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## **A Microsimulation Model of a Congested Freeway using VISSIM.**

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### **ABSTRACT**

A procedure for constructing and calibrating a detailed model of a freeway using VISSIM is presented and applied to a 15-mile stretch of I-210 West in Pasadena, California. This test site provides several challenges for microscopic modeling: an HOV lane with an intermittent barrier, a heavy freeway connector, 20 metered onramps with and without HOV bypass lanes, and three interacting bottlenecks. Field data used as input to the model was compiled from two separate sources: loop-detectors on the onramps and mainline (PeMS), and a manual survey of onramps and offramps. Gaps in both sources made it necessary to use a composite data set, constructed from several typical days. *FREQ* was used as an intermediate tool to generate a set of OD matrices from the assembled boundary flows. The model construction procedure consists of: 1) identification of important geometric features, 2) collection and processing of traffic data, 3) analysis of the mainline data to identify recurring bottlenecks, 4) VISSIM coding, and 5) calibration based on observations from 3). A qualitative set of goals was established for the calibration. These were met with relatively few modifications to VISSIM's driver behavior parameters (CC-parameters).

## 1. INTRODUCTION

It has long been recognized that simulation modeling is a very useful tool for the design of improvements to urban freeway systems. The simulation model enables the engineer to predict the outcomes of a proposed change to the freeway system before it is implemented, and to evaluate the merits of competing designs. This is a very important consideration, given the impacts that such projects can have on nearby communities and on local economies. For the simulation model to correctly predict the system response however, it must first be shown to reproduce the existing traffic condition. The procedure by which the parameters of the model are adjusted so that the simulated response agrees with the measured field conditions is what is known as *model calibration*.

Simulation models are generally classified into *macroscopic* and *microscopic* models, depending on their level of modeling detail. Macroscopic models describe the traffic process with aggregate quantities, such as *flow* and *density*. Microscopic models describe the behavior of the individual drivers as they react to their perceived environments. The aggregate response in the latter case is the result of interactions among many driver/vehicle entities. A macroscopic model is often sufficient for the purpose of evaluating a proposed modification. These models tend to be easier to calibrate, since their parameters can be directly related to field data available from the existing sensor infrastructure. For example, *FREQ*, a popular macroscopic model, is tuned by direct manipulation of sub-section capacities. However, it may sometimes be necessary to use a microscopic model in order to capture the more detailed aspects of the system. In this case, the calibration process may become more difficult, and there is no standard methodology for model calibration. The intent of this paper is not to suggest a general methodology, but to present the steps that were followed in the construction (data collection, coding, and calibration) of a VISSIM-based model of a particular freeway system. Analogous efforts using different microscopic models include (1) (*PARAMICS*), (2) (*CORSIM*), and (3,4) (*INTRAS*).

This work is part of a larger project (PATH/Caltrans T.O. 4136) that has as its central goal to design and implement an improved onramp control system for the Foothill Freeway (I-210 West) in Pasadena, California. The model will be used as a testbed for evaluating different control designs. VISSIM was selected as the environment for constructing the testbed following recommendations from several knowledgeable colleagues. As is described in the paper, I-210 West is a large and heavily congested test site, and presents several complicating features: an HOV lane with an intermittent barrier, several metered onramps with and without HOV bypass lanes, an uncontrolled freeway connector, and three interacting bottlenecks.

Although this paper is based on a single test-case, practitioners wishing to use microsimulation to study unidirectional freeways may find useful many of the details on how certain features were implemented and how problems related to incomplete data were overcome. The paper covers the entire process of model construction: Sections 2, 3, and 4 describe the collection of geometric and traffic data; Section 5 briefly describes the use of *FREQ* to translate the boundary flows to OD matrices; Section 6 is an analysis of the traffic data that is later used in the model calibration phase; Section 7 provides details on the coding of VISSIM; Section 8 describes several important driver behavior parameters; and Sections 9 and 10 describe the parameter adjustment procedure and its results.

## 2. DESCRIPTION OF THE TEST SITE - SOURCES OF GEOMETRIC INFORMATION

The site and time period chosen for the simulation study is the westbound direction of I-210 from Vernon St. to Fair Oaks (on SR-134, just beyond the 210/134 junction), between 5:30 am and 10:30 am (Figure 1). This is a 15-mile stretch of freeway that sustains heavy congestion during the morning commute. Congestion usually begins around 6:00 am, peaks at 7:30 am, and finally dissipates at around 10:00 am. The site has 21 onramps, 20 of which are metered and equipped with a complete set of loop-detectors (all except the 605-NB/210-WB freeway connector). Each metered onramp has a corresponding mainline detector station for traffic-responsive control, and some, but not all, have HOV bypass lanes. There is a median-side HOV lane that spans the entire site, and is separated from the mixed-traffic lanes by an intermittent barrier (shown in Figure 1). The cut-off occupancy for the HOV lane is 2 or more passengers per vehicle, and is enforced at all times.

Simulation models require a detailed and complete description of the layout of the site in order to produce a realistic output. The important features that are usually represented include the location of onramps and offramps, the number of lanes and location of lane drops, freeway curvature, auxiliary lanes, and weaving sections. In the case of

**Figure 1 : 65 sections is the test site**

I-210, additional features were also considered important. For example, the positions of the HOV *gates* – the gaps in the intermittent barrier where vehicles enter and exit the HOV lane. Also, the arrangement of loop-detectors and metering lights on the onramp and mainline. In particular, the position of the *queue* detector with respect to the metering light is especially important for control applications, since it determines the maximum permitted queue length, when queue length restrictions are enforced.

Three sources of geometric information were used for this study:

1. A set of photocopies of scaled aerial photographs obtained from Caltrans HQ. These photographs are black-and-white and printed on 11" × 17" paper, with a 1:2400 scale.
2. A set of *as-built* maps indicating the arrangement of loop-detectors on onramps and the mainline. These were provided by the District 07 Ramp Metering Group.
3. Un-scaled aerial photographs in bitmap format downloaded from MapQuest ([www.mapquest.com](http://www.mapquest.com)).

All of the desired features were extracted from the aerial photographs (source 1), with the exception of the arrangement of sensors and metering lights, which was measured from the as-built maps (source 2). Each of the important features was assigned a single section in Figure 1. In total, the site was divided into 65 sections (the first three sections have negative indices because they were appended after the initial numbering). Figure 1 also provides the lengths and number of mixed-flow lanes in each section. The features mentioned above were marked on a large overhead view of the site compiled from source 3, and thus encoded into VISSIM.

### 3. TRAFFIC DATA SOURCES

The traffic demand was defined in VISSIM as a set of OD matrices, which contain the average numbers of vehicles going from every freeway origin to every destination, at 15-minute intervals. (This is one of two available methods. The alternative is to use aggregate vehicle sources, and to direct traffic using turning percentages). This and the next few sections describe the procedure that was followed to gather and process traffic data in order to generate the OD matrices. The first step was to compile a complete and representative set of boundary flows, covering every onramp, offramp, and the two mainline boundaries. *FREQ* was then used to translate the boundary flows into the required set of OD matrices.

Two sources of traffic data were used:

1. **PeMS:** The PeMS database gathers 30-second and 5-minute data from over 30,000 miles of freeway in California (5). This database was used to assemble a history of traffic measurements for every loop-detector station in the site. Three examples of speed contour maps generated from the PeMS mainline data are shown in Figure 2. These represent a heavy, a typical, and a light day of congestion on I-210. Speed contour plots such as these were used to characterize the three major bottlenecks in the system (Section 6), and played a significant role in the calibration effort.
2. **Manual counts:** The District 07 Traffic Operations Group provided the results of a biennial survey of freeway ramp volumes gathered between 10/2001 and 1/2002. The collected data consists of 15-minute estimates of volumes on most of the onramps and offramps in the test site (all except the Marengo St. offramp and the 210 and 710 freeway connectors). The D07 survey did not include any mainline data.

Close agreement between the two sources was found in most cases. Instances where significant differences were noted were usually attributable to malfunctioning loop-detectors (i.e. errors in PeMS). Manual counts were generally favored over the PeMS loop-detector measurements for the ramps. PeMS data was primarily used where mainline measurements were needed. That is, to determine the upstream and downstream mainline flows and to construct the contour plots used for model calibration.

### 4. BOUNDARY FLOWS FROM THE CALTRANS D07 SURVEY AND PEMS

The ramp counts collected by the biennial District 07 survey were gathered manually, by counting the number of vehicles that used every onramp and offramp, at 15-minute intervals, throughout the day. Each ramp was surveyed over a period of about 14 consecutive days. This data set constituted a complete picture of the traffic demand entering and exiting the test site using the ramps, but it did not include any mainline data. Conversely, the PeMS database provided mainline measurements that were practically complete, but lacked information from several key ramps, including the heavy freeway connector from 605 NB (MP 36), and several offramps where loop-detectors had either failed or were missing.

The main difficulty encountered with the D07 boundary data was that there was no single day in which all ramps were surveyed simultaneously. This situation is common in real-world settings, since it is rare to find a complete and reliable sensor structure. As a consequence, it was necessary to assemble a single composite day using ramp counts from several different days considered as *typical*. The set of typical days was created by first discarding all Mondays, Fridays, weekends, and days that strayed from the normal (i.e. average) pattern. From this set, a single day was selected for each onramp and offramp.

### Figure 2 : Processed PeMS speed contour plots

Measurements for the two mainline boundaries (Vernon and Fair Oaks in Figure 1) were obtained from PeMS. Again, it was necessary to select a single typical day for the mainline boundary flows from a number of days. The selection of typical days for the mainline boundaries was based three criteria: completeness of the data set, how well the flow data followed the day-to-day trend, and the resulting "scale factor". *Scale factors* are defined as the ratio, for each 15-minute period, of the total number of vehicles entering the system to the total number of vehicles that exit. They are computed in FREQ as a first step to finding an OD table (Section 5). They can also be used to identify possible problems in the data set, since they are expected to fall within 10% of 1.00, for a normal (incident-less) traffic scenario, and their average over a 5-hour period should be very close to 1.00. The scale factors resulting from the final selection of ramp and mainline were found to be within the acceptable range. The aggregate scale factor for the 5-hour period was 1.02.

### 5. ESTIMATING OD MATRICES WITH THE FREQ MODEL

The translation of ramp counts to the set of OD matrices required by VISSIM was achieved with FREQ. FREQ is a macroscopic deterministic freeway corridor model for the development and evaluation of freeway operational strategies, developed by Adolf May at U.C. Berkeley (6). The OD matrices are computed in FREQ as the solution to a steady-state optimization problem. In our case, the FREQ optimization generated a sequence of 20 OD matrices – one for each 15-minute time interval – each with dimensions  $(22) \times (19) = (21 \text{ onramps} + 1 \text{ mainline origin}) \times (18$

offramps + 1 mainline destination). An intermediate step was performed here to incorporate the information of the percentage of HOV vehicles present in each of the source flows. As is explained in Section 7.3, each OD matrix in VISSIM applies to a specific *traffic composition*. Since the I-210 model includes two traffic compositions (MIX\_TC and HOV\_TC, defined in Section 7.3), each FREQ OD matrix spawned two VISSIM OD matrices, giving a total of 40 matrices. The following assumptions were made based on available data and on suggestions from Caltrans staff. They were sufficient to make the conversion from 20 to 40 OD matrices.

- The number of vehicles using the HOV lane at the upstream mainline boundary (Vernon St.) is a given time-varying fraction of the total (mixed-lanes plus HOV lane). This fraction was derived from PeMS data.
- In addition to the HOV vehicles in the HOV lane, 5% of the vehicles in the Vernon St. mixed-flow lanes are also HOV.
- 12% of the vehicles entering the freeway through onramps are HOV.
- Of the total number of HOV vehicles that reach the downstream mainline boundary, 20% are in mixed-flow lanes, and 80% are in the HOV lane.

## 6. IDENTIFICATION OF RECURRING BOTTLENECKS

The first step in the model calibration process was to identify the location and causes of congestion on I-210. This information was later used as a guide in the parameter tuning phase (Section 10). Figure 2 shows congestion patterns for a heavy, a typical, and a light day of traffic. From these and other similar contour plots, three distinct problem areas, or bottlenecks, were identified. They are:

- B1:** Near Huntington St. (MP 33.049).
- B2:** Near the Rosemead and Michillinda St. ramps (MP 30.139).
- B3:** Near Hill St. (MP 26.8).

These three bottlenecks are illustrated in Figure 3. Mainline stations are depicted in the figure with a ×, ○, or ⊗, depending on whether the station is characterized by heavy congestion (speeds often < 40 mph), by free flow (speeds > 55 mph), or by decreased speeds not reaching full congestion (speeds between 40 mph and 55 mph). Distances between ramps are marked on the figure along with the number of mixed-flow lanes in each section. The number accompanying each onramp and offramp is a representative (approximately average) level of flow on the ramp when congestion begins.

The following conclusions were reached on the probable causes of congestion at each bottleneck:

- B1:** This bottleneck is not easily explained with a simple comparison of nominal capacities and demands. The Myrtle ramps make no net contribution to the amount of traffic on the freeway (600-600=0). The Huntington ramps supply about 500 vph to the mainline, but this should be easily absorbed by the auxiliary lane between Huntington and Santa Anita. The observed deceleration of the traffic stream must therefore be due to a reduction in capacity near the Huntington ramps, or somewhere between Huntington and Santa Anita. Localized reductions in capacity have a variety possible causes, including grades, curves, reduced visibility, street signs, and direct oncoming sunlight. In this case, the most probable cause is the series of reverse curves between Myrtle and Huntington (as suggested by Caltrans staff).
- B2:** Bottleneck B2 is less stable than B1, in the sense that its location and congestion pattern are less predictable. Congestion initiates somewhere near the Rosemead and Michillinda ramps (MPs 30.139 to 29.879), however, complete breakdown, with speeds in the 20's and 30's, only occurs upstream near the Baldwin onramp (MP 30.779). The Rosemead and Michillinda detectors sometimes register speeds decreasing as low as 40 mph, but seldom less than that. Congestion in this region is probably caused by the two heavy onramps from Rosemead and Michillinda, which add approximately 1700 vph to the freeway. These onramp flows should be easily accommodated by the two additional auxiliary lanes. However, it appears that this increased capacity is not being fully utilized, probably due to increased weaving in that area.
- B3:** Mainline traffic near Hill St. (MP 26.8) is usually slow, and sometimes fully congested. Traffic near Altadena (MP 28.03) almost always becomes completely congested. As with the previous two, bottleneck B3 cannot be

easily explained by comparing demands and nominal capacities, since the heavy flow from the Hill onramp is supported by an auxiliary lane. The observed congestion must therefore again be explained by a reduction in capacity. In this case, at least two probable causes exist: the S-shaped bend between Hill and Lake, and the heavy weaving that takes place in the 800-foot auxiliary lane before the Lake offramp.

**Figure 3 : Three major bottlenecks**

## 7. THE VISSIM MODEL

### 7.1 Overview of the program

VISSIM is the microscopic/stochastic traffic simulator that was used to create the detailed model of I-210 West. In the past, it has been used primarily as a tool for the design of urban public transportation systems, but has been shown to be capable of reproducing freeway traffic behaviors as well. Its traffic model is based on the work of R. Wiedemann (7,8), which combines a perceptual model of the driver with a vehicle model. The behavioral model for the driver involves a classification of reactions in response to the perceived relative speed and distance with respect to the preceding vehicle. Four driving modes are defined: Free driving, approaching, following, and braking. In each mode the driver behaves differently, reacting either to its following distance, or trying to match a prescribed target speed. These reactions result in a command acceleration given to the vehicle, which is processed according to its capabilities. Drivers can also make the decision to change lanes. This decision can either be forced by a routing requirement, for example when approaching an intersection, or made by the driver in order to access a faster-moving lane.

Traffic signals can be simulated, and are controlled in VISSIM by the Signal State Generator (SSG), which is a separate module from the traffic simulation module. One important feature of the SSG is that it is programmable - the user is allowed to specify signal control logics with a descriptive language called VAP (Vehicle Actuated Phasing). Through the VAP interface, the user can access loop-detector measurements, and use them to generate commands for the traffic signals. A trace file can be exported from the VAP process to record loop-detector and signal related variables. These traffic signaling features can be used, for example, on freeway onramps to simulate onramp metering control. Further descriptions of the VISSIM model and software can be found in (9,10).

### 7.2 Coding of the network geometry

As was described in Section 2, the relevant features of the I-210 test site were marked on a composite aerial photograph, which was downloaded from MapQuest. Scale was established on this image by matching landmarks with the scaled aerial photographs obtained from Caltrans HQ. Links and link connectors were then traced on this background image in VISSIM.

#### *Control Hardware*

In addition to the freeway geometry, coding of the supply side of the model also entailed the placement of the control hardware elements: loop-detectors and signal heads. All onramp signals were held on green for the calibration runs of this document. It should be mentioned that this is not the current situation on I-210. District 07 uses a combination of local traffic-responsive and fixed-time onramp metering for this freeway. However, the survey counts used as input to the VISSIM model closely follow the measurements from the *entrance* loop recorded in PeMS. This loop-detector is placed at the gore of the onramp, beyond the metering light. It was therefore inferred that the survey counts represent the actual number of vehicles entering the freeway, not the demand entering the back of the onramp queue. It should also be pointed out that all freeway *offramps*, including the two bifurcating freeway connectors, were left uncontrolled, based on information received from Caltrans D07 that none of the offramps in the test site are affected by external queues (e.g. emanating from surface street traffic lights).

#### *HOV lanes*

Another important aspect of the network coding is the implementation of HOV lanes. VISSIM allows particular lanes of a link to be closed to certain vehicle types (vehicle types are defined in the next section). HOV-only restrictions were enforced by creating a separate vehicle type for the HOV vehicles, and by closing the HOV-only lanes to all non-HOV types. This method was used to create the HOV lanes on the mainline as well as the HOV bypass lanes on the onramps.

#### *Freeway connector*

Almost all of the onramp merges were modeled following the method recommended in (10), where vehicles entering from the onramp join the mainline stream by changing lanes within a merge section. It was found however, that this



approach only worked well for onramps with small or moderate flows. It failed for the heavy freeway connector from 605 NB (MP36), where it produced a large queue on the onramp. An alternative configuration was designed to shift some of the burden of the merge away from the onramp and onto the mainline, by forcing a percentage of the mainline vehicles to evacuate the right-most lane upstream of the ramp junction, thereby opening space for the flow from 605 NB. This was accomplished using VISSIM's *partial routing decisions* (see (10) for further details).

### 7.3 Coding of traffic demands

#### *Vehicle types and Traffic Compositions*

The vehicle population in VISSIM is categorized into *vehicles types*. A single type gathers vehicles that share common vehicle performance attributes. These attributes include model, minimum and maximum acceleration, minimum and maximum deceleration, weight, power, and length. All of these, except for model and length, are defined in VISSIM with probabilistic distributions (as opposed to scalars). Four vehicle types were created to model I-210: LOV, HOV, HGV\_MED, and HGV\_LARGE. The LOV type represents passenger vehicles with a single occupant. HOV vehicles have 2 or more occupants and are allowed to use the HOV and bypass lanes. The vehicle specification for these two types are identical to those of the default CAR type in VISSIM (10). The HGV\_MED and HGV\_LARGE types represent, respectively, medium and large size trucks. *Traffic compositions* are the proportions of each vehicle type present in each of the source flows. Two traffic compositions were defined: MIX\_TC for mixed-flow lane sources (93% LOV, 3.5% HGV\_MED, 3.5% HGV\_LARGE) and HOV\_TC for HOV lane sources (100% HOV type).

#### *Dynamic Assignment*

VISSIM supports two different forms of input for the traffic demands. We chose to use its *dynamic assignment* module, which automatically determines inlet flows and routing information based on a user-supplied set of *OD matrices*. Routes, or traffic assignments, are generated by the dynamic assignment module by assigning a cost to every route available to each OD pair, and then choosing the route with minimum cost. The cost function in VISSIM includes terms penalizing the total distance, total travel time, and a *link cost*. This last term serves to model other factors not covered by the first two, such as tolls. The link cost was used here, as explained below, to encourage the use of the HOV lanes by HOV vehicles.

#### *HOV lanes and the link cost*

The idea behind dynamic assignment is that repeated simulations using this method for generating routes, and updating the travel time cost between iterations, should eventually converge to an equilibrium solution, in the sense that traffic assignments and travel times will eventually stop changing between iterations. In the case of I-210, the only routing decision to be made is whether and where the HOV vehicles will access the HOV lane. The simulation runs presented in this document are based on a single iteration of dynamic assignment. Travel time was therefore not a consideration in the selection of routes for HOV vehicles (this is because travel time is only known after the first iteration). Instead, the HOV lane was given a favorable cost by using the *link cost* coefficient. A separate link cost coefficient can be assigned to each vehicle type. The LOV vehicle type's link cost coefficient was set to 0.0, whereas the HOV type was given a value of 1.0. In computing a cost for each route, the program multiplies this coefficient by a link cost associated with each link in a given route, and adds them up. HOV lanes were given a preferred status by attaching a lesser link cost to HOV lanes, as compared to mixed traffic lanes. Thus, the minimum-cost route available to HOV-type vehicles was always to enter the HOV lane at the gate nearest to its origin, and to exit it at the gate nearest to its destination. Non-HOV vehicles were declined the use of HOV lanes with type-specific lane closures (described in Section 7.2).

## 8. CHANGEABLE MODEL PARAMETERS - DEFAULT VALUES

Section 7.3 listed the model parameters related to the physical attributes of the vehicle. These were assigned separately for each vehicle type. Fixing the vehicle population, we now look at the parameters of the driver model. We have assumed that driver behavior is not correlated with vehicle type, but instead with the position of the driver/vehicle in the network. For example, drivers might behave differently on curved sections, as compared to

straight sections. Thus, the parameters described in this section apply equally to all vehicle types, but were adjusted for each *link type*. Link types are analogous to vehicle types. They gather links with similar driver behavior parameters. Six link types were created to model I-210. These are described in Section 10. The driver behavior parameters that were changed from their default values to define each link type are described below. This is a subset of the total number of adjustable driver behavior parameters available in VISSIM. A complete list can be found in (10).

#### *Necessary lane change (weaving behavior)*

The dynamic assignment module provides to each vehicle a sequence of links to follow that will take it from its origin to its destination. The parameters related to necessary lane changes dictate how far in advance each vehicle will be able to anticipate the next bifurcation (i.e. offramp) or lane drop on its list, and how aggressively that vehicle will change lanes to reach it. The first two items below – *look-back distance* and *emergency stop distance* – are the only driver behavior parameters that are not grouped into link types, but must be specified for each link connector separately (in VISSIM *the link connector* is the boundary between two links).

- *Look-back distance*: Distance in anticipation of a bifurcation that the driver will begin maneuvering towards the desired lane. Range=(0,∞). Default = 200 m.
- *Emergency stop distance*: Distance before the bifurcation where the driver will stop if it has not reached its desired lane. Range=(0,∞). Default = 5 m.
- *Waiting time before diffusion*: A vehicle that has come to a halt at the emergency stop position will wait at most this amount of time for a gap to appear in the adjacent lane. After the waiting time has elapsed, the vehicle is removed from the simulation. Range=(0,∞). Default = 60 seconds.

#### *Vehicle following behavior*

VISSIM includes two versions of the Wiedemann model: urban driver and freeway driver. Only the freeway driver model was used. The car-following mode of the freeway driver model involves 10 tunable parameters: CC0 through CC9. Below are described only those CC-parameters that were modified from their default values.

- CC0 and CC1: Coefficients used in the calculation of the safe bumper-to-bumper distance (in [m]):  $dx\_safe = CC0 + v \cdot CC1$ , where  $v$  (in [m/s]) is the speed of the trailing vehicle. According to (10), CC1 is the parameter with the strongest influence on freeway capacity. In fact, it can be related almost directly to capacity by noting that  $(dx\_safe + \text{vehicle length}) \cdot \text{capacity} = \text{freeflow speed}$ . With reasonable values of capacity,  $dx\_safe$ , and freeflow speed, and default CC0, this calculation gives  $CC1 = 1.5$  seconds. The range for both CC0 and CC1 is (0,∞). Default values are  $CC0 = 1.5$  m and  $CC1 = 0.90$  s.
- CC4 and CC5: These are dimensionless parameters influencing the coupling between leader and follower accelerations. Smaller absolute values result in driver behaviors that are more sensitive to changes in the speed of the preceding vehicle. It is recommended in (10) that these two parameters have opposite signs and equal absolute values. Default values are  $CC4 = -0.35$  and  $CC5 = 0.35$ . The absolute value of CC4 (or CC5) can be understood as the inverse of a stiffness coefficient between consecutive vehicles.

These three CC-parameters (CC0, CC1, and the CC4/CC5 pair) were used to reproduce the curvature-induced capacity drops that are the supposed culprits of bottlenecks B1 and B3. We can infer from their definitions that increments in CC0, CC1, or in the absolute values of CC4 and CC5 will lead to reductions in freeway capacity.

## 9. VARIATIONS OF SELECTED DRIVER BEHAVIOR PARAMETERS

With model inputs (network supply and traffic demand) fixed as described in Section 7, an initial simulation experiment was run using default driver behavior parameters. The resulting speed contour plot is shown in Figure 4. The immediate observation here is that there is a severe blockage near the downstream end of the freeway that produces a queue which quickly overruns the entire site. This problem was caused by a large number of vehicles

attempting to exit through the last two offramps (the 210 and 710 freeway connectors), but were unable to complete the necessary lane changes before reaching and stopping at the emergency stop position. Several adjustments to the routing-imposed lane change parameters were made to correct this problem.

#### *Adjustments to the look-back distance*

It was determined that the default look-back distance of 200 m is too small for large numbers of vehicles crossing over several lanes of traffic to reach their exits. On the other hand, increasing this value too much had the unrealistic effect of bunching up all of the exiting vehicles in the right-most lane, far upstream of their intended offramp. These vehicles then obstructed other upstream offramps and onramps. It was therefore necessary to tune the look-back distances individually for each offramp, in a way that allowed vehicles sufficient weaving space while ensuring that these lane-change regions did not overlap.

#### *Adjustments to the Waiting time before diffusion*

Another modification that was found useful for eliminating the offramp blockages was to decrease the *waiting time before diffusion* parameter, from its default 60 seconds to 1 second. With this setting, vehicles that stopped at the emergency stop position on the mainline (at the offramp bifurcation) were immediately removed from the simulation, thereby minimizing the obstruction to the freeway. Eliminating these vehicles has little impact on the total travel time, since they are few and very close to their exit anyway. However, this adjustment is only recommended after the number of affected vehicles has been minimized by tuning the look-back distances. Also, one should be careful not to affect other bifurcations and/or lane drops within the network where larger waiting times are desired. For example, in the case of I-210, vehicles attempting to enter the freeway also frequently reached the emergency stop position at the end of the onramp/mainline merge sections (which contain a lane drop). To avoid these vehicles from being evaporated, a set of *merge link types* was created. These match their non-merge counterparts in all features except for the waiting time, which was set to 60 seconds for the merge types (see Table 1). Merge link types were used on all onramps and onramp merge sections.

### **Figure 4 : Simulated speed contour plot with default driver behavior parameters**

#### *Link types - Variations of following behavior (CC-) parameters*

The remainder of the calibration effort focused on finding a suitable set of values for the CC-parameters mentioned in Section 7. Three separate sets of CC-parameters were defined: Freeway, HardCurve, and SoftCurve. Each was paired with a *merge link type* (with a 60 second diffusion time), giving a total of 6 link types. The Freeway and Freeway Merge types were used almost everywhere. The HardCurve and SoftCurve link types were applied only to the curved sections that affect bottlenecks B1 and B3 respectively (see Figure 3). As is described in the next section, one of the findings of this study is that only modest adjustments to the CC-parameters were required to produce the

desired simulation response. Also, that capacity drops due to curvature can be reproduced with changes to the CC1 parameter alone.

## 10. CALIBRATION GOALS - CC-PARAMETER SELECTION

Having assembled the onramp and offramp flow inputs using data from several different days, it is not immediately obvious how the simulation results should be evaluated. The usual method of computing an error norm with respect to the measured data, and tuning the model parameters to minimize that norm is not applicable in this case due to the composite nature of the input data. The question arises, should a single typical day be used, or a composite day, as was done with the boundary flows? Added to this difficulty is the fact that none of the data sets considered as typical had a complete set of mainline measurements. Furthermore, there seems to be more variability in the mainline measurements than appears in the onramp flows, suggesting the influence of unseen factors, such as weather, day-to-day variations in driver behavior, traffic incidents, etc.

Instead, the goal for the calibration was to match more qualitative aspects of the freeway operation. These were:

1. location of the three identified bottlenecks,
2. initial and final times for each of the three mainline queues,
3. extent of the queues,
4. utilization of the HOV lane,
5. onramp performance.

The first three items pertain to the simulated response of the mixed-flow lanes. Target values for these (Table 2) were extracted from contour plots similar to those shown in Figure 2. The goal for the HOV lane was to approximate the flow values from PeMS. For the onramps, the only objective was to avoid large onramp queues that might obstruct the vehicle sources.

The parameter selection methodology consisted of iterated runs, visual evaluation of the results using speed contour plots (e.g. Figure 6), and manual adjustments of the parameters. These adjustments were limited to the CC-parameters described in Section 8, and were aided by the bottleneck analysis of Section 6 and by the physical interpretation of the parameters of Section 8. The iterative procedure was stopped when all of the qualitative calibration goals were met (see Sections 10.1, 10.2 and 10.3). This approach was favored over a more automatic and exhaustive search method because of the potentially huge number of parameter variations, as well as the approximately 3 hour running time (PC/Windows XP, 2.6 GHz, 500 Mb RAM), and the advantage that it leads to a more sensible result.

**Table 1 : Calibrated CC values (defaults: CC0=1.5 , CC1=0.9 , CC4/CC5 = -0.35/0.35 , Waiting time = 60)**

The final selection of driver behavior parameters is shown in Table 1. This parameter set is the most parsimonious among those sets that also met the calibration goals. Notice that the CC4/CC5 parameter was increased (in absolute value), but was kept uniform throughout the freeway. It was found that this parameter, in addition to CC1, also has an important influence on capacity. Its default value of -0.35/0.35 produced almost no congestion. The CC0 parameter was also increased globally from 1.5 to 1.7. As expected from its definition, this parameter was more influential at low speeds (i.e. within the mainline queues), and was used to regulate the queue lengths. The CC1 parameter on the other hand, was changed only locally, at two locations. The HardCurve link type was used on the reverse curve near Huntington St. and the SoftCurve type was used on the curved section between Hill and Lake St.

(see Figure 3). CC1 was adjusted in both cases to achieve the correct activation times for bottlenecks B1 and B3 respectively. Interestingly, bottleneck B2 did not require a separate CC1 value. This result supports the interpretations provided in Section 6 for the causes of the three bottlenecks; that B1 and B3 are probably caused by curvature, whereas B2 is probably due to weaving.

### 10.1 Onramp response

One of the qualitative goals for the CC-parameter calibration was to avoid unrealistic queues on the onramps that might obstruct the vehicle sources. The only onramp queuing problem that arose was on the freeway connector from 605 NB (MP 36). As was mentioned in Section 7.2, this was corrected at an earlier stage with *partial routing decisions* and was not a factor in tuning CC-parameters. All other onramps were checked by comparing the supplied onramp flows with the simulated onramp flows. These were a close match in all cases, indicating that none of the vehicles sources were obstructed by excessive onramp queues.

### 10.2 HOV lane response

The goal of matching the utilization of the HOV lane was verified by checking the simulated HOV lane flows. Samples of simulated and field-measured HOV lane flows are shown in Figure 5. Recall that the upstream boundary flows (at Vernon) are an input to the model. The differences at other locations may reflect modeling errors, such as errors in the provided percentage of HOV vehicles at onramps (Section 5), and/or errors in the modeling of route choice by HOV drivers (Section 7.3). In general, the result is considered a sufficiently good match for the control purposes of this model. However, this aspect of the model can be improved with a refinement of the HOV input percentages (Section 5), and/or more iterations of VISSIM's dynamic assignment routine.

**Figure 5 : Measured and simulated HOV lane flows (vph)**

### 10.3 Mixed-flow lane response

The bulk of the calibration effort was dedicated to matching the response of the mixed flow lanes, in terms of the start time, end time, and extent of the queue generated by each of the three major bottlenecks. The iterative procedure was stopped when all of the 9 indicators for the mixed-flow response fell within their target ranges. Target and simulated values for these 9 indicators are given in Table 2. The resulting speed contour plot, shown in Figure 6, is compared to the typical PeMS contour of Figure 2. Notice that the model has approximately matched the period of activation and queue length for the three bottlenecks. This was accomplished with a few global changes to the default parameter values, and with a couple local changes that were based on the analysis of field data and freeway geometry.

**Table 2 : Measured and predicted congestion patterns****Figure 6 : Simulated speed contour plot with final parameter selection.****11. SUMMARY AND CONCLUSIONS**

This document has outlined a complete methodology for constructing and calibrating a simulation model of a unidirectional freeway with onramp control. The procedure included gathering and processing of field data from the PeMS database, estimation of OD matrices with FREQ, and microscopic simulation with VISSIM. Deficiencies in the field data were dealt with by assembling a composite typical day using data from several different days. The procedure was applied to I-210 West, a freeway that presents several challenging features: 20 metered onramps, with and without HOV bypass lanes, an HOV lane with an intermittent barrier, an uncontrolled freeway connector, and several interacting bottlenecks. All of these features were included in the model. Analysis of the supply and demand characteristics of the freeway lead to the conclusion that two of these bottlenecks were geometry-induced, while another was caused by weaving. A successful calibration of the VISSIM model was carried out based on this observation. As a conclusion, this study has shown that the VISSIM simulation environment is well-suited for such freeway studies involving complex interactions. With few and well reasoned modifications to its driver behavior parameters, the simulation model is capable of reproducing the field-measured response on the onramps, HOV lanes, and mixed-flow lanes.

Research will now continue using the calibrated VISSIM model to investigate a wide variety of ramp control strategies for the westbound I-210 freeway during the morning peak period. Ramp control strategies will include local and system-wide alternatives. Caltrans will consider implementing improved ramp control strategies based on their assessment of the predicted results.

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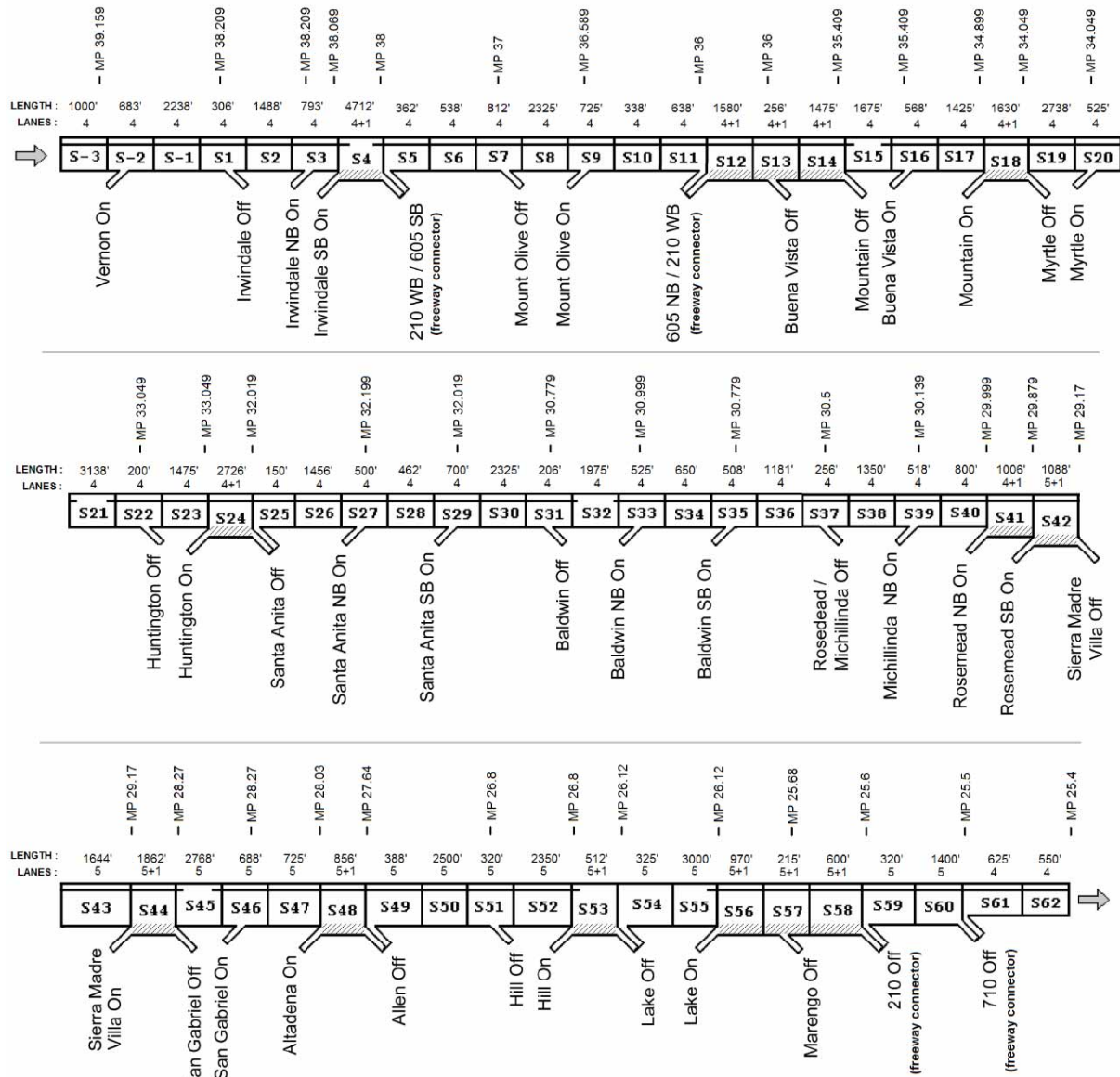


Figure 1 : 65 sections is the test site

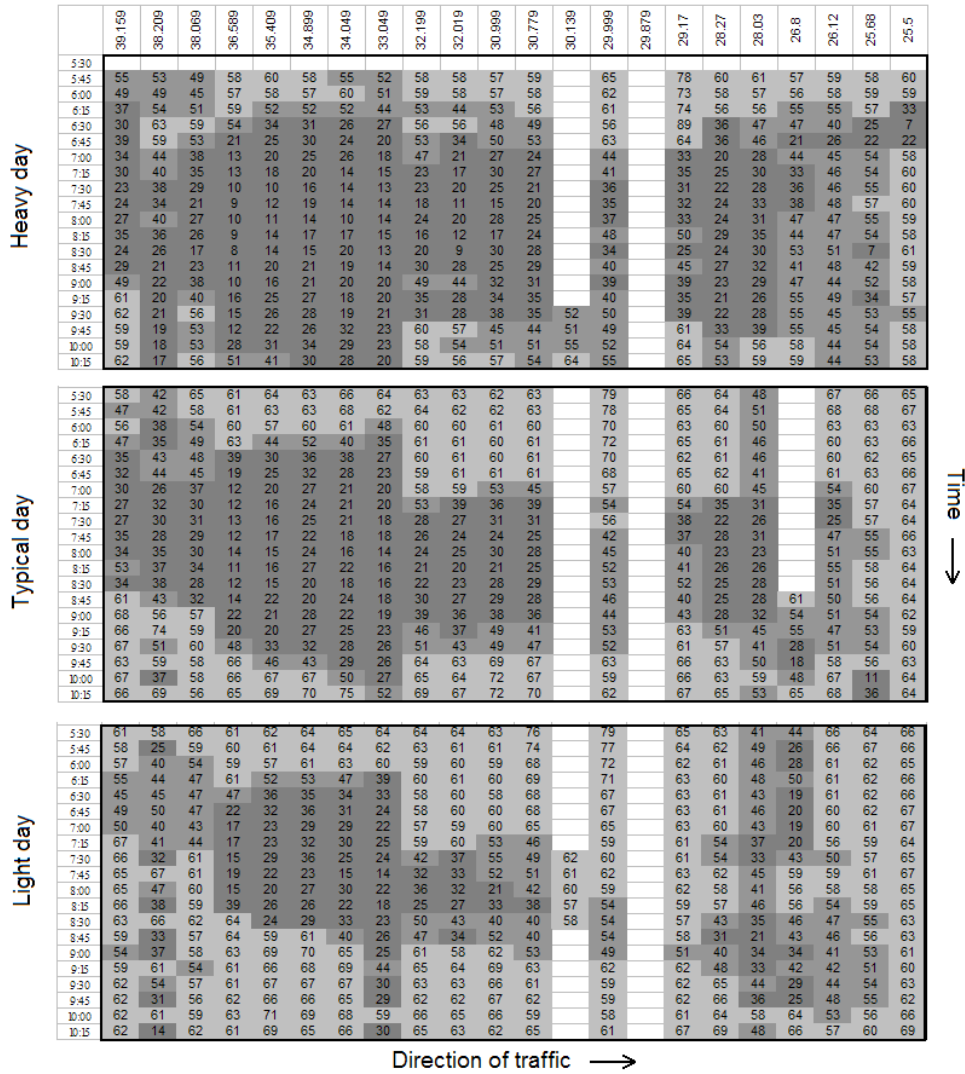
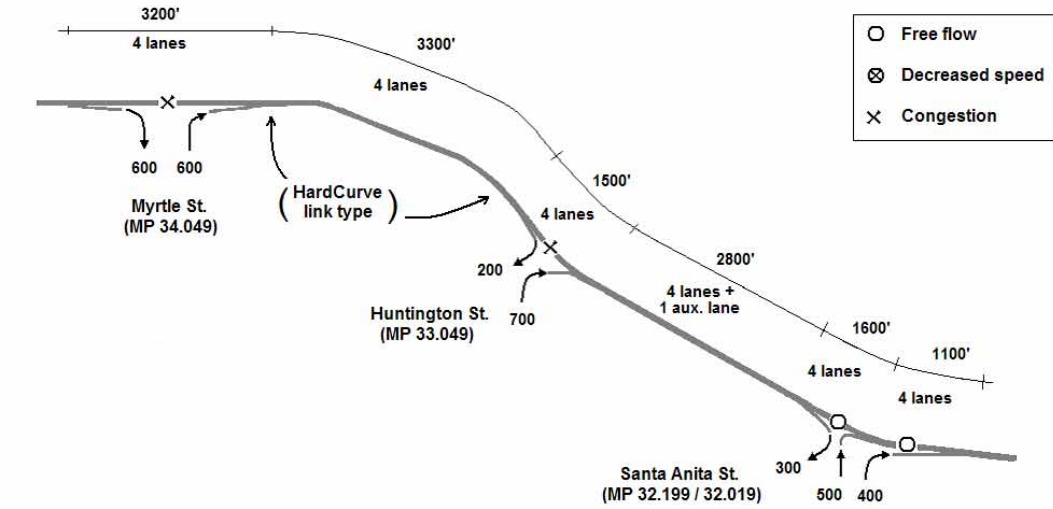
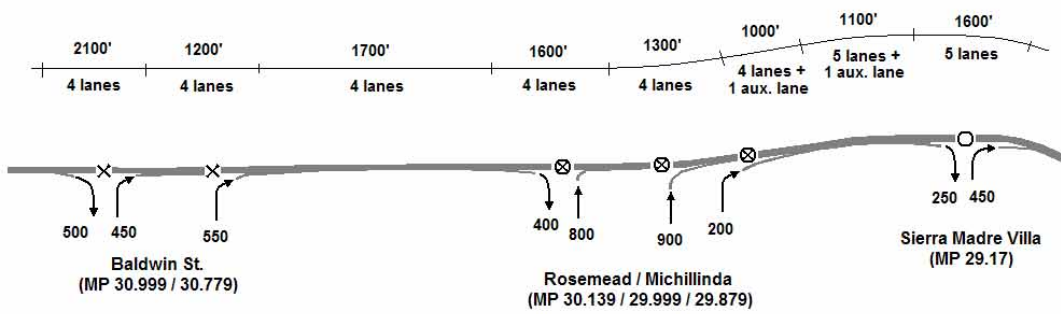


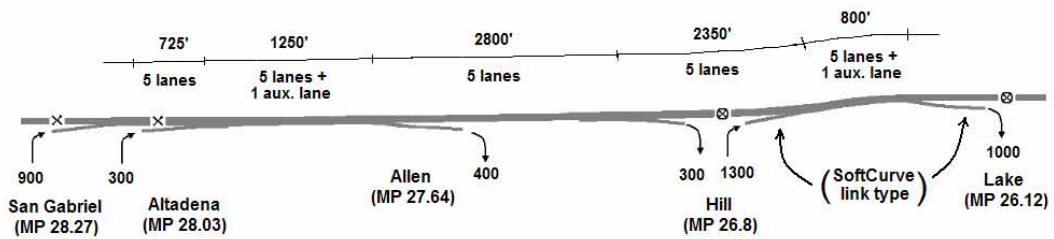
Figure 2 : Processed PeMS speed contour plots



**BOTTLENECK B1**



**BOTTLENECK B2**



**BOTTLENECK B3**

**Figure 3 : Three major bottlenecks**

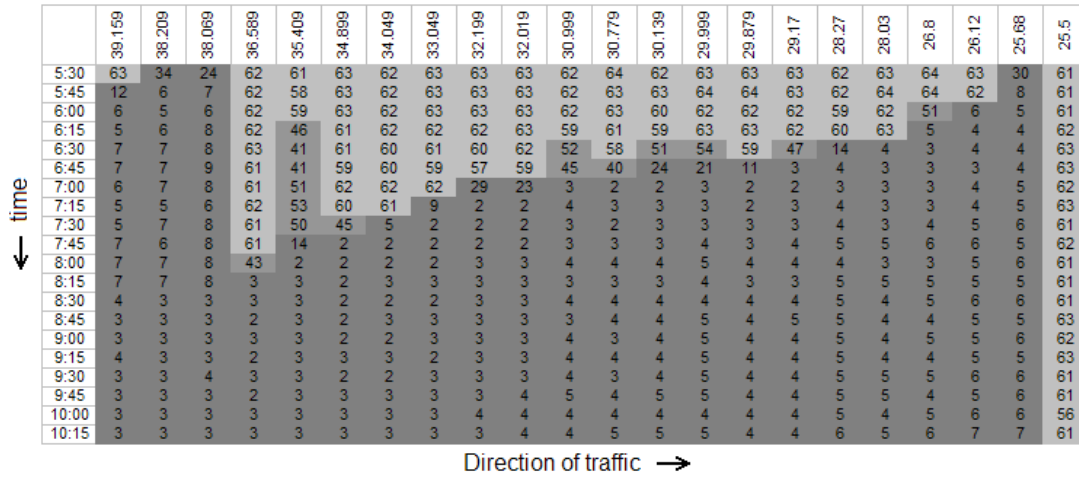
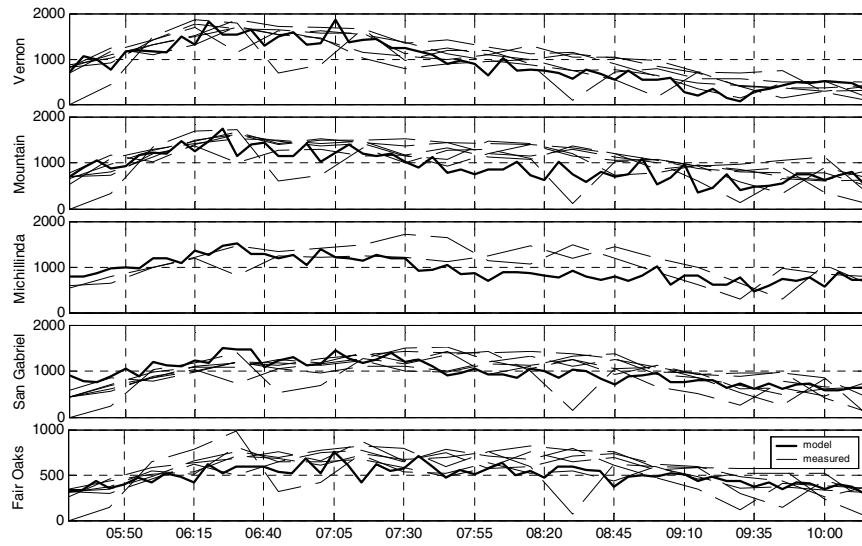


Figure 4 : Simulated speed contour plot with default driver behavior parameters

**Table 1 : Calibrated CC values (defaults: CC0=1.5 , CC1=0.9 , CC4/CC5 = -0.35/0.35 , Waiting time = 60)**

Link type	CC0	CC1	CC4 / CC5	Waiting time before diffusion
Freeway	1.7	0.9	-2.0 / 2.0	1
SoftCurve	1.7	1.1	-2.0 / 2.0	1
HardCurve	1.7	1.4	-2.0 / 2.0	1
Freeway Merge	1.7	0.9	-2.0 / 2.0	60
SoftCurve Merge	1.7	1.1	-2.0 / 2.0	60
HardCurve Merge	1.7	1.4	-2.0 / 2.0	60



**Figure 5 : Measured and simulated HOV lane flows (vph)**

**Table 2 : Measured and predicted congestion patterns**

	Bottleneck	Location	Start time	End time	Queue length
Target	B1	MP 33.049	6:00 – 6:30	10:00 – 10:30	To MP 39.159
	B2	MP 30.779 / 30.139	6:45 – 7:15	9:00 – 9:45	Into B1
	B3	MP 28.03 / 26.8	7:00 – 7:30	9:15 – 9:45	To MP 29.17
Simulated	B1	MP 33.049	6:00	10:15	To MP 39.159
	B2	MP 30.779	7:00	9:45	Into B1
	B3	MP 26.8	7:15	9:30	To MP 29.17

	39,159	38,209	38,069	36,589	35,409	34,899	34,049	33,049	32,199	32,019	30,999	30,779	30,139	29,999	29,879	29,17	28,27	28,03	26,8	26,12	25,88	25,5
5:30	63	63	62	64	63	63	64	61	63	63	63	63	64	63	63	64	64	64	63	64	64	64
5:45	51	62	60	64	61	62	63	59	63	63	63	63	63	63	64	64	64	64	63	64	63	64
6:00	49	60	57	63	60	61	52	54	63	62	63	62	63	62	62	63	63	63	62	63	62	64
6:15	59	38	43	62	57	41	21	53	61	62	62	61	63	63	63	63	63	63	62	63	61	64
6:30	63	41	41	30	19	17	17	53	61	61	62	60	57	52	59	62	63	60	60	60	60	62
6:45	63	63	59	11	18	17	16	50	60	57	56	49	58	56	60	62	62	62	60	57	53	61
7:00	63	62	59	11	19	18	17	53	61	51	28	32	50	49	56	59	62	60	49	57	51	62
7:15	63	49	30	11	18	18	17	53	21	26	26	26	29	41	55	61	62	58	46	40	54	62
7:30	36	17	23	11	17	17	17	29	16	20	22	27	29	41	53	60	50	40	29	45	51	62
7:45	21	19	24	11	14	13	12	20	18	21	19	22	24	40	54	60	20	25	31	50	56	63
8:00	49	17	20	10	14	14	12	16	15	19	22	26	30	41	50	23	23	34	31	36	56	62
8:15	62	17	22	10	14	14	13	22	19	23	21	25	28	40	42	21	19	23	33	53	57	63
8:30	53	23	26	12	18	18	14	22	18	24	22	22	23	35	34	23	23	30	39	51	54	62
8:45	63	64	60	12	16	16	15	20	17	21	23	27	32	42	49	23	24	38	41	58	60	62
9:00	64	64	62	32	15	16	16	27	25	31	42	37	40	43	55	39	28	40	43	61	58	63
9:15	64	63	62	64	19	20	18	54	27	32	57	47	57	51	57	61	31	41	39	59	58	63
9:30	64	64	61	64	19	21	18	54	41	43	44	34	58	58	61	62	63	57	46	61	61	63
9:45	64	64	62	64	34	21	18	54	62	60	49	40	57	58	62	63	63	61	59	63	61	64
10:00	64	64	63	64	63	48	18	53	62	59	62	61	62	59	61	63	63	62	62	63	62	64
10:15	64	64	63	64	62	61	26	55	62	62	63	61	63	63	63	64	64	63	62	63	62	64

Figure 6 : Simulated speed contour plot with final parameter selection.