram represents the average speed over multiple Tachruns for a specific mainline freeway subsection. Thus speeds in the figure are shown over time (row summary) and over space (column summary). Three levels of speed are represented by different levels of shading: below 49 mph, between 50 and 59 mph, and over 60 mph. The resulting

speed contour map provides an effective tool to visualize the level of performance of the freeway, to identify the location of the bottlenecks, and the extent of congestion conditions (Gardes, *et al*, 2002, 2003).

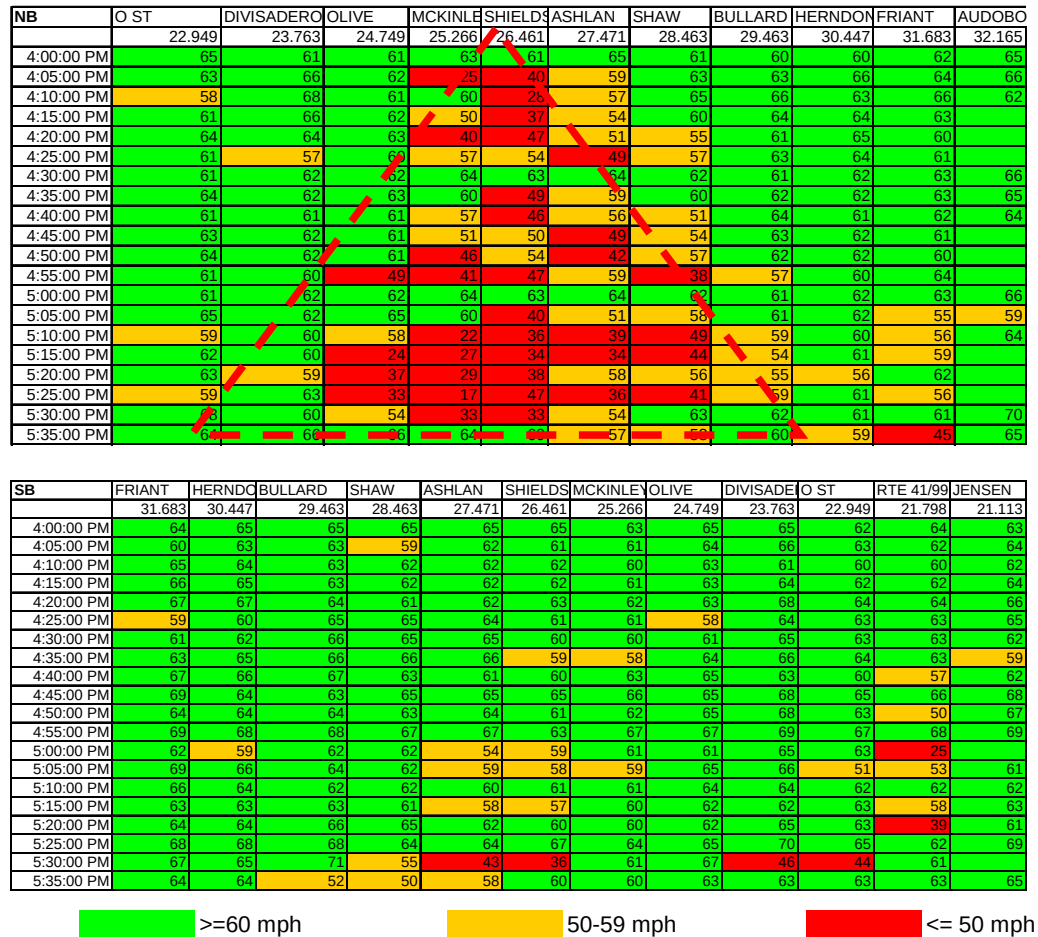


Figure 6 Speed Contour Map for PM Peak of Freeway

We can see from the figure that PM congestion mainly appears on NB of the freeway from 4:00 PM to 5:30 PM. The most congested areas are the Mckinley Ave., Shields Ave., and Friant Ave. However, for SB, there is almost no congestion.

3.6 Data mapping to Paramics Simulation

The objective of this step is to map the data into the appropriate Paramics format. This step is very crucial for the calibration procedure, all data, i.e. volume count data, the Tachrun travel time, and speed data, should be mapped to the Paramics node-link system.

The correlations between physical location and the Paramics simulation give the users more convenience to manually adjust the data in the later calibration process. The sample for the input format will be listed in Figure 7.

Locations	Direction	Node-link	Count	Weight
Frait	NB	247:149	2062	0.9
	SB	148:62	1905	0.9
Herndon	NB	702:157	3160	0.9
	SB	47:158	2687	0.9
Serria	NB	164:161	4720	0.9
	SB	223:159	4169	0.9
Bastow	NB	246:270	5652	0.9
	SB	226:553	5011	0.9
Gettysberg	NB	253:271	6233	0.9

Streets	Leg	Turning	Node-link	Count	Weight	
Blackstone	Herndon	SB	R	820:135:839	353	0.8
Blackstone	Herndon	SB	T	820:135:1259	736	0.8
Blackstone	Herndon	SB	L	820:135:842	488	0.8
Blackstone	Herndon	WB	R	842:135:825	538	0.8
Blackstone	Herndon	WB	T	842:135:839	1334	0.8
Blackstone	Herndon	WB	L	842:135:1259	252	0.8
Blackstone	Herndon	NB	R	834:135:842	298	0.8
Blackstone	Herndon	NB	T	834:135:825	933	0.8

Figure 7 Data mapping format

CHAPTER 4: NETWORK CHECKING AND MODIFICATION

4.1 Introduction

The network geometry and signal timing were coded in Paramics and checked to ensure they reflect the actual field conditions. The network geometry is a major factor in the vehicles behavior and it is very important to model it correctly. Link attributes such as the number of lanes and gradients are modified as needed. The network geometry is tested by loading a few vehicles onto the network and observing their behaviors. If the geometry was not coded correctly, some revisions need to be conducted, including curb positions, stopline positions and angles, link and intersection description (link gradients, link headway factor, link end speeds, intersection visibility, etc.), barred turns, closures and restrictions, lane usage and behavior of traffic, signposting, and the nextlane function.

Signal timing and ramp metering are also very important parts in network coding. Because in this project, the Actuated Signal and Ramp Control plug-ins in Paramics will be applied, so the detectors locations and names are also need to be take into considered. The other items should be checked, including cycle length, phases green time, movement priorities, and ramp control rate, etc. (Chu, *et al*, 2004; Gomes, *et al*, 2004)

4.2 Network Coding Update

When running Paramics Modeller, the user can assess the results from a visual or a numerical point of view. The visual analysis consists in the observation of the vehicle movements on the screen visualization, in order to check if the traffic is moving in a realistic manner.

4.2.1 Presence loop detector location

Some Presence loop detectors are located far away from the stop line. In these cases, vehicles in queue cannot get the correct green extensions. All these loops are moved forward to close to the stop line.

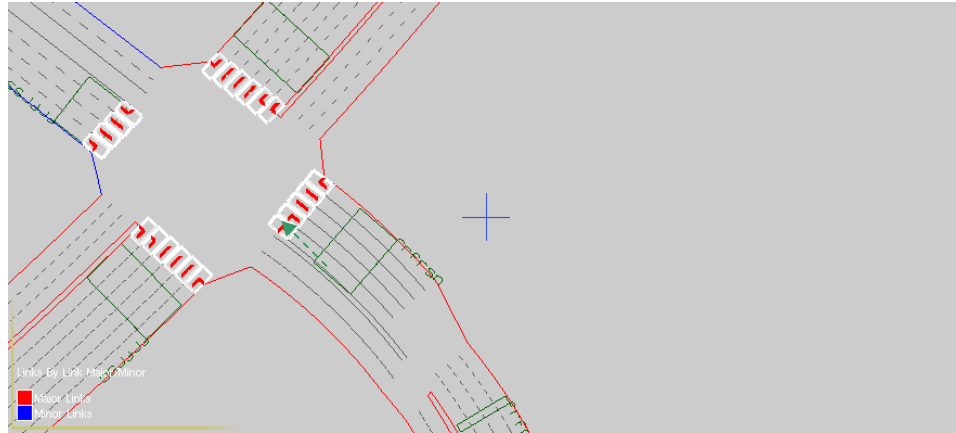


Figure 8 Presence loop detector location update

4.2.2 Advance loop detectors location

Because of the limitation of the **Actuated signal control API**, when one approach has the right turn pocket and the advanced loop detector is not located on the junction link connected to the intersection, the API will not work properly and will not give vehicles extension if they traverse the most outside lane. All of the intersections with this kind of problem will be adjusted. (loops will be located on the junction links)

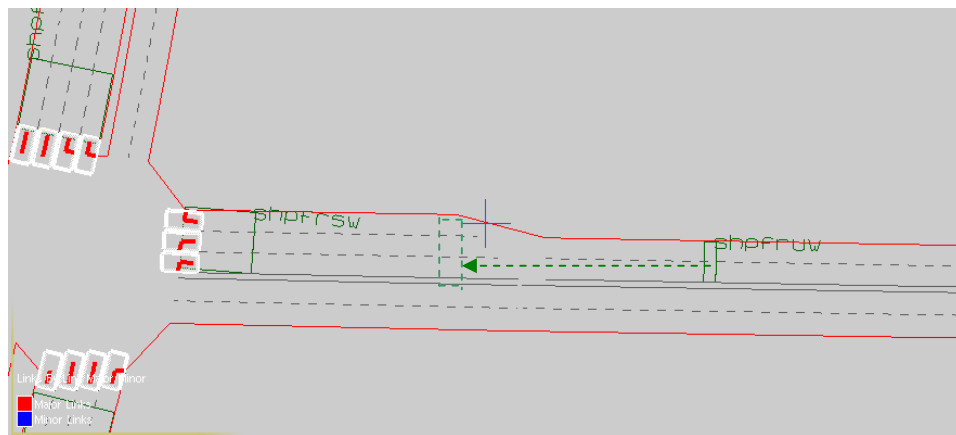


Figure 9 Advance loop detector location update

4.2.3 On-ramp geometry

HOV lanes are added to the network and the ramp metering control are applied

- a. Some on ramps have HOV lanes, the detectors need to be input and configured in ramp_control. To differentiate the HOV vehicles and the normal vehicles, one new vehicle type be created from type: HOV PASSENGER CAR, the percentage be set to 20%, the new HOV restriction and speed strategy is set to HOV lane, so only high occupancy vehicles are allowed to use these lanes. The on-ramp locations are shown in the Table 3. The locations with HOV lanes are shaded, which need to be updated.

Table 3 On ramps description

Locations		HOV	Lanes
Fre 180 EB			
	Blackston/Abby (Direct), PM	Yes	2
Fre 41 NB	Broadway (Direct), PM	No	1
	M Street (Direct), PM	No	1
	Tulare (Loop), PM	No	2
	Divisadero (Direct), PM	Yes	3
	Mckinley (Direct), PM	Yes	2
	Shields (Direct), PM	Yes	2
	Shileds (Loop), PM	Yes	2
Fre 41 SB	Friant (Direct), AM	No	1
	Friant (Loop), AM	No	2
	Herndon (Direct), AM	No	2
	Herndon (Loop), AM	No	2
	Bullard (Direct), AM	Yes	3
	Shaw (Direct), AM	No	2
	Shaw (Loop), AM	No	2
	Ashlan (Direct), AM	Yes	3

- b. Because of the on-ramp design and geometry, sometimes vehicles will have a yielding action when they leave the on-ramp. This action will make the passage loop of ramp controller API count the vehicles twice on the multiple lanes of the on-ramp. This will make API work incorrectly -- the ramp meter will turn to red

even though just one pair of vehicles passed. The yielding happens on the on-ramps with more than two lanes, as show in Figure 10.

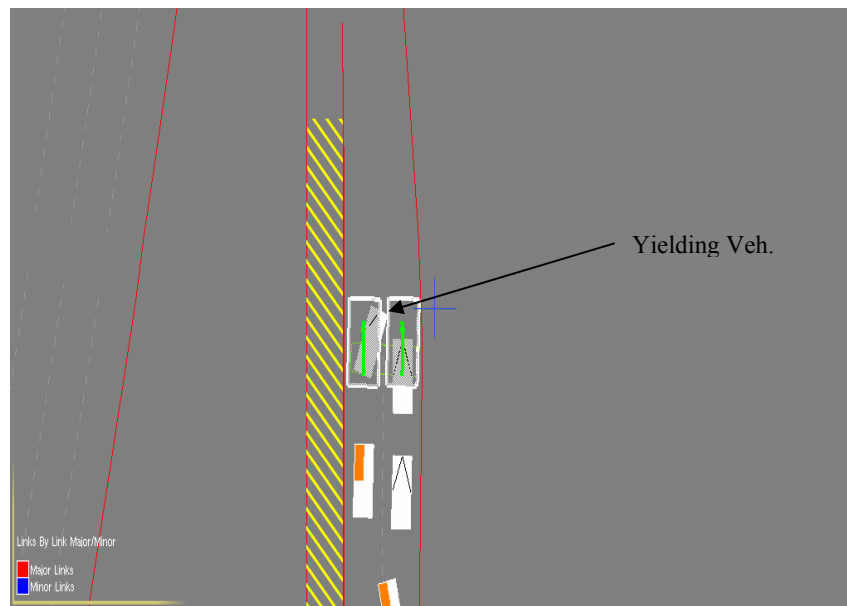


Figure 10 Yielding actions for the on-ramps

The way to correct the error is to update the downstream link from one lane to two lanes, and also adjusting the kerb points to make the vehicles moving smoothly.

4.2.4 Others

There are also some very important issues need to be checked at the same time

(Gardes, *et al*, 2003; Gomes, *et al*, 2004):

- Check geometry based on the AUTOCAD verlay (move kerb points and stop lines as necessary)
- Check link and intersection description (link gradients, link headway factor, link end speeds, intersection visibility)
- Check for barred turns, closures and restrictions
- Check lane usage and behavior of traffic
- Check the curve speed factor

- Check signposting distance
- Check next lane and lane choice setting

4.3 Signal Control Update

For all signalized intersections within the modeled network, signal timings data had to be entered in the model. The attributes of signalized intersections, as specified in

Paramics should be checked, include the following:

- Cycle length, number of phases
- phase length
- assigned link priorities (barred/major/medium/minor) for each phase;
- Lane allocation

4.3.1 Intersection signal time verification

Some intersections have data input error, they are adjusted based on the source signal timing plan file.

1. Since the original signal control uses the MAX2 as the maximum green in the control file, some phase green time will exceed 100 seconds. This is not true and also makes the API work incorrectly. In the project, the MAX1 is used as the maximum green extension

2. For the API definition,

$$\text{Maximum green} = \text{maximum extension} + \text{initial green}$$

4.3.2 Intersection priorities

1. Priority error, because of using the Actuated signal control API, the priority should follow the API's setting.

For example, Shaw&Blackstone, Phase1, the SB left turn is omitted;
Balckstone&Weldon has the same problem

2. Incorrect turning priorities

For Example, at node 1364, the priority of minor road left turn is higher than the main road left turn (blackstone). This makes the main road congested.

3. Change the right turn from “barred” to “minor”, in California the right turn are always allowed if no other restriction applied, some original coding didn’t follow this rule. i.e. Shaw&Fresno

The Actuate signal control plugin requires a file titled “signal_control” to be in the PARAMICS network directory. An example of the “signal_control” file is shown below Figure 11. (Liu, *et al*, 2001)

```
total number of actuated signals is: 93

node 743 SHEPHERD & FRIANT
movements 9 9 3 4 9 6 7 8
ini_green  0 0 4 10 0 10 4 10
extension  0 0 2 5.8 0 5.2 2 5.8
max_green  0 0 20 40 0 45 20 40
recall      4 8
lanes       0 0 1 2 0 2 2 3
rightturn   1 0 0 1
detector1 shpfrsw N/A N/A shpfruw
detector2 shpfrss N/A N/A shpfrus
detector3 N/A N/A N/A N/A
detector4 shpfrsn N/A N/A shpfrun

node 731 AUDUBON & FRIANT
movements 1 2 3 4 5 6 7 8
ini_green  4 7 6 10 4 7 4 10
extension  2 2 2 6 2 2 2 6
max_green  24 37 26 50 24 37 24 50
recall      4 8
lanes       2 2 2 3 2 2 2 2
rightturn   1 1 1 1
detector1 aufrsw N/A N/A aufruw
detector2 aufrss N/A N/A aufrus
detector3 aufrse N/A N/A aufrue
detector4 aufrsn N/A N/A aufrun

.....
```

Figure 11 “signal_control” file example

4.3.3 Ramp metering control

The origin network didn't input any control strategies for on ramp, based on the 2003 ramp metering operation shown in Table 4, by using the Ramp controller API, the on-ramps with metering will be configured.

Table 4 On-ramp metering operation rate

2003 RAMP METERING OPERATIONS - VOLUME RATE						
Route & Direction	Location	G-G Cycle For 1 or 2-Lane (sec)	1 or 2 Lane 5-Min Count (Full)	Hourly vehicle rate	G-G Cycle For 3-Lane (sec)	3 Lane 5-Min Count (Full)
Fre 180 EB	Fulton/Van Ness (Direct)	11.03	108.79	1306		
	Blackston/Abby (Direct)	11.75	102.13	1226		
Fre 41 NB	Broadway (Direct), PM	8.18	73.35	880		
	M Street (Direct), PM	8.18	73.35	880		
	Tulare (Loop), PM	22.19	54.08	649		
	Divisadero (Direct), PM				16.56	108.70
	Mckinley (Direct), PM	15.11	79.42	953		
	Shields (Direct), PM	11.25	106.67	1280		
	Shields (Loop), PM	11.16	107.53	1290		
Fre 41 SB	Friant (Direct), AM	8.25	72.73	873		
	Friant (Loop), AM	11.28	106.38	1277		
	Herndon (Direct), AM	17	70.59	847		
	Herndon (Loop), AM	15.03	79.84	958		
	Bullard (Direct), AM				16.57	108.63
	Shaw (Direct), AM	14.09	85.17	1022		
	Shaw (Loop), AM	11.94	100.50	1206		
	Ashlan (Direct), AM				18.94	95.04

The ramp control plugin requires a file titled "ramp_controller" to be in the PARAMICS network directory. An example of the "ramp_controller" file is shown below Figure 12. (Liu, *et al*, 2001)

```

total number of controlled entrance ramps is 23
control cycle of ramp metering 30

on-ramp signal 389
name 41NB&Broadway(direct)
demand detector 41nbrdb
number of control plans 1
from 15:0 to 19:0 METER_ON with 2 veh per 8.18 sec

on-ramp signal 381
name 41NB&Mstreet(direct)
demand detector 41nmsdb
number of control plans 1
from 15:0 to 19:0 METER_ON with 2 veh per 8.18 sec

.....

```

Figure 12 "ramp_controller" file example

CHAPTER 5: CALIBRATION OF CAPACITY

Capacity calibration is to find a set of (global) model parameters that enable the model to produce as close as possible results to match field measurements of traffic capacities. The choice of locations for field measurements of capacity depends upon existing traffic conditions within the study area. For unsignalized facilities (freeways, rural highways, and rural roads), the analyst should identify locations where queues persist for at least 15 minutes and measure the flow rate at the point where the queue discharges. This observed flow rate is measured only while an upstream queue is present. It is summed across all lanes and converted to an equivalent hourly flow rate. This is the field measured capacity of the facility at this point. (Dowling, *et al*, 2002)

5.1 Calibration Preparations

In this project, we cannot go to the specific congested location to measure the capacity points, but from the speed contour map we can figure out where and when the capacity is reached.

$$\text{Capacity} = \text{peak 15- minutes volume} * 4$$

Here we choose five locations for NB and three locations for SB for the capacity calibration procedure.

Table 5 The freeway selected locations for capacity calibration

	Locations	Peak period	15 minutes volume	Capacity
NB	Belmont Ave.	17:00-17:15	1490	5960
	Flora Dora Ave.	16:35-16:50	1487	5948
	Clinton Ave.	16:05-16:20	1694	6776
	Shields Ave.	16:35-16:50	1662	6648
	Gettysburg Ave.	7:40-7:55	1677	6708
SB	Bastow Ave.	7:25-7:40	1526	6104
	Gettysburg Ave.	7:30-7:45	1648	6592
	Shields Ave.	7:40-7:55	1634	6536

A make-up demand matrix by user will be used in the capacity calibration. Because in this project study, we only concern about the freeway capacity, so a demand which can give freeway selected locations saturation flow rate should be adopted. The demand can be achieved by trial and error procedure.

5.2 Global Parameters

In Paramics, on the other hand, several parameters should be tested and capacity measures collected in order to match with the field observed data. These parameters are listed as follows.

(1) Time Steps per Seconds

The simulation time step determines when calculations are carried out during every second of simulation. The default time step is 2 which means that calculation are done every 0.5 seconds of simulation. If the time step is increased to 5, for example, the calculations will be performed every 0.2 seconds.

(2) Speed Memory

Speed memory in Paramics simulation determines the number of time steps for which a vehicle remembers its speed. In conjunction with the time step change, speed memory can also be changed (e.g. from 3 to 8 time steps) to calibrate the capacity. Changing the size of the speed memory allows the modeling of the same reaction time with smaller time steps.

(3) Headway and reaction time

Three basic models are implemented within Paramics to control the movement of individual vehicles in the network: the vehicle following, gap acceptance and lane

changing models. These models are strongly influenced by two key user specified parameters: the mean target headway and the mean reaction time. The overall behavior of the model can be changed considerably by increasing or decreasing the mean headway and the mean reaction time.

5.3 Method for Capacity Calibration

The capacity calibration can be formulated as an optimization problem. The goal is to minimize the Mean Square Error (MSE) between the model estimates of maximum achievable flow rates and the field measurements of capacity. The MSE is the sum of the squared errors averaged in multiple locations over several model run repetitions. Each set of repetitions has a single set of model parameter values (p) with different random number seeds for each repetition within the set. (Dowling, *et al*, 2002)

The optimization model can be formulated as follows:

$$\min_p MSE = \frac{1}{N} \sum_N \sum_L (S_{nlp} - O_l)^2 \quad (1)$$

subject to:

$p \in [p_{\min}, p_{\max}]$, for all user adjustable model parameters and $p_{\min}, p_{\max}$ denote the lower bound and upper bound of the parameters respectively.

In model (1), notation is listed below.

MSE = Mean squared error

S_{nlp} = in the n th run, the simulation count for location l , with p th parameters combination

O_l = the observed capacity flow at location l

N = the number of simulation runs with p th parameters combination

By solving model (1), the optimal values for parameters can be obtained.

5.4 Results and Conclusions

The default values are 1 second for the mean headway and 1 second for the reaction time. Experience indicates that vehicles on US freeways tend to accept smaller gaps and have lower reaction times than the default values. Therefore, when applying the model to US freeway conditions, it is generally recommended to reduce the target mean headway and/or the mean reaction time. The parameters are selected in the ranges shown in Table 6. The selection of the range refers some experiences from previous researches.

Table 6 Parameters search range

	Default	Search range
Headway	1 second	0.6-1.0 second
Reaction time	1 second	0.6-1.0 second
Time step	2/second	2-8/second
Speed memory	3	5-8

Different parameters combinations are tested in Paramics under given demand, the one combination with minimized MSE will be chosen to be the solution. Part of the test results are also shown in Table 7.

Table 7 Results of Capacity Calibration

Parameter combinations	Ave. MSE
Headway=1.0	4125572
Reaction time=1.0	
Time step=2	
Speed memory=5	
Headway=0.8	520934
Reaction time=0.8	
Time step=5	
Speed memory=8	
Headway=0.8	864739
Reaction time=0.7	
Time step=5	
Speed memory=8	
Headway=0.75	1018423
Reaction time=0.70	
Time step=5	
Speed memory=8	

In our practice, the parameters, time step and speed memory, in most the cases are fixed, they are assumed in the best value. Most of calibration efforts are on the effects of mean headway and reaction time.

CHAPTER 6: OD PATTERN MATRIX ESTIMATION (PME)

6.1 Necessity for Develop PME

Origin-Destination (OD) demand data is a vital component to the microscopic traffic simulation. To obtain a reliable OD demand, data from multiple sources need to be synthesized. Generally, one can start with an initial OD matrix from the transportation planning models, using TRANPLAN, TP+, or TransCAD. However, such models are developed for long-term planning purposes, and its demand data may not reflect the pattern of up-to-date traffic. Therefore substantial amount of work will be needed for fine-tuning the demand data to match the field measurements from the traffic network if direct use of demand data from planning models is applied in micro-simulation studies.

Integrated with the core PARAMICS suite, PARAMICS Estimator is an OD matrix estimation tool developed by Quadstone, aiming to help the OD estimation process. Estimator provides an open/visual framework which places engineers, including their skills and knowledge, at the heart of the system. It can partially solve the difficulty in OD estimation while considering the interactions between OD demand and other parameters such as those for behaviors and route choices.

In order for Estimator to generate reasonable results, however, it needs an initial OD demand pattern matrix as the input. In current state-of-the-practice, the demand data from planning models are usually used for this purpose. As aforementioned, nevertheless, since the planning models can not reflect the up-to-date traffic pattern, the demand pattern matrix from them may be obsolete and differ far from the real pattern. On the other hand, for most simulation studies, data collection will be

performed in the model calibration process. These data may include link counts for road segments and turning volumes for intersections. In this project, we develop a Paramics Pattern Matrix Estimator (PME) together with a user-friendly Graphical User Interface (GUI) to better estimate the initial demand pattern matrix for Estimator. PME utilizes newly collected link counts and turning volume data and the historical demand matrix from planning models, and the results from PME can be either directly used in the simulation studies, or used as the input to Estimator to generate more reliable OD estimations. The role of PME in the entire OD estimation procedure is depicted in FIGURE 11.

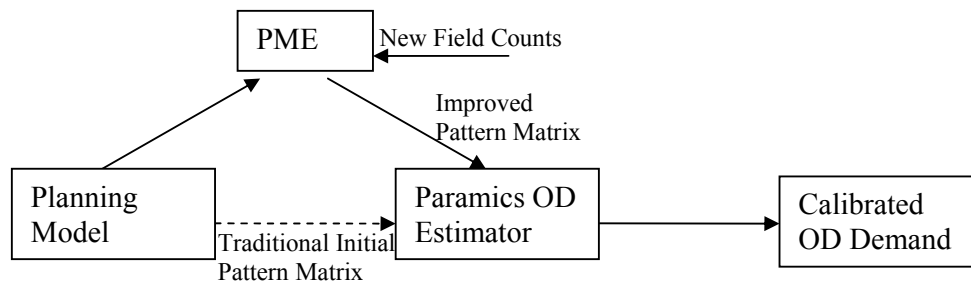


Figure 13 The OD Estimation Procedure

The OD estimation program with initially developed by Piya Chootinan at Utah State University as a course project (2003). To be complete, we include the description of his program in Section 6.2. By incorporate his program, we have developed plugins to integrate the procedure and a controller program will control all of the process running automatically.

6.2 OD Estimation Problem and CGLS

The relationship between O-D matrix and link flows can be expressed through a assignment mapping called link use proportion ($\mathbf{A}$). Basically, it represents the proportion of trips from a particular O-D pair on a specific link and is critical to the estimation problem. The representative methods for deriving O-D matrix from traffic

counts includes the entropy maximization method (Van Zuylen and Willumsen, 1980), maximum likelihood method (Spiess, 1987), and the generalized least square (GLS) method (Cascetta, 1984; Bell, 1991). Due to the fact that traffic counts are usually associated with measurement errors, there may not exist the O-D matrix that can exactly reproduce these traffic counts when assigned onto the network. These methods, which utilize the distance measures, have been proposed to select the O-D matrix with the minimum distance comparing resultant link volumes and traffic counts.

In this study, the constrained generalized least square (CGLS) method proposed by Bell (1991) was applied to calibrate the O-D matrix for a simulation model developed in PARAMICS. In fact, the proposed procedure is similar to a bi-level programming approach proposed by Yang *et al* (1992). Basically, the O-D matrix is adjusted according to CGLS objective, and the link use proportion ($\mathbf{A}$) is updated by the mean of traffic simulation. This procedure will be iterated until the goal of calibration is met (e.g., a distance measure is less than a certain threshold). In addition to traffic counts, the prior O-D matrix can be used to assist the calibration. The preferences (or confidence) of different types of data can also be incorporated.

The Generalized Least Square (GLS) approach utilizes the information from different data sources of which accuracies are always different. The equivalent optimization of problem has the following form.

$$\text{Minimize: } f(\mathbf{q}) = \omega_1 \cdot (\mathbf{q} - \bar{\mathbf{q}})^T \cdot \mathbf{U}^{-1} \cdot (\mathbf{q} - \bar{\mathbf{q}}) + \omega_2 \cdot (\bar{\mathbf{v}} - \mathbf{A}\mathbf{q})^T \cdot \mathbf{W}^{-1} \cdot (\bar{\mathbf{v}} - \mathbf{A}\mathbf{q}), \quad (2)$$

Subject to: $\mathbf{q} \geq 0$.

The inputs to this formulation are a vector of prior O-D demand ($\bar{\mathbf{q}}$), a vector of traffic counts ($\bar{\mathbf{v}}$), variance-covariance matrices for the prior O-D demand and traffic counts ($\mathbf{U}$ and $\mathbf{W}$ respectively), and link use proportion ($\mathbf{A}$). ω_1 and ω_2 are the preferences (weights) given to different data sources (the prior O-D matrix and traffic counts). Under the assumption that the non-negativity constraints in equation (2) are inactive, the optimal solution to the problem can be explicitly expressed as:

$$\mathbf{q} = (\mathbf{U}^{-1} + \mathbf{A}^T \mathbf{W}^{-1} \mathbf{A})^{-1} \cdot (\mathbf{U}^{-1} \bar{\mathbf{q}} + \mathbf{A}^T \mathbf{W}^{-1} \bar{\mathbf{v}}) \quad (3)$$

This expression is very useful in practice. When all information is available, the optimal (adjusted) O-D matrix can be determined using only matrix inversion and multiplication. Unfortunately, due to the assumption made above, we cannot prevent the adjusted O-D matrix from being negative. This assumption is more likely to be violated when a relatively high weight is given to one of data sources, either the prior O-D matrix or traffic counts. Bell (1991) relaxed this assumption and proposed an iterative balancing procedure to adjust the optimal solution obtained by equation (3).

Another issue worthy to consider is the prior information about trip production and trip attraction at any TAZ. Without the consideration of this issue, it is possible that the estimated trips emanating from a particular zone may far exceed the number of residential units or the estimated trips terminating at a particular zone may far exceed its capacity (e.g., parking structure). This information is practically useful and leads the estimation to more reasonable ranges. In addition, this issue is also relevant to PARAMICS, the traffic simulator. Because of the physical constraint, a traffic generator or TAZ can release only a certain number of vehicles during a certain time period. If the estimated demand exceeds this level, there will be a lot of unreleased vehicles, which contribute nothing to the simulation results. In other words, the

modeled network is under-utilized. In this study, only the constraint related to trip production (Equation 4) is incorporated to the CGLS formulation.

$$\mathbf{B}\mathbf{q} \leq \mathbf{C}, \quad (4)$$

where $\mathbf{B}$ is the matrix representing the relationship between O-D pair and the origin (which O-D pair belongs to which origin), and $\mathbf{C}$ is the vector of capacities of TAZs. $\mathbf{C}$ can be determined through the simulation. By incorporating this new constraint, the Lagrangian of this formulation can be written as:

$$\Gamma(\mathbf{q}, \boldsymbol{\mu}, \boldsymbol{\lambda}) = f(\mathbf{q}) + \boldsymbol{\mu}^T (-\mathbf{q}) + \boldsymbol{\lambda}^T (\mathbf{B}\mathbf{q} - \mathbf{C}), \quad (5)$$

where $\boldsymbol{\mu}$ and $\boldsymbol{\lambda}$ are the vectors of Lagrange multipliers for non-negativity constraint and capacity constraint for TAZ respectively. By setting the first derivative of Equation 4 with respect to $\mathbf{q}$ to zero, the adjusted O-D matrix can be expressed as:

$$\mathbf{q} = (\mathbf{U}^{-1} + \mathbf{A}^T \mathbf{W}^{-1} \mathbf{A})^{-1} \cdot (\mathbf{U}^{-1} \bar{\mathbf{q}} + \mathbf{A}^T \mathbf{W}^{-1} \bar{\mathbf{v}} + \boldsymbol{\mu} - \mathbf{B}^T \boldsymbol{\lambda}). \quad (6)$$

If both types of constraints are inactive, the values of Lagrange multipliers remain zero and Equation 6 collapses to equation (3), the regular GLS. If some of constraints are binding, the values of corresponding multipliers need to be adjusted by the iterative balancing technique so that those constraints are satisfied. The detailed description of iterative balancing technique can be found in Bell (1991).

As mentioned earlier, the method applied here has a similar structure to the bi-level programming approach proposed by Yang *et al* (1992). The adjustment process iterates between CGLS problem and traffic simulation. Firstly, the prior O-D matrix is assigned onto the network according to the logic specified in the simulation model. After that the link use proportion is determined from the simulation results and fed back to the CGLS to determine the new O-D matrix. This process is repeated until

the calibration criteria (e.g., $GEH\text{-statistic} \leq 5$ for more than 85 percent of observations). This adjustment procedure is summarized in FIGURE 12.

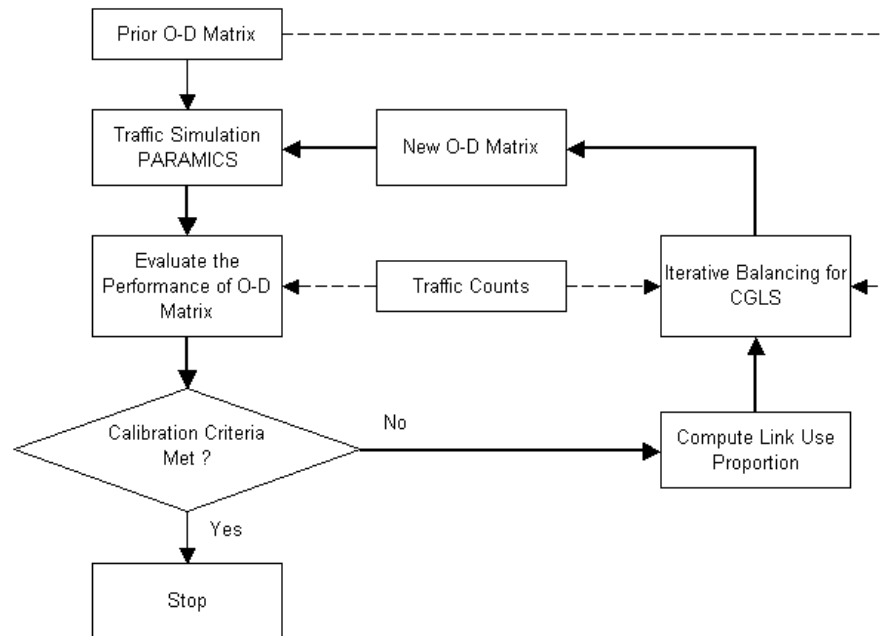


Figure 14 Procedure for Pattern Matrix Update

6.3 Development of PME Package

A streamline of the working process for PME is given in Figure 13; it starts from a Paramics simulation, then the OD estimation process will be followed; the result from OD estimation will be the demand for next simulation. This procedure will be repeated until the maximum simulation number or the set criteria reached. All of the process are controlled by a controller program and running automatically.

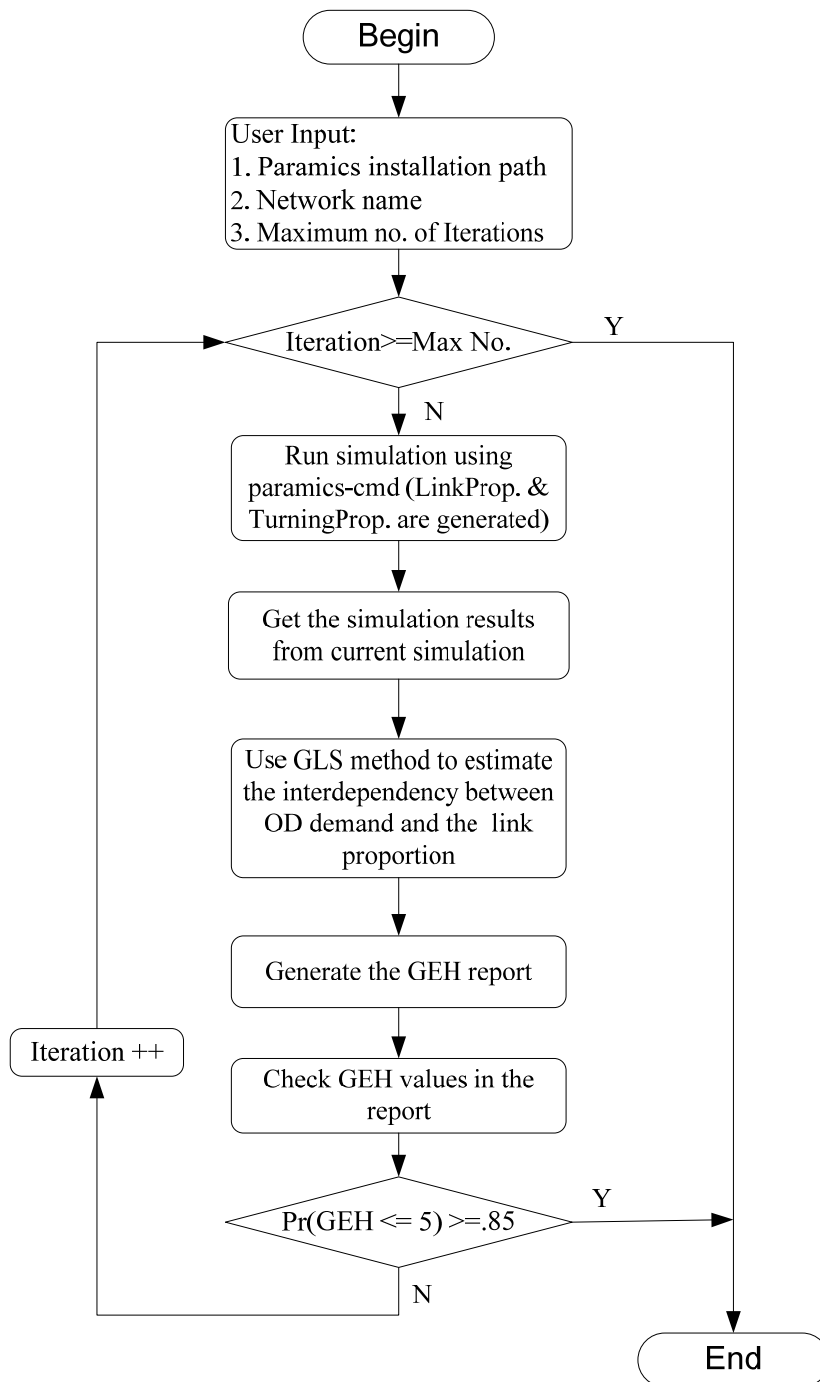


Figure 15 Flow chart for Paramics Pattern Matrix Estimator (PME)

As mentioned earlier, the link use proportion (**A**) is crucial input to the O-D estimation problem. To determine link use proportion in PARAMICS, an API named “LinkProportion.dll” is coded. The API should be loaded with the network, after the each completed simulation, it will generate the link using proportion report, named sgl-linkOD.txt. It contains all the information required to determine the link use proportion. Basically, the number of trips between a particular O-D pair on a particular is identified.

In this project, the intersection turning counts are available in addition to link traffic counts and should be used for O-D matrix estimation. They can be treated in the same way as link traffic counts. In other words, one can think about turning movement as the special link, which is represented by three nodes in sequence instead of two nodes for the regular link. Another API named “TurningProportion.dll” is coded, similar with link proportion one, it also will generate a sgl-turningOD.txt report.

6.4 Results and Conclusions

To test the PME effectiveness, we put both the origin travel planning model and the result OD matrix after PME updating into Paramics Estimator. Without any human adjustment, Estimator will try to match given links and turning counts, the results are shown as below in Figure 14.

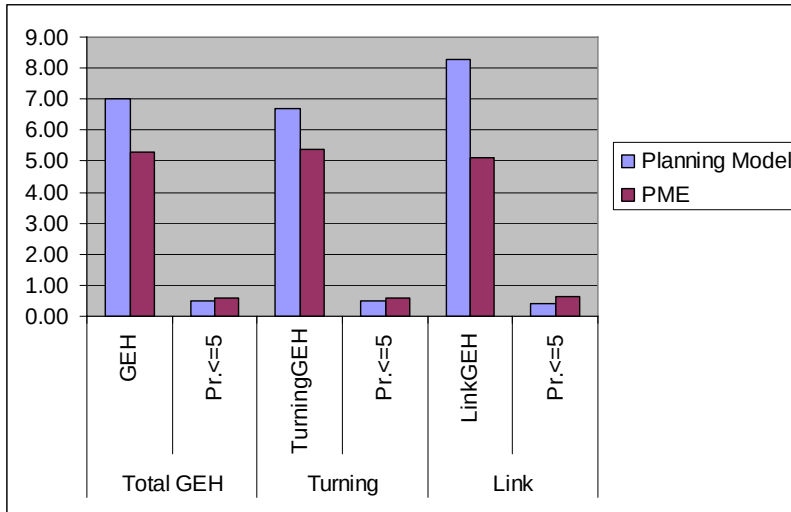


Figure 16 PME performances in Paramics Estimator

We can see that from both turning and link measurements, PME demand has better performance than directly using planning model.

To further compare the performance for planning model, PME, and Paramics Estimator, we four different scenarios: original planning model, optimized planning model by Paramic Estimator, PME model, optimized PME model by Paramic Estimator, all of the scenarios don't have any manual adjusting. They were put into Modeller, the measurement are shown in Figure 15. The scenario combined PME and Paramics Estimator has the most efficiency, for both the average GEH and the probability which GEH less than 5, they performed the best among all scenarios. Note that the performance of only PME is even better than the planning-Estimator scenario.

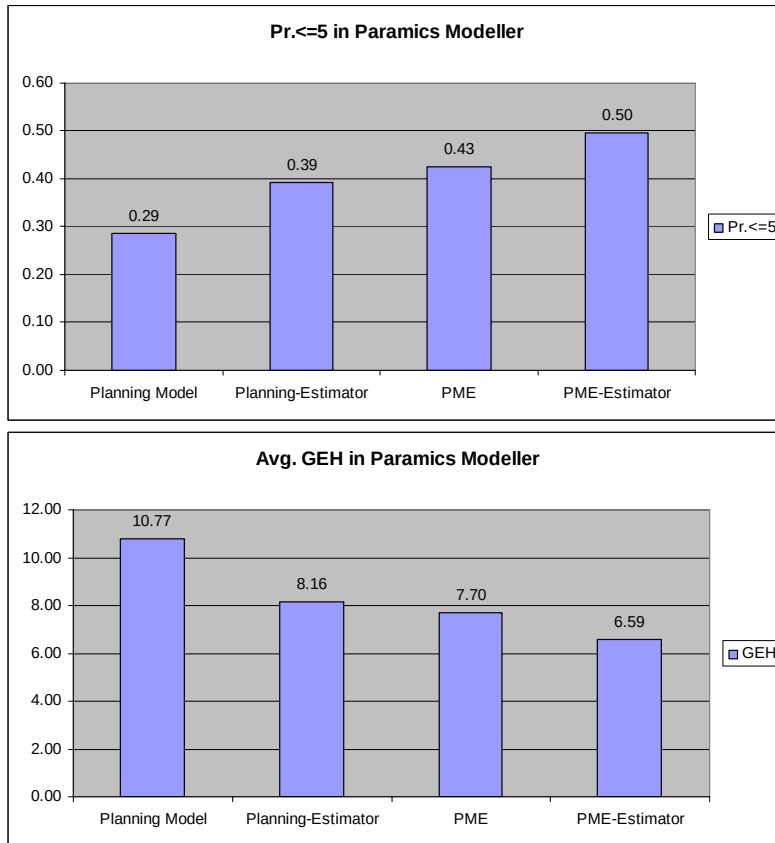


Figure 17 Performance comparison for Planning model, Paramics Estimator, PME

CHAPTER 7: OD ESTIMATION BY PARAMICS ESTIMATOR

7.1 Introduction

Integrated with the core PARAMICS suite, PARAMICS Estimator is an OD matrix estimation tool developed by Quadstone, aiming to help the OD estimation process. Estimator provides an open/visual framework which places engineers, including their skills and knowledge, at the heart of the system. It can partially solve the difficulty in OD estimation while considering the interactions between OD demand and other parameters such as those for behaviors and route choices.

After updating the pattern matrix, it can be input into Paramics Estimator for hourly OD estimation. Paramics estimator is an OD matrix estimation package specifically designed to operate at the microscopic level and integrate seamlessly with the core Paramics tools. (Quadstone, 2004) Compared with the traditional “black box” OD estimation tools, Estimator is a visually interactive tool for OD adjustment. It combines the automatic and manual adjustments, and human intelligence can also be easily imported in the package. Other than the OD estimation, some methods for using Estimator in this study are summarized as follows.

7.2 Initial input setting

- Parameters

Simulation Period: 30 minutes

This parameter is used to define the length of time the simulation in Estimator.

Basically, the larger the network, the longer the simulation time should be.

Trip Demand range: 1-5000

Set the range of one OD pair demand. In this project, no TAZs have the production or attraction over 5000.

Revert to Best: 20%.

Setting this value causes the chosen percentage of Trip values in the Active matrix to be reset to the corresponding values in the Best matrix at the end of each calculation period. This is used to refine a Best matrix. Using the function allows user to fine-tune a Best matrix. However this is not advised at the early stages of an estimation process, as it will cause the solution to get stuck in a local optimum.

Flow Intensity: 10% initial, 10% incremental

This value is a multiplier for vehicle releases in the network. Setting the value to less than 100% gives the estimation process room to vary the trip values without overloading the network. The user can start the estimation process with a low flow intensity avoiding congestion and large switches in travel patterns. As the OD estimation process progresses the flow intensity can be increased refining the active OD to take account of more congestion and larger changes in travel patterns while building from a stable base pattern.

- Input Data

Pattern Matrix

From PME results, weight 0.70

Link Flow

New Freeway mainline counts, weight 0.90

New Freeway connector counts, weight 0.80

New cordon links counts for 9 locations, weight 0.90

Others, 5 counts, weight 0.70

Turn Flow

New screenline intersections counts, weight 0.80

Historical intersections counts, weight 0.70

The weights of the different data set come from their priorities (Chapter 3). The higher the number, the more weight it will take in the OD estimation, the smaller the range it can vary, and vice versa.

7.3 Manual Adjustments

(1) Use initial estimation results to help the network error checking

Even though we conducted the error checking at the first stage of calibration, the network still needs to be improved. However, errors are not easily found unless the demand is close enough to the real situation. A “good” enough OD demands from the Estimator after some estimation can be put into Modeller.

(2) Mapping Estimator results to the network topology

Although Paramics Estimator will generate the detail estimation report after each run, in which the measurement of each link and turning will be list, it is always worth to map them from a series of node number back to the network topology. This will help user identify the estimation results on the physical network scope, this will help the later manual adjustment.

(3) Manually adjust the OD

Since the measurement of matching between simulation data and field counts for every location is known for physical network scope, we can adjust the OD matrix manually based on engineering judgments. Individual OD pair demand adjustment is to produce the best match between simulated results and observed data.

Example 1

In this case, 1, 2, 3, 4 are consequent detectors on the freeway mainline. From the estimation results, 2, 3 matched well, but the simulated result count is less than field data at 1, and more than field data at 4. Short distance trip demands, which traverse the location 1, can be increased to compensate the difference. As similar as location 1, short distance trip from zones near location 4, should be decreased. It is shown in the Figure 16.

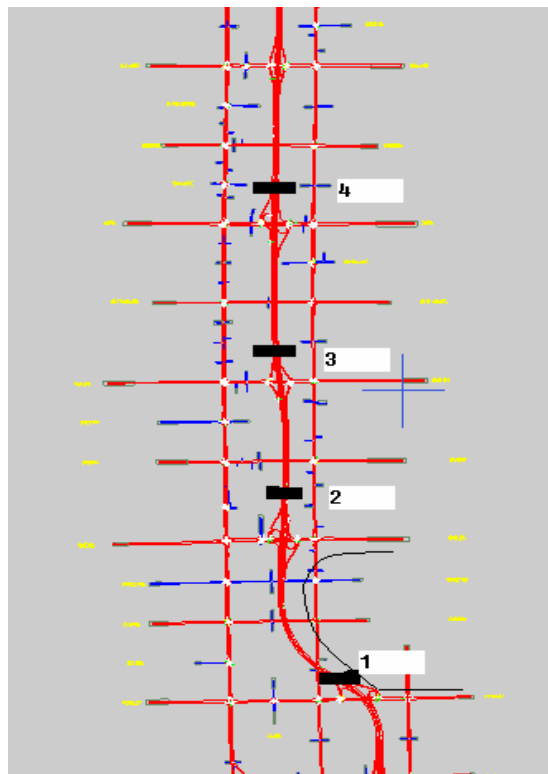


Figure 18 Manual adjustments Example 1

Example 2

In this case, the main arterial cordon links counts (with green bars) already matched well, but the demands on freeway are still lower than the real cases. Therefore, demands from nearby minor zones (with red circles) can be increased to compensate the difference.

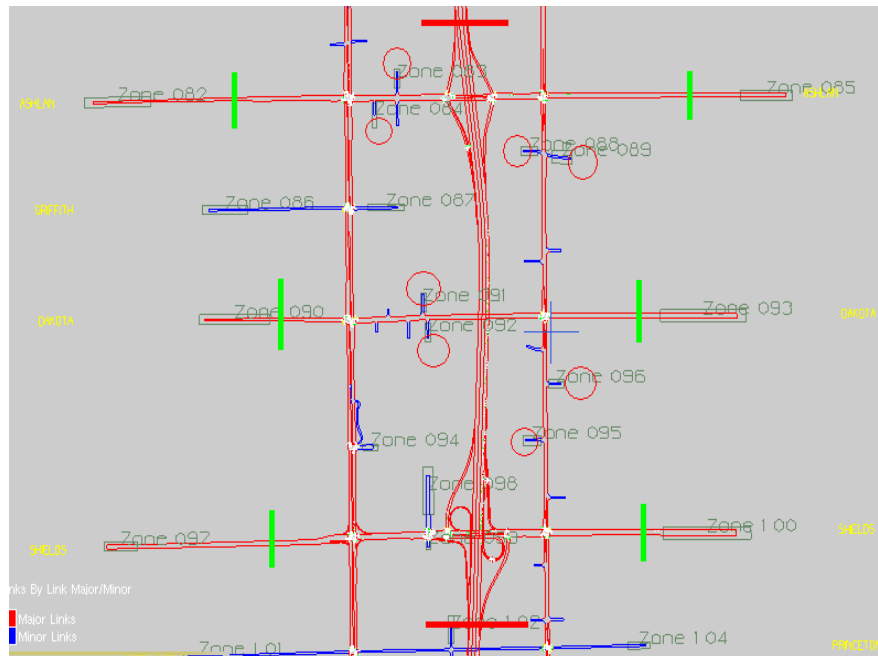


Figure 19 Manual adjustments Example 2

(4) Feedback from Estimator result

Paramics Estimator heavily relies on the quality of the input data (link flow, turn flow, cordon flow, pattern matrix). In some cases, if the initial pattern demands quality is not good enough, the OD estimation always cannot reach a good solution because the search area of Estimator is limited by both the initial pattern and the tolerance range (weight). For example, if the weight of the initial OD is 0.70, and the demand for one OD pair is 100, the searching range of this particular OD pair will be 70-130. This range may not be sufficient to generate any reasonable OD estimation. So when the initial pattern matrices are not good enough to generate the solution, the user need to

replace the input initial pattern in Estimator by the new demand from last estimation. And the process probably need be repeated more than one time to reach the final result.

In this procedure, some operations should be taken cautiously:

- (1) Before conducting the “feedback” step, the critical inputting error and data discrepancy should be corrected first. Because the Paramics Estimator is very sensitive to the input data quality, if discrepancies exist between the inputs, the Estimator will conduct the estimation to make the simulated count to be in the middle between the conflict data, in some cases, the result OD will be far away from the real ones.
- (2) The local optimal solution should be avoided in the “feedback” procedure. From the description of “feedback”, there are the possibilities that the searching is conducted to the wrong directions if the users pick up the “feedback” demand incautious. It is shown in the Figure 18.

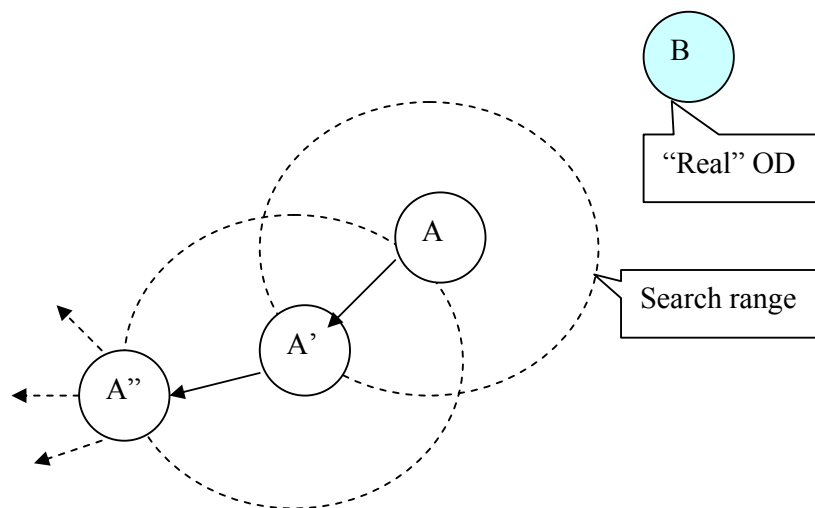


Figure 20 Failed search in OD estimation

In the above figure, B is the “real” OD we want to reach, and A is the initial pattern matrix inputting to Paramics Estimator. If users pick up the wrong directions to

conduct the “feedback”, in this case, A’, the searching will not be able to reach B. To avoid this situation, “feedback” should not be used in the early stages of an estimation process. After enough simulation iterations, the OD estimation will be close to converged, at that time, with human judgments, the “feedback” can be cautiously used.

7.5 Estimation Results and Analysis

The results from Estimator are shown in Table 7.

Table 8 OD Estimation Statistics for Paramics Estimator

		PM 4-5	PM 5-6	PM 6-7
Freeway Mainline	Ave. GEH	2.59	2.07	2.46
	Pr<=5	87%	91.3%	87%
Freeway Ramp &Connector	Ave. GEH	2.49	1.97	3.05
	Pr<=5	100%	100%	87.5%
Arterials Cordon Links	Ave. GEH	2.16	1.37	0.78
	Pr<=5	100%	100%	100%
Arterials Major Intersections (new)	Ave. GEH	2.44	2.63	1.45
	Pr<=5	87.5%	85.7%	99.1%
Arterials Other Intersections (old)	Ave. GEH	2.91	3.03	
	Pr<=5	84.1%	83.5%	

From the results shown above, we can conclude that the OD estimations are very successful. Most of the volume data are matched very well, from both average GEH and probability aspects. In some cases, the volume of arterials intersections turning counts(historical data) are little lower than the specified criteria, but considering that there are traffic pattern changing since historical data collection year, the difference is acceptable.

CHAPTER 8: DYNAMIC MATRIX ESTIMATION (DME)

8.1 Time-Dependent OD Reconstruction

Paramics Estimator can only provide hourly OD demand matrix. However, for Paramics simulation, dynamic (time-dependent) demand, e.g. in a 15-minute interval, is needed. Therefore this section presents the method to assign the whole OD to a series of consecutive time slices. This is the so called dynamic matrix estimator. In the literature, no plausible method has been provided for performing dynamic OD estimation based on hourly demand, due to the following two difficulties.

The first one is that for large scale network like SR41 corridor, all data came from different resources with different details. Some of them are in 5-minute interval, while others may be in hourly interval. If a single OD estimation procedure is conducted, it is possible that not enough data can be used. In this case, the final calibration results may not be capable of reflecting the real traffic condition.

The second difficulty is that it will be too time-consuming if for each individual time period (15 minutes), the same OD estimation procedure will be conducted as that for hourly estimation describe in previous section. If the time intervals decrease to 5 minutes or even smaller, the effort in OD estimation using this way becomes is too huge that the estimation task is hardly accomplished.

Our proposed method, therefore, estimates the time-dependent OD based on the hourly OD demand matrix estimated in the previous step. It can be regarded as a process that assigns the total OD to a series of consecutive time slices. Our method tries to simplify the complex time-dependent OD estimation problem through reconstructing the dynamic OD demands based on a set of demand profiles (Chu, *et al*,

2004). PARAMICS has an enhanced feature of demand loading, i.e. the ability to specify different demand profiles for each OD pair. Through the use of “matrix” and “profile” files, a profile can be specified for a specific OD pair.

Since the 15-minute interval traffic counts at all cordon points of the network are known, the profile of vehicle generation from any origin zone and that of vehicle attraction to any destination zones are thus known, like shown Figure 19 . We further assume a number of initial demand profiles for all OD pairs based on the following criteria:

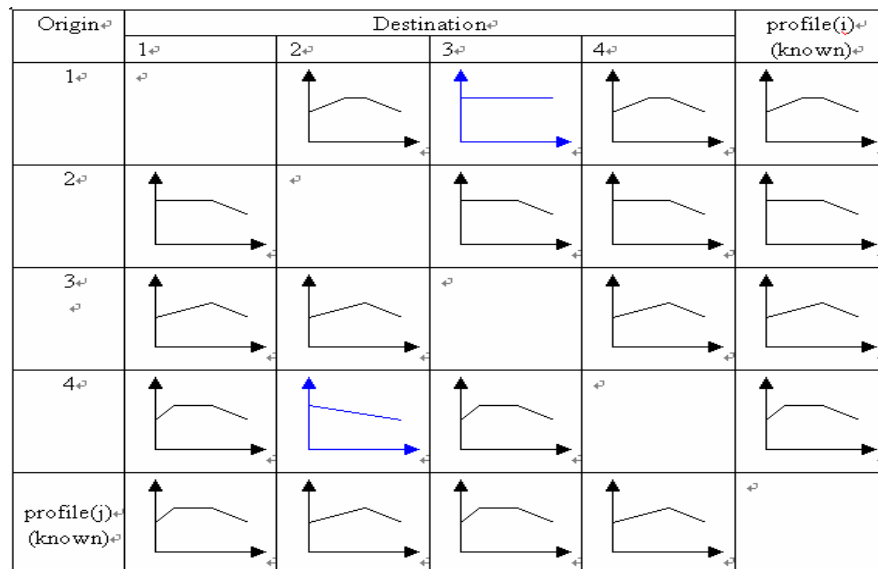


Figure 21 Dynamic OD Demand Generation

- (1) The demand profile from an arterial origin zone to any arterial destination zone has the same profile, which is the same as the vehicle generation profile from this origin zone;
- (2) The profile from a freeway origin zone to an arterial destination zone can be estimated based on the 15-minute loop data at a corresponding off-ramp location.

(3) The profile from an arterial origin zone to a freeway destination zone can be estimated based on the 15-minute loop data at a corresponding on-ramp location.

(4) The demand profiles from a freeway origin zone to a freeway destination zone can be estimated based on the traffic count profile at corresponding loop stations placed on freeway mainline.

Then the procedure for dynamic OD estimation is:

1. Prepare the profiles of all zones Attraction and Production; if no profile exists, use uniform distribution.
2. Set all of the cells in OD to uniform distribution
3. Set each zone's Attraction and Production, and each OD trip (cell) to the first 15-minute demand
4. Using Furness Algorithm to get the 15- minute demands
5. Conduct the next 15- minutes time period
6. Using the "Profiles" function to code the decomposed OD into network

In which the Furness algorithm can be listed as below, which also shown in Figure 20.

1. Denote A_i , the coefficient of each row (production), B_j , the coefficient of each column (attraction)
2. Set $B_j=1$, then for each cell, solve A_i to satisfy the production constraint
3. With the latest A_i , solve for B_j to satisfy the trip attraction constraint
4. Keep repeating the steps above, until the changes are sufficiently small.

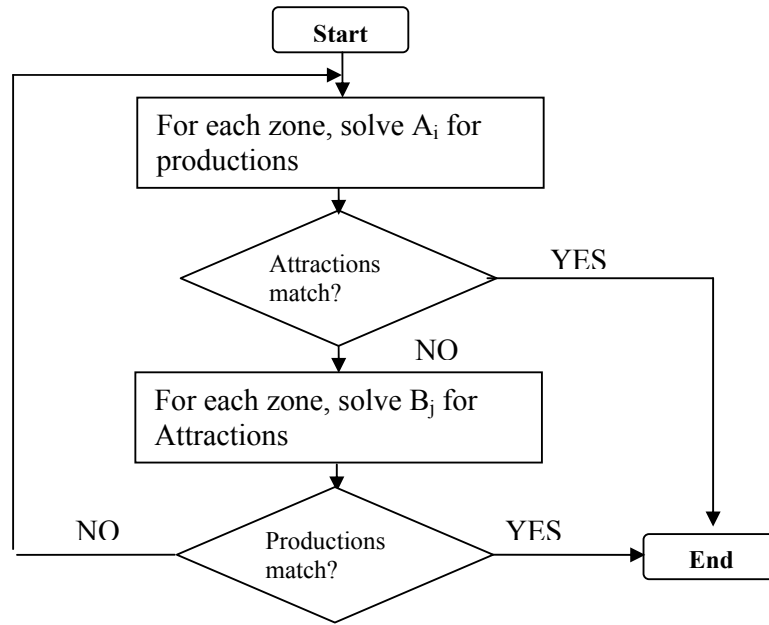


Figure 22 Flow chart of Furness algorithm

The dynamic OD demand by DME can be used directly in Paramics simulation by creating proper “matrix” and “profile” files.

8.3 Usage of DME Package

(1) Hourly demand

As described above, two inputs will be prepared for the DME, the one is the hourly demand, which is from the previous OD estimation from PME and Paramics Estimator.

(2) Zonal demand profiles

In this project, other than the arterials cordon count conducted by Wiltec CO., there is no specified cordon link data collecting, but for some of the collect intersections, they are close to the zones, the turning count can be used to conduct a cordon count.

8.4 Results analysis and conclusions

For the project requirement, the dynamic demands periods will be set 15 minutes, which means for one hour, four new demands will be generated.

The results from DME need to be further verified, they should satisfy the following two criteria:

1. The sum of the total demands of the four new matrixes should be equal to the original hourly total demand. This means the decomposition methods will not change the total volume of the network.
2. In terms of each cell (OD pair), the sum of the all four time periods demand should be not far away from the hourly demand. This means for the individual OD pair demand, the method will not generate the extreme unrealistic high or low demand.

CHAPTER 9: Model Fine Tuning and Improvements

9.1 Introduction

The last step of calibration is to use aggregated traffic data for fine-tuning the established simulation model in order to reflect network-level congestion effects. The driving behavior models need to be further validated locally (intersection-by-intersection or junction-by-junction) and adjusted to reflect the local characteristics.

Although the OD demand from Estimator performed well, it may give different results in Modeler due to different congestion effects and working mechanisms between Modeler and Estimator.

Results from model fine tuning will be feedback to previous stages, and the simulation model will be repetitively modified until the best matching with field data is achieved.

9.2 Model fine tuning

The following parameters are fine-tuned using the trial-and-error method in order to reconstruct traffic variations and match the congestion pattern of the study network.

(1) Link specific parameters, including the signposting setting, the target headway and reaction times of those links at critical bottleneck locations where a very minor change in capacity can have a major effect on congestion. These parameters can be modified with the need of increasing/ decreasing congestion level.

(2) Global parameters for the car-following and lane-changing models, i.e., the mean target headway and driver reaction time. They are two key user-specified parameters in the car-following and lane-changing models that can drastically influence overall

driver behaviors of the simulation. These two parameters were initially set in the Capacity Calibration.

(3) Demand profiles from freeway origin zones to freeway destination zones may need to be further modified in order to adapt traffic congestion along freeways.

Multiple simulation runs for each parameter combination are required and the simulated data of the median simulation run are always used for the comparison with the observed data. Because of high traffic demands during the peak hour and recurrent congestion along the northbound SR41, some network coding problems will show up and be corrected. Due to the congestion and queuing phenomena on freeways, especially the northbound SR41, extra efforts are taken to modify demand profiles from the freeway origin zones to the freeway destination zones.

(4) Route choice adjustments. Due to the existence of freeways and its parallel streets in the studied network, the routing algorithm adopted in the simulation calibration process is important. The three assignment algorithms provided by Paramics, namely the all-or-nothing (AON) assignment, dynamic feedback (DF) assignment and stochastic assignment are tested in the calibration process. Finally, we adopt the dynamic feedback assignment in our simulation study. DF requires the following parameters to be set properly.

- Vehicle familiarity and perturbation

Dynamic feedback assignment diverts vehicles when congestion happens. However those diversions are only applied on the drivers who are familiar with the network. In other words, if no driver is familiar with the network, no diversion will be made. In our study, the familiarity percentage is set to be 50%. The perturbation factor used in

the perturbation of costs in the stochastic routing algorithms, and perturbation used by each vehicle is specified by vehicle type.

- Cost coefficient

In Paramics simulation, the link travel cost is defined as a combination of travel time, distance, and road price (or toll). Three coefficients can thus be defined and used to calculate the cost for a link, measured in minutes, as follows (Quadstone, 2004):

$$cost = aT + bD + cP$$

where:

T is the free-flow travel time (in minutes).

D is the length of the link (in km).

P is the price of the toll (in monetary cost units)

a is unit-less, and is the coefficient for the travel time.

b is in minutes per km, and is the coefficient for distance.

c is in minutes per unit of monetary cost, and is the coefficient for road price.

The length of a link is calculated automatically, but the price of a toll for any link must be specified explicitly by the user.

- Strategy route choice

The Strategic route function effectively allows the user to prevent unrepresentative vehicles routing where multiple routes are available however some are unrealistic in real life. Strategic routes remove perturbation and dynamic feedback effectively enforcing AON assignment to vehicles between the start and end point of a Strategic Route.

9.3 Feedback of Calibration

As the shown streamlined calibration procedure in Figure 2 (Chapter 2), at the end of all the stages, the calibrated model will be run in the Paramics Modeller. Although counts matched very well in the OD estimation process, there are chances some unexpected traffic conditions will be happened. For those cases, the calibration need to be “feedback” to the previous stages, some parameters have to be further modified; the procedure should be repeated until the set criteria reached.

The number of the parameters in Paramics model is tremendous, and each of them could be the reason to occur the unexpected situations, so the “feedback” could be directed to all of the previous stages, including calibration of capacity, PME, Paramics Estimator, model fine tuning, etc. The experiences about how to conduct the feedback are listed below; some of them are just based on the engineering judgment, and may need to be further verified.

- The first step of the feedback is always the model fine tuning stage. The user can observe the locations for which the measurements (volume, speed, etc.) cannot be matched well. At the same time, the detail vehicles moving also will be noticed, by doing this, user can know whether there is the possibility to improve the performance by modify the local parameters (link specified signposting, nextlane, speed, etc.).
- The total demand of the result OD from DME will equal to hourly demand. But for some OD if there exist significant differences, or just one or two 15-minutes measurements cannot match in one hour, users have to adjust the DME results individually.

- In some congestion sections, if there are trips extremely high or low, or with unrealistic pattern beyond real world, the users have to consider adjusting the OD manually, the trips could be decreased or switched to other TAZs.
- If too many OD demands are changed, either the number of the OD pairs, or the total of the trips, the new OD matrix will make the simulation results changed. Some link counts and intersection turning counts will not match the fields count any more, which have small difference previously. In those cases, the new OD estimation should be conducted. The user can start from PME and Paramics Estimator.
- If the simulated volumes in most of the locations are lower than the fields counts, especially the in most the freeway locations, it may indicate that the capacity of the network has to be modified. User should conduct the calibration of capacity step to adjust the global driver behavior parameters.

9.4 Analysis of Stuck Vehicle Problem

When running the simulation, sometimes left turn vehicles will go to the through lanes. Due to this lane changing failure and if there is no other left turn vehicle in the left turn lane, the signal controller will not give left turn green time. As a result, this vehicle will just be stuck there for the rest of simulation. It is shown in Figure 21.

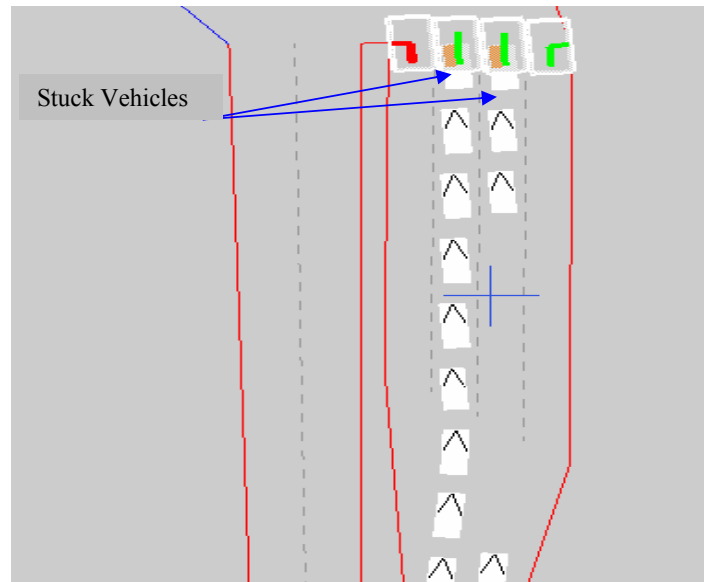


Figure 23 Stuck vehicle problem in the simulation

The stuck vehicle problem results from the combination of intersection coding, left turning flow level, and the signal control logic. So far, we didn't find a certainly good way to solve this problem, but by using some of the efficient function in Paramics itself, we can lower the possibility of triggering the problem.

1. Adjust the Signposting distance and Signposting range

The user can define the Signposting distance from the hazard that the most aware vehicles become aware of the hazard ahead. Signposting range is the distance from the signposting distance towards the hazard that vehicles (with descending awareness) will become aware of the hazard ahead. Adjusting the two factors for specified links can give vehicles more time for lane changing.

2. Increase the driver familiarity

Familiarity is the percentage of vehicles with familiar routing capabilities for this vehicle type. But the familiarity will also effect the route assignment, which we discuss above.

3. Remove/adjust/add the nextlane function for some links

The **nextlanes** file is used to define lane mapping that is not consistent with the Paramics default lane mapping. Lane mapping defines which lane a vehicle exiting a link will adopt in the upstream link. Sometimes the incorrect nextlane call will deteriorate the stuck vehicle problem

4. Set the Reroute Stuck Vehicle function and Wrong Lane Diversion Time

Reroute Stuck Vehicle function reroutes vehicles that are unable to access their correct lane range. Specifically applied to stopline movements at junctions/intersections where vehicles are caught in the incorrect lane to make their desired turn. Wrong Lane Diversion Time is the additional cost a vehicle would tolerate in order to reach its destination by choosing an alternative route from the junction/intersection/intersection. This occurs if the vehicle is unable to use its original lane choice due to stopline queuing.

5. Apply the Lane Choice feature (remote Signposting).

This feature is part of the decision point hierarchy along with signposting/decision point. This allows the user to override the default lane use logic provided by the signposting/decision point model used by default giving the user more freedom to deal with complex junctions, short links, complex freeway on-ramp/off-ramp combinations, and special cases. This function will make vehicles start lane changing when they are one or two links ahead of the stuck link. It works as shown in Figure 22. The table at left is the example of the “lanechoice” file, which configure the function, the right side shows how the function works.

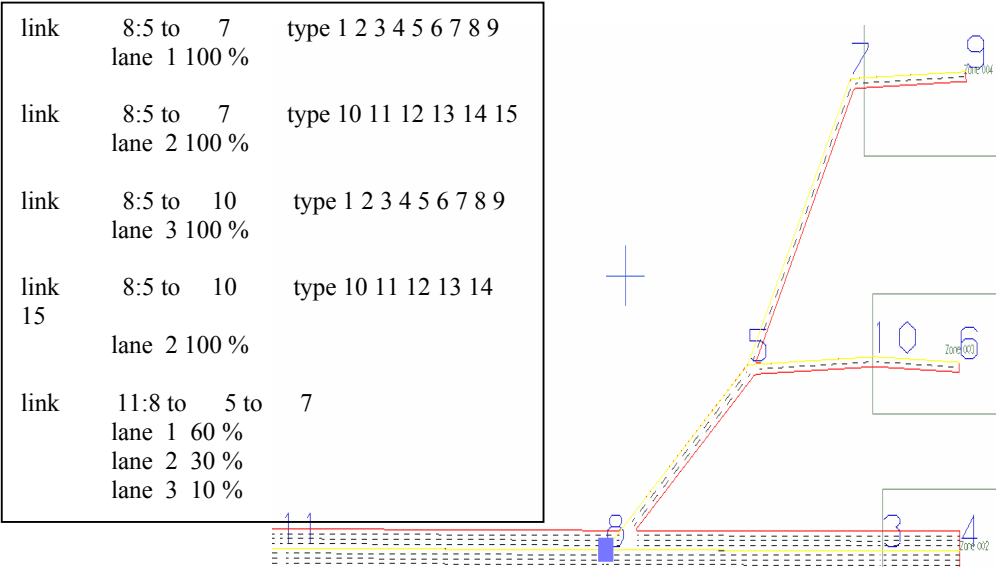


Figure 24 Lane choice (remote signposting) features

6. Adjust some OD demands related to the stuck links (intersections) since unrealistic high left turn demand will result in stuck vehicles.

CHAPTER 10: MODEL EVALUATION AND VALIDATION

10.1 Introduction

The calibrated parameters presented in the previous chapter were applied to the refined SR41 network. Output statistics gathered by the model were checked for validity, in a qualitative and quantitative way. The simulation runs for the base conditions were first studied at the macroscopic network-wide level: overall simulation statistics were computed, and the relationships between speeds, flows and densities were analyzed.

Further analysis consisted in comparing the model outputs to real-life traffic performance, specifically measured speed and flow data.

10.2 Validation of volume

We compare the simulation volume results with the collected field data. Totally 20 major freeway locations and 36 major arterials locations are compared. To test the DME efficiency and the network robust, data are collected from 3 hours consecutive simulation, in 15 minutes time intervals.

From Figure 23 and Table 8, we can conclude that simulated traffic counts correspond well to the observed measurement.

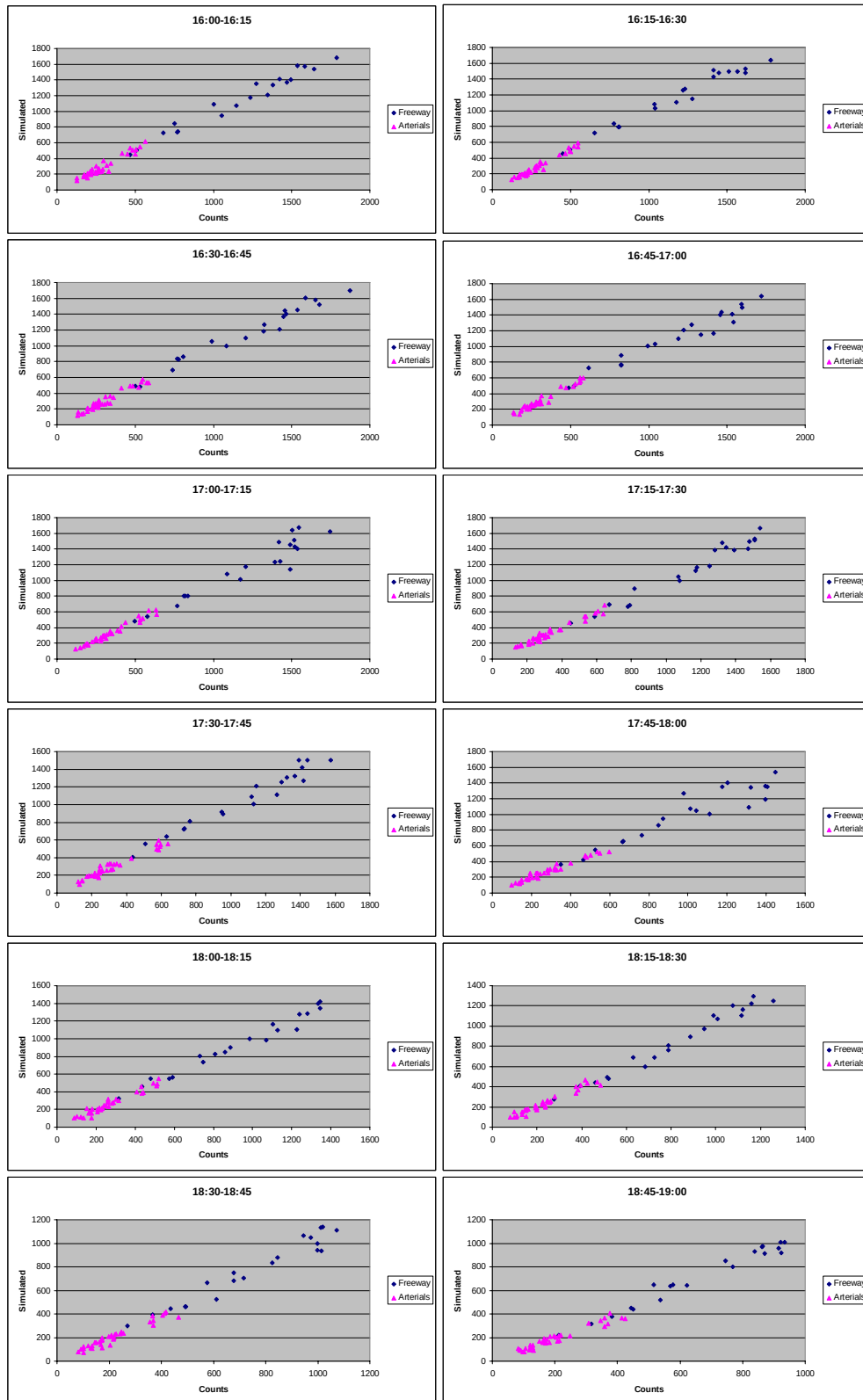


Figure 25 Traffic volume calibrations (15 minutes) at major measurement locations

Table 9 Volume validation statistics

	Freeways		Arterials	
	Avg. GEH	Pr.<=5 (%)	Avg. GEH	Pr.<=5 (%)
16:00-16:15	1.66	100	1.35	100
16:15-16:30	1.45	100	1.15	100
16:30-16:45	1.72	100	1.60	100
16:45-17:00	2.36	95	1.15	100
Sub Total	2.66	85	1.84	97.2
17:00-17:15	2.58	90	1.06	100
17:15-17:30	1.76	100	1.23	100
17:30-17:45	1.68	100	1.69	100
17:45-18:00	2.50	80	1.24	100
Sub Total	2.38	95	1.74	100
18:00-18:15	1.31	100	1.57	97.2
18:15-18:30	1.55	100	1.38	100
18:30-18:45	1.86	100	1.41	97.2
18:45-19:00	1.85	95	1.49	100
Sub Total	2.80	85	2.31	86.1

10.3 Validation of travel time

The freeway travel time calibration results are shown in Table 9, from the results we can see that for all of the time periods travel times have small difference with Tachrun data, (less than 10 %). For the travel time changing trends, the simulated results also are very similar to the observed data. Note that the Tachrun travel time drops low more quickly than simulation did. This is because comparing to real world, micro simulation relieve congestion much slower, if congestion built up.

Table 10 Freeway mainline travel time validation

	Periods	Avg.Tachrun (sec)	Avg.Simulated (sec)	Diff. (sec)	% diff.
Northbound SR41 from O street to Friant Ave.	16:00-16:15	559	538	-21	-3.7
	16:15-16:30	553	510	-43	-7.7
	16:30-16:45	549	483	-66	-12.0
	16:45-17:00	562	528	-34	-6.0
	17:00-17:15	609	553	-56	-9.2
	17:15-17:30	723	680	43	-6.0
	17:30-17:45	574	636	62	10.8
	17:45-18:00	N/A	571	N/A	N/A
	18:00-18:15	N/A	462	N/A	N/A
	18:15-18:30	N/A	457	N/A	N/A
	18:30-18:45	N/A	452	N/A	N/A
	18:45-19:00	N/A	455	N/A	N/A
Southbound SR41 from Friant Ave. To O street	16:00-16:15	503	452	-51	-10.1
	16:15-16:30	499	475	-24	-4.8
	16:30-16:45	504	461	-43	-8.5
	16:45-17:00	492	543	51	10.3
	17:00-17:15	515	506	-9	-1.7
	17:15-17:30	529	471	-58	-10.9
	17:30-17:45	564	495	-69	-12.2
	17:45-18:00	N/A	451	N/A	N/A
	18:00-18:15	N/A	458	N/A	N/A
	18:15-18:30	N/A	455	N/A	N/A
	18:30-18:45	N/A	450	N/A	N/A
	18:45-19:00	N/A	434	N/A	N/A

10.4 Validation of speed contour map

Speed contour map from simulation is shown in Figure 24 and Figure 25. Compared to the real world speed contour map from Tachrun, we can see that they have similar pattern: congestion happened at the same locations on almost the same time.

NB	O ST	DIVISADE	OLIVE	MCKINLEY	SHIELDS	ASHLAN	SHAW	BULLARD	HERNDON	FRIANT
16:00		66.78314	64.48697	57.28026	51.31713	67.43327	64.91564	67.39054	65.30153	59.41277
16:05		71.9884	67.11719	54.71194	48.85124	59.31175	42.70973	70.38919	68.89531	62.03029
16:10		69.25281	62.78851	54.13703	44.63664	66.60417	53.16873	58.91444	66.85691	66.03756
16:15		71.9884	65.59018	58.54592	50.8256	65.91652	63.45883	60.75024	65.30153	51.18137
16:20		72.60435	67.32374	61.41506	58.16308	67.07903	63.86011	62.33567	53.84221	51.09376
16:25		72.799	67.60522	60.41481	59.47485	70.2695	67.75267	68.89669	66.91917	49.57204
16:30		72.50741	65.16494	54.55102	60.3995	69.4775	67.86976	70.22473	69.76486	56.15636
16:35		71.70326	66.32715	54.02665	60.45824	67.19248	65.99434	66.89061	65.40853	58.65007
16:40		70.45674	66.48129	56.78918	56.47216	68.33548	67.14774	67.37796	64.63196	64.32969
16:45		71.42037	64.65513	52.11393	56.166	68.06229	64.30156	67.85968	59.73218	66.24274
16:50		71.79806	66.1855	57.90617	51.1302	69.70778	66.30382	64.59065	63.65858	44.33016
16:55		71.27041	63.74637	57.47551	52.28526	68.71636	67.12223	67.36537	41.88006	35.79873
17:00		71.30784	65.41712	56.44354	62.33782	66.34463	66.14253	61.98216	61.42743	34.57144
17:05		71.30784	66.13842	58.34334	61.73638	67.95879	64.90372	63.43197	63.26625	42.04871
17:10		70.25621	65.19922	62.32308	61.45734	68.14012	67.97417	54.72223	69.41442	67.21733
17:15		71.12107	65.46318	48.31297	49.70505	71.44908	65.39606	59.06882	67.88004	66.66686
17:20		71.53326	66.43379	51.30663	43.95575	60.08928	41.766	71.18101	70.55951	52.72429
17:25		69.55437	65.41712	54.3751	46.71655	29.50414	67.9611	65.85251	65.93669	66.31141
17:30		71.15835	66.05619	56.13604	54.55341	43.91196	64.77289	61.46459	67.99566	64.01697
17:35		72.68208	66.76774	59.40854	56.87817	68.91504	60.42148	40.11949	68.06006	54.11345
17:40		73.38926	68.06302	61.61909	61.62271	50.63464	24.87969	70.67885	68.40995	46.38295
17:45		71.81705	67.54383	60.73133	61.94732	19.79686	23.34802	70.00664	69.6972	69.40547
17:50		72.41074	67.67904	59.40854	57.29006	43.30562	60.88987	63.98336	65.99725	62.44556
17:55		72.0457	65.41712	58.9366	59.70334	68.14012	66.36607	67.91079	68.8821	40.38011

Figure 26 PM peak hour speed contour map of simulation model (NB)

SB	FRIANT	HERNDON	BULLARD	SHAW	ASHLAN	SHIELDS	MCKINLEY	OLIVE	DIVISADE	O ST
16:00		66.29275	64.94657	67.24669	67.16284	66.01528	63.61178	65.98503	65.11122	65.61604
16:05		66.17435	67.82194	66.74838	56.50054	65.72371	63.57438	61.64617	65.07697	65.98923
16:10		64.17804	67.542	64.75697	67.26511	63.6391	64.40764	64.00035	64.13219	63.31209
16:15		67.39813	65.66925	66.88468	63.96577	66.0519	62.23847	62.85331	67.05256	66.35019
16:20		65.53065	67.32726	67.43548	64.73912	66.83058	63.56503	61.10908	63.60454	65.34291
16:25		64.67279	67.82194	67.2216	64.12827	68.01421	63.93154	65.03332	65.55987	61.75896
16:30		66.89115	68.28506	66.08727	46.94618	68.00126	64.76455	63.10464	65.76903	65.85895
16:35		64.71044	67.02641	65.09626	59.7988	44.91795	64.37888	63.52802	63.80139	65.8427
16:40		66.23349	68.09133	66.63728	67.52214	64.28053	63.04606	60.46521	65.03135	65.61604
16:45		68.79552	69.08441	67.67614	68.93132	65.19581	64.42683	56.69971	66.52364	63.28206
16:50		62.96027	67.51666	63.76	66.25626	62.91045	61.76731	51.7141	64.54494	67.35499
16:55		67.70602	66.62944	68.24011	65.08488	65.4707	64.73546	49.64011	67.99869	64.44348
17:00		61.71925	66.69115	67.56193	55.16873	67.50003	64.05464	61.03031	64.5674	67.50834
17:05		66.75056	63.49186	64.46731	54.68217	67.48727	62.65328	62.21322	66.14418	65.58379
17:10		67.0829	67.86029	61.02774	28.98711	70.40068	65.12544	57.0241	66.79908	66.48243
17:15		69.17011	66.50634	67.12142	42.75476	59.44451	63.97883	61.12881	67.60227	68.33814
17:20		69.48358	68.05271	66.23305	65.8366	65.31504	64.09262	58.21612	66.5475	65.04033
17:25		67.26557	68.75455	66.47745	65.48284	67.10685	62.8171	56.63189	66.90748	66.69844
17:30		68.85945	69.65922	66.95926	62.76165	65.2673	61.78496	57.82505	66.42837	65.5033
17:35		66.07601	69.97062	67.14644	65.14486	68.31344	63.22118	55.53579	65.94435	66.51557
17:40		67.3063	66.38371	66.62496	34.69915	69.49653	65.16469	65.10039	68.80565	68.25076
17:45		66.23349	67.542	64.40968	40.3023	65.76002	61.90879	60.91252	66.88336	64.74053
17:50		67.16397	67.35245	66.66194	67.20116	65.72371	46.3934	40.40474	68.16107	66.46587
17:55		71.23125	67.44077	66.72366	68.98514	64.97046	60.44631	46.62162	67.12534	66.20205

Figure 27 PM peak hour speed contour map of simulation model (SB)

CHAPTER 11: CONCLUSIONS AND FUTURE STUDY

11.1 Conclusions

This project proposed a general micro simulation calibration procedure for large scale corridor network simulation studies, including data collection and analysis, capacity calibration, OD estimation, final tuning, and calibration validation. A streamline framework of the calibration was presented and reasonably accurate calibration results were achieved. The proposed procedure follows the traditional step-by-step calibration framework and thus can be easily understood and used by traffic engineers. The resulting methodology of this project can be used as a framework for conducting simulation studies on other corridor networks in California, a template for Caltrans to conduct similar planning and operational studies in the future is developed.

The following is a list of works conducted in this project.

- Conducted OD Estimation and Calibration for SR-41 Corridor Network
- Summarized the calibration procedures and experiences obtained from the SR-41 simulation study
- Developed APIs and Programs

11.2 Simulation study of improvements

The next phase for the simulation study is examining potential short-term and medium term operational improvements and conducting simulation analysis.

From a planning perspective, Caltrans is interested in evaluating a long time horizon (e.g. 20 years). But from the current practice of applying microscopic traffic simulation, the short term or immediate operational improvements, such as re-timing

of traffic signals, could be evaluated on the calibrated network. For the medium term network improvement, such as building an auxiliary lane in a few years, additional analysis for the transportation planning model forecasting may need to be conducted.

There are various operational improvements could be conducted for the current and future year model, include short term and medium improvements. Some of them are list below.

- Add or expand freeway lanes
- Individual intersection traffic signal improvements
- Signal Coordination
- Adaptive Ramp Metering
- Incident Management with/without signal or ramp improvements

Some of these operational improvements cannot be simulated directly with Paramics, so some APIs developed in the previous California PATH projects will be used, including signal coordination, adaptive signal, ramp metering controller, etc. And some new API may also need to be developed according to the project requirement.

For each simulation run, a number of performance measures will be developed for review and analysis. These will include, but not limited to:

- Mobility results- travel time, delay, speed
- Productivity results-flow rates by sections, change in flow rates

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