Title

Simulation Modeling Of The Santa Monica Freeway

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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.

The authors would like to acknowledge the help of the many individuals whose assistance has been essential in this project. First, the other members of the UC Berkeley research team, Vinton Bacon and John Windover, have been essential in the development of the corridor network. Their advice and comments on the freeway research are much appreciated. Professor Michel Van Aerde of Queens' University in Canada has been an invaluable guide to the INTEGRATION model, and has generously provided time to make refinements in the model as were needed. Also, Bruce Hellinga, a Ph.D. candidate at Queens, provided much help with the QUEENSOD origin-destination synthesis tool.

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The help of several individuals from UC Berkeley should also be recognized. Lannon Leiman of the Institute for Transportation Studies Systems Unit was a source of much expertise with the FREQ model. Also, Randall Cayford assisted with file extraction in the data collection process. Most importantly, Yonnel Gardes helped provide the foundation with essential research on INTEGRATION and the Santa Monica Freeway Corridor. Finally, Vassilios Alexiadis of JHK & Associates provided a macro for demand data triangulation.

This report is part of an effort to simulate various IVHS strategies on the Santa Monica Freeway Corridor (I-10) in Los Angeles. This corridor is also known as the "Smart Corridor" because of the project of the same name that is currently underway on the corridor. While many of the data used for this report were obtained from the agencies involved in the Smart Corridor project, it should be made clear that this research was conducted at the University of California at Berkeley and is not a part of the Smart Corridor project itself. The results arrived at in this report do not necessarily reflect the views of any of the agencies involved in the Smart Corridor project.

Abstract

Report Title: Simulation Modeling of the Santa Monica Freeway
Authors: Loren D. Bloomberg, Adolf D. May

As part of a project investigating the benefits of Intelligent-Vehicle Highway Systems (IVHS) technology using simulation, two models of the Santa Monica Freeway in Los Angeles were developed. This report describes the work performed to create, test, and apply these simulations.

The study area is a section of the Santa Monica Freeway (I-10) in Los Angleles, including ***60*** off- and on-ramps for a typical day between 6:30 A.M. and 6:30 P.M. Four major activities were included in the study: data collection, model development, model calibration, and investigation. Data collection was an extensive process that involved finding sources for supply, demand, and control data. The supply data were gathered fi-om photographs and maps of the fieeway, and by applying the theoretical concepts of highway capacity and the relationship between speed and flow. Several sources of demand data were consolidated to create a chart of flows (mainline and ramps) for a typical day with recurring congestion on the fieeway. The final component, control data, were collected fiom ramp metering and signal timing plans.

Two independent simulations were coded (using FREQ and INTEGRATION) fiom the available data. The report describes the strategies, limitations, and assumptions needed to code the Santa Monica Freeway using the two simulation tools. After coding the models, calibrating the output to match traflic performance from a typical day was needed to insure that the simulations would be useful for IVHS investigations.

The final step was to perform initial investigations using the FREQ model of the fi-eeway. Three representative studies are described. These investigations (considering future demand **growth,** ramp metering, and HOV lanes) are representative of the potential for study using simulation. The report ends with individual evaluations of the two models for fieeway simulations and suggestions for future research.

Key Words: Freeways, Intelligent Vehicle Highway Systems, Animation and Simulation

Executive Summary

As part of a project at the University of California at Berkeley investigating the benefits of Intelligent-Vehicle Highway Systems (IVHS) technology using simulation, two models of the Santa Monica Freeway in Los Angeles were developed using FREQ and INTEGRATION. This report describes the work performed to create, test, and apply these simulations.

The study area includes a **9.3** mile section of the I-10 Santa Monica Freeway between the I-405 and SRllO interchanges. While the work here supports a larger study of the entire corridor (including five parallel arterials), the findings reported only consider the fi-eeway and its 60 off- and on-ramps. Four major activities were included in the study: data collection, model development, model calibration, and investigation. Each is described in detail in a separate section of this report.

Data collection was an extensive process that involved finding sources for supply, demand, and control data. The supply data were gathered from photographs and maps of the fi-eeway, as well **as** by applying the theoretical concepts of highway capacity and the relationship between speed and flow. Demand data were more difficult to obtain: several sources were consolidated to create a chart of flows (mainline and ramps) for a typical day with recurring congestion on the fieeway. Then, these data were used to synthesize a table of origin-destination pairs using FREQ. The final component, control data, were collected fi-om ramp metering and signal timing plans.

Once the data were assembled, the model development process was begun. Two independent simulations were coded (using FREQ and INTEGRATION) fi-om the available data. The report describes the strategies, limitations, and assumptions needed to code the Santa Monica Freeway using the two simulation tools. After coding the models, calibrating the output to match traffic performance from a typical day (from 6:30 **A.M.** to 6:30 P.M.) was needed to insure that the simulations would be useful for IVHS investigations. Calibration was performed using available output and custom utility programs to compare results fi-om FREQ, INTEGRATION, and empirical data.

The final step was to perform initial investigations using the FREQ model of the freeway. While the focus of the research effort was to create a working subsection of the full corridor simulation (and further research on the INTEGRATION model), three representative studies are described. These investigations (considering future demand growth, ramp metering, and **HOV** lanes) are representative of the potential for study using simulation. The report ends with individual evaluations of the two models for fieeway simulations and suggestions for future research.

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Section 1: Introduction

This report is presented as part of a multi-year, multi-person research project on the application of simulation modeling to the study of Intelligent Vehicle-Highway Systems **(IVHS)** technology. The project has focused on the Santa Monica Freeway Corridor (I-10) in Los Angeles **as** an example of how simulation can be used to study the potential benefits of **IVHS.** It is currently funded through December 1994 and is under the direction of Professor Emeritus Adolf D. May at the University of California at Berkeley.

A major goal of the project was to develop a calibrated simulation of the fieeway corridor (which includes about 10 miles of the fieeway, five parallel arterials, and a network of other surface streets). Once this model is **fully** developed and tested for baseline conditions, it will be used to simulate and test the effectiveness of a variety of **IVHS** scenarios.

However, the development of the simulation (using the INTEGRATION model) has proven to be no simple task. Few **traffic** simulations the size of the Santa Monica Freeway Corridor have ever been developed, so it was important to develop the model in steps. One of these critical steps was to develop **an** understanding of the potential and limitations of *freeway* simulation. Since the fieeway is the most important road in the network, the ability to simulate it correctly was essential to developing a properly coded model of the entire corridor.

That is the motivation for the work described in this report. ***As*** part of the project, two simulations of the fieeway were developed, using the FREQ and INTEGRATION models. In the process, much was learned about the two tools. In addition, the simulations of the fieeway are being used to test and refine the INTEGRATION simulation of the entire Santa Monica Freeway Corridor.

This report describes the results of approximately 18 months of study of fieeway simulation modeling. Section **2** outlines the data collection efforts for the simulation, and Section **3** considers how those data were coded into the FREQ and INTEGRATION models. These sections should serve as a guide for anyone attempting future projects involving simulation with either of the models. Then, Section 4 describes the calibration process, and Section 5 considers some applications of the simulation. Finally, Section 6 provides some conclusions, and the technical appendices and the references complete the report.

Section 2: Data Collection

An essential component in the development of a simulation model of a real-world system is data collection. For many projects, this may the most difficult, expensive, and time-consuming part of the process of developing a working model. The data needed to simulate the entire Santa Monica Freeway corridor is substantial in both quantity and scope, so simulating even a subset of the network (i.e., the fieeway) requires a great deal of data. This section describes the data needs for the simulation and outlines the work undertaken to collect these data.

In general, data for a transportation network can viewed in terms of three facets: supply, demand, and control. For a traffic system, the **supply** components include the directly measurable aspects of the physical street and highway network (e.g., street lengths, number of lanes, and intersection geometries) and the theoretical characteristics of the network (e.g., the maximum capacities and densities of the roadways in the network). The **demand** in a transportation network consists of people desiring travel. This may be expressed in several ways, but two common means of describing demand are origin-destination pairs (the number of people who want to go between two points) and traffic performance **data** (the number of vehicles on the network at a specific point, in terms of vehicle flows, densities, or other statistics). Both of these measures are used in this study, and both are functions of time across the study period. The final piece of data collection involves **control.** For a traffic system, control elements might include signals, ramp meters, lane restrictions, or directional controls. For the study of the Santa Monica Freeway, the critical control element simulated was ramp metering. High-occupancy vehicle (HOV) lane controls are also included.

The discussion of the data collection effort for this project is presented in terms of these three facets of data. Each is described in some detail in the following subsections.

2.1 Supply

The first step for collecting supply data for the freeway was to define the exact scope of the fieeway simulation. The larger research effort (of which this paper is a part) considered the complete fieeway corridor network centered on Interstate 10 in Los Angeles, and included five parallel arterials (Olympic, Pico, Venice, Washington, and Adams) and approximately 80 other roads. However, the fieeway simulation did not include any surface streets (e.g., arterials); only the fieeway and its on- and off-ramps are part of the simulation. Figure 1 is a map of the area of the simulation: the fieeway in both directions from just west of the I-405 (San Diego Freeway) interchange to just east of the SR1 10 (Harbor Freeway) interchange.

Approximately **9.3** miles of linear fi-eeway are included. This section of the Santa Monica Freeway includes ***26*** on-ramps and ***26*** off-ramps in each direction. Also, there are a total of four freeway connector on-ramps fiom the 1-405 (northbound and southbound) to eastbound 1-10, and from SR1 10 (northbound and southbound) to the westbound 1-10. There are also four connector off-ramps, to the 1-405 (northbound and southbound) fiom westbound 1-10 and SR1 10 (northbound and southbound) fi-om eastbound 1-10. Therefore, there are a total of 60 ramps (30 on-ramps and **30** off-ramps) are included in the simulation model.

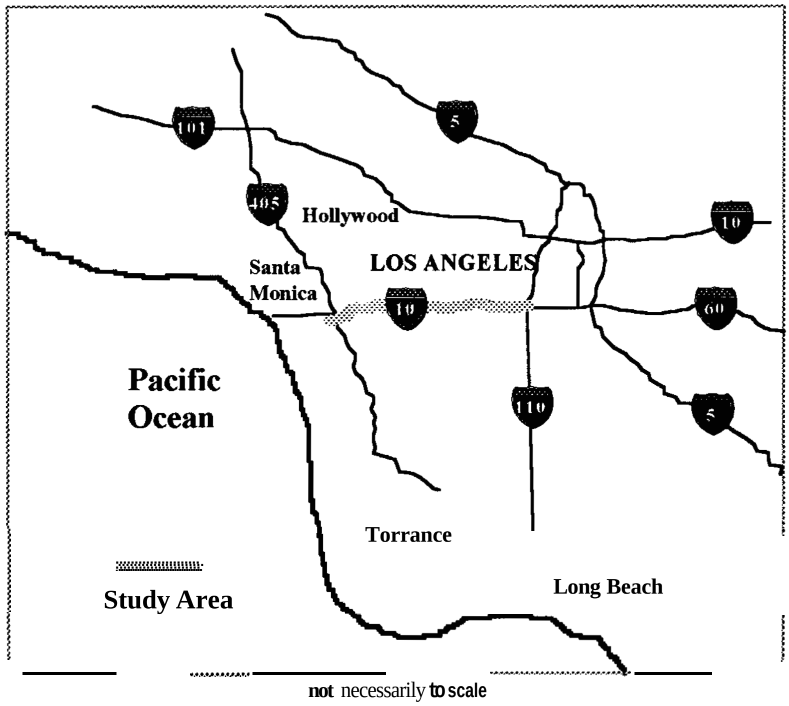

Figure 1: Map of the Study Area

Another way to describe the supply side of the network is in terms of sinks and sources. This is also useful when considering the demand data in the network. Simply put, sources are points where traffic can enter the network, and sources are where traffic can leave the system. Since the entire universe in a simulation model is the network under study, vehicles are effectively created at sources and destroyed at sinks. The **32** sources in the network included **26** on-ramps, **4** connectors from other freeways, and **2** freeway ends. Similarly, there are **32** sinks in the network: **26** off-ramps, **4** connectors to other fieeways, and the **2** endpoints of the freeway. Figure **2** (on the next page) is a general diagram of the freeway and the major arterials crossing it.

2.1.1 Geometry

Once the scope of the simulation of the freeway was precisely defined, the next step was to record the physical characteristics of the system. The usual practice is to describe the network in terms of nodes and links; this was followed here. The parameters of the nodes and links included the geometry of the network (i.e., where ramps connect to the fieeway), link lengths (i.e., the distances between ramps), and the number of lanes (for both the freeway and the ramps).

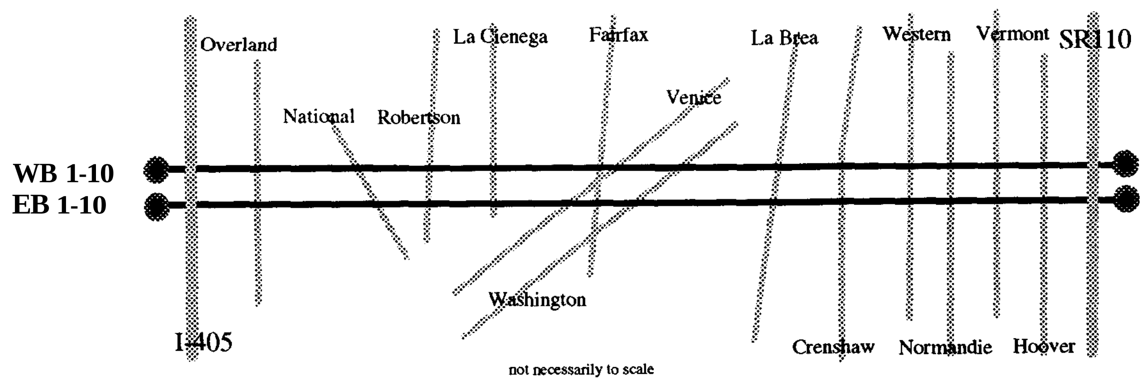

Figure 2: Schematic of Study Area

A number of sources were available for this information. First, Zach Kerfan of Caltrans District 07 provided aerial photographs of the freeway section under study. Each photo was taken to an exact scale (1 inch to 100 feet), so geometry data could be obtained simply by making measurements from the photos and converting to an appropriate metric. Next, several sets of maps of the freeway corridor from other studies were obtained from Caltrans and JHK & Associates. These maps described the networks in node/link format; attention was given to code the network in a similar fashion to allow comparison to others' work. Commercially available maps were also used to check details. Finally, personal knowledge of the freeway was helpful; it should be noted that direct observation of a transportation system provides invaluable benefits to the developers of a simulation model.

One limitation of these sources was that each only provided a relative reference of the components of the network; i.e., only the distance between two ramps was available, not the exact physical coordinates. This was an issue because each source of supply data had a different scale and varying detail. Therefore, in order to compare the information from two different maps, it was important to have absolute references from the freeway network. This was addressed by using a scanned map of the freeway corridor area where several anchor coordinates (e.g., freeway interchanges and intersections of major arterials) were located and coded with a coordinate system. Then, the other nodes in the network (e.g., the locations of lane drops) were located with a relative reference (e.g., 0.4 miles east and 0.1 miles north). This method proved to be the most effective in terms of minimizing the effort required to code nodes and the accuracy of the model.

As a final check, the supply data were compared to the freeway geometries that were found in earlier research [Bloomberg et al 1993b]. Freeway subsection lengths (i.e., the distances between ramps) and the number of lanes were compared and the values were found to be comparable. Also, the total freeway distances eastbound and westbound were equal. These tests confirmed the accuracy of the data collected for the freeway geometry. The next step was to estimate capacity of the roadways in the network.

2.1.2 Capacity

For any traffic simulation (and especially for a freeway model) the issue of highway capacity is a critical one. In the real world, bottlenecks, queues, and congestion are caused because the traffic demand on a section of roadway is greater than some theoretical capacity value. When simulating such a system, it is necessary to specify this value for each section of roadway. However, there is no perfect method for determining the capacity of a given roadway. Some trial and error was needed to develop a reasonable set of capacity estimates for the Santa Monica Freeway.

As a start, a working range of 1800 to 2000 vehicles/hour/lane was assumed. The Highway Capacity Manual suggests fieeway capacities as high as 2300 passenger cars/hour/lane under ideal conditions [Transportation Research Board, 19941. However, capacities this high on the Santa Monica Freeway may be unrealistic, for several reasons. First, the on-ramps and off-ramps (some spaced at relatively close distances) create weaving sections that wlr reduce effective capacity. Second, the presence of heavy vehicles (e.g. buses and trucks) should limit capacity. Finally, the fieeway section includes numerous collector/distributor (C/D) lanes that are included in the mainline counts. Speeds and capacities are often lower on these facilities, so the average (per lane) capacity of the fieeway is reduced in these sections.

The next step was to find a starting point for each freeway subsection. Each mainline lane was assumed (at first) to have a capacity of 2000 vehicles/hour/lane. For those sections that began with an on-ramp, the capacity of the first (right lane) was reduced to 1800 vehicledhour. Also, those sections that included C/D lanes were estimated at 1800 vehicles/hour for those lanes to recognize the fact that more weaving would be present in these sections so capacity may be reduced. As an example, a four lane section of roadway after an on-ramp that had 2 parallel C/D lanes was assumed to have a capacity of 3(2000) + 1800 + 2(1800) = 11400 vehicledhour.

Next, the FREQ simulation model was used to estimate the impact of weaving on sections after an on-ramp. More details about the coding of the FREQ model are given in Section 3, but at this point it is sufficient to explain that FREQ includes a feature called weaving analysis that simulates the impact of weaving on capacity. The working estimate was used in a FREQ simulation run (with the weaving analysis engaged) and the fieeway performance tables (by time slice) were examined. The FREQ output includes a column labeled "**WEAVE** EFF", which indicates the reduction in capacity for those weaving sections. In subsequent runs, the weaving analysis was disengaged, and the capacity values were adjusted accordingly.

For some sections, detector data were available that provided volume counts for freeway sections. These data gave a floor for capacity (i.e., it was not possible to have a section with a capacity of 6500 vehicledhour where flows were measured at 7500 vehicledhour). Where necessary, the capacity values were adjusted (upward).

Finally, in some cases the simulation output included bottlenecks in places where the real-world data suggested there were none (see Section 4 for a more thorough description of the calibration process). In these instances, it was concluded that capacity was underestimated, so the values were increased appropriately until the bottleneck was eliminated.

The final capacity values that were used in the simulation are shown in Figures **3** and 4. The chart in Figure 3 lists each subsection (these do not correspond exactly to either the FREQ subsections or INTEGRATION links that were coded, because more detail was used, but they do cover the entire fieeway) along with its capacity. The average capacity (in vehicles/hour/lane) is shown graphically in Figure 4. The reader should note that in most cases, capacities are between about 1900 and 2000 vehicles/hour/lane. The graph shows some fluctuation which represents the fact that subsections with weaving sections have reduced capacity, but the adjacent (non-weaving sections) do not. Finally, some of the longer subsections have average capacities around 2100 vehicledhour; the geometry of these sections should permit higher flows.

For ramps, capacities varied depending on the geometry of the ramp merging section. Figure ***5*** shows the basic assumptions for capacities on ramps with different geometries. The capacity of a single-lane ramp without an accompanying lane added on the freeway was estimated at 1500 vehicledhour. If the freeway section did have an additional lane adjacent to the ramp, the number of weaving maneuvers would be reduced and capacity increased. Dependmg on the length of the weaving section, capacity was increased to 1800 or 2000 vehicledhour. For multi-lane ramps (used at the interchanges to the I-405 and SR110), capacity was estimated at 3000 vehicledhour (1500 vehicles/hour/lane).

2.1.3 Speed/Flow Relationships

The traffic performance on a highway section is strongly influenced by the (theoretical) relationships between speed, flow, and density for vehicles on that section. **A** complete discussion of these concepts is better left to a traffic engineering text, but a short explanation of the theoretical model used for this study may be appropriate.

The FREQ model was used as the baseline for the speedflow model in the simulation runs. FREQ allows simulations to be run using 5 different sets of curves, corresponding to free flow speeds of 50, 55, 60, 65, or **70** miles per hour (up to nine user-defined curves can also be entered). It was felt that the 65 mph curves were most appropriate for this study.

Within FREQ, three different functional equations are used to describe the relationship between the volume/capacity (v/c) ratio and the vehicles speeds (densities and other measures can easily be derived once volumes and speeds are known). For undersaturated conditions (i.e., where demand is less than capacity), FREQ uses two different curves depending on the v/c ratio:

$$\text{for } v/c < 0.95: \quad Speed = 63 - 8.421 \times v/c$$

$$\text{for } v/c > 0.95: \quad Speed = v/c \times (14856.2 - 7823.6 \times v/c) - 6997.4$$

	EASTBOUND (read down)				WESTBOUND (read down)			
link#	description (to end of link)	#lane	len (feet)	capac. (vphpl)	description (to end of link)	#lane	len feet	capac. (vphpl)
1	I-405 overpass	3	850	2000	SR110 overpass	3	600	2200
2	SB I-405 on	3	1900	2000	connector ramp	3	200	2200
3	SB 1-405 off	4	50	1960	SB SR110 on	4	600	1900
4	National off	5	2900	1960	NB SR110 on	6	1450	1833
5	Overland on	4	1400	2100	20th Street off	7	700	1800
6	detector	5	1650	1880	20th Street on	7	1150	1943
7	Manningon	5	2150	1880	Vermont off	7	300	1800
8	Roberston off	5	1150	1980	Vermont on	7	1650	1943
9	detector	5	2100	1920	detector	7	600	1900
10	National on	5	300	1920	lane drop	7	100	1900
11	SB La Cienega off	5	1900	2000	Normandie off	6	100	1900
12	SB La Cienega on	5	1000	2000	lane add	6	400	1933
13	NB La Cienega	6	350	2000	lane drop	7	450	1943
14	Fairfax off	5	300	2000	Normandie on	6	700	1933
15	detector	5	1300	1960	Western off	6	550	1900
16	Venice on	5	400	1960	lane add	6	150	1933
17	Washington off	5	1550	1920	lane drop	7	400	1914
18	SB La Brea off	5	3800	2000	Western on	6	1550	1933
19	SB La Brea on	5	700	2100	Arlington off	6	500	1833
20	detector	6	200	1950	Arlington on	5	1750	2080
21	NB La Brea off	6	150	1950	Crenshaw off	6	2900	1950
22	NB La Brea on	5	1100	1920	detector	5	250	2000
23	Crenshaw off	5	2500	2040	Crenshaw on	5	1950	2000
24	detector	5	1450	1960	NB La Brea off	5	2650	2040
25	Crenshaw on	5	950	1960	detector	5	625	1960
26	Arlington off	6	2750	1967	NB La Brea on	5	125	1960
27	Arlington on	5	1650	2080	SB La Brea off	6	300	1900
28	Western off	6	450	1900	SB La Brea on	5	850	2000
29	lane add	6	1200	1933	Washington off	5	3550	1960
30	Western on	7	1150	1943	Venice off	5	1050	2000
31	Normandie off	7	850	1800	detector	4	750	2000
32	lane drop	7	400	1943	Fairfax on	4	1400	2000
33	Normandie on	6	1250	1933	La Cienega on	4	1800	2025
34	lane add	6	300	1900	Robertson off	5	1950	1820
35	Vermont off	7	350	1886	Robertson on	4	3350	2050
36	detector	7	1800	1943	National off	5	850	1880
37	Vermont on	7	150	1943	detector	4	1150	2100
38	Hoover off	7	400	1843	Overland off	4	3100	2100
39	Hoover on	6	1600	1933	Overland on	4	1250	1800
40	SB SR110 off	6	450	1967	SB I405 off	5	2050	1800
41	NB SR110 off	6	1250	1833	NB I405 off	4	1650	1925
42	lane add	5	200	1920	end	3	1525	2000
43	end	6	675	1767				

Figure 3 - Santa Monica Freeway Subsection Characteristics

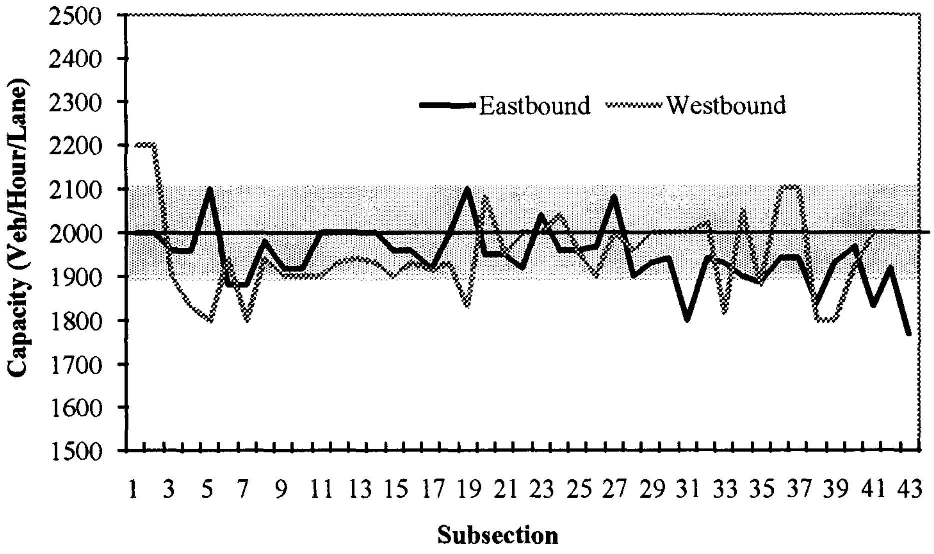

Figure 4 - Santa Monica Freeway: Capacityper Lane vs. Distance

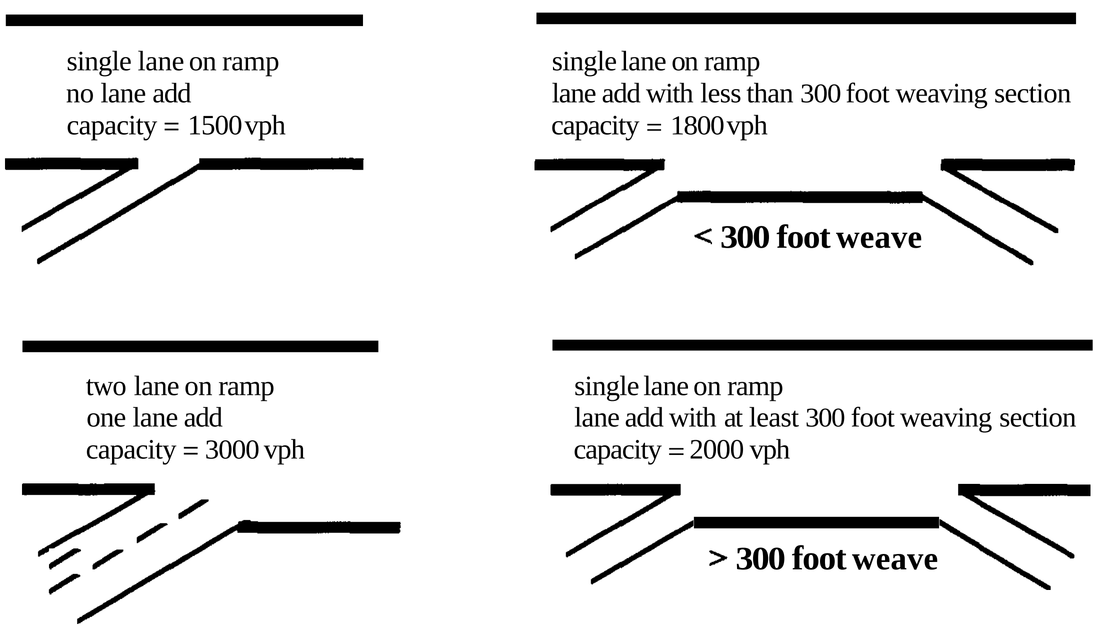

Figure 5 - CapacityAssumptionsfor Different Ramp Geometries

For oversaturated conditions (when demand exceeds capacity), a different relationship is used to describe speed in terms of the v/c ratio (which is between 0 and 1):

$$Speed = (20 \times v/c + 8) \times v/c$$

For the INTEGRATION model, two different models are available to describe the speedflow relationship. The program developer suggests that the more robust be used; it is based on an approach integrating a car-following model and a generic speed-flow relationship [Van Aerde 1993b]. Four parameters are needed to describe traflic conditions in this model: the fiee-flow speed (v_f), the speed at capacity (v_c), the jam density (k_j), and the capacity of the roadway **(C).**

It was important to develop a speed flow relationship, using these parameters, *so* that the INTEGRATION model was using a model very similar to that of FREQ. To accomplish this, the equations describing the relationship between v/c and speed were entered onto a spreadsheet, where the four traflic parameters could be varied. With two sets of curves, one for FREQ and one for INTEGRATION, it was possible to vary these parameters to obtain the best possible match.

The results of this process were as follows. The best fit was found where the free flow speed (for fieeway mainline sections) is 99.8 kph *(62* mph) and the speed at capacity (v_c) is 70.8 kph **(44** mph). Since ramp speeds were lower, they were scaled down to ***64*** kph (40 mph) and **45** kph **(28** mph). The jam density (k_j) is constant at 130.5 veh/km (210 veh/mile) for both mainline lanes and ramps and the capacity values vary as described in the previous section. Figure *6* is a plot of the FREQ curves for speed vs. v/c ratio (in three parts) and the INTEGRATION curves (in two parts). Some technical notes on these derivations can be found in Appendix 5.

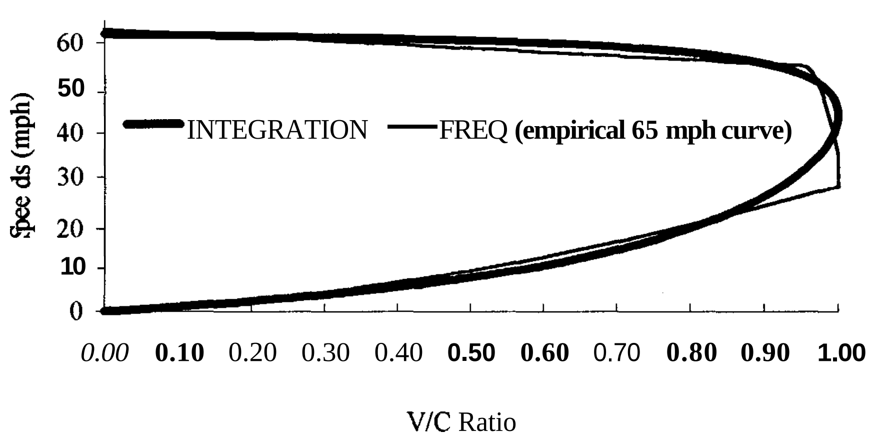

Figure 6: Comparison of V/ C Ratio vs. Speed Curves

As shown in the graph, it was not possible to obtain a perfect fit between the speed-flow curves described by the parameters above (in INTEGRATION) and the empirical curves used in FREQ. However, FREQ does include a feature that allows user-defined speed-flow relationships to be used in the model. To use this feature, specific data points describing the relationship between velocity and the v/c ratio can be entered into the program. Using the spreadsheet model once again, **23** points were found (by trial and error) that very closely approximated the speed flow curves used in INTEGRATION. Shown in Figure 7, these were entered as a user-defined curve in FREQ and used for all of the runs. (In future versions of INTEGRATION, this curve-fitting feature may be available). Note that the points shown in Figure **7** are somewhat different from the original FREQ empirical curve shown in Figure 6. The new (user-defined) FREQ points shown below form a curve that is nearly identical to the INTEGRATION curve shown in Figure 6.

point #	v/c ratio	speed (mph)	point #	v/c ratio	speed (mph)
1	0	62.0	13	.89	24.7
2	.72	59.0	14	.84	20.9
3	.85	56.9	15	.78	17.3
4	.91	55.1	16	.71	14.0
5	.95	53.0	17	.63	11.1
6	.98	50.3	18	.52	7.9
7	.99	48.6	19	.43	5.9
8	1.00	44.0	20	.32	4.0
9	.99	38.6	21	.18	2.0
10	.98	36.1	22	.10	1.0
11	.96	32.6	23	.00	0.0
12	.93	28.6			

Figure 7 - Datafor the User-Defined FREQ Speed-Flow Curve

To summarize, the FREQ empirical data for speed-flow curves based on a 65 mph free flow speed were used as a baseline. Then, traffic parameters available in INTEGRATION were determined that yielded speed-flow relationships that closely matched the FREQ curves. Finally, the FREQ curves were modified slightly (as in Figure **7)** to reflect the differences in the empirical and theoretical model. With this approach, the speed-flow relationships used in all of the simulation runs were nearly identical, and the research efforts could focus on the differences in the models, and not the coding.

2.1.4 Spreadsheet Summary

The final step was to encode all of the supply data to a single source. **A** spreadsheet describing each of the nodes and links in the freeway network was created. Each node and l i i was given a separate row, with columns containing relevant information (e.g., node coordinates; link capacities, lengths, and number of lanes; and speed/flow relationships). Links on the spreadsheet were described in terms of nodes using dynamic cross-referencing. **A** more technical description can be found in Appendix 2.

2.2 Demand

While it is often relatively straightforward to collect supply information for a traffic network, demand data collection is an operation that can be exceedingly more laborious, for several reasons. First, traffic demand data are by their nature dynamic, so data must be collected temporally. Generally, traffic flows (volumes) are used to derive demand. For this study, it was desired to have **30** minute traffic counts for 14 hours/day for a minimum of three days: **84** total counts for each location. Second, demand data collection requires presence (human or mechanical) at the site (again for long periods of time). Finally, the demand data for a fieeway involves large numbers of vehicles, so mechanical devices (e.g., detectors, hoses, video cameras) are essential. For all of these reasons, the resources available to collect data (both fiom the research efforts at U.C. Berkeley and at outside agencies) were taxed by the demand data requirement. Therefore, it was important to develop a sound data collection strategy. The process is described below.

2.2.1 Sources of Data

To develop the models (INTEGRATION and FREQ) of the Santa Monica Freeway, demand data were a key input. The final format of these data was origin-destination (0-D) information: the number of vehicles traveling between each pair of nodes in the network during each time period. This information would be nearly impossible to collect directly; fortunately, both models include facilities to synthesize these data.

The input for the synthetic 0-D models was traffic flow data, taken at key points in the network. These "key points" are the sinks and sources discussed earlier, including ramps and fieeway ends. The demand data collection effort focused on gathering traffic demand data (i.e., volume counts) for a typical (i.e., under recurring congestion conditions) fourteen hour day ***(6*** A.M. to **8** P.M.).

Three goals were considered when sources for these data were sought. It was important for data to be timely (optimally, fiom the past year), complete (available for all s i and sources), and accurate. In a best case scenario, a complete dataset would have been available that met these requirements. Unfortunately, it was not possible to obtain all of these data fiom a single source. Therefore, multiple sources of data were collected to try to develop a timely, complete, and accurate demand dataset. These sources are described below.

The first source of demand data was Caltrans. With a system of loop detectors throughout the L.A. freeways, Caltrans is able to provide traffic data through its MODCOMP computer system. Using this system, traffic counts for three days (May ***25*** to May **27, 1993)** were gathered. These data included traffic flows at on- and off-ramps, as well as on the mainline fieeway. (See [Bloomberg 1993b] for a complete discussion of this undertaking.)

Once these data were assembled, the next step was to determine what additional data were needed. The MODCOMP system did not provide detector data for every ramp in the network; data for off-ramps were especially limited. **A** chart of the available data was developed to help identify what was missing. Figure **8** shows the beginnings of this chart: a line was included for each fi-eeway location ***(26*** on-ramps, ***26*** off-ramps, **8** fieeway connectors, and 11 mainline detectors). Where data were available from MODCOMP, a time series of demand data were entered on the chart. For those locations without these data, the line was left blank. (Note that only 3 of the 28 time slices, and only a few of the locations are shown.)

Location	Dir	Source	Date	6-6:30	6:30-7	7-7:30
West of I405	EB					
NB I-405 on ramp	EB					
SB I-405 on ramp	EB					
I-405 on ramps (after merge)	EB					
National off ramp	EB					
Overland on ramp	EB	MODCOMP data	WE 05/25/93	400	820	650
		MODCOMP data	WED 05/26/93	450	810	700
		MODCOMP data	THU 05/27/93	480	840	740
Mainline 6.745 (Motor)	EB	MODCOMP data	WE 05/25/93	4140	7040	9190
		MODCOMP data	WED 05/26/93	4440	7200	8890
		MODCOMP data	THU 05/27/93	4340	7310	9130

Figure 8: Start of Demand Datu Spreadsheet

Obviously, it was critical to have traffic counts at all of these locations, so other sources for these data were used. A few other databases were available. The first, and most useful, was a printed record of Caltrans traffic counts for all freeway ramps (and some mainline locations). These data were used for other studies and included at least one day **of** hourly traffic volumes for each location from some point between 1989 and 1992. Also available were counts from the simulations from a previous study [Gardes et al 1993a]. Half-hour volume counts for the morning *peak* **(6 A.M.** to 10 **A.M.)** were collected during 1988. Another source of data was the new ATSAC system. The City of Los Angeles developed a system of detectors at signalized intersections (on surface streets) called ATSAC [Bacon et al 1993]. Since many freeway ramps begin or end at signalized intersections in the Santa Monica Freeway Corridor, the system was a source of data for some ramps. Finally, mainline counts were available from a preliminary study [Bloomberg et al 1993a] of the detectors on the MODCOMP system.

2.2.2 Manipulating the Data

All of these data were added to the demand spreadsheet described above. In many cases, a single location (e.g., the on-ramp to the eastbound freeway at Venice) had multiple rows, with each row representing one day of demand data at that location. Therefore, it was necessary to decide which of these entries would be used for a typical day. However, before doing this, some manipulation of the demand data was needed. Three steps were performed for this process: demand triangulation for hourly counts, demand formulation at the freeway ends, and demand adjustment using **scale** factors. Each is discussed below.

<u>2.2.1.1 Demand Triangulation</u>

The reader may have noted that the volume data from the historical Caltrans studies were summarized as hourly volumes, while the simulation required half hour counts. Therefore, it was necessary *to* consider how these data might be converted. One option was to simply assume each half hour time period would have one half the traffic of that hour. However, this approximation would have been crude at the beginning and ends of the peak periods, when traffic demands are changing relatively rapidly. For example, if demands from 6-7 A.M. and 7-8 A.M. were 600 and 1200 vehicles/hour, 30 minute breakdowns of 200, 400, 550, and 650 vehicles would probably be more appropriate than 300,300,600, and 600 vehicles.

To calculate these triangulated demand figures, a spreadsheet macro (originally developed by JHK & Associates and refined by the author) was employed. For any demand data reported in hourly volumes, the macro was used to create 30 minute counts. *An* example (the Fairfax off-ramp from the eastbound freeway) **is** shown below as Figure 9 (all times are period starts, and all counts are in vehicledhour):

Time	Input Volume	Output Volume
6:00 A.M.	221	168
6:30 A.M.		274
7:00 A.M.	436	388
7:30 A.M.		484
8:00 A.M.	604	582
8:30 A.M.		624
9:00 A.M.	593	608
9:30 A.M.		578
10:00 A.M.	486	494
10:30 A.M.		478
11:00 A.M.	525	526
11:30 A.M.		524

Figure 9: Demand Triangulation Example

2.2.2.2 Demand Manipulation at Freeway Ends

Another serious limitation of the available demand data was that no counts were available for the freeway ends: the mainline freeway west of 1-405 and east of **SR1** 10. These data were critical, however, and since they were not readily available from Caltrans it was decided that the only feasible way of determining the counts was to infer the values from available adjacent data.

To accomplish this, the available freeway mainline counts upstream or downstream of the freeway end were considered for each time slice. Then the ramp counts between the freeway end and the mainline detector were added and subtracted to obtain a time series of mainline flows at the four ends of the freeway. The volume counts that resulted were believed to be a reasonable approximation of freeway demand at these locations. Figures 10 and 11 graphically depict these formulated counts.

It was recognized that this method might be somewhat inaccurate, for two reasons. First, the ramp data was from different days (actually a different year) than the mainline counts. It is certainly possible that demand changed over time, or at least that there were daily fluctuations that would introduce errors into the calculation. Secondly, the ramp and mainline data were collected by different techniques (hose counters vs. loop detectors). It seemed reasonable to assume that these means of data collection would realize **similar** results, but it is not certain that the two sources are perfectly calibrated.

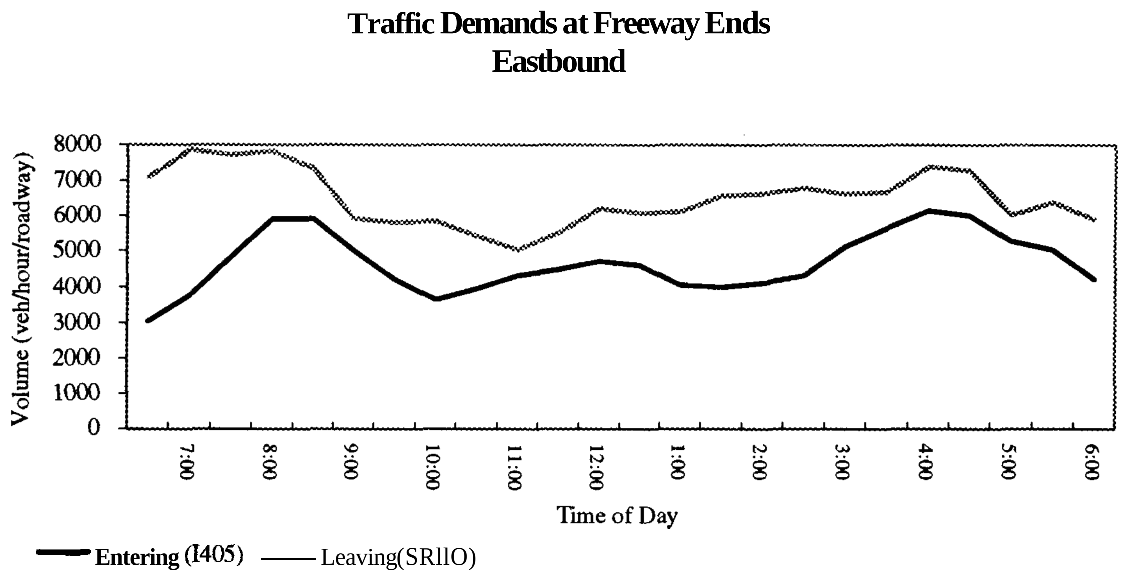

Figure 10: Demand at Eastbound Freeway Ends

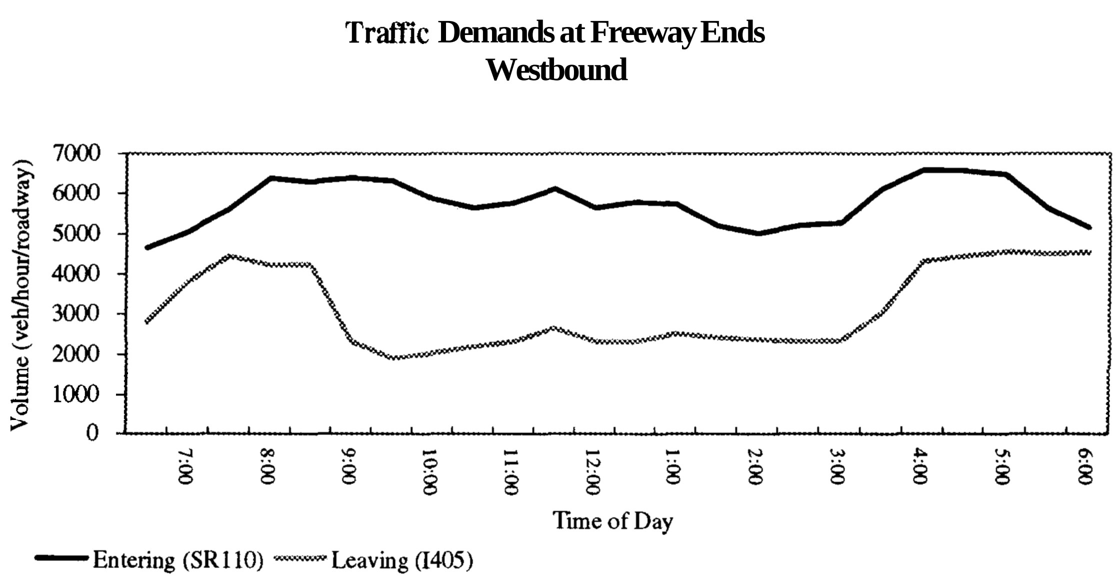

Figure 11: Demand at Westbound Freeway Ends

2.2.1.3 Demand Adjustment Using Scale Factors

For many of the ramp counts (14 of 27 eastbound and 15 of 25 westbound), data were not available from the MODCOMP data collection effort in May, 1993. For these stations, data were used from older counts (1989-1992). However, demand data are not static over time, so care was taken *to* compare these data to more recent figures. For those stations where data were available from both MODCOMP and the old Caltrans counts, scaling factors were used to correct for changes in demand over time.

It was thought appropriate to consider data from two different groups: "**high**" and "low" volume ramps. The ramp data were sorted into these groups, with high volume ramps experiencing peak demands over about 900 vehicledhour. About half of the ramps were classified as high volume. Then, for those ramps where data were available from both MODCOMP (the new data) and the historical Caltrans counts (the old data), the average ratio was determined. The results are shown below as Figure 12. *Also* shown are the ratios for three different time periods (for all ramps).

There did not appear to be significant changes in demand levels from 1989-1990 to 1993. There were slightly heavier demand at low volume ramps and slightly lighter demand at high volume ramps in the 1993 data. Also interesting to note is the fact that peak traffic demand declined somewhat, which might be indicative of the sluggish economy. However, midday (off-peak) traffic increased, which is most likely because of population growth.

Average low volume ramp flow data ratio (new/old) = 0.996
Average high volume ramp flow data ratio (new/old) = 1.016
Average morning peak flow data ratio (new/old) = 0.971
Average midday flow data ratio (new/old) = 1.055
Average afternoon peak flow data ratio (new/old) = 0.986

Figure 12: Comparison Between MODCOMP (new) and Caltrans (old) Ramp Counts

For those locations where only historical data (i.e., Caltrans counts) were available, the traffic volumes were multiplied by one of the two factors (for high or low volume ramps) shown in Figure 12. Since the magnitudes of these factors (relative to 1.0) were small, they may not have a strong influence, but it was thought important since even small changes in demand on congested roadways can cause significant changes in traffic performance.

The final step was to coalesce **all** of the available demand data to a single chart. This was helpful to the research effort (when coding the demand in the simulations) but also may prove to be valuable for other purposes. This research could find no single source for demand data on the Santa Monica Freeway; the chart of demand data from multiple sources is the best available summary.

Figure 13 shows an excerpt from the final spreadsheet that includes traflic volumes (by half hours) for a typical day (*6* A.M. to 8 P.M.). The two left columns indicate the location and direction of the data (note that mainline locations include a mile marker). The "Source" and "Date" columns describe where the data was collected: from MODCOMP (in May, 1993 or December, 1992), ATSAC (in October, 1993), the Caltrans historical counts (1989-1992), or the original Santa Monica freeway studies at **U.C.** Berkeley (from 1988). **In** some cases, data were converted using the triangulation macro and are indicated as "(converted)". The "(SIMULATION DATA)" line contains the demand data used in the simulation. This line is generally copied from one of the sources below it (MODCOMP if it is available), or copied and multiplied by a scaling factor (for historical Caltrans data). For example, the simulation data for the Robertson off-ramp is the only available data (the Caltrans counts) which have been triangulated and multiplied by an appropriate scaling factor. On the other hand, MODCOMP data were available for the National on-ramp, so these are used directly.

Location	Dir	Source	Date	6-6:30	6:30-7	7-7:30
Robertson on ramp	EB	(Simulation Data)		323	528	752
	EB	Caltrans hourly ct.	TUE 11/28/89	419	419	826
	EB	(converted)		318	520	912
	EB	previous UC study	1980s	447	529	864
Mainline 7.99 (National)	EB	MODCOMP data	TUE 05/25/93	3850	6920	8980
	EB	MODCOMP data	WED 05/26/93	4050	7010	8610
	EB	MODCOMP data	THU 05/27/93	3960	7080	8900
	EB	MODCOMP data	TUE 12/08/92	3890	6196	7894
Yational on-ramp	EB	(Simulation Data)		260	470	440
	EB	Caltrans hourly ct.	TUE 11/28/89	389	389	509
	EB	(converted)		360	420	496
	EB	MODCOMP data	TUE 05/25/93	260	470	440
	EB	MODCOMP data	WED 05/26/93	270	470	420
	EB	MODCOMP data	THU 05/27/93	280	470	400
	EB	previous UC study	1980s	351	374	332
	EB	ATSAC data	TUE 10/19/93	86	114	136

Figure 13: Excerptfrom Final Demand Data Spreadsheet

Finally, volume data (in vehicles/hour/roadway) are included for each half-hour (where available) from *6* A.M. to 8 **P.M.** The complete dataset is included in Appendix 1.

23 Control

Control data were the easiest element of the data collection effort. Caltrans provided charts detailing the phase length for each on-ramp meter during a typical day. Ramp metering plans were in place throughout the peak periods (morning and afternoon) at each on-ramp in the study area (except for the freeway interchanges). The phase lengths were converted to metering rates (in vehicledhour), that were used in the ramp metering investigations (Section ***5).*** These data were also added to the node/link spreadsheet (described in Appendix 2).

Section 3: Model Development

Once the demand data were assembled, the next step was the development of the simulation models of the fieeway. Two different freeway simulations were developed using two different models: FREQ and INTEGRATION. Each has specific advantages for simulation, and the synthesis of the two simulation developments provided good opportunity to test, calibrate, and experiment with models of the Santa Monica Freeway.

3.1 The FREQ Model

FREQ is perhaps the most recognized model for freeway simulations. The family of models were originally developed in the 1960s and have been continually refined at the Institute for Transportation Studies (ITS) at UC Berkeley. FREQ is a macroscopic deterministic model that is ideally suited for freeway studies along a linear directional freeway corridor [May 19931. Enhancements to the program have included the ability to model priority lanes (HOV), priority entry controls, and modal and spatial response. Output includes detailed tables and contour maps of traffic performance measures, both at the level of individual subsections and time slices, and for aggregate data. The program includes a dynamic user interface and is relatively fast and straightforward to run on a personal computer.

FREQ was originally chosen as an appropriate tool for studying the Santa Monica Freeway for several reasons. First, as a well-established tool, a FREQ simulation would provide an excellent comparison for the newer INTEGRATION model. Secondly, the model was readily available, and the experience of the program developer (Dolf May) and principal programmer (Lannon Leiman) were at hand. Finally, the relative speed of coding and running the FREQ model meant that simulating the freeway could begin early in the project, and gross errors could be quickly removed.

Version 11 of the FREQ model was used for this study. Because of the size of the simulation **(42** or 43 mainline freeway subsections in each direction), this newest release of the model was the only one suitable. The program was run on a IBM-compatible **PC** with a 486DX processor (including a math co-processor) with **8** megabytes of RAM.

3.1.1 Supply Coding with FREQ

Because FREQ is a unidirectional model, two separate networks were developed to model the Santa Monica Freeway (eastbound and westbound). Although **FREQ** includes the functionality to model a single parallel arterial set, only the freeway was coded in order to limit the focus of the simulations to a manageable size. ***As*** previously mentioned, it was thought that developing an effective model of the freeway by itself would be a major step toward completing the model of the entire corridor.

Most of the coding of the supply-side of the freeway was straightforward using FREQ. The model's interface allows the user to input the length, number of lanes, and capacity of each freeway subsection. Also, a separate speed-flow curve can be entered for each subsection (in this case the user-defined curve shown in Figure **7** (named #1) was used in each case).

Because these data were previously assembled in the data collection effort, it was simply a matter of typing numbers into screens like Figure 14.

```
                                 |  |  |  |  |
                                 |  |  |  |  |
 ORIGIN +------+     ---------+  |  |  |  |                    +-----------+
   3    | 2000 |     1--->    |  |  |  |  |                    | SUBSEC  4 |
 LIMIT  +------+     ------+  |  |  |  |  |                    +-----------+
                           |  |  |  |  |  |            +-----------------------+
                           |  |  |  |  |  |            |NB I405 ON - NAT'L OFF |
                           |  |  |  |  |  |            +-----------------------+
                           |  |  |  |  |  |                         +-------+
                           |  |  |  |  |  |                 LENGTH  |  2900 |
                           |  |  |  |  |  |                 CAP     | 10000 |
                           |  |  |  |  |  |                 SPEED   |    65 |
                           |  |  |  |  |  |                         +-------+
                           |  |  |  |  |  |
                           |  |  |  |  |  |
                           |  |  |  |  |  |
                           |  |  |  |  |  |
                           |  |  |  |  |  |
                           |  |  |  |  |  |
 DEST   +------+     ------+  |  |  |  |  |
   1    | 2000 |     <---1    |  |  |  |  |
 LIMIT  +------+     ---------+  |  |  |  |
                                 |  |  |  |  |
F1: ED SCRN  F2: CHNG DESIGN  F3: SCRN UP  F4:SCRN DWN  Choose your option:
F5: ADD/INSRT NXT SS  F6: DELETE THIS SS  F7: SPLT THIS SS  F10: EXIT
```

Figure 14 - Sample Input Screenfrom FREQ

Ramps are coded for each subsection; on-ramps can start a subsection of fieeway, and off-ramps can be found at the end of subsections. The start of the first subsection is the mainline entry to the freeway, and the end of the last subsection is the mainline exit fiom the fieeway. For both the eastbound and westbound simulations, 43 subsections were used to model the fi-eeway (breaks between subsections were needed for on-ramps, off-ramps, lane drops, lane adds, and mainline detectors).

A few assumptions were needed to effectively code the real-life freeway into the FREQ model. First, the collector/distributor (C/D) lane system on the eastern end of the fi-eeway (near downtown) does not exactly fit the straight-line freeway model used in FREQ. Essentially, the real system has two parallel fi-eeways (the mainline and C/D lanes), with merging allowed only at certain points. Since this kind of system cannot be modeled directly with FREQ, it was thought appropriate to combine the two systems into a single set of mainline lanes (obviously, merging would be allowed at any point). ***As*** discussed earlier, capacity for the additional (i.e., collector/distributor) lanes was reduced somewhat. While this was not a perfect representation, it should be reasonably reflective given that the traffic on the Santa Monica Freeway generally balances itself between the mainline and C/D lanes. Also, the assumption of the merged lanes allowed the research to consider both the FREQ and INTEGRATION models (the lane combination was used identically in INTEGRATION).

Another assumption was needed to code the interchange of the 1-405 and the eastbound Santa Monica Freeway. ***As*** shown in Figure 15, the on-ramps from the northbound and southbound San Diego Freeway (1-405) merge to a single on-ramp (with two lanes) ***before*** merging with the mainline freeway. This could not be coded with FREQ, so an adjusted model was used, as shown in the figure. Since the capacity of the short (theoretical) subsection between the on-ramps was very high, it did not increase congestion on the mainline (as might happen with two close, high-volume on-ramps). Therefore, it was felt that the adapted model of the 1-405 interchange used in FREQ was appropriate.

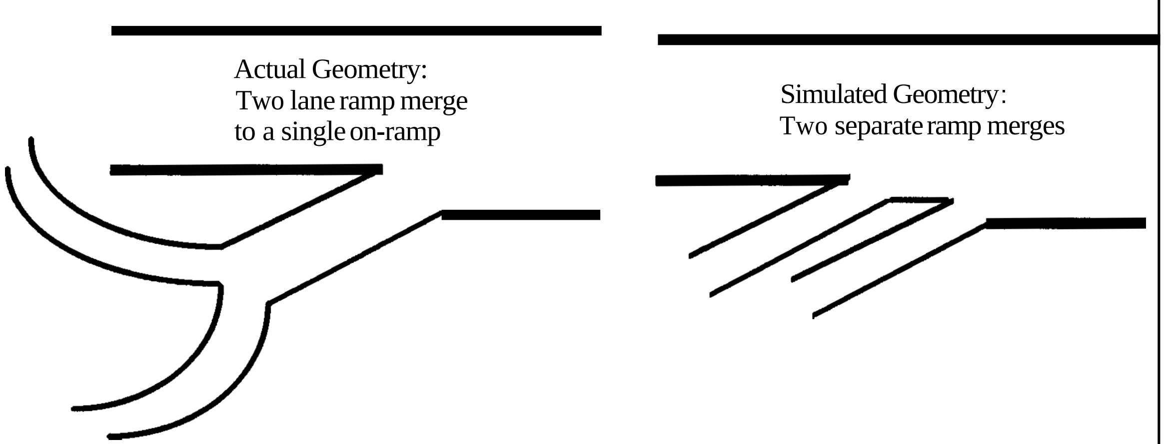

Figure 15: Coding of the I-405 Interchange Using FREQ

Finally, note that ramp lengths are not specified in FREQ (though ramp capacities and the number of lanes are entered). Therefore, vehicles can queue at ramps (and thus incur waiting time) but do not accumulate travel distance (or travel time) on the ramps. This is not a limitation of the model, but comparisons with INTEGRATION (where ramps where explicitly modeled) must be done with care.

3.1.2 Demand Coding with FREQ

Once again, the initial coding of the demand data in FREQ was simply a matter of typing in the data previously collected (i.e., Figure 13) into the model. For each on-ramp and off-ramp (including the fieeway ends) the time series of ramp volume counts were entered; an example is shown in Figure 16. Note that only **24** thirty minute time slices (fi-om 6:30 **A.M.** to 6:30 P.M.) were used in FREQ. The number of time slices available in FREQ is limited to **24** in version 11, so a 12 hour simulation period was used for both the FREQ and INTEGRATION fieeway-only simulations described here. Volume data were collected for the entire **14** hour period for the fieeway for use in the INTEGRATION fieeway corridor simulations (to be performed later).

Note that no mainline counts are entered in FREQ (except at the ends of the fi-eeway). Also, data must be entered for each time slice at each ramp.

```
                                    |  |  |  |  |
                                    |  |  |  |  |
+-------------+       ---------+  |  |  |  |  |                    +-----------+
| TS DEMANDS  |       1--->    |  |  |  |  |  |                    | SUBSEC  4 |
+-------------+       ------+  |  |  |  |  |  |                    +-----------+
 ORIGIN  3 LIMIT 2000       |  |  |  |  |  |                     DEST  1  LIMIT 2000
   +-----+     +-----+      |  |  |  |  |  |                       +-----+     +-----+
 1 | 1474| 13 | 1575|      |  |  |  |  |  |                     1 |  540| 13 | 1506|
 2 | 1418| 14 | 1749|      |  |  |  |  |  |                     2 |  683| 14 | 1032|
 3 | 1291| 15 | 1796|      |  |  |  |  |  |                     3 |  842| 15 |  900|
 4 |  966| 16 | 1816|      |NB I405 ON - NAT'L OFF                4 | 1052| 16 |  988|
 5 | 1048| 17 | 1731|      |  |  |  |  |  |                     5 | 1159| 17 | 1008|
 6 | 1611| 18 | 1504|      |  |  |  |  |  |                     6 | 1209| 18 | 1044|
 7 | 1834| 19 | 1382|      |  |  |  |  |  |                     7 | 1161| 19 | 1060|
 8 | 1846| 20 | 1303|      |  |  |  |  |  |                     8 |  898| 20 | 1042|
 9 | 1878| 21 | 1269|      |  |  |  |  |  |                     9 |  944| 21 | 1083|
10 | 1878| 22 | 1305|      |  |  |  |  |  |                    10 | 1297| 22 | 1221|
11 | 1806| 23 | 1307|      |  |  |  |  |  |                    11 | 1460| 23 | 1239|
12 | 1591| 24 | 1480|      |  |  |  |  |  |                    12 | 1615| 24 | 1171|
   +-----+     +-----+------+  |  |  |  |  |                       +-----+     +-----+
                      <---1    |  |  |  |  |
                      ---------+  |  |  |  |
                                    |  |  |  |  |
F1: EDIT SCREEN  F2: TIMESLICE INFO  F3: PREV ORIG-DEST  Choose your option:
F4: NEXT ORIG-DEST  F10: EXIT
```

Figure 16: Sample FREQ Ramp Data Input Screen

It might be noted that the ramp counts entered in FREQ are not precisely demand data. The on-ramp counts could be accurately described as demand (as long as queues do not form on the ramp itself), but the off-ramp data are definitely not. The volume data at the off-ramps reflect the number of vehicles that passed by the ramp count station during a given time slice, not necessarily the volume that wanted to (i.e., demanded that ramp). Whenever there was congestion on the freeway system, cars were delayed and the off-ramp volumes were not a true reflection of demand.

FREQ handles this dilemma by the way it does internal calculations to create **an** origin-destination ***(OD)*** table of demands. Nearly every simulation program requires demand data in the form of an ***O D*** table. FREQ is no exception, but it is able to synthesize this table from volume counts through an internal process. FREQ assumes that all vehicles entering the system at a given time slice desire (i.e., demand) to exit the system at the same time slice. If the sum of the inputs (on-ramp counts) does not equal the sum of the outputs (off-ramp counts), then an adjustment is necessary. For example, a simple two time slice system might have aggregate on-ramp counts of 10,000 and 9,000 vehicles for each time slice, respectively. The off-ramp counts might be 9,500 for both time slices. This would suggest that some of the vehicles entering the system in the first time slice did not leave the system until the second. FREQ compensates by adjusting the off-ramp volumes by a scaling factor equal to the sum of the on-ramp counts divided by the sum of the off-ramp counts. In this case, if there were 19 off-ramps in the system (each with a flow of 500 vehicles/time slice), each would be adjusted by a factor of 10,000/9,500 for the first time slice. Demands would be about ***526*** vehicles/off-ramp.

The scaling factors for the eastbound and westbound freeway sections are shown by time slice in Figure **17.** Note the peaks during the early parts of rush hours - during these times the number of vehicles entering the fkeeway is greater than those exiting, and congestion is increasing. **As** the end of the peak periods, more vehicles leave the fkeeway (so the scale factors drop below 1.0). During relatively flat periods of demand (i.e., early afternoon), the scaling factors are near 1.0.

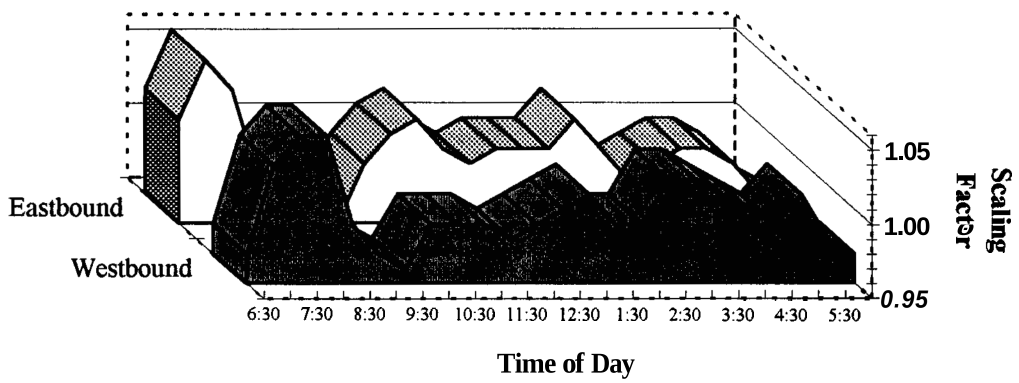

Figure 17: FREQ Scaling Factors

The **final** step for the demand data **is** the 0-D synthesis internal to FREQ. This process will not be described here, but the final result is a table of 0-D pairs for each time slice **[May,** 19931. These data include counts of vehicle demands between each pair of on-ramps and off-ramps in the system, for each time slice. The sum of the demands from the on-ramps equal the sum of the demands to the off-ramps for every time slice in the model. The 0-D data are output (if desired) by the FREQ program for each run; a sample is shown in Figure **18** (on the next page).

3.1.3 Control Coding with FREQ

For the baseline simulation runs of the Santa Monica Freeway, no ramp metering was employed. However, the current ramp metering plans supplied by Caltrans (given in Appendix *6)* were entered into the FREQ models for use in the ramp metering investigations (discussed in some detail in Section *5).* FREQ contains a set of procedures for optimizing ramp metering plans, but only when optimization **is** requested are they run. In other words, if ramp metering optimization parameters are specified but no optimization is performed, the system is analyzed as if there were no ramp metering.

INSTITUTE OF TRANSPORTATION STUDIES FREQ11PE REL 3.0 05/11/94
UNIVERSITY OF CALIFORNIA, BERKELEY
TIME SLICE 3 OF 24

ORIGINAL INPUT DEMAND--
5306. 2420. 1291. 1181. 520. 390. 560. 349. 966. 480. 840. 1060. 1056. 710. 502. 720. 451.

ORIGINAL OUTPUT DEMAND--
842. 926. 173. 538. 450. 138. 260. 325. 354. 173. 431. 410. 842. 1390. 3081. 7830.

TOTAL ORIGINAL INPUT = 18802. TOTAL ORIGINAL OUTPUT= 18163.

EACH OUTPUT VOLUME MULTIPLIED BY SCALE FACTOR, SCALEF= 1.04
TOTAL OUTPUT NOW MATCHES OBSERVED TOTAL INPUT

8 ITERATIONS REQUIRED FOR CONVERGENCE OF CELL VALUES

** ALL VEHICLES **

ORIGINS DOWN / DESTINATIONS ACROSS

ORIGINS DOWN	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	SUM
1	513	467	84	245	205	54	98	113	112	50	117	107	208	332	735	1868	5308
2	234	213	38	112	93	25	45	51	51	23	54	49	95	151	335	852	2421
3	125	114	20	60	50	13	24	27	27	12	29	26	51	81	179	454	1292
4	0	115	21	60	50	13	24	28	28	12	29	26	51	82	181	460	1180
5	0	51	9	27	22	6	11	12	12	5	13	12	23	36	80	203	522
6	0	0	8	2 2	18	5	9	10	10	4	11	10	19	30	66	168	390
7	0	0	0	3 2	27	7	13	15	15	7	15	14	27	44	97	247	560
8	0	0	0	0	0	5	9	10	10	5	11	10	19	31	68	172	350
9	0	0	0	0	0	14	25	29	28	13	30	27	53	84	187	476	966
10	0	0	0	0	0	0	13	14	14	6	15	14	27	43	94	240	480
11	0	0	0	0	0	0	0	26	26	12	27	25	48	76	170	431	841
12	0	0	0	0	0	0	0	0	34	15	35	32	63	100	221	561	106t
13	0	0	0	0	0	0	0	0	0	15	36	33	64	102	227	577	1054
14	0	0	0	0	0	0	0	0	0	0	25	23	44	70	155	394	711
15	0	0	0	0	0	0	0	0	0	0	0	17	32	51	114	289	503
16	0	0	0	0	0	0	0	0	0	0	0	0	48	76	168	428	720
17	0	0	0	0	0	0	0	0	0	0	0	0	0	51	113	287	451
SUM	872	960	180	558	465	142	271	335	367	179	447	425	872	1440	3190	8107	18810

Figure 18: Sample FREQ 0-D Table

Within these optimization procedures are an option to specify the minimum and maximum allowable metering rates at each ramp. If these two values are the same, FREQ wl select the unique metering plan based on this single set of values. This strategy was used to enter the baseline metering plan from Caltrans. HOV-2 cutoffs (**only** vehicles with occupancies of at least two persons) were used for all ramps; this parameter can be specified in FREQ.

3.2 The INTEGRATION Model

The INTEGRATION was originally developed by Michel Van Aerde for his doctoral dissertation at Waterloo University in Canada. Since that time, the model has undergone extensive development at Queen's University (also in Canada), sponsored in part by the Ontario Ministry of Transportation [Gardes 1993a] and has become a promising tool for trafiic simulation. INTEGRATION is unique in its ability to simultaneously simulate deterministic traffic flow and replicate dynamic route choice behavior (i.e., traffic assignment). The model combines elements of macroscopic flow theory and microscopic (individual) vehicle simulation, and provides a real-time graphic interface to monitor traffic on the network. Finally, INTEGRATION provides the functionality to model a variety of advanced traffic management and driver information scenarios, including dynamic information provision, signal optimization, and HOV facilities.

With all of these features, INTEGRATION was a natural choice to model the Santa Monica Freeway Corridor and analyze IVHS technology. While some of its features (e.g., traffic assignment) are not applicable to a freeway-only system, its relevance for this study should be obvious. By developing a working simulation of the freeway alone using INTEGRATION, the effort needed to create a corridor model is greatly reduced. *Also,* the research using INTEGRATION answered many questions about the model and eased the development effort for the full corridor.

However, FREQ is also an effective model for analyzing freeways; the tradeoffs in functionality between the two models are discussed in this paper. Regardless of specific functionality, the use of both models provided more knowledge about the freeway than either one alone. Especially for a network as complex as the Santa Monica Freeway, the ability to compare (often different) results obtained from the two simulation was critical to testing and debugging.

Version 1.5 of the INTEGRATION model was used to simulate the Santa Monica Freeway. During the period of development, four different versions of INTEGRATION (named v1.5, v1.5b, v1.5c, and v1.5d) were made available by Michel Van Aerde. The studies described here were among the first tests of the new version of the model, and the developer made modifications based on results from this project. Note that the results suggested here are valid for each of the specific versions of INTEGRATION (v1.5, v1.5b, v1.5c, and v1.5d) except where noted.

3.2.1 Supply Coding with INTEGRATION

On the supply side, INTEGRATION requires specification of the nodes and links that make up the network. The model uses standard ASCII files as input for its simulation. Several different input files are required to make a run; the formats are specified in the users' manual [Van Aerde 1993a]. For the network supply, two different files must be created. Figure 19 shows an excerpt from the node and link files that describe the eastbound portion of the Santa Monica Freeway. Details on the meaning of each parameter will not be provided here (the interested reader is directed to the INTEGRATION users' manual), but note that the second and third parameters for each link reference two nodes (that are described in the node file).

Since the input to the INTEGRATION model via prepared files (instead of a user interface like FREQ), the preparation process could be automated. Using the node/link spreadsheet described earlier, it was straightfonvard to export data to create node and link files like Figure 19. Appendix **2** provides more details on this process.

```
INTEGRATION Freeway Node Coordinate File (EB) - 2/94
100 1.0 1.0
  1    19.87  13.44  2   -1   0  Off-ramp (EB) to SB La Cienaga end
  2    23.98  13.00  2   -2   0  Off-ramp (EB) to NB La Brea end
  3    24.00  13.00  2   -3   0  Off-ramp (EB) to SB La Brea end
  4    26.49  13.11  2   -4   0  Off-ramp (EB) to Crenshaw end
  5    28.95  13.39  2   -5   0  Off-ramp (EB) to Arlington end
  6    30.26  13.47  2   -6   0  Off-ramp (EB) to Western end
  7    31.58  13.45  2   -7   0  Off-ramp (EB) to Normandie end
  8    32.90  13.42  2   -8   0  Off-ramp (EB) to Vermont end
  9    36.03  12.89  2   -9   0  East end of EB ML (east of I-110)
  10   14.51  12.12  2   -10  0  Off-ramp (EB) to National end


INTEGRATION Freeway Link Characteristics File (EB) - 2/94
99 1.0 1.0 1.0 1.0 1.0
 1   17  34 0.259 100 2067 3 0 71 131 0 0 0 0 0  0 0 0 0 1 EB ML start-405 ovrps
 2   34  35 0.594 100 2067 3 0 71 131 0 0 0 0 0  0 0 0 0 1 EB ML ovrps-405 onrps
 3   35  36 0.884 100 2000 5 0 71 131 0 0 0 0 0  0 0 0 0 1 EB ML 405 ons-Ntl off
 4   36  37 0.427 100 2050 4 0 71 131 0 0 0 0 0  0 0 0 0 1 EB ML Ntl off-Ovld on
 5   37  38 0.503 100 2000 5 0 71 131 0 0 0 0 0  0 0 0 0 1 EB ML Ovld on-Mtr det
 6   38  39 0.655 100 2000 5 0 71 131 0 0 0 0 0  0 0 0 0 1 EB ML Mtr det-Mang on
 7   39  40 0.350 100 1980 5 0 71 131 0 0 0 0 0  0 0 0 0 1 EB ML Man on-Rbtn off
 8   40  41 0.640 100 1980 5 0 71 131 0 0 0 0 0  0 0 0 0 1 EB ML Rbt off-Ntl det
 9   41  42 0.091 100 1980 5 0 71 131 0 0 0 0 0  0 0 0 0 1 EB ML det-National on
 10  42  43 0.579 100 2000 5 0 71 131 0 0 0 0 0  0 0 0 0 1 EB ML Ntl on-SBLC off
```

Figure 19 - Sample Node and Link Files for INTEGRATION

Unlike FREQ, INTEGRATION can be used to code any network (subject to computer memory constraints). Therefore, it was possible to code the Santa Monica Freeway in a single network (i.e., as a bi-directional fieeway). However, since FREQ simulations and results were available for each direction of freeway, it was more convenient to run two different INTEGRATION simulations (one for each direction of freeway). Since the run times for INTEGRATION were often rather long (measured in hours), it was also more efficient to only use the model to simulate the specific direction under study.

Nodes that serve as origins or destinations are special cases in INTEGRATION. These special nodes must be specified in the node file (as the fourth parameter) as a destination (called type **2** nodes in INTEGRATION), origin (type **3** nodes), or both (type 4 nodes). Each of these nodes must also be included in a cluster (indicated with a negative number), which is a group of nodes that serve as a common source or sink of trips in the model. For example, all of the nodes shown in Figure 19 are destination nodes in unique clusters.

For a complex model (like the fieeway corridor), it is often necessary to group the origin and destination nodes into clusters to reduce the number of calculations needed to find minimum path trees. **A** model with **x origin** nodes and **y** destination nodes will require xy calculations for each time slice. By grouping the **x** origin nodes into x/4 origin clusters (averaging four nodes per cluster) and grouping the destination into y/4 clusters, the total calculations required **will** be reduced to a factor of **xy/16**, a significant improvement.

However, the fieeway-only model did not require clustering. Since there were only about 16 origins and 16 destinations for each direction, the number of minimum path tree calculation was manageable. *Also*, the minimum path trees for a uni-directional freeway are trivial, so it was not necessary for INTEGRATION to make these calculations. In any case, note that the cluster number (the fifth parameter) for each origin or destination (type 1, 2, or **3)** is unique.

Ramps are coded as links connected to the mainline freeway. The points where they meet (at nodes) are the merge points for the freeway on- and off-ramps. Note that in most cases, ramps for the Santa Monica Freeway do not contain a constant number of lanes. For most of the on-ramps, there is a two lane section (which includes an HOV bypass lane) which merges to a single lane (after the ramp meter) before the freeway. Similarly, most of the off-ramps permit a single lane of traffic exiting the freeway, which widens to two or three lanes at the surface street intersection (where separate turning lanes are usually provided at the signal). The model was coding using a separate link for each section of a given number of lanes. Nodes on the ramps were used as locations where there are changes in the number of lanes (adds or drops).

The start of the first link (in each direction) is the mainline entry to the freeway, and the end of the last link is the mainline exit from the freeway. Figure 20 summarizes the links and nodes used to code each freeway network. (Note that the eastbound freeway includes one less link, or subsection in INTEGRATION because the dummy mainline link used for the 1-405 interchange was not needed in INTEGRATION.)

INTEGRATION Feature	EB	WB	total	**FREQ** Feature	EB	WB	total
Mainline links	42	43	85	Subsection	43	43	86
On-ramp links	**33**	28	61				
Total on-ramps	16	14	**30**	Total on-ramps	16	14	30
Off-ramp links	24	29	53				
Total off-ramps	15	15	**30**	**Total off-ramps**	15	15	30
Total links	99	100	199				
Origin nodes	17	15	32	***Origins***	17	15	32
Destination nodes	16	16	32	Destinations	16	16	32
Total nodes	100	101	201				

Figure 20 - Summary Statistics for INTEGRATION and FREQ Freeway Networks

Once again, the assumption that the C/D lanes could be described as additional mainline lanes was used to code INTEGRATION. ***As*** previously mentioned, although an INTEGRATION network could be easily coded to replicate the parallel mainline and C/D lanes, it was found that it was easier to compare the two models if the networks were coded as similarly as possible.

3.2.2 Demand Coding with INTEGRATION

INTEGRATION also uses a prepared **ASCII** file as the source of its demand data. These data are in the form of origin-destination counts to and from specific nodes in the network.

For each time slice, the number of vehicles traveling fiom each origin cluster to each destination cluster must be specified as input to INTEGRATION. Figure 21 shows an excerpt fiom the 0-D file for the eastbound freeway. Note the third line suggests that the demand rate between zones 17 and 10 for the first time slice is ***268*** vehicledhour.

```
INTEGRATION Freeway Origin-Destination File (EB) - 2/94
4096 1.0 1.0
 1  17  10  268 1.0     000   1800 1.0 0.0 0.0 0.0 0.0    0.0 1.0
 2  17  11  212 1.0     000   1800 1.0 0.0 0.0 0.0 0.0    0.0 1.0
 3  17   1   37 1.0     000   1800 1.0 0.0 0.0 0.0 0.0    0.0 1.0
 4  17  12  103 1.0     000   1800 1.0 0.0 0.0 0.0 0.0    0.0 1.0
 5  17  13   93 1.0     000   1800 1.0 0.0 0.0 0.0 0.0    0.0 1.0
 6  17   2   28 1.0     000   1800 1.0 0.0 0.0 0.0 0.0    0.0 1.0
 7  17   3   68 1.0     000   1800 1.0 0.0 0.0 0.0 0.0    0.0 1.0
 8  17   4   69 1.0     000   1800 1.0 0.0 0.0 0.0 0.0    0.0 1.0
 9  17   5   40 1.0     000   1800 1.0 0.0 0.0 0.0 0.0    0.0 1.0
10  17   6   39 1.0     000   1800 1.0 0.0 0.0 0.0 0.0    0.0 1.0
```

Figure 21 - Sample Origin-DestinationFilefor INTEGRATION

The next issue was how to accomplish the origin-destination synthesis for the INTEGRATION runs. The model includes a synthetic 0-D model (called QUEENSOD) that could be used to develop **0-D** estimates from the flow data. However, synthetic counts fiom QUEENSOD were found to be different fiom the demand data synthesized by FREQ. It would have been difficult to compare the results fiom FREQ and INTEGRATION if the demand inputs (i.e., the synthesized 0-D data) were different. Therefore, it was decided to copy the demand data synthesized by FREQ for use in the INTEGRATION runs. This enabled comparisons between the two models to be made based on identical input data.

To accomplish this, it was necessary to capture the FREQ O/D data into a file for INTEGRATION. A custom utility program (*odconver.pas* can be found in Appendix **3)** was used to read the synthesized O/D from the FREQ output file. The program converted the ramp-numbering scheme in FREQ to the INTEGRATION node number. Finally, it rewrote the data in the correct format (as in Figure **2**1) for use in INTEGRATION.

3.2.3 Control Coding with INTEGRATION

Once again, coding the control portion of the INTEGRATION network was done using **ASCII** files. In the model, any links that end at a signal (at an intersection or ramp meter) include a parameter in the link file that specifies a signal number. Then, all of the signals are described in a separate input file (a sample is shown in Figure 22).

```
INTEGRATION Freeway Signal File (EB) - 2/94
7 1 43200
1
  1    90   90  90     0    2   42    3   42    3                  0
  2    90   90  90     0    2   42    3   42    3                  0
  3    90   90  90     0    3   33    3   20    3   28    3        0
  4    90   90  90     0    3   31    3   22    3   22    3        0
  5    90   90  90     0    3   31    3   22    3   22    3        0
  6    90   90  90     0    2   42    3   42    3                  0
  7    90   90  90     0    2   42    3   42    3                  0
```

Figure 22 - Sample Signal File for INTEGRATION

For the fieeway-only network, both ramp meters and surface (intersection) traffic signals are relevant (most off-ramps end at traffic signals). However, neither signal was used in the FREQ runs. No ramp metering was used in the baseline FREQ runs, so these signals were not used. Similarly, since the FREQ off-ramps are not explicitly ended, traffic signals are not found. For the baseline run, then, the file was replaced by a dummy file containing no signals (the signal specifications in the link file were also removed).

However, it was necessary to code the INTEGRATION signal file for subsequent runs, so some discussion of how this was done is appropriate. INTEGRATION requires that signals be coded in terms of cycles, with green times specified in integer numbers of seconds. For example, a two phase signal might have a cycle length of **70** seconds, and include two **32** second green phases (one for each direction). Ramp meters are coded this way also, except only one green phase **is** needed. For example, a signal with a four second cycle length and a single one or two second green phase would let one car through every **4** seconds, or 900 vehicledhour.

This worked well for the surface street signals, but was problematic in coding the ramp meters. **In** FREQ, metering rates are specified directly as vehicledhour. Since integer green times are used in INTEGRATION, some rates could not be described using a single phase. For example, the **4** second cycle described above yielded an effective flow of 900 vehicledhour, and a ***5*** second cycle would give **720** vehicledhour. However, there is no direct way to specify an intermediate value (e.g., 800 vehicledhour) with a single integer cycle length.

This problem can be managed somewhat using by using two phases in a single cycle. ***As*** an example, consider a two phase signal (one second per green phase) with lengths of **4** and ***5*** seconds. In this case, two vehicles would pass every 9 seconds, or 800 vehicledhour.

Unfortunately, only two green phases can be specified for any link. Thus, there are many metering rates that are currently impossible to model using INTEGRATION. **A** future enhancement of INTEGRATION will allow intervals of 0.1 seconds to be included for phase lengths. This will enable coding many more ramp metering plans (although not every integer flow can be described). Until then, however, INTEGRATION's ability to model ramp metering is not as complete as that of FREQ.

Section 4: Model Calibration

Once the two simulations were coded using FREQ and INTEGRATION, the next step was to confirm that they were producing output that was indicative of the real system. In order for the simulations to be useful for developing the entire corridor model (or for freeway-only investigations of potential **IVHS** strategies) it was important to assure that the simulation data was reasonably accurate.

The phrase "reasonably accurate" could be interpreted in many ways, however. Obviously, the best way to calibrate the models would be to compare the output against the traffic performance for an actual day (one with typical, recurring congestion) of freeway traffic. Unfortunately, since the input demand data were compiled from several different sources, it was not possible to study the performance from any one day. Since the ***input*** for the simulations was aggregated for a typical day, it was thought appropriate to compare the ***output*** to that of a typical day. This was accomplished in several steps.

The first step was to eliminate any gross coding errors from the simulations. Given the volume of data that were necessary to code the models, it was not reasonable to expect that the input process would be error-free. Therefore, some time was allocated to debugging the models to eliminate these errors. This was accomplished by running the models and looking for obviously strange performance characteristics (e.g., large queues at a single ramp, bottlenecks on the freeway where queues never dissipate, etc.). Then, the input data were checked at those points where coding errors were noted and corrected.

The next step was to compare freeway performance with general knowledge of the system. For example, it was obvious that traffic should be heaviest on the freeway during the morning and afternoon peak periods. *Also,* the eastbound freeway was expected to have its heaviest traffic during the morning peak period (as commuters headed toward the downtown business district). Similarly, the westbound freeway should have more congestion during the afternoon. Finally, some queueing could be expected during both peak periods (in both directions), and queues could be expected to grow during the early parts of the peak period and dissipate around the end of the rush hour.

As an example, consider Figures 23 and 24, summaries of FREQ simulation runs. The first chart shows the average speed of traffk for all mainline lanes on the eastbound freeway during the study period (6:30 A.M. to 6:30 P.M.). Note the sharp decrease in speed during the morning and afternoon peak periods, and also that the magnitude of the congestion is greater during the morning period. Figure 24 is a chart of the maximum demand/capacity ratio (for all links) on the westbound freeway. This statistic indicates those periods where a bottleneck starts (where demand exceeds capacity). During the other periods, the ratio gives a measure of the level of congestion. The general trends in the chart are predictable; the heaviest congestion periods are from 6:30 to 9:30 A.M. and from 4:00 to 6:30 P.M.

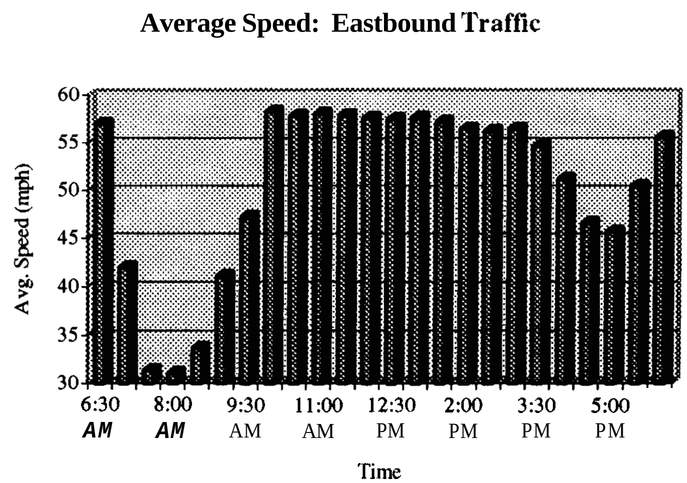

Figure 23 - Average Speed (Eastbound) from FREQ

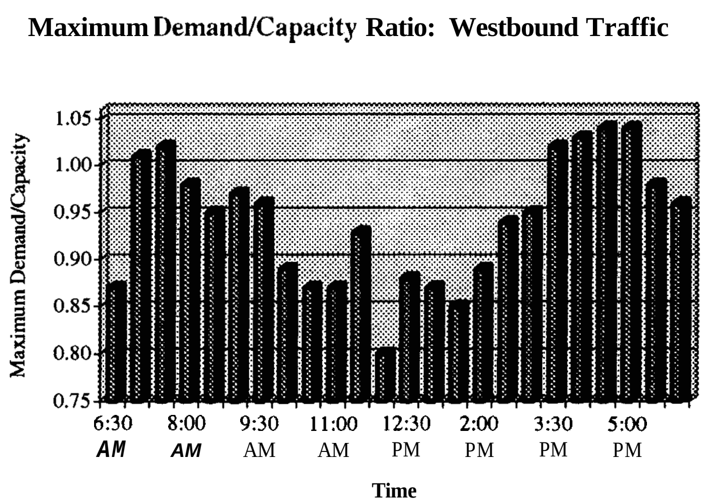

Figure 24 - Maximum Demandcapacity Ratio (Westbound) from FREQ

More specific performance data were also used for comparison in the calibration effort. Caltrans monitors congestion on the Los Angeles freeway system in an annual report [California Department of Transportation 1991, 1992]. The 1992 report suggests the period of congestion is 6:15 to 9:30 A.M. (for eastbound traffic) and about 3:00 P.M. to 6:30 P.M. (for both eastbound and westbound traffic). Therefore, queueing could be expected during these periods, and should not be found at other times.

Another source of data were the mainline freeway detectors. Mainline flows (from several different days) were available from many detectors on the freeway (in both directions). Figure 25 lists the mainline detectors where reasonable data were available (for more information, see

[Bloomberg 1993b]). Note that not all of the detectors were coded as nodes on the network (only 5 or **6** in each direction) to limit the **size** of the network. Detector nodes were coded approximately every 1.5 miles; this length was chosen to minimize the differences in location (the working detectors were found in bunches) and direction (more working detectors were available for the eastbound freeway). However, all of the detectors are referenced to a specific link (FREQ subsection) so that the output from the simulations could be compared against expected volumes from the detectors.

Eastbound Location	**Mile Marker**	**Link Number**
Overland	6.50	*5*
Motor	6.73	**6**
Manning	7.27	7
National	7.99	10
Venice	9.01	15
Fairfax	9.21	16
Washington	9.51	17
La Brea 1	10.23	19
La Brea 2	10.53	21
Harcourt	10.70	22
West	11.00	23
Crenshaw	11.53	24
Arlington 1	12.23	27
Arlington 2	12.45	28
Gramercy	12.58	29
western 2	12.95	*30*

Westbound Location	**Mile Marker**	**Link Number**
Budlong	13.53	9
Normandie	13.21	14
western 2	12.95	16
Gramercy	12.58	20
Arlington	12.23	21
Crenshaw	11.53	22
West	11.06	24
La Brea 2	10.53	25
Fairfax	9.21	31
Manning	7.22	37
Motor	6.73	38

Figure 25 - Mainline Detectors Used for Calibration

For both of the models (FREQ and INTEGRATION), all of these comparisons were made to insure reasonable results fi-om the simulations. Also, additional procedures were implemented for each of the two models to facilitate the calibration process. These are described in the next two sections. In addition, some mention is given to what was done when discrepancies were found between the expected results and the actual output from the simulations.

4.1 FREQ Calibration

The FREQ program provides a detailed set of output data with each run. The user can specify which output data will be produced; these include statistics on link flows, travel times, queueing delays, and vehicle speeds. The output is available in both tabular form and in quasi-graphical contour map format. FREQ's rich output files made possible a number of specific comparisons; two are described here.

The first detailed analysis for the FREQ simulation was a comparison of mainline flows to detector volumes. FREQ provides performance data for each time slice that includes flows on each subsection in the network. (These can be found in the "ADJUSTED VOLUME" column in the output file.) These data were extracted (using a custom utility program called *freqcomp.pas*) and compared to the mainline detector data (see Figure 25) in a spreadsheet.

A sample of the results is shown in Figure **26,** where FREQ data from subsection **24** are compared against the average daily flow for the mainline detectors at the Crenshaw (eastbound) station. In this case, the comparison is very good: there is never a difference in flow of more than 200 vehicles/hour during any half-hour time slice. For other detector stations, the Et was not nearly as good. Often, the FREQ flows were consistently higher than the detector data. Since not every detector was functional at every station, there were often cases when data were not available for all lanes of the freeway (especially the collector/distributor lanes). In these cases, the reason for the discrepancies seemed clear; there were other cases where it was not so obvious.

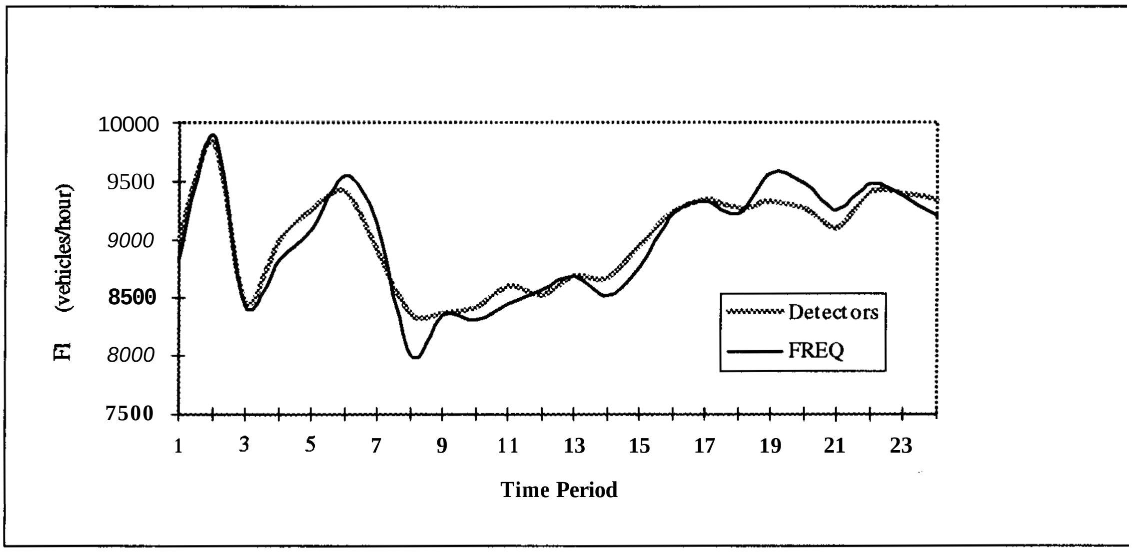

Figure 26 - Comparison of FREQ Flows with Detector Datu

Another powerful tool for comparison were the contour diagrams in FREQ. Charts can be produced that describe the value of a particular statistic in time and space on the network. These statistics include speed, density, v/c ratio, and queues. Figure **27** shows an excerpt from the FREQ contour diagram of traffk density for *part* of the eastbound freeway. The horizontal axis is the subsection number, scaled by the length of the section (i.e., the first section is **3** characters wide and the second is **8** characters, so the length of subsection **2** is about **8/3** that of subsection 1). The time slices **(24** half hour periods from **6:30 A.M.** to **6:30 P.M.)** are on the vertical axis. The data in the chart are traffic density values, in units of 10 vehicles/mile. For example, the series of "1"s in time slice one indicate that the density of traffic on subsections 1 and **2** was between 10 and **20** vehicles per mile from 6:30 to 7:00 **A.M.**

These were compared with the empirical data shown in Figure **28,** on the next page. This chart was created using the available detector occupancy data (generally from the median lane, or the lane with the best available data) for any subsection with a working detector. Overall, about half the subsections do not have data. In some cases (where the FREQ subsection was divided by a detector) the occupancy data were copied onto both subsections (since the traffic was the same on each side of the detector). The occupancy data were converted to density using an assumption of a constant detection length (equivalent to average vehicle length plus average detector length) of 25 feet.

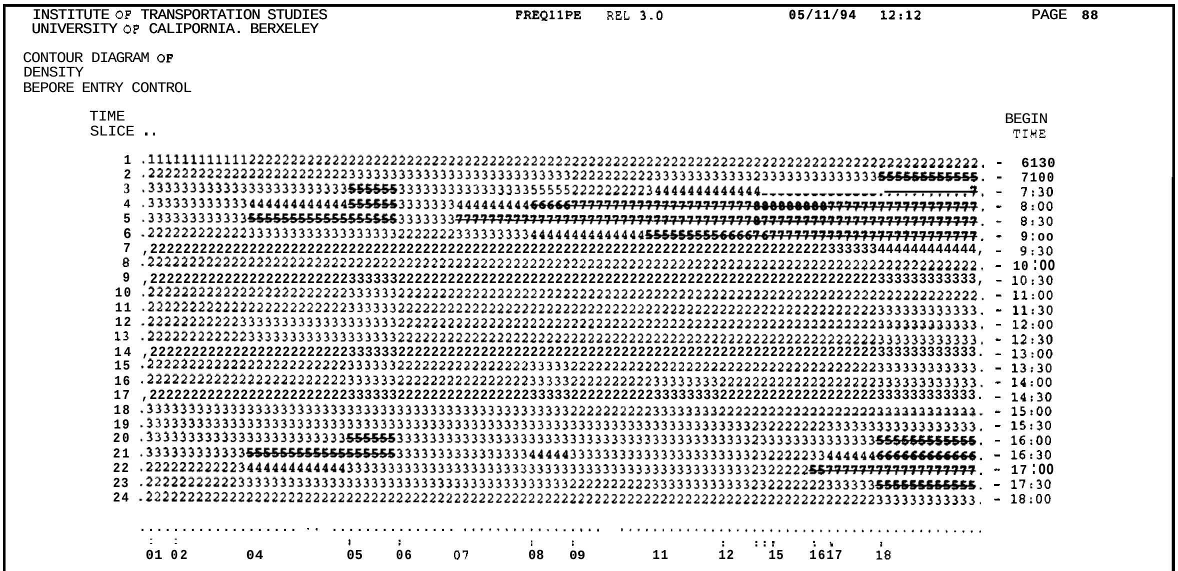

Figure 27 - FREQ Density Contour (West Side of Eastbound Freeway)

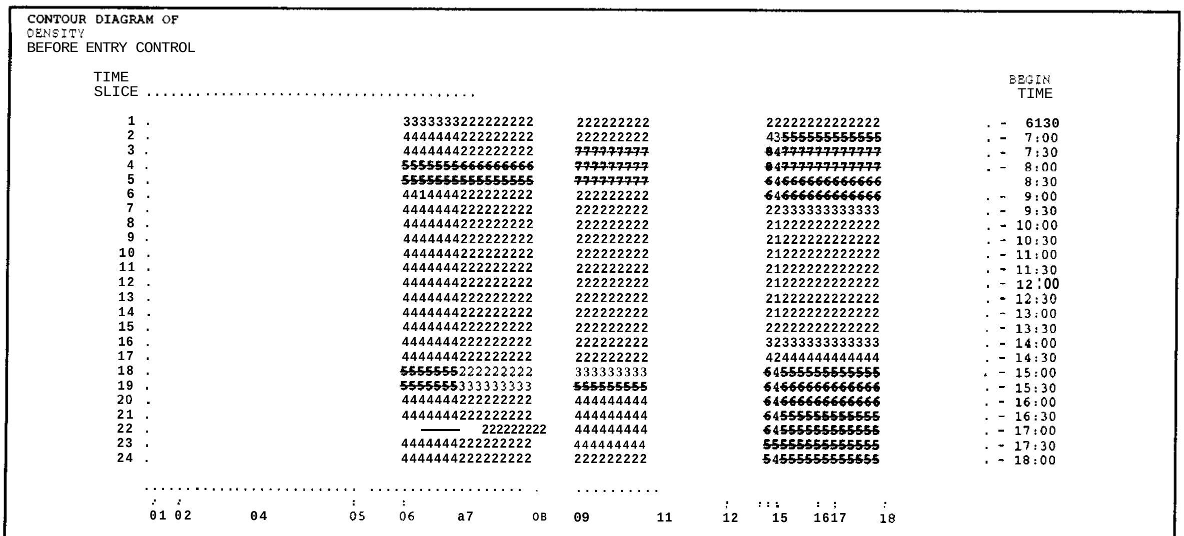

Figure 28 - Available Empirical Densities (West Side of Eastbound Freeway)

Where densities of at least 50 vehicles/mile are found, the value is shown in bold and strikethrough on the figures. This arbitrary point gives a rough idea of where congestion is present in the network. Note that even with the assumptions and limitations of the detector dataset, there is a reasonable correlation between the two charts.

Once the coding errors were corrected in the FREQ simulations, the results from the model were generally good. The only significant changes that were made in the calibration process for FREQ were capacity adjustments (both for the mainline lanes and the ramps). As was discussed earlier, the theoretical estimates for capacity (as discussed in Section 2.1.2) were subject to some scrutiny, and the results of the initial runs indicated that (in some cases) adjustments were needed. Generally, these were slight increases in capacity (plus or minus 100 vehicles/hour/lane) of a mainline bottleneck section that was causing queueing past the peak period. Conversely, there were sections that should have been bottlenecks (as indicated by the empirical data) where the traffic volume was just below the capacity. In these cases, the capacity was reduced slightly.

4.2 INTEGRATION Calibration

Most of the calibration of the INTEGRATION freeway simulation was performed after the FREQ models were calibrated. As with FREQ, the INTEGRATION simulation was checked for gross errors and traffic performance data were examined for general reasonableness. The process for checking INTEGRATION was somewhat easier because FREQ had already been calibrated.

However, there were two practical issues that hampered the INTEGRATION calibration process. The first was the performance of the simulation. For the initial runs (using version 1.5a), the time to run a 12 hour simulation of the freeway (in one direction only) was about three to four hours. As the new features were added to later versions of INTEGRATION (v1.5b, v1.5c and v1.5d), however, run times increased significantly. The last set of runs (using version 1.5d) took approximately 30 hours to complete (i.e., the ratio of simulation to real time was 2.5: 1).

For a limited set of runs, these increased run times would not be very significant, because INTEGRATION can be set to make a run (or series of runs) overnight or over a weekend. Generally, the calibration process did not require a large number of runs; usually a single run was made and some time was needed to analyze the results and make changes to the network. However, the lengthy run times did put a practical limit on the number of calibration runs that could be made.

The second issue was the format of the INTEGRATION output. Unlike FREQ, the INTEGRATION model does not provide any quick means to check results (e.g., like the contour maps from FREQ). Several output files are created with each run, but data is listed in tabular form, by time slice and then by link. There is no direct way to quickly examine the simulation results for a single link (across all time slices) or a series of links. *Also,* it is difficult to determine congested areas from the tabular output.

To address this problem, a utility program was developed to manipulate the INTEGRATION output into a more useful form. This program (called INTOMAN) is described in detail in Appendix 4, but some of the output from the INTOMAN program (which uses output from the INTEGRATION program) is given here to illustrate the calibration process.

Contour maps were found to be the best means of comparison. **As** an example, consider the speed contour maps shown in Figures 29 and 30. Figure 29 shows the speeds simulated by INTEGRATION for the eastbound freeway during the first five hours (6:30 to 11:30 A.M.), and Figure 30 shows the same location and times in FREQ. Speeds under 40 mph (i.e., where the number is 3 or less on the map) are shown in bold and strikethrough to highlight the congestion patterns. (The maps should be read from right to left and then top to bottom. The top part of Figure 29 shows the western half of the eastbound freeway, while the bottom part shows the eastern part of the freeway.) Note that the general pattern of congestion is roughly the same in both models (INTEGRATION and FREQ).

The contour map shown in Figure 29 is from the last set of simulation **runs** using INTEGRATION version 1.5a, which gave the closest agreement to the traffic performance data **as** generated by FREQ. It was not feasible nor necessarily desirable to tune the INTEGRATION simulation to perfectly match the FREQ output, for several reasons. First, there are intrinsic differences in the simulations that make getting a perfect match very unlikely. At the simplest level, FREQ is a macroscopic simulation, while INTEGRATION uses elements of microscopic modeling, so there are bound to be some differences. However, if both models are valid, the same general results should be found for each model.

The same steps were used to study the output from later version of INTEGRATION (versions 1.5b, 1.5c, and 1.5d). The final contour map from the runs using version 1.5d is provided in Figure 31. Note that the pattern of congestion is (very) roughly the same, but there is significantly more congestion using the newest version of INTEGRATION. Unfortunately, time was not available to furhter calibrate the network using version 1.5d

Figure 32 highlights the differences between the models in terms of travel time on the eastbound freeway (from end to end). Note that there is fairly good correlation between the earlier version of INTEGRATION (version 1.5a) and FREQ, but signiticant differences between the two versions of INTEGRATION (versions 1.5a and 1.5d).

There are different possible explanations for the differences. First, one could argue that version 1.5d of INTEGRATION is more accurate than previous versions (which did not include car-following algorithms) and FREQ (which makes only macroscopic calculations). On the other hand, there is better correlation between the earlier version of INTEGRATION and FREQ, which suggests that the car-following algorithms in version 1.5d may need to be further refined. Previous work [Gardes 1993a] indicated that INTEGRATION was an effective tool for freeway modeling, but no detailed investigations have been made on the newer versions (the work by Gardes et al was performed using version 1.4).

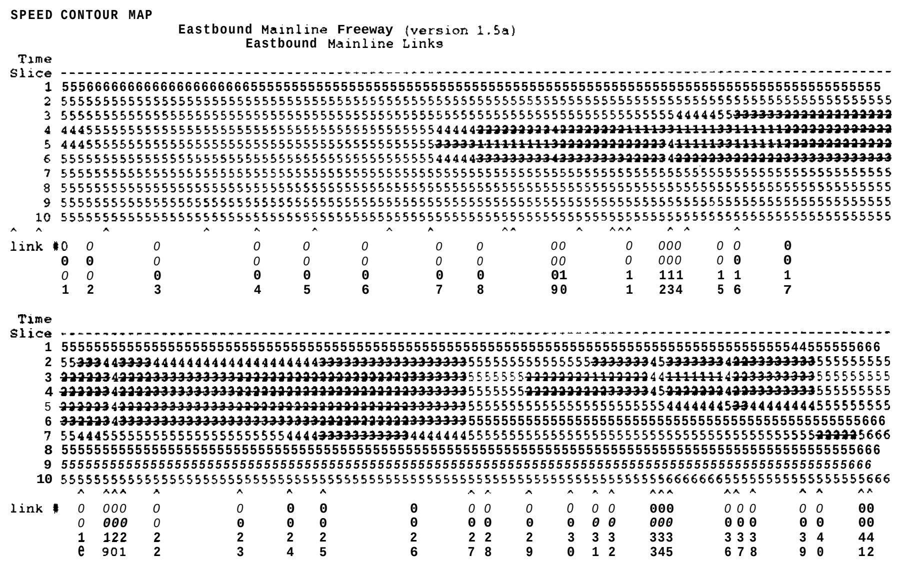

Figure 29 - Speed Contour Map from INTEGRATION v1.5a (Eastbound)

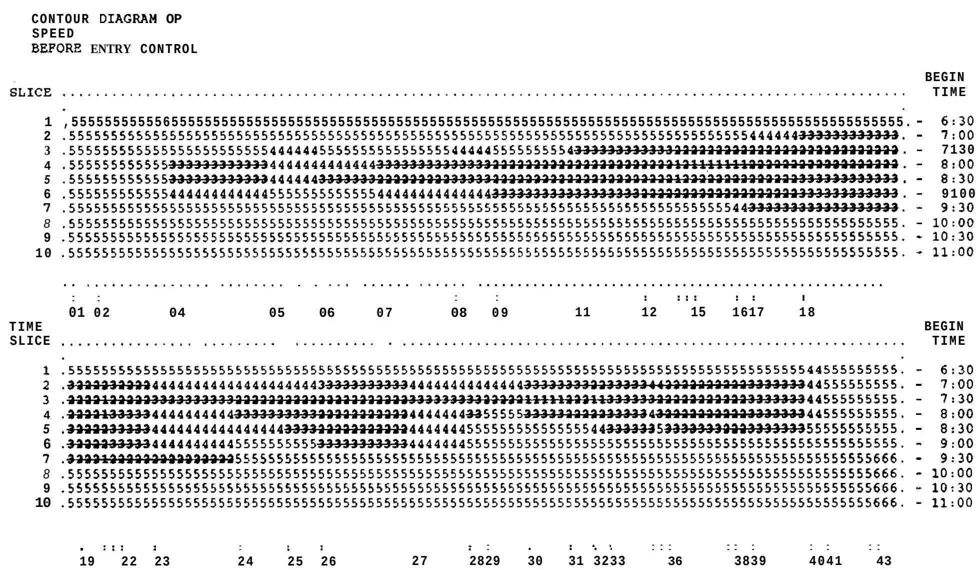

Figure 30 - Speed Contour Map from FREQ (Eastbound)

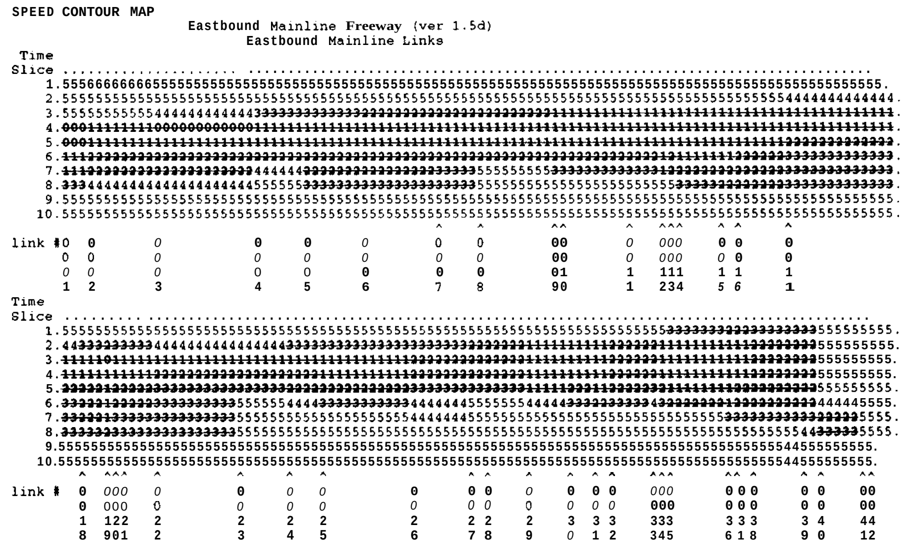

Figure 31 - Speed Contour Map from INTEGRATION v1.5d (Eastbound)

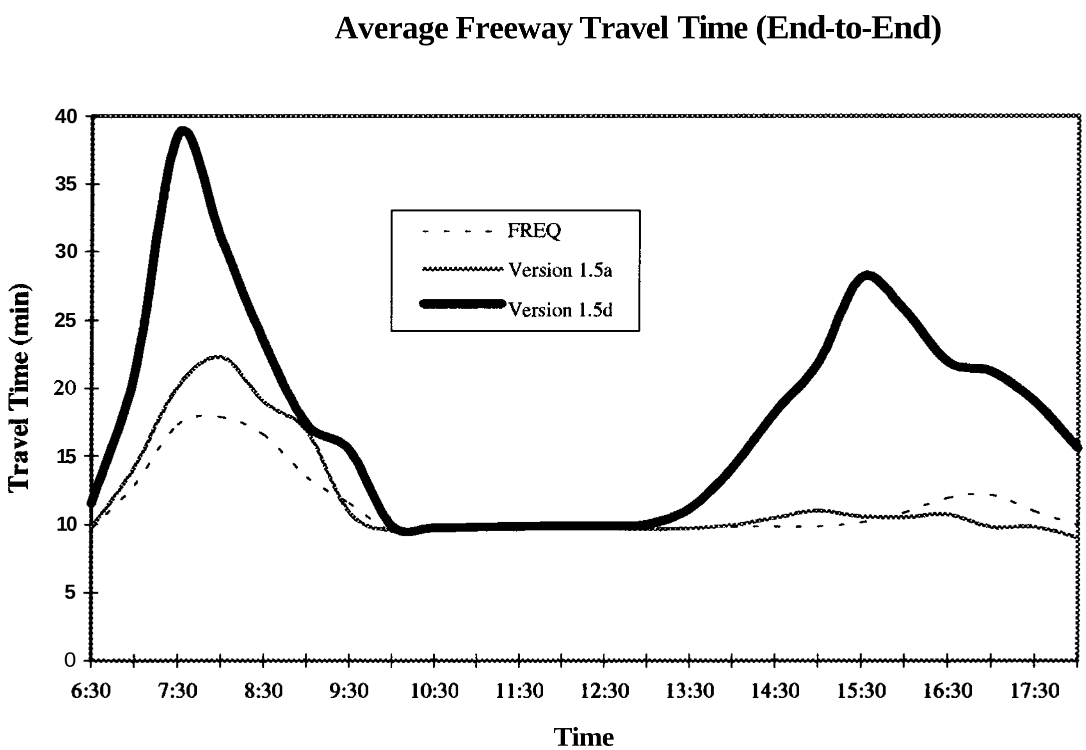

Figure 32 - Average End-to-End Freeway Travel Time (Eastbound)

In any case, more work may be needed on freeway calibration before any conclusions about the effectiveness of INTEGRATION version 1.5 can be determined. For this research, there were limited resources for calibrating the freeway alone; the main purpose of the project was to develop a freeway corridor model. Also, having a calibrated freeway-only model is no guarantee that the corridor simulation will provide reasonable traffic performance data for the freeway. Since the origin-destination process will be different for the corridor simulation, it will be difficult to compare directly the results of those runs with the output from FREQ or the freeway-only INTEGRATION runs.

Still, much has been accomplished during the calibration of the freeway simulations. Approximate goals for traffic performance were established (using FREQ and version 1.5a of INTEGRATION) that matched the expected congestion patterns from the empirical data and knowledge of the system. The results from the latest version do not match exactly, but the results are close enough to suggest that INTEGRATION version 1.5d provides the functionality to reasonably simulate the freeway.

Section 5: Investigations

Once the calibrated freeway simulations were available, a potential use of the models was specific investigations of **IVHS** strategies. This section describes some of these studies that were performed using the FREQ model. (The INTEGRATION model was not used for investigation because different versions of the model were being tested during the project. As new versions were made available, the emphasis was on testing and calibration, not experimentation. Without a stable version of INTEGRATION, it was difficult to make a definitive set of investigations.)

It should be noted that extensive resources were not allocated for investigations using the freeway models; the focus was on supporting the development of the freeway *corridor* simulation. Still, studies were performed (using FREQ only) that considered potential demand increases and incidents, ramp metering policies, and HOV lane implementation. Each is described below in a separate subsection.

5.1 Future Demand Growth and Incidents

One important use of simulation modeling is to investigate the impact of potential changes in supply and/or demand on traffic performance. The most obvious example of a change in supply is an incident (which reduces capacity of the roadway for a period) or time. For demand, a good example are the impacts of future growth (which will increase traffk demand). Both of these changes can **be** easily investigated using FREQ.

Using the calibrated FREQ simulations of the freeway (in both directions), changes in supply and demand (alone and in combination) were considered. (It was assumed that there was no corresponding increases in supply (e.g., additional lanes) or control changes.) On the demand side, traffic growth factors (from 1.00 to 1.10 in increments of 0.02) were applied using FREQ. The results (traffic performance) under these conditions were noted. Also, incidents were introduced to the system. For each freeway direction, two incident scenarios were used; they are described in Figure **33.**

Eastbound:

Incident A: **1** lane reduced capacity **from** 7:00 to 7:30 **A.M.**
subsection 14 (between the **NB** La Cienega off-ramp and **the** Fairfax on-ramp)

Incident B: **1** lane reduced capacity **from 4:00** to **430 P.M.**
0.5 lanes reduced capacity *from* 4:30 to 5:00 P.M.
subsection 27 (between the Arlington off-ramp and on-ramp)

Westbound:

Incident A: **1** lane reduced capacity **from** 7:00 to 7:30 **A.M.**
subsection **33** (between the **Fairfax** on-ramp and the **La** Cienega off-ramp)

incident B: **1** lane reduced capacity from **4**:00 to **4**:30 **P.M.**
0.5 lanes reduced capacity **from 4:30** to **5**:00 **P.M.**
subsection 22 (between the Crenshaw off-ramp **and** on-ramp)

Figure 33: Simulated Freeway Incidents

The results are shown in tabular form in Figure 34 for the westbound freeway. Every combination of growth factors and incidents was considered for both freeway directions. The data shown are average vehicle speeds for the entire simulation (12 hours). These data are graphed in Figure 35, which shows several general patterns. First, there is an approximately linear decrease in system performance as a function of demand growth. Most likely, this linear pattern would not be present for all growth factors, but it suggests a linear relationship could be a useful prediction of traffic performance given growth factors of 0 to 10%.

Growth Factor	Incident			
	none	A	B	A and B
1.00	50.0 mph	46.5 mph	48.2 mph	44.9 mph
1.02	47.4 mph	45.3 mph	46.4 mph	43.4 mph
1.04	45.2 mph	42.9 mph	44.5 mph	42.2 mph
1.06	43.5 mph	41.2 mph	43.1 mph	40.9 mph
1.08	41.8 mph	39.9 mph	41.6 mph	39.7 mph
1.10	40.3 mph	38.7 mph	40.2 mph	38.7 mph

Figure 34: Average Speeds With Incidents and Demand Growth Factors (Westbound)

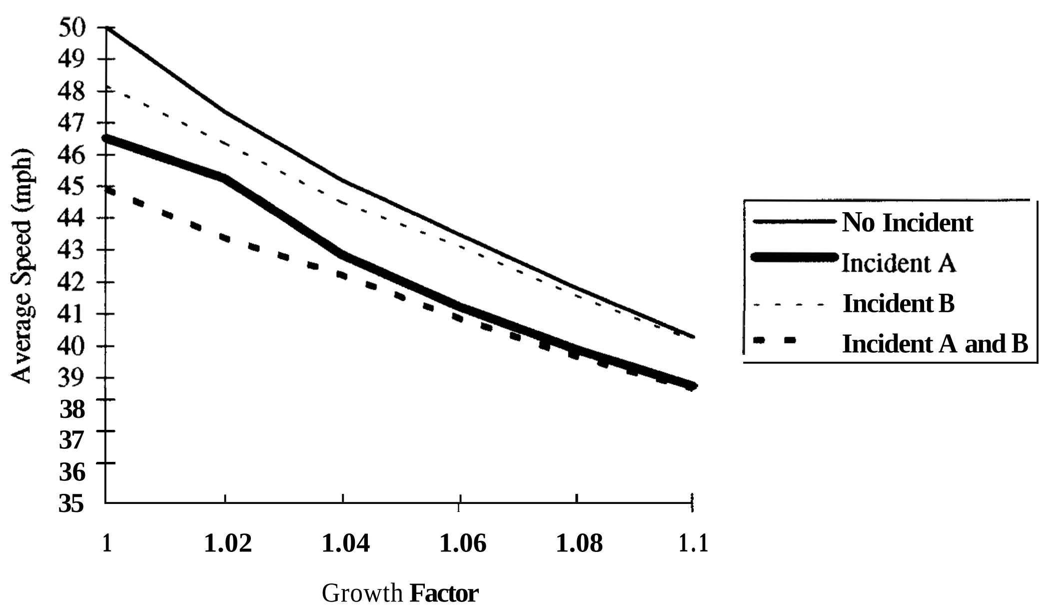

Figure 35: Graph of Average Speeds With Incidents and Growth Factors (Westbound)

The data shown in the previous graphs suggests the traffic performance from a user perspective. Also important is the system perspective, which is illustrated in the figures below. The data shown in Figure 36 are total passenger travel times for the fieeway system with different growth factors **and** incidents scenarios. Note the similar patterns of the curves, but also that a 10% increase in growth factor (in the no incident scenario) results in **an** increase in passenger travel time of over 50%. **Similar** results are found under the incident scenarios.

Growth Factor	Incident			
	none	A	B	A and B
1.00	21850 pax-hrs	23483 pax-hrs	23010 pax-hrs	24643 pax-hrs
1.02	23737 pax-hrs	25387 pax-hrs	24982 pax-hrs	26632 pax-hrs
1.04	25623 pax-hrs	27030 pax-hrs	26652 pax-hrs	29029 pax-hrs
1.06	27532 pax-hrs	28955 pax-hrs	28384 pax-hrs	29807 pax-hrs
1.08	30152 pax-hrs	31413 pax-hrs	30946 pax-hrs	32207 pax-hrs
1.10	33177 pax-hrs	34438 pax-hrs	33765 pax-hrs	35026 pax-hrs

Figure 36: Total Passenger Travel Times With Incidents and Demand Growth Factors (Westbound)

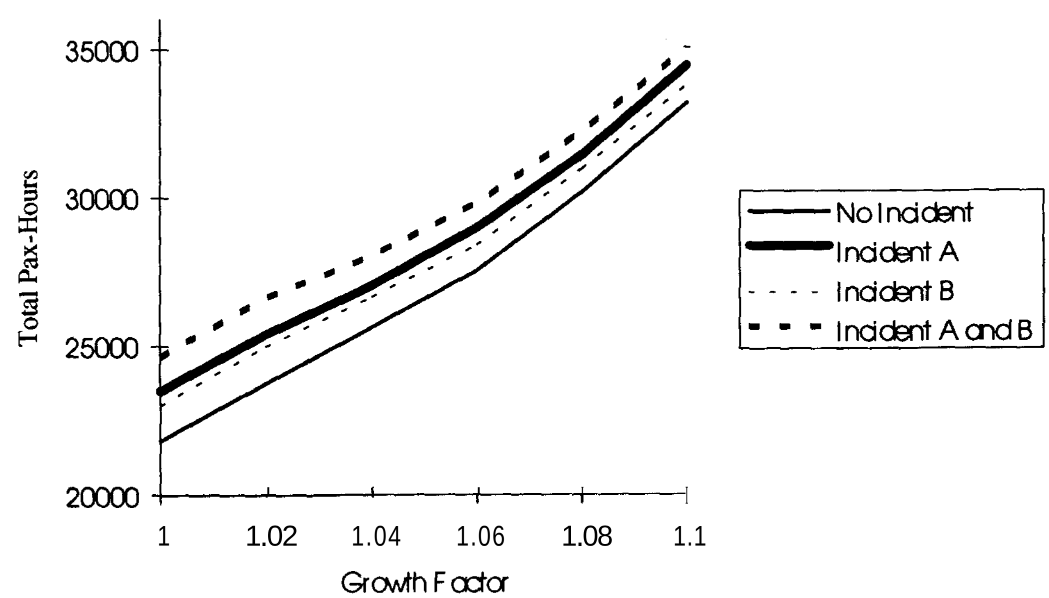

Figure 37: Graph of Total Passenger Travel Times With Incidents and Growth Factors (Westbound)

Note that in both cases, incident A causes more congestion that incident B. This is somewhat counter to what might be expected because incident B occurs during the afternoon rush hour, when traffic is heaviest in the westbound direction. What is probably occurring is that traffic is near capacity during the morning, but running at relatively high speeds. With the influence of incident A, however, there is enough reduction in capacity to make a significant change in system speeds. Incident B occurs when there is already significant congestion, so speed reductions are less significant. **(Similar** results occur in the eastbound direction. Incident B, during the afternoon **peak** period, has a greater impact than the incident during the morning **peak** period.) When both incidents are simulated, there is even a greater decrease in average system speeds.

These results are by no means a definitive study of the impact of growth or incidents. However, they should suggest possibilities for study using simulation. The investigations described here are straightforward to do using FREQ (or INTEGRATION) and more extensive studies of supply or demand changes could be performed using the calibrated simulations.

5.2 Ramp Metering Investigations

After considering the impact of supply and demand changes, an obvious next step was to look at control strategies. Ramp metering, a common control technique, can be an effective tool for managing freeway congestion. There are many sources of information about the benefits and limitations of priority entry controls, so the topic will not be considered here. Rather, this section will describe how the FREQ simulation of the freeway was used to perform basic ramp metering optimization.

As previously discussed, FREQ includes the functionality to specify two separate limiting values for ramp metering rates at each on-ramp to the freeway (if these values are the same, only one single plan will be simulated). These minimum and maximum values constrain the optimization routines in FREQ to metering rates in a given range. Values can be set differently for each ramp, and the two values can be the same (when **an** exact metering rate is known). *Also,* two different types of entry controls can be employed: normal and priority entry. The priority entry feature (used in this study) lets high occupancy vehicles bypass the metering lights at the ramps.

The HOV priority entry restriction must be specified: the minimum number of passengers needed for a vehicle to bypass the ramp meter and have unrestrained access to the fieeway. In this example, priority control was set at HOV-2. In terms of demand, an assumed split of 15% HOV-2 and 5% HOV-3 vehicles was implemented (these values agreed with limited occupancy data available). FREQ allows separate occupancy data to be entered for each ramp input, but these data were not available, so the same values were used at each on-ramp. With 20% of the vehicles given priority entry, the flow at a on-ramp is effectively increased by at least 20%. For example, ramp with a demand of 600 vehicles per hour will have 120 HOV vehicles per hour. If the metering rate were 400 vehicledhour, then 520 vehicles would enter the freeway: 400 non-HOV vehicles (who queue at the ramp meter) and 120 priority entry vehicles (who would bypass the queue), While Caltrans provided ramp metering data for the freeway (these could be applied using FREQ), it was decided to try to determine an optimal ramp metering policy (that could be different than the one provided). Some experimentation with the FREQ ramp metering optimization procedure was needed to determine the best policy; this is explained here.

The first attempt was to set a minimum rate of 180 vehicledhour and a maximum rate of 900 vehicledhour at all on-ramps (except the freeway connectors from the I405 and SR110; these were left unmetered). Congestion was eliminated, but this was not a feasible solution because many ramps had demands much higher than 900 vehicledhour, and ramp queues with extremely long delays were present. Therefore, maximum rates at selected ramps (where demand was greater than 1200 vehicledhour) were increased to 1800 vehicledhour and the minimum rate was doubled, to 360 vehicledhour. There are two possible physical interpretations of this strategy. First, it could be assumed than an extra lane could be added on these ramps (so that there would be 1 HOV priority entry lane and 2 regular lanes). More practically, the meters could be set so that two vehicles are allowed through in each meter cycle.

Also, metering was introduced at the freeway connectors (using a metering rate range of 360 to 1800 vehicledhour) to further limit freeway traffic. The result (for both directions) was that mainline congestion was eliminated, but excessive queues were forming at some on-ramps. The final step was to introduce queue limits at selected ramps.

Using *trial* and error, these queue limits were set at 40, 100, or 200 vehicles at various ramps. With the combination of minimum/maximum metering rates, connector metering, and ramp queue limits, congestion was nearly completely eliminated from the freeway. Figure **38** highlights the results.

Eastbound:

Min/Max Metering Rates:	180/900 *or* 360/1800 vehicledhow at all ramps
Connector Metering:	360/1800 vehicledhour minimum/maximum
Queue Limits:	100 *or* 200 vehicles at all ramps and connectors
Results:	Small queues (1-2 subsections) for 30-60 minutes in A.M. No congestion during P.M. Average mainline speed increased from 46.7 to 53.8 mph

Westbound:

Min/Max Metering Rates:	180/900 *or* 360/1800 vehicles/hour at all ramps
Connector Metering:	360/1800 vehicles/hour minimum/maximum
Queue Limits:	40 *or* 100 vehicles at all ramps and connectors
Results:	Very small queues (<1 subsection) for 30 minutes in P.M. No congestion during A.M. Average mainline speed increased from 50.0 to 54.5 mph

Figure 38: Ramp Metering Strategies and Results

Again, these results should not necessarily be interpreted as the final word on optimal ramp metering strategy for the Santa Monica Freeway. For example, spatial and modal responses are important considerations for a ramp metering system; these were not considered here (only day+1 conditions were modeled). Rather, it is hoped that these results are suggestive of the use and power of simulation as one of many tools for analyzing traffic management strategies like ramp metering. Now, another strategy (HOV control) will be considered.

5.3 HOV Implementations

High-occupancy vehicle (HOV) facilities are much discussed as an **ATMS** strategy. In contrast to the priority entry controls discussed in the previous section (where a specific vehicle occupancy allows drivers to bypass ramp meters), priority lane HOV facilities are dedicated on-freeway lanes where only HOV vehicles may travel. In many areas of the country (e.g., Seattle, Houston, Washington **D.C.**, Los Angeles, and the San Francisco Bay Area) HOV lanes are currently being used as part of a (mainline) freeway facility and are under study in many others.

However, much is still unknown about the best way to utilize these facilities. At first glance, implementation of a HOV lane should promote carpooling and reduce congestion, energy use, and air pollution. However, obtaining a quantitative estimate for these reductions is often difficult without a systematic investigation. Without these data, any realistic analysis of the tradeoffs between the facilities value and its costs are impossible. More importantly, while it may be possible to determine the immediate (day+1) effects, the long-term impacts of HOV facilities are far more difficultto predict.

In any case, simulation modeling of freeways that include HOV facilities has been recognized as a valuable approach. This section describes some initial investigations of HOV facilities that were undertaken using the FREQ simulation of the Santa Monica Freeway.

Before describing the HOV simulations using the FREQ model, a brief discussion of the capabilities of FREQ for HOV modeling may be appropriate. The FREQ11PL model adds HOV functionality to FREQ. The program allows the user to specify the creation of an HOV lane that will be added to the existing facility. (To model a scenario where an existing mixed-flow lane is replaced by an HOV lane, the number of lanes and capacity is first reduced in the affected subsections, and then an HOV lane is added). The new HOV lane can be "built" alongside any or all of the existing freeway, and the capacity and speed-flow relationship of the new lane can be specified. Also, barriers between the HOV and mixed-flow lanes (where non-HOV vehicles may travel) can be specified. These barriers force exiting HOV vehicles to enter the mixed-flow lanes at some point. For example, in Figure **39,** HOV vehicles wishing to exit at off-ramp **3** in must enter the mixed-flow mainline lanes before off-ramp 1 to ensure they will be able to exit.

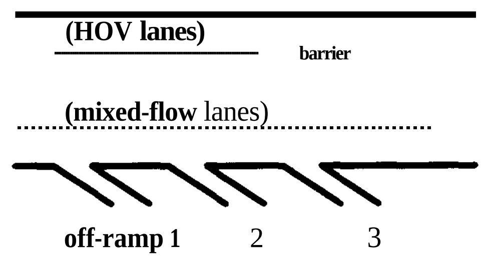

Figure 39: HOV Barriers in FREQ

Finally, FREQ allows specification of the HOV cutoffs for the new facility. This level can be HOV2+ (i.e., vehicles with occupancy of at least two passengers may use the lane), HOV3+, or buses only. For each on-ramp in the system, a breakdown of vehicles by occupancy must be specified. The system defaults are 80% single occupancy vehicles (SOV's), 15% HOV2's, 5% HOV3's (or greater), and 0% buses. The occupancy of the HOV3+'s (vehicles with at least 3 passengers) has a default value of 3.2 passengers, and buses have a default occupancy of 40 passengers. Both of these parameters can be modified.

Using the FREQ11 model, simulation output for a number of scenarios can be generated. In every case, a baseline model (often called day-1) is simulated, where HOV and non-HOV vehicles both use the existing facilities (together). Then, freeway conditions (for both the HOV and mixed-flow lanes) after implementation of the HOV lane(s) are provided by the simulation. In addition to these day+1 conditions, FREQ also provides the facility to simulate spatial shift (to/from a parallel arterial) and modal shift (to carpools and/or buses); these features are not explored here.

FREQ is limited by an assumption that the HOV lanes and the existing (mixed-flow) lanes can be modeled as two separate facilities. HOV vehicles will only use the mixed-flow lanes when they entering the system from an on-ramp or exiting to an off-ramp. If they are able, they will always use the HOV lanes. This assumption breaks down when congestion on the HOV facility is greater than that on the mixed-flow lanes (in general this is an inappropriate design, but it can occur in both real and simulated system). In these instances, HOV vehicles should exit the HOV lanes and balance traffic among the two facilities, This will not occur in FREQ; this limitation is exampled later in this discussion.

The FREQ simulation of the freeway was easily modified to support a variety of HOV investigations. Attention was given to the "add a lane" scenario, where the existing network was simulated with an additional priority (HOV only) lane. For this case, the only modifications to the freeway were made under the "HOV operational design" menu in FREQ, where the specifications of the new HOV lane are permitted. For the eastbound freeway, a single HOV lane was added to the Santa Monica Freeway between the National off-ramp (at the start of subsection 5) and the Hoover on-ramp (at the end of subsection 39). Therefore, the HOV section covered the entire freeway between the freeway interchanges. (The new lane was assumed to have a capacity of 1600 vehicles/hour (the FREQ default) and no barriers were included. **A** cutoff level of HOV2+ (vehicles were required to have at least two passengers to **use** the HOV lane) was used.

Due to personnel time and resource limitations, HOV facilities were added to only the eastbound fi-eeway. Doing so allowed more in-depth studies of HOV analysis than could be accomplished using both directions. However, it is thought that the results described here should be applicable to the westbound freeway **as** well.

One critical unknown was the vehicle occupancy in the system. **A** limited study by Caltrans suggested about 10% HOV-2 vehicles, but it was thought important to vary this percentage to attempt a sensitivity analysis. (Actually, what was varied was the percentage of ***passengers*** in HOV vehicles. For example, if the average occupancy of HOV vehicles is 2.2 passengers/vehicle, and the percentage of HOV vehicles is 12%, then about 23% of all passengers will be in HOV vehicles. **A** simple algebraic derivation relates the two factors, and percentage of HOV passengers parameter was used as the dependent variable.)

Multiple runs with varying occupancy levels on the new HOV system were compared to each other and the baseline (day-1) conditions. Eight hours of demand data were used, but the simulations were run for nine hours (including a concludmg hour of zero demand) to allow vehicles queued at the end of the last time slice to complete their trips and be counted. In each case, the parameters of interest were the average trip speeds and trip times for both HOV and non-HOV vehicles; the results are shown in Figure 40.

Several points might be made about these data. In the baseline run (not shown) with 10% HOV vehicles, the average trip time is about 6 minutes for all vehicles (with a system speed of 47 mph). Once the HOV lane is added, overall speeds should increase (and travel times decrease) because more roadway capacity is in place. The run with 20% HOV passengers (and 10.2% HOV vehicles) provides the most direct comparison, because the total number of vehicles remains constant. In this scenario, average speeds increase to about **49** mph and average trip times decrease to 5.7 minutes (about 20 seconds, or ***6%).*** Not surprisingly, the HOV vehicles are enjoying most of the benefit, with a trip time of just under four minutes, while the non-HOV vehicles only get about a **6** second average trip time improvement from the baseline. Overall travel times decrease about 700 hours, to 12881 vehicle-hours.

The trends in vehicle speeds are shown in Figure 41. ***As*** might be expected, the performance of the HOV lane degrades as vehicle occupancies increase. Overall, though, the system improves with occupancies because the number of vehicles decreases. Also, note that at 27% HOV passengers (equivalent to 14.4% HOV vehicles), the performance for HOV vehicles is actually worse than the non-HOV vehicles. This result might be easily predicted given the geometry and the model. The eastbound freeway has seven lanes near the east end (close the downtown L.A.) and is congested during the morning rush hour. If exactly one-seventh of the traffic (or 14.3%) were forced to **use** a parallel one lane facility (assuming identical capacity), nearly the same traffic conditions should result. With a slightly higher percentage (or slightly lower capacity), the one-lane system would be overloaded. This is exactly what is occurring in the last line of Figure 40. With 14.4% of the vehicles forced to take a parallel one-lane facility (with slightly lower average capacity), the congestion is worse on the HOV lane that the mixed-flow lanes. Unfortunately, FREQ does not allow HOV traffic to shift back to the mixed-flow lanes if it is advantageous. This result is borne out in the results from higher-occupancy runs, where the model crashes. In these cases, there is simply too much HOV traffk for the new facility, and it is overloaded. (In these cases, a better design to consider might be one that includes a higher cutoff level for HOV vehicles.) Investigations where HOV vehicles can divert to mixed-flow facilities are more difficult to do with FREQ, and might be better undertaken with another model.

		Trip Speeds (mph)			Trip Times (min)		
%HOV pax	%HOV vehicles	HOV vehicles	non-HOV vehicles	all vehicles	HOV	non-HOV vehicles	all vehicles
0.0	0.0	NA	30.9	30.9	NA	8.6	8.6
1.0	0.5	61.3	32.6	32.6	3.8	8.2	8.2
2.0	0.9	61.6	32.7	32.8	3.8	8.2	8.2
3.0	1.4	61.4	33.8	34.0	3.8	8.0	8.0
4.0	1.9	61.6	33.9	34.1	3.8	8.0	7.9
5.0	2.3	61.3	35.2	35.5	3.8	7.7	7.6
6.0	2.8	61.2	36.5	36.9	3.8	7.5	7.4
7.0	3.3	61.2	36.7	37.1	3.8	7.5	7.4
8.0	3.8	61.1	38.0	38.4	3.8	7.3	7.1
9.0	4.3	60.9	38.3	38.8	3.8	7.2	7.1
10.0	4.8	60.8	39.2	39.7	3.8	7.1	6.9
11.0	5.3	60.6	41.1	41.7	3.9	6.8	6.6
12.0	5.8	60.5	41.1	41.8	3.9	6.8	6.6
13.0	6.4	60.5	42.9	43.6	3.9	6.5	6.4
14.0	6.9	60.3	44.1	44.8	3.9	6.4	6.2
15.0	7.4	60.2	44.0	44.8	3.9	6.5	6.2
16.0	8.0	60.0	45.3	46.1	3.9	6.2	6.1
17.0	8.5	60.0	45.3	46.1	3.9	6.2	6.0
18.0	9.1	59.8	47.2	48.0	3.9	6.0	5.8
19.0	9.6	59.7	48.6	49.4	3.9	5.9	5.7
20.0	10.2	59.5	48.6	49.4	3.9	5.9	5.7
21.0	10.8	59.4	49.8	50.5	3.9	5.8	5.5
22.0	11.4	59.2	49.7	50.5	3.9	5.8	5.5
23.0	12.0	58.9	50.8	51.5	4.0	5.6	5.4
24.0	12.6	57.1	52.1	52.6	4.1	5.5	5.3
25.0	13.2	53.0	52.1	52.2	4.4	5.5	5.3
26.0	13.8	48.6	53.1	52.5	4.8	5.4	5.3
27.0	14.4	42.4	53.1	51.5	5.5	5.4	5.4

Figure 40: Traffic Performance With Different Vehicle Occupancies

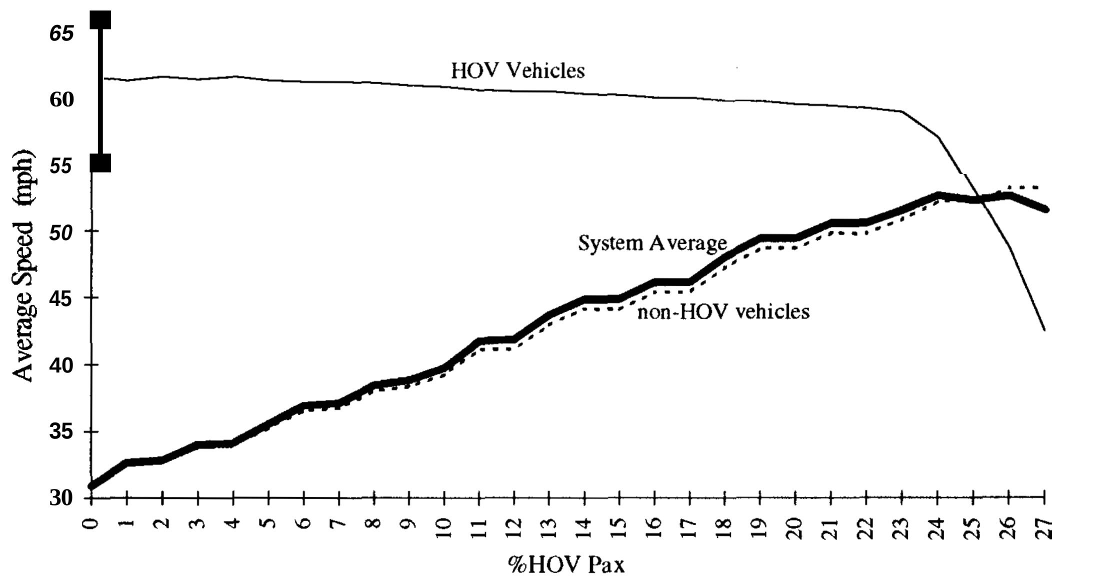

Figure 41: Average Speeds with HOV Control

Section 6: Conclusions

The simulations of the Santa Monica Freeway described in this report should by no means **be** viewed as the ultimate goal of this research. While investigations like the ones described in the previous sections can be useful studies, even more important results should come from work with the full corridor network. The development of the freeway simulations should primarily be considered **as** a means to that end. The development of the complete corridor model is nearly complete as of this writing and the freeway simulations are a major part of that model.

At the same time, however, some important findings have come from this work, and they are worth considering here. This section will examine the strengths and limitations of each of the models (FREQ and INTEGRATION) and provide some advice for anyone using the models. Also, some suggestions for potential future research are offered. The benefits of simulation modeling are becoming more widely known, but much more work is needed to test **and** apply these models. FREQ and INTEGRATION are both viable tools for a wide variety of modeling efforts, and it is hoped that the work discussed in this report will encourage others to do further research with one or both of these simulations.

6.1 General Comments

Before looking at the two models, it is appropriate to make a general statement about data collection for simulation modeling. At first glance, the data collection required to simulate a traffic network may not seem overwhelming. However, the time and resources needed to collect data for the Santa Monica Freeway (not a huge network) were underestimated. Even though much effort was invested in data collection, more data would have been beneficial. It is hoped that developers of other network simulations will consider that overestimating the effort for data collection is not likely, and that some desirable data may not **be** available. Also, the approaches and techniques for data collection described in Section **2** may be helpful to others involved in **similar** efforts.

6.2 FREQ

Overall, FREQ is an effective tool for freeway modeling that is relatively easy to **use** and apply. The data requirements are not insignificant (at a minimum, roadway geometries and flows must be known, and estimates of the capacities and speedflow curves for each section must be made), but they are not unreasonable. The data input process is straightforward, although it can be tedious at times. FREQ's interface in relatively intuitive, and function keys are **as** consistent **as** possible throughout the model. For some functions, there are several layers of menus that may get confusing, but the basic data input process can be accomplished with minimal training. The biggest drawback of FREQ's input routines is the fact that everything must **be** typed directly into the model. Since the file formats are proprietary, there **is** no way to automate the simulation model development process (i.e., through a spreadsheet or utility program). Without "cut and paste" or other common editing facilities, much data entry is needed to create a FREQ simulation.

Simulation runs are fast and easy to do using FREQ. The simulation times were always measured in seconds, so multiple runs (e.g., for sensitivity analysis) could be done quickly. Unfortunately, there is no easy way to automate the process (i.e., to set up batch runs), but making a run requires only a few keystrokes, so this may not be a big issue. The results (output files) are easy to use and understand, and FREQ gives the option of specifying which output data are produced with each run. The contour maps in the output files are an excellent way of quickly determining traffic performance, and much of the other data are in tabular form that is easy to manipulate.

In terms of functionality, FREQ's biggest (and most obvious) limitation is the types of networks that can be modeled. Only uni-directional freeway segments (with or without a set of parallel arterials) can be coded. For some network features (e.g., the 1-405 on-ramps to the eastbound freeway and the parallel collector/distributor lanes), it is possible to work around this limitation with some coding techniques. In other cases, it may be impossible, so some networks cannot be modeled with FREQ. For freeway networks, however, FREQ provides particularly good functionality: automatic origin-destination synthesis, ramp metering optimization, incident simulation, and modeling of HOV facilities are all included. *Also,* freeway corridor studies using FREQ can use its spatial and modal response features. For most simulations of freeway networks, FREQ should be a sound choice.

6.3 INTEGRATION

The INTEGRATION model should also be considered as a potential freeway modeling program. However, many of its strongest features are not relevant to a freeway-only study, while nearly all of its limitations are. For the project described here (where a freeway-only network was developed as a subset of an entire freeway corridor), INTEGRATION was a sound decision, but developers of simulations of networks consisting of only a fkeeway (and perhaps a parallel arterial) should consider the comments here.

INTEGRATION also can be used to develop simulations relatively quickly. For any simulation, much data is required, and INTEGRATION is no different. However, network data (flows, geometries, capacities, speed-flow relationships, and control information) are all straightforward. The only caution is that the origin-destination synthesis program (QUEENSOD) in INTEGRATION was not thoroughly tested for the Santa Monica Freeway, so the quantity and accuracy of traffic data needed as input for the demand data estimation process is not known. In terms of data input, INTEGRATION's external input files permit automation and easy editing that greatly speed the simulation development time. However, the input files **do** include many different parameters, so the program requires start up time to learn these parameters. No user interface is included for data entry; this probably limits novice users. Perhaps the best interface would be a combination of those from FREQ and INTEGRATION: an automated interface that allowed novice users to easily create files, and an accessible file format so that more experienced developers could automate the input file creation process.

Perhaps the biggest limitation of INTEGRATION at present is its performance. For the simulations of the freeway (with about 100 nodes and links) for twelve hour periods, the run times were measured in hours. For the earlier version of the model (1.5a), the runs were **2-4** hours, and these times increased to 20-30 hours for version 1.5d. Although it is easy to set up batch runs, the long run times effectively prohibit detailed sensitivity analyses. Finally, the output files give a great deal of traffic performance data, but some manipulation is necessary. Programs (like the INTOMAN program described in this report in Appendix 4) may be required to efficiently use the output from INTEGRATION.

INTEGRATION probably provides more functionality than any other simulation tool. Nearly any conceivable network can be modeled (within the limitations of available computer resources), so highly realistic models can be developed. Its ability to model IVHS features (route guidance, HOV facilities, driver information, and incidents) is impressive and can be used to perform some interesting studies. Some of its features are somewhat limited (e.g., signals can only be optimized for single intersections but not networks, and ramp metering rates are constrained to certain values), but the model is being refined. For freeway networks, INTEGRATION may not be the most efficient model to use, though its features and potential for network modeling should be considered carefully if the freeway study is expanded to a larger area.

6.4 Recommendations for Future Work

To complete this report, a few possible studies extending fi-om the work presented here are provided. This is not an exhaustive list, but it may be useful starting point. The possibilities for future studies are:

- More data are needed for the Santa Monica Freeway before making any definitive statement about the applicability of IVHS strategies to the real network. The lack of robust detector data throughout the network is not a promising sign for a system that is data intensive. The simulations described here provided a feasible means for study of the features of FREQ and INTEGRATION, but they have been developed around a "typical day" on the freeway which has not been thoroughly compared with the real-life network.
- More research is needed on the new speedflow relationships and car-following models introduced in version 1.5 of the INTEGRATION model. Previous work at UC Berkeley validated earlier versions of the model (ie., 1.4), but similar studies are essential before INTEGRATION can be used for any definitive simulation work.
- QUEENSOD was not extensively tested for the freeway simulations. Obviously, for the complete corridor network, QUEENSOD will be critical because the origin-destination synthesis routines in FREQ will not be applicable to the entire network. Therefore, a study of the use, strengths, and limitations of QUEENSOD with respect to a large network (like the Santa Monica Freeway Corridor) is needed.
- Finally, the studies outlined in Section 5 were limited. As a first step, it would be desirable to repeat the demand growth, ramp metering, and HOV investigations with INTEGRATION. Then, more complexities could be added to the experiments to gain further knowledge on both the use and applications of FREQ and INTEGRATION and the potential benefits of IVHS strategies on the Santa Monica Freeway.

Appendix 1: Demand Data

The charts on the following pages contain the complete demand data collected for the Santa Monica Freeway. Section 2.2 in the main report describes these data and the process by which they were obtained. As mentioned previously, this may be the best available single source of these data, so they are provided here for reference.

To make these data readable, the charts were split into two sets of pages. Each line on pages 52-59 is a single source of demand data for a single location on the freeway (e.g., the Overland on-ramp to the eastbound freeway as captured by the MODCOMP system on Tuesday May 25, 1993). Each subsequent column is the hourly flow observed (measured in vehicledhour) for half hour time slices from 6:00 A.M. to 11:30 A.M. Pages 60-67 contain similar information for the remainder of the typical day. Each line contains the observed flows at the same locations from 11:30 A.M. to 8:00 P.M.

Location	Dir	Source	Date	600	630	ROO	7:30	8:00	8:30	9:00	930	1000	1030	11:00
West of I405	EB	(SIMULATION DATA)	10/04/93	1810	3005	3776	4806	5924	5934	5019	4199	3625	3928	4326
		calculated		1818	3018	4394	5228	5648	5658	5040	4618	4042	3944	4344
		Previous UCB studies	1980s	I499	2854	3648	3856	4271	4409	3814	3657			
NB 1-405 **on ramp**	EB	(SIMULATION DATA)		1553	1474	1418	1291	966	1048	1611	1834	1846	1878	1878
		Smart Corridor data	11/21/90	1520	1520	1360	1360	1010	1010	1730	1730	1870	1870	1850
		(converted)		1560	1480	1424	1296	970	1052	1618	1842	1854	1886	1886
SB 1-405 **on ramp**	EB	(SIMULATION DATA)		1269	1679	2161	2420	2480	2460	2259	2163	2129	2053	1900
		Smart Corridor data	11/21/90	1480	1480	2300	2300	2480	2480	2220	2220	2100	2100	1920
		(converted)		1274	1686	2170	2430	2490	2470	2268	2172	2138	2062	1908
I-405 on ramps (after merge)	EB	(SIMULATION DATA)		3193	3356	3587	3615	3336	3434	3916	4099	4067	4135	4280
		Caltrans Hourly Count	WED 05/16/90	3288	3288	3616	3616	3399	3399	4023	4023	4118	4118	4300
		(converted)		3206	3370	3602	3630	3350	3448	3932	4116	4084	4152	4298
		Smart Corridor data	11/21/90	3000	3000	3660	3660	3590	3590	3950	3950	3970	3970	3770
		(converted)		2834	3166	3584	3736	3554	3626	3902	3998	3994	3948	3792
		Previous UCB studies	1980s	2272	3089	3283	2991	2979	3093	3263	3236			
National off ramp	EB	(SIMULATION DATA)		388	540	683	842	1052	1159	1209	1161	898	944	1297
		Caltrans Hourly Count	TUE 11/14/89	466	466	766	766	1109	1109	1190	1190	925	925	1384
		(converted)		390	542	686	846	1056	1164	1214	1166	902	948	1302
		Previous UCB studies	1980s	467	529	709	872	947	1016	994	871			
		ATSAC data	TUE 10/19/93	758	982	1254	1266	1594	1462	1552	1440	1454	1346	1494
Overland on ramp	EB	(SIMULATION DATA)		665	852	1093	1181	1113	1066	970	930	950	906	783
		Caltrans Hourly Count	TUE 11/14/89	762	762	1141	1141	1094	1094	954	954	932	932	788
		(converted)		668	856	1098	1186	1118	1070	974	934	954	910	786
		MODCOMP **data**	TUE 05/25/93	400	820	650	730	780	720	700	700	920	910	900
		MODCOMP data	WED 05/26/93	450	810	700	790	930	750	690	750	860	870	850
		MODCOMP data	THU 05/27/93	480	840	740	750	1030	870	690	760	850	840	940
		Previous UCB studies	1980s	571	772	1010	1101	900	885	776	755			
Mainline 6.745 **(Motor)**	EB	Caltrans Hourly Count	WED 09/19/90	6001	[illegible]	8803	8803	9036	9036	8617	8617	8119	8119	8135
		(converted)		5302	6702	8408	9198	9060	9012	8732	8502	8178	8058	8126
		Caltrans Hourly Count	TUE 06/16/92	6078	6078	8742	8742	7302	7302	9450	9450	8099	8099	7885
		(converted)		5412	6744	8578	8904	7218	7386	9346	9554	8290	7906	7810
		MODCOMP data	TUE 05/25/93	4140	7040	9190	8440	8370	8310	8260	8400	7800	7590	7280
		MODCOMP data	WED 05/26/93	4440	7200	8890	8490	8160	7860	8260	7880	7200	7430	7620
		MODCOMP data	THU 05/27/93	4340	7310	9130	8460	8060	8120	8300	8170	7710	7770	7600
Manning on ramp	EB	(SIMULATION DATA)		190	490	570	520	470	490	530	470	460	400	400
		Caltrans Hourly Count	TUE 11/28/89	369	369	543	543	513	513	484	484	432	432	39I
		(converted)		326	414	524	560	520	506	494	474	444	420	394
		MODCOMP data	TUE 05/25/93	190	490	570	520	470	490	530	470	460	400	400
		MODCOMP data	WED 05/26/93	220	490	590	420	520	460	580	480	460	380	430
		MODCOMP data	THU 05/27/93	190	480	590	520	500	490	480	460	440	380	450
		Previous UCB studies	1980s	211	357	387	358	372	405	382	337			
Robertson off ramp	EB	(SIMULATION DATA)		323	528	752	926	1091	1101	900	859	920	929	916
		Caltrans Hourly Count	TUE 11/28/89	419	419	826	826	1079	1079	866	866	909	909	897
		(converted)		318	520	740	912	1074	1084	886	846	906	914	902
		Previous UCB studies	1980s	447	529	579	864	927	1012	1003	931			
Mainline 7.99 **(National)**	EB	MODCOMP data	TUE 05/25/93	3850	6920	8980	7290	7550	7780	8070	7880	7550	7010	7420
		MODCOMP data	WED 05/26/93	4050	7010	8610	7330	6860	7330	8350	7600	7170	7120	7210
		MODCOMP data	THU 05/27/93	3960	7080	8900	7900	7030	7950	7780	7550	7330	7260	7500
		MODCOMP data	TUE 12/08/92	3890	6196	7894	7220	6882	6876	6922	7044	6932	6894	6800

Location	Dir	Source	Date	6:00	630	7:00	730	800	830	900	930	1000	1030	11:00
National on ramp	EB	(SIMULATION DATA)		260	470	440	390	380	390	540	630	690	800	730
		Caltrans Hourly Count	TUE 11/28/89	389	389	509	509	486	486	614	614	664	664	708
		(converted)		360	420	496	522	474	500	592	638	652	676	698
		MODCOMP data	TUE 05/25/93	260	470	440	390	380	390	540	630	690	800	730
		MODCOMP data	WED 05/26/93	270	470	420	390	370	390	530	580	630	650	580
		MODCOMP data	THU 05/27/93	280	470	400	460	360	470	480	580	640	660	690
		Previous UCB studies	1980s	351	374	332	336	322	339	400	404			
		ATSAC data	TUE 10/19/93	86	114	136	224	112	156	86	60	72	64	78
SB La Cienega off ramp	EB	(SIMULATION DATA)		59	100	148	I73	173	181	197	203	199	209	242
		Caltrans Hourly Count	TUE 11/28/89	78	78	159	I59	174	I74	198	198	201	201	241
		(converted)		58	98	146	170	I70	178	194	200	196	206	238
		Previous UCB studies	1980s	52	99	129	I29	126	135	152	I75			
SB La Cienega on ramp	EB	(SIMULATION DATA)		390	540	660	560	600	620	580		600	590	600
		Caltrans Hourly Count	TUE 11/28/89	505	505	598	598	598	598	640	640	661	661	617
		(converted)		482	528	588	608	592	604	632	648	664	658	612
		MODCOMP data	TUE 05/25/93	390	540	660	560	600	620	580	400	0	0	420
		MODCOMP data	WED 05/26/93	360	500	550	510	580	580	580	500	600	590	600
		MODCOMP data	THU 05/27/93	310	430	560	490	410	500	520	540	520	540	520
		Previous UCB studies	1980s	61	279	312	385	380	500	452	507			
NB La Cienega off ramp	EB	(SIMULATION DATA)		179	297	410	538	725	788	725	707	699	681	634
		Caltrans Hourly Count	TUE 11/28/89	234	234	468	468	745	745	705	705	679	679	625
		(converted)		176	292	404	530	714	776	714	6%	688	670	624
		Previous UCB studies	1980s	142	I76	237	413	491	501	530	563			
Fairfax off ramp	EB	(SIMULATION DATA)		170	270	320	450	440	620	620	530	570	480	560
		Caltrans Hourly Count	TUE 11/28/89	221	221	436	436	604	604	593	593	486	486	525
		(converted)		168	274	388	484	582	624	608	578	494	478	526
		MODCOMP data	TUE 05/25/93	170	270	320	450	440	620	620	530	570	480	560
		MODCOMP data	WED 05/26/93	170	270	330	460	410	530	620	600	460	470	440
		MODCOMP data	THU 05/27/93	170	270	360	480	450	630	560	550	490	460	510
		Previous UCB studies	1980s	151	179	252	251	300	318	372	359			
		ATSAC data	TUE 10/19/93	376	552	674	814	936	898	852	8%	754	780	786
Mainline 9.21 (Fairfax)	EB	MODCOMP data	TUE 05/25/93	4130	7000	8870	7310	7260	7720	7790	7970	7700	7540	7440
		MODCOMP data	WED 05/26/93	4210	7350	8680	6790	7110	7230	8160	7830	7260	7120	7320
		MODCOMP data	THU 05/27/93	4200	7270	8960	7500	6740	8320	7660	7580	7420	7360	7570
		MODCOMP data	TUE 12/08/92	4502	7733	9223	8100	6965	7680	7466	8064	7442	7750	7570
Venice on ramp	EB	(SIMULATION DATA)		258	289	317	349	386	400	392	376	331	339	417
		Caltrans Hourly Count	TUE 11/28/89	269	269	328	328	387	387	378	378	330	330	421
		(converted)		254	284	312	344	380	394	386	370	326	334	410
		MODCOMP data	TUE 05/25/93	120	210	340	270	270	320	300	290	370	410	280
		MODCOMP data	WED 05/26/93	120	230	290	290	270	320	270	270	270	230	230
		MODCOMP data	THU 05/27/93	110	220	270	280	270	310	260	250	230	240	200
		Previous UCB studies	1980s	339	38I	607	636	515	473	385	346			
Washington on ramp	EB	(SIMULATION DATA)		944	956	980	966	890	892	968	992	980	996	1032
		Caltrans Hourly Count	TUE 11/28/89	954	954	977	977	895	895	984	984	992	992	1052
		(converted)		948	960	984	970	894	896	972	996	984	1000	1036
		Previous UCB studies	1980s	587	1029	975	894	796	766	858	815			
SB La Brea off ramp	EB	(SIMULATION DATA)		69	95	132	I38	108	116	163	181	185	189	I87
		Caltrans Hourly Count	TUE 12/05/89	81	81	133	133	110	110	168	168	183	183	188
		(converted)		68	94	130	136	106	114	160	178	182	186	184
		Previous UCB studies	1980s	80	86	I04	110	146	77	110	131			
		ATSAC data	TUE 10/19/93	134	I26	176	150	172	172	222	134	274	274	284

Location	Dir	Source	Date	6:00	630	7:00	7:30	800	830	900	930	1000	10:30	11:00
SB La Brea on ramp	EB	(SIMULATION DATA)		440	530	440	480	400	450	420	490	510	520	570
		Caltrans Hourly Count	TUE 12/05/89	566	566	674	674	528	528	552	552	520	520	59R
		(converted)		538	594	678	668	542	514	552	552	516	526	582
		MODCOMP data	TUE 05/25/93	440	530	440	480	400	450	420	490	510	520	570
		MODCOMP data	WED 05/26/93	360	550	420	460	420	450	440	450	520	500	510
		MODCOMP data	THU 05/27/93	380	520	430	390	390	430	470	510	470	490	550
		Previous UCB studies	1980s	422	478	424	356	318	393	413	450			
Mainline 10.53 (La Brea)	EB	MODCOMP data	TUE 05/25/93	4520	7530	8530	6740	7320	7480	7460	7920	7550	7180	7440
		MODCOMP data	WED 05/26/93	4570	7610	8050	6670	6760	7130	7680	7700	7270	7270	7360
		MODCOMP data	THU 05/27/93	4570	7560	8240	6820	6930	7600	7750	7670	7320	7600	7530
		MODCOMP data	TUE 12/08/92	4584	7542	8686	7718	7130	7666	7446	7938	7190	7494	7338
NB La Brea off ramp	EB	(SIMULATION DATA)		180	250	350	260	210	390	470	590	870	560	600
		Caltrans Hourly Count	TUE 12/05/89	215	215	242	242	323	323	430	430	417	417	474
		(converted)		208	222	228	254	298	346	418	442	412	422	468
		MODCOMP data	TUE 05/25/93	180	250	350	260	210	390	470	590	870	560	600
		MODCOMP data	WED 05/26/93	180	270	350	240	130	270	460	260	280	490	500
		MODCOMP data	THU 05/27/93	150	300	330	280	240	300	190	470	280	500	540
		Previous UCB studies	1980s	165	202	240	249	249	267	362	438			
NB La Brea on ramp	EB	(SIMULATION DATA)		590	940	1040	840	730	790	720	630	680	450	660
		Caltrans Hourly Count	TUE 12/05/89	830	830	852	852	738	738	660	660	605	605	601
		(converted)		824	836	864	840	762	714	678	644	612	598	5%
		MODCOMP data	TUE 05/25/93	590	940	1040	840	730	790	720	630	680	450	660
		MODCOMP data	WED 05/26/93	550	1030	1050	800	560	620	760	380	410	630	680
		MODCOMP data	THU 05/27/93	590	960	1020	790	750	570	210	620	360	660	620
		Previous UCB studies	1980s	799	827	844	694	626	664	594	768			
Mainline 10.710 (La Brea)	EB	Caltrans Hourly Count	WED 12/13/89	7850	7850	8686	8686	10262	10262	9880	9880	8988	8988	9208
		(converted)		7640	8060	8388	8984	10110	10414	10040	9720	9070	8906	9204
		Caltrans Hourly Count	WED 09/30/92	7751	7751	10819	10819	9840	9840	9941	9941	9815	9815	9224
		(converted)		6984	8518	10546	11092	9948	9732	9944	9938	9904	9726	9292
crenshaw off ramp	EB	(SIMULATION DATA)		258	280	299	325	354	3%	471	504	502	4%	469
		Caltrans Hourly Count	TUE 12/05/89	265	265	306	306	368	368	480	480	491	491	465
		(converted)		254	276	294	320	348	390	464	4%	494	488	462
		Previous UCB studies	1980s	149	I65	264	262	251	236	312	353			
Mainline 11.53 (Crenshaw)	EB	MODCOMP data	TUE 05/25/93	5260	8940	9910	8610	9420	9240	9510	9190	8400	8110	8400
		MODCOMP data	WED 05/26/93	5390	9080	9560	8350	8750	9130	9460	8720	8290	8400	8390
		MODCOMP data	THU 05/27/93	5320	9000	10060	8450	8820	9420	9260	8830	8400	8580	8470
		MODCOMP data	TUE 12/08/92	5220	8563	9848	9180	8513	9164	8828	8621	7993	8043	8035
Crenshaw on ramp	EB	(SIMULATION DATA)		770	1030	1100	1060	890	830	860	840	840	800	790
		Caltrans Hourly Count	TUE 12/05/89	958	958	1069	1069	92I	92I	877	877	848	848	842
		(converted)		930	986	1074	1064	946	898	886	868	852	844	836
		MODCOMP data	TUE 05/25/93	770	1030	1100	1060	890	830	860	840	840	800	790
		MODCOMP data	WED 05/26/93	790	990	1090	1050	910	900	850	820	770	910	880
		MODCOMP data	THU 05/27/93	800	990	1070	1080	940	860	900	760	870	810	890
		Previous UCB studies	1980s	854	939	1004	1028	943	89I	797	768			
		ATSAC data	TUE 10/19/93	1290	1512	1564	1460	I244	I158	998	976	1054	986	1086
Arlington off ramp	EB	(SIMULATION DATA)		89	183	299	354	335	345	376	358	276	260	301
		Caltrans Hourly Count	TUE 12/05/89	I34	I34	32I	321	335	335	361	361	264	264	298
		(converted)		88	I80	294	348	330	340	370	352	272	256	296
		Previous UCB studies	1980s	49	99	188	228	283	298	242	206			
		ATSAC data	TUE 10/19/93	140	194	258	274	248	252	192	264	226	262	174

Location	Dir	Source	Date	6:00	630	7:00	7:30	800	830	900	9:30	1000	1030	11:00
Arlington on ramp	EB	(SIMULATION DATA)		681	829	1036	1056	894	769	599	492	412	382	422
		Caltrans Hourly Count	TUE 12/05/89	758	758	1051	1051	835	835	548	548	398	398	426
		(converted)		684	832	1040	1060	898	772	602	494	414	384	424
		Previous UCB studies	1980s	712	746	794	1060	762	681	593	433			
		ATSAC data	TUE 10/19/93	742	896	850	878	702	628	534	532	476	458	514
Western off ramp	EB	(SIMULATION DATA)		203	191	173	173	175	226	370	423	400	404	425
		Caltrans Hourly Count	THU 12/14/89	194	194	170	170	198	198	390	390	396	396	412
		(converted)		200	188	170	170	172	222	364	416	394	398	418
		Previous UCB studies	1980s	157	172	180	177	162	143	189	239			
		ATSAC data	TUE 10/19/93	128	144	148	162	164	166	224	230	266	288	304
Western on ramp	EB	(SIMULATION DATA)		520	740	780	710	560	480	490	560	500	550	600
		Caltrans Hourly Count	THU 12/14/89	632	632	606	606	574	574	490	490	571	571	609
		(converted)		638	626	614	600	588	558	490	490	556	586	598
		MODCOMP data	TUE 05/25/93	520	740	780	710	560	480	490	560	500	550	600
		MODCOMP data	WED 05/26/93	500	700	730	730	610	530	540	500	530	590	600
		MODCOMP data	THU 05/27/93	470	790	690	690	560	570	520	480	500	600	590
		Previous UCB studies	1980s	457	605	679	698	543	522	499	433			
		ATSAC data	TUE 10/19/93	570	686	612	578	576	400	496	402	462	514	512
Normandie off ramp	EB	(SIMULATION DATA)		148	238	315	431	679	658	339	262	313	311	299
		Caltrans Hourly Count	THU 12/14/89	190	190	367	367	658	658	2%	296	307	M 7	290
		(converted)		146	234	310	424	668	648	334	258	308	306	294
		Previous UCB studies	1980s	120	189	322	342	344	373	309	275			
Normandie on ramp	EB	(SIMULATION DATA)		508	512	524	502	445	427	439	427	380	384	443
		Caltrans Hourly Count	THU 12/14/89	502	502	505	505	428	428	427	427	376	376	444
		(converted)		500	504	516	494	438	420	432	420	374	378	436
		Previous UCB studies	1980s	377	409	411	397	377	289	283	230			
Vermont off ramp	EB	(SIMULATION DATA)		180	330	380	410	430	530	680	500	470	490	500
		Caltrans Hourly Count	THU 01/18/90	280	280	431	431	522	522	548	548	567	567	594
		(converted)		242	318	400	462	508	536	542	554	562	572	592
		MODCOMP data	TUE 05/25/93	180	330	380	410	4 M	530	680	500	470	490	500
		MODCOMP data	WED 05/26/93	170	300	390	380	370	460	540	610	440	530	500
		MODCOMP data	THU 05/27/93	210	300	430	420	480	470	580	490	630	440	490
		Previous UCB studies	1980s	2%	349	524	543	605	624	595	5%			
Mainline 13.95 (Vermont)	EB	MODCOMP data	TUE 05/25/93	5560	9020	8780	8510	8460	8060	8280	8210	7790	7390	7730
		MODCOMP data	WED 05/26/93	5620	9090	8510	8200	7970	8090	8080	7690	7420	7820	7880
		MODCOMP data	THU 05/27/93	5650	9170	8780	8280	8440	8150	8000	8050	7510	7810	7830
		MODCOMP data	TUE 12/08/93	4979	7941	8692	7356	7212	7507	7194	7246	7177	7060	7052
Vermont on ramp	EB	(SIMULATION DATA)		460	680	900	720	640	500	450	540	570	560	580
		Caltrans Hourly Count	THU 01/18/90	563	563	638	638	547	547	484	484	504	504	605
		(converted)		544	582	640	636	566	528	488	478	490	520	592
		MODCOMP data	TUE 05/25/93	460	680	900	720	640	500	450	540	570	560	580
		MODCOMP data	WED 05/26/93	450	690	680	710	530	460	510	530	500	530	600
		MODCOMP data	THU 05/27/93	420	680	680	720	580	470	500	590	540	550	510
		Previous UCB studies	1980s	276	388	367	621	344	286	276	313			
Hoover off ramp	EB	(SIMULATION DATA)		285	478	699	842	914	958	974	910	729	653	633
		Caltrans Hourly Count	THU 01/18/90	383	383	773	773	940	940	946	946	693	693	628
		(converted)		286	480	702	846	918	962	978	914	732	6%	636
		Previous UCB studies	1980s	357	431	585	633	598	654	743	572			
Hoover on ramp	EB	(SIMULATION DATA)		414	431	449	451	441	419	366	351	364	388	449
		Caltrans Hourly Count	THU 01/18/90	416	416	443	443	423	423	353	353	369	369	4%
		(converted)		408	424	442	444	434	412	360	346	358	382	442
		Previous UCB studies	1980s	354	362	368	358	359	280	263	2%			

Location	Dir	Source	Date	600	630	7:00	7:30	8:00	8:30	9:00	9:30	1000	10:30	11:00
SB 110 off ramp	EB	(SIMULATION DATA)		1295	1346	1446	1390	1141	1077	1125	1185	1314	1398	1470
		Caltrans Hourly Count	TUE 01/23/90	1326	1326	1425	1425	1114	1114	1159	1159	1361	1361	1488
		(converted)		1300	1352	1452	1396	1146	1082	1130	1190	1320	1404	1476
		Previous UCB studies	1980s	1300	1396	1445	1325	1153	1084	1020	1034			
NB 110 off ramp	EB	(SIMULATION DATA)		2888	2968	3089	3081	2870	2920	3294	3286	2924	27%	2760
		Caltrans Hourly Count	WED 05/16/90	2939	2939	3098	3098	2907	2907	3304	3304	2872	2872	2783
		(converted)		2900	2980	3102	3094	2882	2932	3308	3300	2936	2808	2772
		Previous UCB studies	1980s	2349	3594	3323	2891	2638	2633	2625	2620			
East of SRllO	EB	(SIMULATION DATA)	10/04/93	1476	7081	7862	7730	7835	7344	5929	5818	5831	5439	5027
		calculated		1482	4632	3966	3618	3948	3496	3224	3152	3160	2904	3288
		calculated from previous studies		3901	5694	6264	6279	3587	5503	4490	4345			
East of SRllO	WB	(SIMULATION DATA)	10/04/93	2810	4639	5067	5610	6395	6288	6406	6329	5850	5640	5754
		calculated		2822	3818	3382	2214	2802	3424	3942	3896	3192	3664	3732
		Previous UCB studies	1980s	4744	6026	6301	6159	6207	6191	6290	6564			
SB 110 on ramp	WB	(SIMULATION DATA)		2832	2725	2605	2513	2404	2416	2567	2651	2735	2762	2725
		Smart Corridor data	11/21/90	2790	2790	2570	2570	2420	2420	2620	2620	2760	2760	2730
		(converted)		2844	2736	2616	2524	2414	2426	2578	2662	2746	2774	2736
		Previous UCB studies	1980s	2625	2937	4488	2694	2532	2676	2888	2998			
NB 110 on ramp	WB	(SIMULATION DATA)		1255	1083	868	783	787	831	948	1050	1195	1227	1133
		Caltrans Hourly Count	WED 01/24/90	1174	1174	830	830	813	813	1004	1004	1216	1216	1127
		(converted)		1260	1088	872	786	790	834	952	1054	1200	1232	1138
		Smart Corridor data	11/21/90	830	830	590	590	710	710	970	970	1050	1050	920
		(converted)		890	770	604	578	664	756	926	1014	1058	1044	912
		Previous UCB studies	1980s	1047	1054	959	803	769	802	996	1090			
20th Street off ramp	WB	(SIMULATION DATA)		152	262	3%	447	392	402	455	469	449	441	429
		Caltrans Hourly Count	THU 01/18/90	204	204	415	415	390	390	455	455	437	437	423
		(converted)		150	258	390	440	386	3%	448	462	442	434	422
		Previous UCB studies	1980s	216	273	484	503	504	524	473	413			
20th Street on ramp	WB	(SIMULATION DATA)		414	490	597	614	324	492	467	484	563	597	605
		Caltrans Hourly Count	THU 01/18/90	445	443	596	5%	500	500	468	468	570	570	601
		(converted)		408	482	588	604	516	484	460	476	554	588	5%
		Previous UCB studies	1980s	340	462	675	603	541	446	521	519			
Vermont off ramp	WB	(SIMULATION DATA)		264	299	329	372	441	482	502	510	504	494	465
		Caltrans Hourly Count	THU 01/18/90	277	277	344	344	453	453	498	498	491	491	452
		(converted)		260	294	324	366	434	414	494	502	4%	486	458
		MODCOMP data	TUE 05/25/93	420	530	590	640	650	680	660	710	640	700	610
		MODCOMP data	WED 05/26/93	440	490	460	540	520	600	650	620	710	620	670
		MODCOMP data	THU 05/27/93	410	500	460	620	520	630	640	660	690	660	670
		Previous UCB studies	1980s	274	348	366	452	462	409	409	292			
Vermont on ramp	WB	(SIMULATION DATA)		433	451	482	475	429	414	423	429	439	465	514
		Caltrans Hourly Count	THU 01/18/90	435	435	471	471	416	416	419	419	445	445	518
		(converted)		426	444	474	468	422	408	416	422	432	458	506
		MODCOMP data	TUE 05/25/93	580	790	850	670	600	620	6M)	730	740	7M)	790
		MODCOMP data	WED 05/26/93	530	850	890	720	620	630	650	700	740	720	770
		MODCOMP data	THU 05/27/93	6M)	780	800	640	630	380	620	660	750	770	800
		Previous UCB studies	1980s	381	418	487	528	441	410	441	413			
Normandie off ramp	WB	(SIMULATION DATA)		234	295	370	400	368	392	465	504	508	542	614
		Caltrans Hourly Count	WED 12/13/89	260	260	379	379	374	374	477	477	517	517	617
		(converted)		230	290	364	394	362	386	458	496	500	534	604
		Previous UCB studies	1980s	242	337	513	547	517	573	518	498			

Location	Dir	Source	Date	600	6:30	7:00	7:30	8:00	830	900	930	1000	1030	11:00
Normandie on ramp	WB	(SIMULATION DATA)		380	550	560	430	390	380	330	380	330	410	350
		Caltrans Hourly Count	THU 01/18/90	502	502	505	505	428	428	427	427	376	376	444
		(converted)		500	504	516	494	438	420	432	420	374	378	436
		MODCOMP data	TUE 05/25/93	380	550	560	430	390	380	560	280	230	200	160
		MODCOMP data	WED 05/26/93	380	530	500	400	420	360	330	380	330	410	350
		MODCOMP data	THU 05/27/93	350	530	520	430	370	370	330	390	350	360	390
		Previous UCB studies	1980s	336	413	447	426	384	339	292	284			
Mainline 13.21 (Normandie)	WB	MODCOMP data	TUE 05/25/93	7620	8230	7370	5890	6200	6740	7380	7470	7060	7640	7660
		MODCOMP data	WED 05/26/93	7600	7530	6810	5200	5350	6560	7190	7680	7590	7850	7840
		MODCOMP data	THU 05/27/93	7840	7880	7310	5170	5270	5860	6670	7480	7590	7880	8040
		MODCOMP data	TUE 12/08/92	4494	7882	6630	4422	3576	4702	4756	4714	6204	7374	7556
Western off ramp	WB	(SIMULATIONDATA)		637	777	944	1034	1042	1095	1209	1205	1070	1056	1143
		Caltrans Hourly Count	TUE 12/12/89	710	710	993	993	1073	1073	1212	1212	1066	1066	1160
		(converted)		640	780	948	1038	1046	1100	1214	1210	1074	1060	1148
		Previous UCB studies	1980s	317	560	1091	1096	1005	1000	932	712			
		ATSAC data	TUE 10/19/93	622	808	852	1006	924	934	866	958	936	924	970
Western on ramp	WB	(SIMULATION DATA)		290	350	360	300	220	270	240	310	340	390	320
		Caltrans Hourly Count	TUE 12/12/89	591	591	604	604	494	494	453	453	533	533	543
		(converted)		588	594	618	590	514	476	448	458	522	544	542
		MODCOMP data	TUE 05/25/93	290	350	360	300	220	270	240	310	340	390	320
		MODCOMP data	WED 05/26/93	270	350	300	260	220	200	270	330	300	330	400
		MODCOMP data	THU 05/27/93	260	390	320	280	240	260	280	300	300	350	340
		Previous UCB studies	1980s	350	312	292	320	243	267	241	246			
		ATSAC data	TUE 10/19/93	364	482	444	376	388	216	284	218	250	312	284
Arlington off ramp	WB	(SIMULATIONDATA)		241	442	669	82I	854	1002	1398	1305	675	516	61I
		Caltrans Hourly Count	TUE 12/12/89	343	343	749	749	933	933	1357	1357	598	598	617
		(converted)		242	444	672	824	858	1006	1404	1310	678	518	614
		Previous UCB studies	1980s	306	482	799	868	901	620	606	584			
		ATSAC data	TUE 10/19/93	446	654	862	870	820	686	534	560	572	562	590
Arlington on ramp	WB	(SIMULATIONDATA)		280	510	530	610	440	400	380	340	270	320	340
		Caltrans Hourly Count	TUE 12/12/89	400	400	553	553	424	424	393	393	310	310	321
		(converted)		362	438	550	556	444	404	408	378	318	302	320
		MODCOMP data	TUE 05/25/93	280	510	530	610	440	400	380	340	270	320	340
		MODCOMP data	WED 05/26/93	310	500	580	600	450	330	360	380	360	340	340
		MODCOMP data	THU 05/27/93	330	520	550	640	530	560	360	330	320	290	330
		Previous UCB studies	1980s	339	497	605	628	501	502	450	359			
		ATSAC data	TUE 10/19/93	254	246	292	220	212	186	176	168	152	174	146
Mainline 11.53 (Crenshaw)	WB	MODCOMP data	TUE 05/25/93	9120	10850	9860	7660	7340	8290	8810	9000	8170	9510	8890
		MODCOMP data	WED 05/26/93	9160	10210	9190	7270	7140	7760	8740	9320	8930	9370	9230
		MODCOMP data	THU 05/27/93	9380	10160	9740	6760	6720	7330	8340	9160	9170	9510	9060
		MODCOMP data	TUE 12/08/92	4365	7856	6518	4770	3928	so42	5461	5354	7226	7595	7506
Crenshaw off ramp	WB	(SIMULATION DATA)		572	749	920	1107	1340	1476	1617	1480	978	817	854
		Caltrans Hourly Count	TUE 12/12/89	663	663	1019	1019	1415	1415	1555	1555	901	901	857
		(converted)		574	752	924	1112	1346	1482	1624	1486	982	820	858
		Previous UCB studies	1980s	662	776	93I	818	911	935	996	1042			
		ATSAC data	TUE 10/19/93	708	886	984	1348	1380	1416	1216	1086	1012	1070	1214
Crenshaw on ramp	WB	(SIMULATION DATA)		443	626	857	939	861	798	689	614	542	512	528
		Caltrans Hourly Count	TUE 12/12/89	526	526	884	884	818	818	642	642	518	518	516
		(converted)		436	616	844	924	848	786	678	604	534	so4	520
		Previous UCB studies	1980s	416	743	827	839	70I	630	551	261			
		ATSAC data	TUE 10/19/93	616	710	778	692	600	512	504	514	492	592	544

Location	Dir	Source	Date	6:00	630	7:00	7:30	8:00	830	9:00	930	10:00	10:30	11:00
Mainline 10.710 (La Brea)	WB	Caltrans Hourly Count	WED 12/13/89	8120	8120	7295	7295	8405	8405	9465	9465	9165	9165	9983
		(converted)		8326	7914	7260	7330	8134	8676	9368	9562	9102	9228	9928
		Caltrans Hourly Count	TUE 06/23/92	10498	10498	8245	8245	7613	7613	9001	9001	%13	9613	10137
		(converted)		11062	9934	8598	7894	7520	7704	8748	9254	9472	9754	10090
NB La Brea off ramp	WB	(SIMULATION DATA)		420	460	310	310	370	370	510	580	510	600	600
		Caltrans Hourly Count	WED 12/06/89	375	375	237	237	313	313	408	408	576	576	535
		(converted)		410	340	244	230	292	334	376	440	558	592	532
		MODCOMP data	TUE 05/25/93	420	460	310	310	370	370	510	580	510	600	600
		MODCOMP data	WED 05/26/93	420	390	310	310	290	410	560	590	520	570	620
		MODCOMP data	THU 05/27/93	420	400	330	300	320	410	420	600	570	630	610
		Previous UCB studies	1980s	264	303	332	274	315	406	479	525			
		ATSAC data	TUE 10119193	406	394	354	268	306	394	478	536	608	564	630
NB La Brea on ramp	WB	(SIMULATION DATA)		170	380	390	390	340	330	270	210	230	210	170
		Caltrans Hourly Count	WED 12/06/89	418	418	802	802	642	642	357	357	248	248	209
		(converted)		324	516	772	834	700	584	402	310	266	230	206
		MODCOMP data	TUE 05/25/93	170	380	390	390	340	330	270	210	230	210	170
		MODCOMP data	WED 05/26/93	140	370	400	400	360	310	270	180	170	200	170
		MODCOMP data	THU 05/27/93	160	340	440	400	320	280	250	220	130	120	130
		Previous UCB studies	1980s	308	406	600	650	391	300	220	95			
Mainline 10.53 (La Brea)	WB	MODCOMP data	TUE 05/25/93	7920	9490	8330	6640	6450	6780	7650	8020	7220	8390	7770
		MODCOMP data	WED 05/26/93	7890	8670	7920	6440	5940	6740	7530	8090	8040	8290	7960
		MODCOMP data	THU 05/27/93	7980	8920	7890	6130	5730	6630	7200	8150	7940	8500	6330
		MODCOMP data	TUE 12/08/92	4672	8272	6810	5196	4836	5712	6344	6036	7852	8288	8164
SB La Brea off ramp	WB	(SIMULATION DATA)		748	589	382	315	323	417	723	794	658	610	561
		Caltrans Hourly Count	WED 12/06/89	658	658	343	343	364	364	747	747	623	623	553
		(converted)		736	580	376	310	318	410	712	782	648	600	552
		Previous UCB studies	1980s	537	617	894	549	431	403	476	579			
SB La Brea on ramp	WB	(SIMULATION DATA)		280	382	502	561	571	545	451	410	392	390	423
		Caltrans Hourly Count	WED 12/06/89	326	326	524	524	549	549	425	425	385	385	417
		(converted)		276	376	494	552	562	536	444	404	386	384	416
		Previous UCB studies	1980s	266	328	515	442	498	464	388	185			
Washington **off** ramp	WB	(SIMULATION DATA)		1249	1101	928	827	739	769	964	1038	1044	1042	1006
		Caltrans Hourly Count	WED 11/29/89	1180	1180	881	88I	758	758	1005	1005	1048	1048	1002
		(converted)		1254	1106	932	830	742	772	968	1042	1048	1046	1010
		Previous UCB studies	1980s	1031	1065	886	704	559	608	673	533			
		ATSAC data	TUE 10/19/93	898	764	800	600	706	732	800	840	8%	862	942
Venice off ramp	WB	(SIMULATION DATA)		928	916	882	908	1002	1052	1083	1091	1068	1058	1066
		Caltrans Hourly Count	WED 11/29/89	926	926	899	899	1030	1030	1092	1092	1066	1066	1052
		(converted)		932	920	886	912	1006	1056	1088	1096	1072	1062	1070
		Previous UCB studies	1980s	531	706	1060	1085	989	974	969	508			
Fairfax on ramp	WB	(SIMULATION DATA)		270	330	430	540	450	360	360	380	410	350	390
		Caltrans Hourly Count	WED 11/29/89	488	488	879	879	781	781	605	605	432	432	475
		(converted)		390	586	840	918	816	746	650	562	448	416	460
		MODCOMP data	TUE 05/25/93	270	330	430	540	450	360	360	380	410	350	390
		MODCOMP data	WED 05/26/93	320	340	370	520	460	370	370	370	480	390	450
		MODCOMP data	THU 05127193	300	350	430	530	460	360	390	380	430	410	750
		Previous UCB studies	1980s	362	549	821	1062	762	540	515	252			
Mainline 9.21 (Fairfax)	WB	MODCOMP data	TUE 05/25/93	6800	8560	8120	6750	6860	6730	7460	7240	6500	7240	7070
		MODCOMP data	WED 05/26/93	6700	8080	7800	6720	6260	6710	7310	7350	7240	7430	7340
		MODCOMP data	THU 05/27/93	6750	8270	7740	6090	5940	7050	7060	7560	7170	7480	11720
		Previous UCB studies	1980s	7135	8680	9659	8259	7380	8305	7262	7741			
		MODCOMP data	TUE 12/08/92	3974	7446	6154	5314	5626	6284	6860	5870	6946	7406	7170

Location	Dir	Source	Date	600	6:30	7:00	7:30	800	830	900	930	10:00	1030	11:00
La Cienega on ramp	WB	(SIMULATION DATA)		286	557	886	1044	1020	1032	1042	985	819	786	868
		Caltrans Hourly Count	WED 11/29/89	415	415	950	9%	1010	1010	999	999	790	790	873
		(converted)		282	548	872	1028	1004	1016	1026	970	806	774	854
Robertson off ramp	WB	(SIMULATION DATA)		733	657	548	526	564	653	880	948	858	860	920
		Caltrans Hourly Count	TUE 11/21/89	698	698	539	539	611	611	918	918	862	862	926
		(converted)		736	660	550	528	566	656	884	952	862	864	924
		ATSAC data	TUE 10/19/93	560	710	764	664	862	964	1024	1166	1134	1132	1106
Robertson on ramp	WB	(SIMULATION DATA)		333	610	1065	1292	1382	1333	1048	933	880	874	955
		Caltrans Hourly Count	TUE 11/21/89	494	494	1160	1160	1336	1336	915	915	863	863	952
		(converted)		328	660	1048	1272	1360	1312	1032	918	866	860	940
Mainline 6.73 (Motor)	WB	MODCOMP data	TUE 05/25/93	6690	8920	9240	9000	8780	8690	8990	8310	7170	7890	7 m
		MODCOMP data	WED 05/26/93	6650	8750	8820	8890	8460	8680	8790	8530	8030	8260	8180
		MODCOMP data	THU 05/27/93	6680	8880	8670	8400	8380	8710	8360	8110	8120	8270	8380
National off ramp	WB	(SIMULATION DATA)		504	500	477	506	589	636	664	677	6%	6%	677
		Caltrans Hourly Count	TUE 11/21/89	494	494	484	484	603	603	659	659	645	645	662
		(converted)		496	492	470	498	580	626	654	666	646	646	666
		ATSAC data	TUE 10/19/93	5%	580	630	630	738	810	798	808	718	736	684
Overland off ramp	WB	(SIMULATION DATA)		651	705	761	807	838	878	946	930	809	791	854
		Caltrans Hourly Count	TUE 11/21/89	681	681	786	786	862	862	943	943	803	803	862
		(converted)		654	708	764	810	842	882	950	934	812	794	858
Overland on ramp	WB	(SIMULATION DATA)		440	815	1263	1486	1504	1428	1141	1024	990	970	990
		Caltrans Hourly Count	TUE 11/21/89	630	630	1379	1379	1472	1412	1088	1088	984	984	1004
		(converted)		442	818	1268	1492	1510	1434	1146	1028	994	974	994
SB I405 off ramp	WB	(SIMULATION DATA)		1924	1665	1348	1203	1119	1247	1707	1950	2089	2171	2141
		Caltrans Hourly **Count**	TUE 11/21/89	1802	1802	1281	1281	1188	1188	1836	1836	2139	2139	2151
		(converted)		1932	1672	1354	1208	1124	1252	1714	1958	2098	2180	2150
NB I405 **off** ramp	WB	(SIMULATION DATA)		2794	3045	3404	3428	3109	2910	2677	2561	2561	2539	2549
		Caltrans Hourly Count	TUE 11/21/89	1932	2932	3430	3430	3023	3023	2630	2630	2560	2560	2542
		(converted)		2806	3058	3418	3442	3122	2922	2688	2572	2512	2550	2560
West of I405	WB	(SIMULATION DATA)		1239	2808	3802	4434	4222	4242	2330	1908	2036	2194	2320
		calculated		1244	3808	4502	4534	4622	4442	4130	3208	2036	2694	2320

Location	11:30	12:00	12:30	1:00	1:30	200	230	3:00	330	4:00	430	5:00	5:30	6:00	6:30	7:00	7:30
West of I405	4497	4708	4603	4053	3997	4104	4319	5132	5637	6154	6020	5290	5033	4203	3617	33%	3049
	4516	4728	4622	4070	4014	4322	4538	4852	4958	4874	4840	4910	4652	4020	3632	3370	3062
NB I-405 on ramp	1806	1591	1575	1749	1796	1816	1731	1504	1382	1303	1269	1305	1307	1480	1109	0	0
	1850	1590	1590	1780	1780	1780	1780	1450	1450	1290	1290	1310	1310	1300	1300	0	0
	1814	1598	1582	1756	1804	1824	I738	1510	1388	1308	I274	1310	1312	1486	1114	0	0
SB 1-405 on ramp	1926	2163	2219	2131	2131	2243	2159	1798	1808	2147	2332	2597	2482	2155	1468	0	0
	1920	2200	2200	2140	2140	2210	2210	1810	1810	2250	2250	2550	2550	1820	1820	0	0
	1934	2172	2228	2140	2140	2252	2168	1806	1816	2156	2342	2608	2492	2164	1474	0	0
I-405 on ramps **(after merge)**	4284	4119	4109	4206	4274	4412	4350	4077	3924	3806	3728	3728	3659	3485	3499	3679	3804
	4300	4131	4131	4259	4259	4398	4398	4017	4017	3783	3783	3709	3709	3507	3507	3757	3757
	4302	4136	4126	4224	4292	4430	4368	4094	3940	3822	3744	3744	3674	3500	3514	3694	3820
	3770	3790	3790	3920	3920	3990	3990	3260	3260	3540	3540	3860	3860	3120	3120	0	0
	3748	3770	3808	3896	3944	4074	3906	3316	3206	3466	3616	3914	3804	3654	2586	0	0
National off ramp	1460	1615	1506	1032	900	988	1008	1044	1060	1042	1083	1221	1239	1171	1091	974	866
	1384	1567	1567	970	970	1001	1001	1056	1056	1067	1067	1236	1236	1136	1136	924	924
	1466	1622	1512	1036	904	992	1012	1048	1064	1046	1088	1226	1244	1176	1096	978	870
	1424	1518	1566	1532	1638	1628	I572	1604	1478	1502	1464	1488	1596	1512	1560	1430	1236
Overland on ramp	787	912	966	992	1000	956	978	1070	1087	1034	IO44	1113	1115	1087	1010	874	757
	788	944	944	1000	1000	971	971	1082	1082	1043	1043	1120	1120	1053	1053	819	819
	790	916	970	996	1004	960	982	1074	1092	1038	1048	1118	1120	1092	1014	878	760
	850	860	1000	970	900	640	700	720	650	690	650	720	690	690	760	870	500
	890	920	890	1030	990	700	740	750	670	640	780	700	760	740	780	990	520
	890	920	970	1000	1030	810	880	810	680	840	750	910	840	940	1000	1020	760
Mainline 6.745 (Motor)	8135	8181	8181	8331	8331	8798	8798	8950	8950	8616	8616	8374	8374	7250	7250	6868	6868
	8142	8158	8206	8254	8406	8720	8876	8972	8926	8688	8544	8546	8202	7436	7064	6964	6772
	7885	8697	8697	7928	7928	8619	8619	8871	8871	8653	8653	8841	8841	7716	7716	6835	6835
	7960	8692	8702	7938	7920	8500	8736	8868	8876	86%	8648	8960	8722	7964	7466	7054	6614
	7810	7840	7900	8020	8430	8690	8970	9180	9210	8940	8810	9310	8950	7940	8310	7220	4200
	8090	7090	7950	8110	8310	8760	8880	9320	8950	8800	8640	8340	7400	7810	7450	7810	4310
	7710	7010	7460	7980	7930	8390	8450	8980	8680	7680	7440	7310	7370	8240	7830	7590	6630
Manning on ramp	430	380	440	380	420	520	540	530	460	440	460	550	580	540	520	420	250
	391	402	402	434	434	547	547	589	589	455	455	586	586	500	500	384	384
	386	398	408	416	450	526	566	602	578	456	454	580	592	526	474	414	354
	430	380	440	380	420	520	540	530	460	440	460	550	580	540	520	420	250
	430	420	410	460	380	500	490	540	400	440	420	510	500	530	460	470	260
	460	470	400	490	460	550	540	480	440	460	430	460	490	570	500	450	380
Robertson off ramp	906	878	876	902	910	882	929	1087	1097	959	931	991	961	872	798	719	640
	897	863	863	891	89I	892	892	1075	1075	930	930	96I	96I	822	822	669	669
	892	864	862	888	896	868	914	1070	1080	944	916	976	946	858	786	708	630
Mainline 7.99 (National)	7280	7270	7370	7460	7840	8290	8540	8490	8660	8270	8180	8780	8540	8360	7970	6860	3930
	7240	7490	7490	7580	6230	8180	8580	8370	8150	8050	8430	8160	8360	8570	7810	7590	4050
	7360	7500	7390	7450	5920	8040	8120	7850	8140	7630	7870	7710	8070	8300	7400	7330	6360
	6968																

Location	11:30	12:00	12:30	1:00	1:30	2:00	230	300	3:30	4:00	430	500	530	6:00	6:30	7:00	7:30
National on ramp	670	660	670	640	720	720	740	690	610	620	660	650	610	680	640	550	320
	708	753	753	699	699	850	850	687	687	612	612	705	705	592	592	501	501
	718	754	752	686	710	852	848	716	658	610	614	708	702	618	566	524	478
	670	660	670	640	720	720	740	690	610	620	660	650	610	680	640	550	320
	720	680	700	630	680	710	640	720	580	590	640	670	540	670	670	610	320
	660	760	720	730	680	750	720	700	630	590	620	680	590	600	620	590	440
	62	66	68	62	78	66	90	66	92	66	92	84	92	88	76	54	54
SB La Cienega off ramp	250	242	232	199	205	248	262	258	256	262	238	I73	I54	I77	163	122	91
	241	232	232	199	I99	251	251	253	253	245	245	161	161	166	166	105	105
	246	238	228	I96	202	244	258	254	252	258	234	170	152	174	160	120	90
SB La Cienega on ramp	680	610	580	580	650	640	610	630	500	580	550	660	570	680	630	520	300
	617	705	705	635	635	677	677	627	627	527	527	616	616	576	576	539	539
	622	704	708	633	632	678	676	646	608	528	526	610	622	586	566	548	530
	680	610	580	580	650	640	610	630	500	580	550	660	570	680	630	520	300
	560	590	590	610	600	600	660	600	490	520	510	600	580	630	540	540	360
	520	580	580	540	570	550	490	530	500	600	530	560	480	530	520	580	430
NB La Cienega off ramp	636	687	709	723	717	683	670	683	670	624	618	654	652	628	597	551	510
	625	687	687	710	710	666	666	666	666	610	610	642	642	603	603	522	522
	626	676	698	712	706	672	660	672	660	614	608	644	642	618	588	542	502
Fairfax off ramp	490	510	550	550	560	589	591	709	642	650	630	820	770	770	650	560	320
	525	481	481	477	477	565	565	617	617	705	705	763	763	585	585	439	439
	524	486	476	468	486	548	582	600	634	686	724	780	748	626	546	474	402
	490	510	550	550	560	589	591	709	642	650	630	820	770	770	650	560	320
	490	570	530	510	580	580	600	690	650	660	630	730	680	760	610	550	330
	510	490	510	450	510	560	570	660	550	600	670	620	710	720	580	540	450
	848	780	866	808	884	922	942	980	936	1018	1062	1074	1022	1006	870	832	730
Mainline 9.21 (Fairfax)	7470	7290	7410	7450	7900	8238	8438	8214	8129	8180	8280	8620	8580	8520	8220	6790	3940
	7430	7350	7580	7550	7650	8210	8460	8140	8130	8120	8240	8220	8530	8340	7990	7520	4120
	7650	7640	7630	7870	7610	8200	8020	7770	8060	7950	7880	8090	8120	8520	7380	7280	6300
	8150																
Venice on ramp	439	425	417	394	402	449	461	441	449	467	504	591	579	479	410	343	276
	421	414	414	392	392	448	448	438	433	478	478	576	576	439	439	305	305
	432	418	410	388	3%	442	454	434	442	460	496	582	570	472	404	338	272
	210	220	190	250	240	248	33I	306	284	300	350	370	370	290	260	160	90
	270	200	210	240	220	250	330	310	280	300	340	370	380	290	220	220	I00
	210	220	250	220	280	310	340	280	290	300	360	370	330	300	270	160	180
Washington on ramp	1064	1113	1125	1099	1097	1117	1113	1081	1079	1101	1113	I129	1117	1074	1034	988	946
	1052	I124	1124	1103	I103	1I20	1120	1085	1085	1112	1112	1129	1129	1058	1058	971	971
	1068	1118	1130	I104	1102	I122	1118	1086	1084	1106	1118	1134	1122	1078	1038	992	950
SB La Brea off ramp	I95	209	217	226	234	246	254	250	274	327	360	404	394	325	276	223	I73
	188	211	211	225	225	245	245	258	258	338	338	392	392	297	297	195	195
	192	206	214	222	230	242	250	246	270	322	354	398	388	320	272	220	170
	280	294	274	314	336	374	376	406	372	422	400	374	402	338	312	286	216

Location	11:30	12:00	1230	1:00	1:30	2:00	2:30	300	3:30	400	4:30	500	530	600	6:30	7:00	7:30
SB La Brea on ramp	540	560	620	580	560	669	694	539	557	480	450	510	580	510	450	470	230
	598	633	633	669	669	640	640	571	571	488	488	523	523	517	517	426	426
	612	624	642	668	670	652	628	590	552	494	482	520	526	530	504	448	404
	540	560	620	580	560	669	694	539	557	480	450	510	580	510	450	470	230
	550	530	620	630	630	670	700	540	550	440	440	580	550	500	410	470	260
	610	530	570	600	570	570	660	550	550	480	480	540	510	530	510	450	440
Mainline 10.53 (La Brea)	7600	7390	7500	7620	7800	8207	7832	7861	7729	7610	7710	8150	7850	7890	8200	6930	3900
	7590	7310	7700	7570	7790	8170	7850	7810	7680	7710	7730	7870	8000	7740	7610	7580	4210
	7750	7740	7700	7900	7750	8150	7500	7490	7610	7630	7270	7720	7680	7970	7560	6970	6250
	7732																
NB La Brea off ramp	550	530	510	430	570	513	558	542	527	490	460	500	560	610	630	490	370
	474	468	468	416	416	421	421	442	442	427	427	414	414	501	501	408	408
	480	476	462	422	410	418	424	442	442	430	422	406	422	502	500	432	384
	550	530	510	430	570	513	558	542	527	490	460	500	560	610	630	490	370
	480	500	530	480	510	520	550	540	530	400	460	490	460	560	610	580	280
	460	530	520	510	480	530	520	490	480	360	500	420	420	600	570	430	490
NB La Brea on ramp	570	560	590	660	630	709	725	817	825	760	770	750	710	620	660	610	350
	601	657	657	634	634	724	724	675	675	689	689	580	580	572	572	521	521
	608	652	662	626	642	720	730	678	670	702	678	594	566	580	566	534	508
	570	560	590	660	630	709	725	817	825	760	770	750	710	620	660	610	350
	530	710	690	610	620	710	720	820	830	820	820	750	640	680	660	700	380
	650	600	660	690	700	810	810	860	840	740	780	680	680	660	660	840	550
Mainline 10.710 (La Brea)	9208	9027	9027	9382	9382	9810	9810	9658	9658	9744	9744	9569	9569	8771	8771	8037	8037
	9214	9006	9048	9284	9480	9774	9844	9666	9650	9754	9734	9690	9446	8962	8580	8220	7852
	9224	9270	9270	9411	9411	9927	9927	10259	10259	10068	10068	10063	10063	9793	9793	9176	9176
	9158	9246	9294	9330	9492	9820	10034	10242	10276	10092	10044	10098	10030	9906	9682	9330	9022
Crenshaw off ramp	473	510	530	563	555	488	482	514	557	630	699	807	807	697	630	569	504
	465	511	511	550	550	477	471	526	526	655	655	794	794	654	654	528	528
	466	502	522	554	546	480	474	506	548	620	688	794	794	686	620	560	496
Mainline 11.53 (Crenshaw)	8450	8420	8540	8340	8950	9294	9388	9322	9249	9260	9120	9550	9440	9280	9390	7820	4410
	8590	8580	8730	8690	9000	9340	9370	9280	9390	9360	9260	9450	9510	9320	8740	8830	4750
	8750	8570	8780	9000	8880	9070	9290	9210	9360	9210	8930	9240	9230	9450	8720	8230	7000
	8431																
Crenshaw on ramp	880	870	810	950	980	954	848	860	1001	910	860	880	860	800	850	770	430
	842	887	887	965	965	961	961	856	856	720	720	677	677	737	737	731	731
	846	872	902	954	974	976	946	886	826	742	698	674	680	730	744	732	730
	880	870	810	950	980	954	848	860	1001	910	860	880	860	800	850	770	430
	900	870	860	960	890	950	860	870	970	910	830	910	860	780	810	790	490
	930	930	1000	870	1010	930	930	890	870	820	850	900	860	840	800	800	700
	1100	1098	1204	1176	1200	1158	1092	1118	1088	1186	1108	1082	1082	984	926	880	694
Arlington off ramp	305	268	276	335	354	333	356	412	449	469	492	524	516	475	423	349	280
	298	268	268	340	340	339	339	424	424	473	473	511	511	442	442	310	310
	300	264	272	330	348	328	350	406	442	462	484	516	508	468	416	344	276
	286	272	308	288	318	344	412	414	468	494	450	570	472	504	422	368	266

Location	11:30	12:00	12:30	1:00	1:30	2:00	2:30	3:00	330	400	430	5:00	530	600	630	7:00	7:30
Arlington on ramp	426	410	414	430	458	532	524	428	402	414	414	418	416	412	398	378	360
	426	415	415	446	446	530	530	417	417	415	415	420	420	407	407	371	371
	428	412	416	432	460	534	526	430	404	416	416	420	418	414	400	380	362
	482	586	566	5%	542	584	486	520	446	458	486	506	548	570	498	492	416
Western off ramp	414	368	368	417	415	410	391	347	351	414	437	439	431	402	390	390	388
	412	363	363	415	415	395	395	344	344	419	419	428	428	390	390	383	383
	408	362	362	410	418	404	386	342	346	408	430	432	424	396	384	384	382
	296	352	300	344	324	380	374	406	386	418	374	424	404	402	394	334	262
Western on ramp	660	580	610	640	640	630	660	610	650	630	540	550	540	530	510	580	370
	609	660	660	669	669	718	718	557	557	489	489	498	498	557	557	596	596
	620	654	668	662	678	734	704	584	528	4%	482	490	506	544	570	586	606
	660	580	610	640	640	630	660	610	650	630	540	550	540	530	510	580	370
	600	590	540	630	630	640	640	410	0	0	0	0	0	0	0	0	0
	600	670	730	620	680	670	590	610	590	570	490	520	510	570	520	610	560
	590	618	588	702	528	654	524	574	540	492	476	510	474	584	514	500	418
Normandie off ramp	293	297	291	268	274	299	335	404	439	451	463	471	461	425	404	394	378
	290	289	289	267	267	312	312	415	415	450	450	458	458	408	408	380	380
	288	292	286	264	270	294	330	398	432	444	456	464	454	418	398	388	372
Normandie on ramp	459	447	463	508	526	534	520	475	451	431	429	441	449	457	465	467	473
	444	447	447	509	509	518	518	455	455	423	423	439	439	454	454	463	463
	452	440	456	500	518	526	512	468	444	424	422	434	442	450	458	460	466
Vermont off ramp	480	580	510	520	530	500	540	460	560	560	590	620	500	570	650	520	230
	594	586	586	596	596	477	477	41I	411	546	546	660	660	647	647	549	549
	596	586	586	610	582	500	456	404	420	514	578	646	674	662	632	572	524
	480	580	510	520	5%	500	540	460	560	560	590	620	500	570	650	520	230
	510	480	500	550	450	490	470	560	580	620	530	560	560	470	520	530	660
	470	490	540	480	500	450	450	440	470	560	580	500	540	590	470	1030	370
Mainline 13.95 (Vermont)	8040	7320	7910	7820	8120	8790	8550	8250	8140	7540	8060	7790	7880	7500	6990	6970	4150
	7970	7780	7800	8050	8210	8650	8060	4850	0	0	0	0	0	0	0	0	0
	8210	8050	8250	8300	8120	8260	8360	8270	8010	7850	7570	7460	7030	7940	7620	7470	6510
	7670																
Vermont on ramp	550	630	640	690	740	740	700	640	580	520	560	610	500	670	700	730	420
	605	607	607	686	686	699	699	607	607	475	475	52I	52I	533	533	605	605
	618	596	618	674	698	710	688	636	580	484	466	514	528	522	544	588	624
	550	6%	640	690	740	740	700	640	580	520	560	610	500	670	700	730	420
	680	730	630	680	690	790	670	420	0	0	0	0	0	0	0	0	0
	630	640	670	710	690	780	660	610	590	550	620	670	620	640	680	740	650
Hoover off ramp	619	639	645	647	663	691	713	717	757	827	896	1006	1024	992	868	641	446
	628	644	644	658	658	706	706	740	740	865	865	1019	1019	934	934	546	546
	622	642	648	650	666	694	716	720	760	830	900	1010	1028	996	872	644	448
Hoover on ramp	479	479	506	559	587	599	589	545	512	459	459	520	536	524	526	540	551
	456	484	484	564	564	585	585	521	521	452	452	519	519	517	517	537	537
	472	472	498	550	578	590	580	536	504	452	452	512	528	516	518	532	542

Location	11:30	12:00	12:30	1:00	1:30	2:00	230	300	3:30	4:00	4:30	5:00	530	6:00	630	7:00	7:30
SB 110 off ramp	1494	1434	1460	1555	1635	1755	1781	1735	1665	1516	1468	1508	1492	1432	1412	1416	1412
	1488	1453	1453	1601	1601	1775	1775	I707	1707	1498	3498	1506	1506	1428	1428	1420	1420
	1500	1440	1466	1562	1642	I762	I788	1742	1672	1522	1474	1514	1498	1438	1418	1422	1418
NB 110 off ramp	2782	2954	2954	2798	2745	2776	2699	2504	2418	2436	2340	2085	2077	22%	2420	2515	2623
	2783	2966	2966	2782	2782	2749	2749	2471	2471	2398	2398	2091	2091	2368	2368	2580	2580
	2794	2966	2966	2810	2756	2788	2710	2514	2428	2446	2350	2094	2086	2306	2430	2526	2634
East of SRllO	5498	6194	6087	6117	6555	6622	6786	6624	6684	7383	7290	6032	6403	5908	2776	2898	191
	3596	2744	3328	3348	3634	4136	3916	3810	3784	3194	3788	3684	37%	3276	2788	2910	192
East of SRllO	6116	5641	5789	5745	5204	5004	5213	5246	6123	6593	6576	6480	5643	5160	3027	*4800*	2376
	3650	1576	3752	3130	3106	2986	2812	2534	2042	2264	2492	2256	2114	990	3040	4820	2386
SB 110 on ramp	2713	2695	2705	2745	2772	2754	2882	3254	3298	3045	2952	2928	2868	3171	2348	0	0
	2730	2710	3790	2770	2770	2830	2830	3290	3290	3010	3010	2910	2910	2770	2770	0	0
	2724	2706	2716	2756	2784	2766	2894	3268	3312	3058	2964	2940	2880	3184	2358	0	0
NB 110 on ramp	1111	1127	1105	1018	1050	1227	1261	1177	1139	1115	1066	974	932	924	916	920	920
	1127	1121	3790	1037	1037	1249	1249	1163	I163	1095	1095	957	957	923	923	925	925
	1116	I132	1110	1022	1054	1232	1266	1182	1144	1120	1070	978	936	928	920	924	924
	920	1110	3790	1070	1070	910	910	1050	1050	1030	1030	970	970	790	790	0	0
	926	1092	1130	1096	1044	912	908	1034	1066	1040	1020	1000	940	924	656	0	0
20th Street off ramp	431	463	467	451	427	386	370	384	360	307	268	228	211	211	234	286	327
	423	458	458	432	432	372	372	366	366	284	284	216	216	219	219	302	302
	424	456	460	444	420	380	364	378	354	302	264	224	208	208	230	282	322
20th Street on ramp	616	620	628	616	670	819	868	831	819	794	784	792	782	762	717	640	573
	601	613	613	633	633	830	830	813	813	777	777	775	775	728	728	597	597
	606	610	618	606	660	806	854	818	806	782	772	780	770	750	706	630	564
Vermont off ramp	453	461	445	400	392	417	417	404	382	354	313	236	221	262	291	339	380
	452	446	446	389	389	410	410	387	387	328	328	224	224	272	272	353	353
	446	454	438	394	386	410	410	398	376	348	308	232	218	258	286	334	374
	660	620	610	660	600	550	530	650	550	410	400	400	380	370	470	540	330
	630	690	370	480	600	630	590	360	0	0	0	0	0	0	0	0	0
	620	600	650	640	580	600	660	680	530	490	400	420	400	370	490	610	490
Vermont on ramp	540	549	567	595	607	614	620	630	622	595	579	563	567	599	610	610	612
	518	549	549	592	592	607	607	616	616	578	578	555	555	595	595	601	601
	532	540	558	586	598	604	610	620	612	586	570	554	558	590	600	600	602
	780	800	800	910	810	870	920	840	860	860	780	930	8 W	840	860	820	510
	790	780	810	830	780	880	930	880	790	880	850	960	910	800	810	710	570
	830	890	770	810	860	960	870	950	840	970	860	1030	770	810	830	810	740
Normandie **off** ramp	640	644	622	561	522	488	*482*	512	508	471	465	473	492	545	545	496	463
	617	624	624	533	533	477	477	502	502	461	461	475	475	535	535	473	473
	630	634	612	552	514	480	474	504	500	464	458	466	484	536	536	488	4%

Location	11:30	1200	12:30	1:00	1:30	2:00	2:30	300	3:30	4:00	430	5:00	530	600	6:30	7:00	7:30
Normandie on ramp	440	440	440	410	480	700	550	460	390	410	420	290	360	330	360	270	190
	444	447	447	509	509	518	518	455	455	423	423	439	439	454	454	463	463
	452	440	456	500	518	526	512	468	444	424	422	434	442	450	458	460	466
	150	140	440	410	480	700	550	460	390	410	420	290	360	330	360	270	190
	440	440	460	470	440	650	550	460	360	400	400	320	340	300	350	340	230
	450	400	380	440	440	680	530	470	340	420	370	360	370	570	430	320	280
Mainline 13.21 (Normandie)	7580	5460	7700	7210	7400	7650	7700	7610	7130	7120	7260	7020	6790	5890	7030	6330	3790
	7860	7360	7410	7620	7790	7760	6890	7560	7000	6440	6140	5450	5760	6070	6220	6450	4120
	8000	7540	7690	7650	7840	7880	7890	7490	7350	7250	7560	7550	6690	6790	6820	6700	5920
	7420																
Western off ramp	1167	1175	1149	1074	1030	994	974	1004	934	769	657	524	500	607	611	548	506
	1160	1167	1167	1057	1057	987	987	973	973	716	716	514	514	612	612	529	529
	1172	1180	1154	1078	1034	998	978	1008	933	772	660	526	502	610	614	550	508
	928	910	912	842	874	840	880	844	782	824	770	886	874	932	818	758	728
Western on ramp	370	440	450	340	340	400	370	400	350	330	280	270	260	280	320	310	230
	543	545	545	588	588	641	641	567	567	480	480	441	441	387	387	392	392
	544	540	550	576	600	644	638	586	546	496	464	452	430	394	380	392	392
	370	440	450	340	340	400	370	400	350	330	280	270	260	280	320	310	230
	360	380	390	340	370	410	380	380	310	260	290	270	290	330	310	340	200
	340	400	420	370	380	410	360	350	340	310	260	270	240	300	290	300	280
	392	334	350	438	308	382	342	322	340	342	284	324	258	334	278	284	246
Arlington off ramp	617	621	597	526	506	504	540	635	699	781	783	691	661	695	631	490	316
	617	612	612	518	518	524	524	670	670	785	785	679	679	666	666	435	435
	620	624	600	528	508	506	542	638	702	784	786	694	664	698	634	492	378
	594	580	610	662	616	676	684	688	796	754	842	744	862	816	740	700	490
Arlington on ramp	370	300	330	360	370	330	290	80	460	460	450	530	500	510	330	350	200
	321	322	312	325	325	453	453	398	398	426	416	450	450	435	435	175	175
	324	320	324	308	340	444	462	402	396	420	432	448	450	458	412	316	236
	370	300	330	360	370	330	290	80	460	460	450	530	500	510	380	350	200
	340	320	330	390	370	420	230	400	350	490	480	550	590	600	480	340	170
	370	290	370	90	390	410	390	490	420	430	380	530	470	440	400	330	270
	154	154	142	170	202	202	222	202	222	192	244	200	230	230	188	180	134
Mainline 11.53 (Crenshaw)	9050	7810	9430	8740	8860	9270	9690	9210	8490	9420	9800	9420	8680	7260	8660	7880	5820
	9240	8810	8870	8950	9490	9060	9020	9600	8100	8400	7900	7970	8570	8590	8250	8390	4920
	9410	9040	8990	9050	9460	9160	9680	8980	9610	9430	9960	10100	8760	8990	8970	8400	7140
	7181																
Crenshaw off ramp	852	906	878	763	739	759	835	1044	1085	978	936	900	888	938	890	761	659
	857	896	896	754	754	800	800	1069	1069	961	961	897	897	917	917	713	713
	856	910	882	766	742	762	838	1048	1090	982	940	904	892	942	894	764	662
	1164	1126	1080	1092	1052	1162	1224	1116	1200	1084	1106	970	846	766	1122	1052	840
Crenshaw on ramp	520	492	506	571	601	622	601	530	486	447	425	406	414	465	469	437	414
	516	492	492	577	577	602	602	500	500	429	429	404	404	460	460	419	419
	512	484	498	562	592	612	592	522	478	440	418	400	408	458	462	430	408
	620	658	620	650	662	596	628	526	516	438	478	430	472	476	492	488	432

Location	11:30	1200	12:30	1:00	1:30	200	2:30	3:00	330	4:00	430	5:00	530	600	6:30	7:00	7:30
Mainline 10.710 (La Brea)	9983	9611	961I	9509	9509	10668	10668	10439	10439	10216	10216	8969	8969	9457	9457	852I	8521
	10040	9670	9552	9380	9638	10550	10786	10496	10384	10402	10030	9060	8876	9514	9400	8756	8288
	10137	9978	9978	10167	10167	10116	10116	10034	10034	10407	10407	10129	10129	9317	9317	8435	8435
	10184	9976	9982	10150	10184	10134	10098	9998	10070	10396	10418	10266	9992	9530	9106	8654	8214
NB La **Brea off** ramp	550	540	660	560	540	550	610	540	550	520	500	450	420	380	540	460	360
	535	597	597	595	595	51I	511	483	483	439	439	413	413	413	413	433	433
	536	588	604	606	584	526	496	492	474	448	430	416	408	412	414	428	438
	550	540	660	560	540	550	610	540	550	520	500	450	420	380	540	460	360
	550	640	530	580	580	540	580	600	520	510	410	330	380	410	420	480	270
	600	620	510	640	560	580	520	520	570	460	500	470	460	430	500	520	430
	590	524	530	578	588	542	582	530	556	568	534	464	372	344	368	474	534
NB La **Brea on** ramp	130	180	140	130	150	160	220	230	240	170	220	220	180	170	140	100	80
	209	272	272	267	267	319	319	373	373	322	322	340	340	281	28I	183	183
	212	264	280	260	274	306	332	372	374	326	318	346	336	300	260	208	160
	130	180	140	130	150	160	220	230	240	I70	220	220	180	170	140	100	80
	I50	110	170	I80	I60	220	240	270	210	230	190	230	210	140	180	I50	80
	150	160	180	210	180	190	270	290	220	230	240	230	220	180	160	140	130
Mainline 10.53 (La **Brea)**	8100	6900	8290	7850	7890	7990	8790	7840	6940	7990	8290	7990	7510	7080	8430	7080	5120
	8250	7810	7840	7910	X380	7090	8110	8270	6280	7350	6420	7090	7130	7270	6810	7510	4470
	8380	7940	8180	7980	8240	8560	8500	7720	8150	8020	8400	8430	7280	7690	7640	7550	6290
	7896																
SB La **Brea off** ramp	563	646	648	565	583	705	746	725	752	833	839	782	727	638	591	579	555
	553	637	637	565	565	714	714	727	727	823	823	743	743	605	605	558	558
	554	636	638	556	574	694	734	714	740	820	826	770	716	628	582	570	546
SB La **Brea on** ramp	427	417	408	392	394	423	425	408	408	421	419	394	392	400	419	455	488
	417	406	406	387	387	417	417	403	403	413	413	387	387	402	402	464	464
	420	410	402	386	388	416	418	402	402	414	412	388	386	394	412	448	480
Washington off ramp	990	974	1002	1091	1135	1161	1163	1151	1115	1036	978	930	868	773	763	827	866
	1002	992	992	1118	1118	1167	1167	I138	1138	1012	1012	902	902	771	771	849	849
	994	978	1006	1096	1140	1166	1168	1156	1120	1040	982	934	872	776	766	830	870
	908	960	962	932	1074	1008	1062	1038	960	892	786	722	652	684	718	672	664
Venice off ramp	1032	942	918	942	970	1024	1064	1123	I105	998	948	918	920	968	992	1008	1026
	1052	934	934	960	960	1048	1048	I118	1118	977	977	922	922	984	984	1021	1021
	1036	946	922	946	974	1028	1068	1128	1110	1002	952	922	924	972	996	1012	1030
Fairfax on ramp	500	470	460	510	470	500	550	420	420	380	360	350	350	380	460	360	210
	475	554	554	513	513	61I	61I	593	593	525	525	530	530	556	5%	452	452
	490	550	558	506	520	6W	622	604	582	532	516	526	534	566	546	478	426
	500	470	460	510	470	500	550	420	420	380	360	350	350	380	460	360	210
	500	440	480	450	430	470	490	410	410	360	290	190	320	360	510	390	260
	530	480	480	490	510	510	570	520	430	360	360	350	350	350	420	410	390
Mainline 9.21 (Fairfax)	7210	6170	7490	6960	7040	7440	7700	6330	6890	7320	7620	7890	7220	7360	8210	6310	3780
	7440	6920	7150	6890	7350	6270	7640	7090	5750	7070	5920	6930	6970	7210	7090	7150	4440
	7590	7170	7310	7090	7320	7640	7660	7260	7430	7550	7760	7750	7280	7270	7460	7350	5770

Location	11:30	12:00	1230	1:00	1:30	2:00	2:30	300	330	400	430	5:00	530	600	630	7:00	7:30
La Cienega on ramp	906	953	967	935	937	971	959	914	882	833	83I	882	894	898	876	819	772
	873	945	945	92I	921	950	950	884	884	820	820	875	875	874	874	783	783
	892	938	952	920	922	956	944	900	868	820	818	868	880	884	862	806	760
Robertson off ramp	924	878	864	872	860	836	829	854	825	745	691	63I	627	715	707	627	572
	926	876	876	870	870	835	835	843	843	72I	72I	632	632	713	713	601	601
	928	882	868	876	864	840	832	858	828	748	694	634	630	718	710	630	574
	1160	1092	1164	1148	I188	1064	1122	976	962	946	852	850	826	912	892	786	676
Robertson on ramp	979	973	975	963	977	1020	1046	1083	1087	1032	1052	1166	1178	1136	1032	851	697
	952	958	958	955	955	1017	1017	1068	1068	1026	1026	I154	1154	1067	1067	761	761
	964	958	960	948	962	1004	1030	1066	1070	1016	1036	1148	1160	1118	1016	838	686
Mainline 6.73 (Motor)	8350	7350	8300	8030	8080	8430	8450	6950	7850	8510	8520	8660	8410	8580	8840	7430	4280
	8360	8120	8180	7820	7230	7910	8650	7190	6770	7710	6850	8380	8200	8230	8260	7700	5280
	8730	8290	8290	82M	8170	8510	9040	8400	8590	8120	8710	8590	8200	8410	8560	8380	6810
National off ramp	668	620	628	685	723	770	786	766	768	784	807	857	851	794	754	709	668
	662	614	614	693	693	765	765	755	755	783	783	842	842	761	761	678	678
	658	610	618	674	712	758	774	754	7%	772	794	844	838	782	742	698	658
	686	624	640	670	734	766	784	744	770	756	814	740	794	688	638	506	436
Overland off ramp	862	838	829	81I	831	892	936	966	1016	1093	1123	1115	I107	1103	1046	924	825
	862	837	837	824	824	919	919	995	995	1114	1114	1115	1115	1079	1079	878	878
	866	842	832	814	834	8%	940	970	1020	1098	1128	1120	1112	1108	1050	928	828
Overland on ramp	1012	1052	1079	1099	1099	1068	1072	1101	1117	1125	1137	1139	1181	1297	1303	1213	1155
	1004	1070	1070	1103	1103	1074	1074	1114	1114	1136	1136	I164	I164	1305	1305	1189	1189
	1016	1056	1084	1104	I104	1072	1076	1106	1122	I130	I142	I144	1186	I302	1308	1218	I160
SB I405 off ramp	2155	2185	2193	2167	2185	2269	2243	2121	2028	1926	1852	1830	1731	1466	1524	1890	2153
	2157	2197	2197	2184	2184	2264	2264	2083	2083	1897	1897	1788	I788	1500	1500	2029	2029
	2164	2194	2202	2176	2194	2278	2252	2130	2036	1934	1860	1838	1738	1472	1530	1898	2162
NB I405 off ramp	2513	2414	2398	2434	2509	2691	2721	2633	2523	2314	2239	2241	2294	2478	2517	2444	2406
	2542	2416	2416	2482	2482	2717	2717	2589	2589	2286	2286	2277	2277	2508	2508	2435	2435
	2524	2424	2408	2444	2520	2702	2732	2644	2534	2324	2248	2250	2304	2488	2528	2454	2416
West of I405	2654	2336	2324	2526	2424	2369	2328	2358	3026	4312	4432	4552	4504	4532	4280	2659	1898
	3154	2336	3324	3026	2924	2868	2828	1558	2626	3512	3632	3752	3604	4032	4298	2670	1906

Appendix 2: INTEGRATION Input File Creation

The supply data (described in Section 2.1 in the main report) collected for the simulation runs were entered on a single spreadsheet. This spreadsheet served as the single source of data for both simulations (INTEGRATION and FREQ). For the FREQ runs, data were entered directly into the model from the spreadsheet. When the INTEGRATION input data files were prepared, the process was even easier: exports from the spreadsheet could be used (almost) directly as input to the model.

Since the supply data collection process was iterative, and multiple files were created from the spreadsheet, it was important to create a flexible and dynamic spreadsheet to manipulate these data. This appendix describes that spreadsheet.

The spreadsheet consists of three separate sections: nodes, links, and signals. The signal columns are straightforward and will not be described here. However, there are some unique characteristics of the node and link sections that will be discussed in some detail.

The Node Data

A total of 12 columns were used to describe each of the 201 nodes in the network (one row was used for each node). An excerpt from the spreadsheet is shown in Figure **A.** 1.

					INTEGRATION Node File						
Node ID			**Actual (in km)**			**Screen (in.)**					
Ref	**No**	**JHK**	**xcoord**	**ycoord**	**node#**	**xcoord**	**ycoord**	**o-d**	**Clstr**	**CM**	**Description**
EFF	31	**a66**	20.637	4.941	31	30.31	13.47	3	-31	0	on-ramp (EB) Western
EFH	32	a67	21.547	4.941	32	31.63	13.45	3	-32	0	on-ramp (EB) Normndie
EFJ	33	**a68**	22.102	4.941	33	32.95	13.52	3	-33	0	on-ramp (EB) Vermont
BFB	34	<>	8.729	5.023	34	11.88	12.49	4	0	0	EB ML at I-405 overpass
BFC	35	r150	9.308	5.023	35	12.63	12.49	4	0	0	EB ML I-405 on-ramps
BFD	36	r151	10.261	5.023	36	14.01	12.39	4	0	0	EB ML Nat'l off-ramp
BFE	37	r152	10.521	5.023	37	14.45	12.39	4	0	0	EB ML Ovrlnd on-ramp
BFF	38	<>	10.875	5.023	38	15.10	12.36	4	0	0	EB ML Motor detector

Figure A.1: Excerpt from Supply Spreadsheet (Nodes)

Each row can be considered a separate node in the network; these include the start and end points of ramps (e.g., the end point of an on-ramp would be a node on the mainline freeway) and nodes at points where lanes are added are dropped. *Also,* some nodes are used to indicate detector locations (e.g., node 38 in the example) and ramp meters. Each of these nodes is identified by the description.

In addition to the node numbering scheme (1,2,3,...), each node is given a unique identifier consisting of three letters (e.g., EFF, EFH). These labels are arbitrary, but each node has a different label. The signficance of these identifiers are discussed in the description of the link data (on the next page). *Also,* each node was identified by its label in the **JHK** & Associates simulation project.

The location of each node was determined using the scanned map (discussed in Section 2.1.1) and referenced by a distance from a fixed point on the map. These coordinates were then converted to the screen coordinate scheme (measured in inches) given in columns 7 and **8.** Originally, this conversion was a simple linear transformation. However, to improve the clarity of the screen display, some of the node coordinates were later changed (e.g., the relative sizes of the ramps were increased). These changes were made directly on the spreadsheet so they could be used for later simulation runs.

Finally, the other relevant node data (the origin-destination node type, the cluster number, and the location of **CMS** points) are listed. Note that only the seven rightmost columns (highlighted by the shaded area) are actually used in the INTEGRATION runs. When the node files were needed, it was only necessary to print (to a fie) those seven columns, and the INTEGRATION node fie was created. This strategy made the INTEGRATION input file creation process much easier.

The Link Data

Similar to the node data, separate columns (on the same spreadsheet) were used to manage the link data. However, these data were more complex, so the spreadsheet proved to be more valuable in creating the link files for INTEGRATION. Another excerpt is shown in Figure A.2.

								INTEGRATION Link File	
Link ID		Ref. Nodes		Origin		Destination			
No.	JHK	Start	End	xcoord	ycoord	xcoord	ycoord	{Data...}	Description
1	f149	BFA	BFB	8.577	5.023	8.729	5.023	....	on-ramp (EB) **Western**
2	f149	BFB	BFC	8.729	5.023	9.308	5.023	....	on-ramp (EB) Normndie
3	f150	BFC	BFD	9.308	5.023	10.261	5.023	....	on-ramp (EB) Vermont
4	f151	BFD	BFE	10.261	5.023	10.521	5.023	....	EB ML at I-405 **overpass**
5	f152	BFE	BFF	10.521	5.023	10.875	5.023	....	EB ML I-405 on-ramps
6	f152	BFF	BFG	10.875	5.023	11.614	5.023	....	EB ML Nat'l off-ramp
7	f153	BFG	BFH	11.614	5.023	12.370	5.023	....	EB ML Ovrlndon-ramp
8	f154	BFH	BFI	12.370	5.023	12.770	5.023	....	EB ML Motor detector

Figure A.2: Excerptfrom Supply Spreadsheet (Links)

Each link was given a number (1,2,3,...) that would become its link number in INTEGRATION. Again, the corresponding **JHK** link was also listed (note that there was not always a one-to-one relationship between the links in the simulation used here and the **JHK** model).

The next two columns were the critical ones. The two end nodes of the links were entered here, not in terms of the node numbers (as required by INTEGRATION), but by the three character node reference code. The reason for doing so may not be immediately obvious, so some explanation may be appropriate. Since the network structure underwent much revision during the development process, nodes and links were added (and occasionally eliminated) quite frequently. This might have required substantial changes in both the node and link files. For example, nodes must be numbered in a specific order (by their origin-destination type) in INTEGRATION, so adding a type **2** or type **3** node to the network would requite number changes for all of the following nodes. If the links were referenced by these node numbers, nearly all of the links would require changes (by hand), which would be a time-consuming process. By using (arbitrary) labels for nodes, the node references for links could be entered just once.

The next four columns (which are not used directly in INTEGRATION) are the actual x- and y-coordinates of the link endpoints (i.e., nodes). These are found in the spreadsheet by a lookup function, using the reference codes in the previous two columns.

The next columns (not shown in Figure A.2) are the data that was exported to the INTEGRATION link file. Some of these data are shown in Figure A.3. The start and end node columns were again found using a lookup function from the reference nodes for that link. Then, the length (the next column) was computed using the Pythagorean Theorem and the actual node coordinate values (see Figure A.2). The remainder of the values (only a subset are shown) were directly entered onto the spreadsheet; they are easily modified. Finally, link the node data, the INTEGRATION link file data (under the shaded line) was exported to an ASCII file from the spreadsheet and was used directly for the model runs.

INTEGRATION Link File										
Link#	Start Node	End Node	Length	F.F. Speed	Sat Flow	# Lane	Plat Fact	Speed/Flow A	Speed/Flow B	{More Data...}
1	17	34	0.259	100	2067	3	0	71	131	....
2	34	35	0.594	100	2067	3	0	71	131	....
3	35	36	0.884	100	2000	5	0	71	131	....
4	36	37	0.427	100	2050	4	0	71	131	....
5	37	38	0.503	100	2000	5	0	71	131	....
6	38	39	0.655	100	2000	5	0	71	131	....
7	39	40	0.350	100	1980	5	0	71	131	....
8	40	41	0.640	100	1980	5	0	71	131	....

Figure A.3: Excerptfrom Supply Spreadsheet (INTEGRATION Link Datu)

Appendix 3: O/D Conversion Program

In order to easily capture FREQ-synthesized origin-destination data for use with INTEGRATION, it was deemed important to develop a utility program to extract data from FREQ output files into an INTEGRATION file format. This appendix describes that utility program (called ODCONVER) and provides some basic instructions for using it.

Motivation
In order to compare the results from FREQ and INTEGRATION, it was important to use the same demand input (in the form of origin-destination pairs). FREQ provides a table of origin-destination pairs that is synthesized during each run. However, creating a file compatible with INTEGRATION with these data (i.e., lists of origin-destination pairs) would be a time-consuming process. Therefore, an automated procedure was developed to translate the FREQ-generated O-D table to an INTEGRATION input file.

The ODCONVER (short for Origin-Destination CONVERsion) program is custom utility software, developed by the author and written in the Pascal programming language. The program allows the user to create an origin-destination input file for use with the INTEGRATION model.

Input to the Program
In addition to the odconver executable, several additional files are needed to run the utility. They are described below:

- **FREQ output files** (*freq11pe.out* or *freq11pl.out*). When making the FREQ runs, the origin-destination tables for each time slice must be requested.
- **Table matching FREQ ramps with INTEGRATION nodes.** The ODCONVER program creates o-d pair data referencing specific nodes in the INTEGRATION network. These must be described in terms of ramps (i.e., sources and sinks) in the FREQ simulation.

Running the Program
The user starts the ODCONVER program from the DOS prompt simply by typing *odconver*. Then, the user is prompted for the names of the FREQ output file, the FREQ-INTEGRATION conversion table, and the INTEGRATION O-D file to be created. The program then searches the FREQ output for the O-D table, and rewrites the data in the correct format for INTEGRATION.

Source *Code*
The Pascal source code for *odconver.pas* is given on the following pages.

```
Program FREQODtoINTEGRATION (input,output,infile,outfile);
{
                ODCONVER.pas utility program
                INSTITUTE FOR TRANSPORTATION STUDIES
                UNIVERSITY OF CALIFORNIA AT BERKELEY, 1994

        This program takes a FREQ output file (which includes synthesized Origin-Destination data),
        and creates a text file of O-D pairs that is suitable for inclustion in an INTEGRATION
        file type 4.


const
     NUMTIMESLICES = 24;

type
     tableRec = record
          orig: integer;   {1 for orig, 0 for dest}
          FREQ: integer;
          INTG: integer;
     end;
     tableArray = array[0..50] of tableRec;

     odRec = record
           orig,dest: integer;
           demand: integer;
           timeSlice: integer;
     end;
     odArray = array[1..5000] of odRec;

var {global}
     FREQ_Orig: integer;
     FREQ_Dest: integer;
     finished: boolean;
     infile, outfile: text;
     filename: string;
     inputString: string[255];
     convertTable: tableArray;
     c: char;
     i,j,k,l,odpairs,timeslice,demand: integer;
     totalCars: real;
     resultTable: array[1..20,1..20] of integer;
     odPairData: odArray;

Procedure ReadTable(filename: string; var tempTable: tableArray);
{reads in a FREQ-INTEGRATION o/d node translation table]

var
     tablefile: text;

begin
     assign(tablefile,filename);
     reset (tablefile);
     {keep track of some things in record 0}
     tempTable[0].orig := 0;  {number read}
     tempTable[0].FREQ := 0;  {number origins}
     tempTable[0].INTG := 0;  {number destinations}
     while not(eof(tablefile)) do begin
          tempTable[0].orig:=tempTable[0].orig + 1;
          readln(tablefile, tempTable[tempTable[0].orig].orig,
               tempTable[tempTable[0].orig].FREQ,
               tempTable[tempTable[0].orig].INTG);
          if tempTable[tempTable[0].orig].orig = 1
             then tempTable[0].FREQ:= tempTable[0].FREQ + 1
             else tempTable[0].INTG:= tempTable[0].INTG + 1
     end;
     close(tablefile):
end; {function}
```

```
Function FindFREQODTable(var infile: text): boolean;
{ finds the next occurrence of a FREQ O/D table}

var
     found: boolean;
     i: integer:

begin
     found:= false;
     while not(found) do begin
          readln(infile,InputString);
          if (POS('ORIGINS',inputString) <> 0) then found:=true;
          if eof(infile) then found:=true
     end;
     if not(eof(infile)) then for i:=1 to 6 do readln(infile);
     FindFREQODTable:=found;
end;


Function getNextNumber(var infile:text): integer;

var
   c: char;
   i: integer;

begin;
   read(infile,c);
   while ((ord(c) < ord('0')) or (ord(c) > ord('9'))) do read(infile,c);
   i:=ord(c) - ord('0');
   read(infile,c);
   while ((ord(c) >= ord('0') ) and (ord(c) <= ord('9'))) do begin
        i:= 10*i t ord(c) - ord('0');
        read(infile,c);
   end;
   getNextNumber:=i;
end; {function]


Function INTGnode(FREQnode,nodeType: integer; tempTable: tableArray): integer;
{searches the conversion (mapping) table for the correct INTEGRATION node#.}

var
    i: integer;

begin
     for i:=1 to tempTable[0].orig do
         if ((tempTable[i].orig = nodeType) and (tempTable[i].FREQ = FREQnode))
              then INTGnode:=tempTable[i].INTG
end; (function)


begin {main}
     (set up conversion table}
     write('Where is the FREQ-INTEGRATION conversion table? ');
     readln(filename);
     readTable(filename, convertTable);
     FREQ_Orig:=convertTable[0].FREQ;
     FREQ_Dest:=convertTable{0}.INTG;
     writeln('There are ',FREQ_Orig,' origins and ',FREQ_Dest,' destinations.');

     (set up input/output files}
     write('What is the name of the FREQ input file? ');
     readln(filename);
     assign(infile,filename);
     reset(infile);
```

```
(clear results table]
for i:=1 to 20 do
   for j:=1 to 20 do
      ResultTable[i,j]:=0;

write('What is the name of the INTEGRATION output file? ');
readln(filename);

odpairs:=0;
totalCars:=0.0;

for timeSlice:= 1 to NUMTIMESLICES do begin;
     if findFREQODTable(infile) then begin
        writeln('Reading FREQ O/D table for time slice ',timeSlice,'...');
        for i:=1 to FREQ_Orig do begin
             for j:=1 to 7 do read(infile,c);
             for j:=1 to FREQ_Dest do begin
                  demand:= getNextNumber(infile);
                  k:=INTGnode(i,1,convertTable);
                  l:=INTGnode(j,0,convertTable);
                  if ((demand >= 1) and (k<>l)) then begin
                      odpairs:=odpairs t 1;
                      totalCars:= totalCars + demand;
                      odPairData[odPairs].demand:=demand;
                      odPairData[odPairs].orig:=k;
                      odPairData[odPairs].dest:=l;
                      odPairData[odPairs].timeSlice:=timeSlice;
                      resultTable[k,l]:=resultTable[k,l] + demand;
                  end;
             end;
             readln(infile);
             readln(infile);
        end;
        writeln;
     end
     else writeln('Couldn''t find time slice ',timeSlice);
end;
close(infile);

(write results to INTEGRATION o/d file)
assign(outfile,filename);
rewrite(outfile);
for i:=1 to odPairs do begin
     write(outfile,i:4,' ',odPairData[i].orig:3,' ');
     write(outfile,odPairData[i].dest:3,odPairData[i].demand:5,' 1.0 ');
     write(outfile,(odPairData[i].timeSlice-1)*18:5,'00',odPairData[i].timeSlice*18:5,'00');
     writeln(outfile,' 1.0 0.0 0.0 0.0 0.0   0.0 1.0');
end;
close(outfile);

{write results to o/d summary file]
writeln('Writing summary table...');
assign(outfile,'ebsummar.out');
rewrite(outfile);
for i:=1 to 20 do for j:=1 to 20 do
   if resultTable[i,j]<>0 then
      writeln(outfile,i:4,j:4,resultTable[i,j]:7);
close(outfile);

writeln;
writeln('Execution complete.  There were ',totalCars/2:6:0,' cars counted.');
```

Appendix 4: Calibration Program

In order to efficiently interpret the output from **INTEGRATION,** it was deemed important to develop a utility program to manipulate the output files into a more easily readable format. **This** appendix describes that utility program (called **INTOMAN)** and provides some basic instructions for using it.

Motivation
INTEGRATION provides output in the form of **ASCII** files, using several different formats. The two most useful files (numbered 10 and 12) contain traffic performance data for network links by time slice. File type 10 is formatted, and can be read directly; file type 12 is provided in tabular form that is best suited for importing into a spreadsheet. Neither file, however, provides for a quick visual assessment of traffic performance. The lack of such a facility was the motivation for INTOMAN.

INTOMAN (short for INTegration Output MANager), is custom utility software, developed by the author and written in the Pascal programming language. Through menus, the program allows the user to create a number of useful charts and diagrams using the output from INTEGRATION.

Input to the Program
In addition to the INTOMAN executable, several additional files are needed to run the utility. They are described below:

- **INTEGRATION output files** type 10 and/or 12. Each is needed as the data source for creating specific types of output charts.
- **INTEGRATION link file** from the original simulation run.
- **Valid links file** describing the types of links in the network. Any number of groups of links can be described in this file, and the specific link numbers in each group must be listed. Examples of groups might include on-ramps, off-ramps, and mainline links. This file is needed by the program to provide output for specific groups of links.

Running the Program
The user starts the INTOMAN program from the DOS prompt simply by typing *intoman*. Then, the menu shown in Figure **A.4** appears on the screen.

The first step is to consider the files listed in the center of the screen. Since calibration often involved comparing several sets of data, it was useful to maintain several different sets of input files and INTOMAN-generated output files. The current set of files is shown on the main menu screen; this group can be changed by selected main menu option **4,** which calls up the screen shown in Figure A.5.

```
                    INTEGRATION Output Manager
         Institute for Transportation Studies - UC Berkeley
                             Main Menu

 Current Files:  Eastbound Mainline Freeway (ver 1.5c)
       version:  INTEGRATION v1.5b or later

     link file:   eblinks.dat          valid file:  valideb.dat
output file 10:  fway12eb.out      output file 12:  fway12eb.out
  contour file:   contour.eb            flow file:  flowdata.eb
  summary file:  summdata.eb


                    1)  Contour Maps
                    2)  Statistics by Link or Link Type
                    3)  Summary Statistics
                    4)  Change File Names
                    0)  Quit the program

                        Enter your choice:
```

Figure A.4: INTOMAN Main Menu

```
                    INTEGRATION Output Manager
         Institute for Transportation Studies - UC Berkeley
                      Assign File Names Screen

AVAILABLE FILESETS:
1)  Eastbound Mainline Freeway (ver 1.5c)
2)  Westbound Mainline Freeway (ver 1.5c)
3)  Eastbound Mainline Freeway (ver 1.5b)
4)  Westbound Mainline Freeway (ver 1.5b)
5)  Eastbound Mainline Freeway (ver 1.5b)
6)  Westbound Mainline Freeway (ver 1.5b)

Current set #1:  Eastbound Mainline Freeway (ver 1.5c)
       version:  INTEGRATION 1.5b or later
     link file:   eblinks.dat          valid file:  valideb.dat
output file 10:  fway12eb.out      output file 12:  fway12eb.out
  contour file:   contour.eb            flow file:  flowdata.eb
  summary file:  summdata.eb


 New fileset (or 0 to end):
```

Figure A.5: INTOMAN Assign File Names Screen

The user can select the appropriate dataset (the list of datasets and their fies are stored in a file called *intoman.fil*, which can be modified by any **ASCII** editor). Once the correct set of files is selected, typing in 0 will return to the main menu.

Then, the user can select any of three general types of output from the program: contour maps, link statistics, or summary statistics. Each is described below.

Contour Maps
Typing in 1 from the main menu brings up the contour map menu. **A** sample dialogue from this menu is shown in Figure **A.6.**

```
                    INTEGRATION Output Manager
          Institute for Transportation Studies - UC Berkeley
                         Contour Map Menu

                    1)  Speed Contours
                    2)  Density Contours
                    3)  Queueing Diagram
                    0)  Quit this Menu

                        Enter your choice:  1

Please select a group number from the following:

1)  Eastbound Mainline Links
2)  Eastbound On-Ramps
3)  Eastbound Off-Ramps

Your choice:  1

Looking at output file 10...
 Time slice 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Output file was saved as contour.eb.  Hit return to continue.
```

Figure A.6: INTOMAN Contour Map Screen

In this example, the user has selected a speed contour diagram, one of three FREQ-link contour diagrams that can be produced by INTOMAN. Then, the user can select from any of the link groups available for the current dataset; in this case, the mainline links were selected. Finally, the program reads output file 10 (looking at each of 24 time slices in this example) and produces an output file called *contour.eb*. The resulting file will look similar to Figure xx in the main text: a contour map of speed, graphed by link number on the horizontal axis and time on the vertical axis.

Link Statistics
Another function can be performed by typing in **2** from the main menu. **A** sample dialogue from the link statistics menu is shown in Figure **A.7.**

```
                    INTEGRATION Output Manager
        Institute for Transportation Studies - UC Berkeley
                       Link Statistics Menu

              1)  Time-Space Series of Link Volumes
              0)  Quit this Menu

                       Enter your choice:  1

Please select a group number from the following:

1)  Eastbound Mainline Links
2)  Eastbound On-Ramps
3)  Eastbound Off-Ramps

Your choice:  1

Looking at output file 12...
 Time slice 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Output file was saved as flowdata.eb.  Hit return to continue.
```

Figure A.7: INTOMAN Link Statistics Screen

For this function, only volume data output are available. Then, the user can again select which group of data for the output file (called *flowdata.eb*). An excerpt of the results from this sample run (the volume counts for **8** mainline links for the first 6 time slices) are shown in Figure **A.8**

```
                    TRAFFIC STATISTICS SUMMARY
                      Time-Space Series of
               FLOW data (in vehicles/hour/roadway)
              Eastbound Mainline Freeway (ver 1.5c)
                    Eastbound Mainline Links

             Time Slice
Link           1     2     3     4     5     6
-------------------------------------     -----
   1        2982  4558  4870  3006  3828  4276
   2        2944  4532  4624  3048  3842  4328
   3        5912  8036  7190  5208  6624  7496
   4        5330  7296  6284  4726  5912  6620
   5        6096  8358  6930  5528  7026  7998
   6        6018  8320  6502  5660  7052  8094
   7        6440  8860  6824  6198  7548  8662
   8        5850  8054  5792  5664  6770  7792
```

Figure A.8: Sample INTOMAN Link Statistics File

summary statistics

Summary data for the simulation run can be obtained by choosing the third main menu option. Currently, the only data provided are total vehicle-miles by time slice (i.e., for all links in the selected group) and for the entire simulation.

Source *Code*

The Pascal source code for *intoman.pas* is given below and on the following pages.

```
Program IntegrationOutputManager (input, output, infile, outfile);
{
               INTOMAN.pas utility program
               INSTITUTE FOR TRANSPORTATION STUDIES
               UNIVERSITY OF CALIFORNIA AT BERKELEY, 1994

       This program creates several types of summary charts and graphs using output fro
       INTEGRATION simulation runs.  The required input files are:  INTEGRATION output files 1
       and 12, the INTEGRATION link file (input), the valid link input file (describing th
       groups of links in the network), and intoman.fil (the list of dataset groups).
}

{$M 65520 0 655360)   {increase the stack size to accomodate the large
                        data structures)
uses Crt, Dos;

const
   MAXLINKS = 2000;
   MAXGROUPLINKS = 100;
   MAXTSLICES = 24;
   PAGEWIDTH = 80;
   PRINTWIDTH = 200;
   MAXLINKTYPES = 5;
   MAXFILETYPES = 10;
   FLOW = 1;
   SPEED = 2;
   TRAVELTIME = 3;
   DENSITY = 4;

type
   linkRec = record           (data for a specific links)
       linkNum: integer;
       linkLen: real;
       linkGroup: integer;
       orderNum: integer;  (number within linkGroup}
   end;

   bigLinkRec  = record       (data for links used for output}
       linkNum: integer;
       linkLen: real;
       useLink: integer;   {1=true, 0=false, #=group)
   end;

   linkArray = array[-1..MAXLINKS] of linkRec;
   outputArray = array[1..MAXGROUPLINKS, 1..MAXTSLICES] of real;
   outputLinkNumArray = array[0..MAXGROUPLINKS] of integer;

   fileSetSubRec = record     {record of filenames for a single dataset)
       fileSetName: string[60];
       oldVersion: char;
       lf, vf, o10, 012, cf, ff, sf: string[12];
   end;
```

```
   fileSetRec = record {data structure for datasets}
       totalNumber: integer;
       currentNumber: integer:
       fileSetData: array[1..MAXFILETYPES] of fileSetSubRec;
   end:

var  (global variables)
   linkData: linkArray;
   outputData,moreOutputData: outputArray;
   outputLinkNum: outputLinkNumArray;
   numTimeSlices, dataType, groupNum: integer:
   timeslicesize: integer;
   menuItem, subMenuItem: integer;
   simulationName: string[80];
   groupNames: array[1..MAXLINKTYPES] of string[80];
   fileset: fileSetRec;
   linkFile, validFile, outputFile10, outputFile12,
      contourFile, flowFile, summaryFile:  string[12];
   eastbound, oldVersionData: char:


function getValidInt(a,b: integer): integer:
{gets an integer in the range (a,b) from the user}

var
   i: integer:

begin
     repeat
     readln(i);
         if (i<a) or (i>b) then
             write('Please enter a number between ',a,' and ',b,': ');
     until (i>=a) and (i<=b);
     getValidInt:=i;
end:
{***************************************************************************}


Function validFileName(var fn: PathStr): boolean:
{checks to see if a file name is valid)
var
   i: integer:

begin
   if fSearch(fn,'e:')=fn then
      validFileName:=true
   else begin
      write('Sorry, no file named ',fn,' exists.  Hit return to continue: ');
      readln:
      validFileName:=false;
   end:
end;
{***************************************************************************}


Function getChar: char:
{gets one character (lower-case) from the user)

var
   s: string[80];
   c: char:

begin
   readln(s);
   c:=s[1];
   if (ord(c)>=ord('A')) and (ord(c)<=ord('Z'))
   then c:=chr(ord(c) + ord('a')-ord('A'));
   getChar:=c;
end;
{***************************************************************************}
```

```
Function power(a,b: integer): integer;
{raises a to the b power}
var
   i,j: integer;

begin
   j:=1;
   for i:=1 to b do j:=j*a;
   power:=j;
end;
{***************************************************************************}



Function searchFileString (var infile: text; s: string; 1: integer): boolean;
(reads a file until the first 1 chars of s are found}

var
   found, sameStr: boolean;
   inStr: string[80];
   i: integer;

begin
   found:=false;
   while (not(eof(infile)) and not(found)) do begin
      readln(infile,inStr);
      sameStr:=true;
      for i:=1 to 1 do
         if inStr[i] <> s[i] then sameStr:=false;
      found:=sameStr;
   end;
   searchFileString:=found;
end;
{***************************************************************************}


Procedure centerString(var outfile: text; S: string);
{centers a string for an output file}

var
    i,1: integer;
begin
    l:=80-length(s);
    for i:=1 to trunc(l/2) do write(outfile,' ');
    writeln(outfile,s);
end;
{***************************************************************************}


Procedure markValidLinks (var linkData: linkArray);
{reads the selected links from an input file)

var
   linkListCount, numLinkTypes, numLinks, i,j,k: integer;
   fn:  PathStr;
   infile: text;

begin

{There should be a link input file that lists the links to be included in
 the output.  The file format is as follows:

  line 1: Name of Simulation (text)
  line 2: Number of groups
  line 3: Name of Group #1 (text)
  line 4: Number of links in group #1
  line 5-n: Enumerated links in group #1
  line ntl: Name of Group #2....                          }
```

```
   fn:=validFile;
   if validFileName(fn) then begin
      assign(infile, fn);
      reset(infile);
      readln(infile);
      readln(infile,numLinkTypes);
      if numLinkTypes > MAXLINKTYPES then numLinkTypes:=MAXLINKTYPES;
      linkData[0].linkGroup:=numLinkTypes;
      linkListCount:=1;
      for i:=1 to numLinkTypes do begin
         readln(infile,groupNames[i]);  {name of link type)
         readln(infile,numLinks);
         if (numLinks > MAXGROUPLINKS) then begin
             writeln;
             writeln('The number of links in group #',i,' exceeds the maximum (',
                       MAXGROUPLINKS,')- excess links will be ignored.');
             write('Hit return to continue ');
             readln:
         end;
         for k:=1 to numLinks do begin
             readln(infile,j);
             if k<=MAXGROUPLINKS then
                for linkListCount:=1 to linkData[0].linkNum do
                   if linkData[linkListCount].linkNum = j
                   then begin
                      linkData[linkListCount].linkGroup:=i;
                      linkData[linkListCount].orderNum:=k;
                   end;
         end;
      end:
      close(infile);
   end;
nd;
*************************************************************************}


'rocedurereadLinkData(var linkData: linkArray);
Reads in data about links from input file type 2)

  var
     fn: pathStr;
     infile: text;
     numLinks,i,j: integer;

  begin
     {write('Please enter the name of the INTEGRATION link file (#2): ');}
     fn:=linkFile;
     if validFileName(fn) then begin

        assign(infile,fn);
        reset(infile);
        readln(infile);    {skip first blank line of input file}
        readln(infile, numLinks);

        {read in link data to bigLinkArray}
        linkData[0].linkNum:= numLinks;
        for i:=1 to numLinks do if i<MAXLINKS then begin
            read(infile, linkData[i].LinkNum);
            read(infile,j,j);  {skip over start/end node data)
            read(infile,linkData[i].linkLen);
            readln(infile);
            linkData[i].linkGroup:= 0;
            linkData[i].orderNum:=0;
        end;

        {determine which links are to be studied)
        markValidLinks(linkData);
     end
```

```
      else begin {no data was read}
         linkData[0].linkNum:=0;    {total links to study}
         linkData[0].linkGroup:=0;  {number of link groups}
       end;
   end; {procedure]
{************************************************************************}


Procedure readOutputData(var outputData: outputArray; var numTimeSlices: integer;
                         var linkData: linkArray; groupNum, dataType: integer);
[reads general data from INTEGRATION output file 10}

   var
      infile: text;
      i,j,k,l,linkNum: integer;
      c: char;
      compareStr: string[15];
      whitespace: integer:    {how much space to skip in reading input]
      simTime,r: real;
      numLinks: integer;
      fn: pathStr;

   begin
      numLinks:= linkData[0].linkNum;
      case dataType of
           SPEED:  whiteSpace:= 86;  {average speed)
           FLOW:   whiteSpace:= 52;  {flow)
           TRAVELTIME: whiteSpace:= 66;
      end;

      fn:=outputFile10;
      if validFileName(fn) then begin
         assign(infile, fn);
         reset(infile);
         if oldVersionData='y' then compareStr:= '    - File: 15'
                                else compareStr:= '    - File: 19';
         if searchFileString(infile,compareStr,13) then begin
            readln(infile);
            for i:=1 to 24 do read(infile,c);
            readln(infile,simTime);
            for i:=1 to 26 do read(infile,c);
            readln(infile,timeSliceSize);
            if timeslicesize < 0 then timeSliceSize:= -1*timeSliceSize;
            numTimeSlices:=trunc(simTime/timeSliceSize);
            if numTimeSlices > MAXTSLICES then numTimeSlices:=MAXTSLICES;

            writeln('Looking at output file 10...');
            write(' Time slice');
            for i:=1 to numTimeSlices do
            if searchFileString(infile,' LINK FLOW SUMMARIES',20) then begin
               if i>9 then write(i:3)
               else write(i:2);
               for j:=1 to 5 do readln(infile);
               k:=0;
               for j:=1 to numLinks do begin
                  read(infile,linkNum);
                  {skip the next n characters, depending on whitespace}
                  for l:=1 to whiteSpace do read(infile,c);
                  readln(infile, r);    {get the relevant datal
                  if linkData[j].linkGroup = groupNum then begin
                     k:=k+1;
                     outputLinkNum[k]:=j;
                     outputData[k,i]:=r;
                     outputLinkNum[0]:=k;    {total in group}
                  end;
               end;
            end;  (if..then}
            writeln;
         end;  {if..then}
```

```
         close(infile);
      end  {if..then}
      else
         linkData[0].linkNum:=0;      {flag that no output data was read)
   end;  (procedure)
{*************************************************************************}


Procedure readLinkStatistics(var outputData: outputArray; var linkData: linkArray;
                             groupNum, dataType: integer);
{reads general data from INTEGRATION output file 12}

var
   infile: text;
   s: string;
   fn: pathstr;
   i,j,k,1,timePeriods: integer;
   r: array[1..12] of real;
   linkNum, numLinks, totalLinks: integer;
   c: char;

begin
   fn:=outputFile12;
   if validFileName(fn) then begin
      writeln('Looking at output. file 12.. ');
      write(' Time slice');
      assign(infile,fn);
      reset (infile);
      readln(infile);  {file title)
      read(infile, timePeriods);
      readln(infile, timeSliceSize) ;
      if timeSliceSize < 0 then timeSliceSize:=-1*timeSliceSize;

      numLinks:=linkData[0].linkNum;
      linkData[-1].linkNum:=timePeriods;

      for j:=1 to timePeriods do begin
         readln(infile);    {time and period number)
         if j<10 then write(j:2)
         else write(j:3);
         1:=0;
         for i:=1 to numLinks do begin
              for k:=1 to 12 do read(infile,r[k]);    (get some fields1
              readln(infile);
              if linkData[i].linkGroup = groupNum then begin
                  l:=l+1;
                  outputLinkNum[l]:=i;
                  outputLinkNum[0]:=l;    {total number in group}
                  case dataType of
                      FLOW:  outputData[l][j]:=trunc(r[2]);
                      DENSITY: outputData[l][j]:=trunc(r[11]);
                  end;  {case}
              end; (if..then]
         end;
      end;
      writeln;
      close(infile);
   end
   else
      linkData[0].linkNum:=0;      {flag that no output data was read}
end;
{*************************************************************************}
```

```
Procedure findDensityData(var outputData: outputArray; linkData: linkArray);
{converts densities in cars/link to veh/mile}

var
   i,j: integer;

begin
   for j:=1 to linkData[-1].linkNum do   (loop through time slices]
      for i:=1 to outputLinkNum[0] do
          outputData[i,j]:= outputData[i,j] /
                     linkData[outputLinkNum[i]].linkLen/ 1.609;
end;
{************************************************************************}


Procedure findSpeedData(var arrayl, array2: outputArray;
                             linkData: linkArray; t: integer);
{separates aggregate travel times in arrayl into time slice stats by using
 cumulative flows in array2, and then determines speeds using link lengths]

var
    i,j: integer;

begin
    for i:=1 to outputLinkNum[0] do for j:=t downto 2 do begin
        if array2[i,j] - array2[i,j-1] = 0 then
           array1[i,j]:=-1.0
        else begin
            array1[i,j]:= (array1[i,j] - array1[i,j-1]) /
                      (array2[i,j] - array2[i,j-1] )/60;
            if array1[i,j]> 0 then
               array1[i,j]:=linkData[outputLinkNum[i]].linkLen/array1[i,j]
            else array1[i,j]:=-1.0
        end;
    end;
    for i:=1 to outputLinkNum[0] do
       if (array1[i,1] <= 0) or (array2[i,1] <= 0)
       then array1[i,1]:= -1.0
       else
          array1[i,1]:= linkData[outputLinkNum[i]].linkLen/
                         (array1[i,1]/array2[i,1]/60);
end;
{************************************************************************}


Procedure writeContourToFile(outputData: outputArray; numTimeSlices: integer;
                              linkData: linkArray; groupNum, dataType: integer);
{creates a contour map from outputData[i,j]}

   var
      i,j,k,p,map: integer;
      origStart: integer;
      linkNum,linkCol,offset: integer;
      origLinkNum, origLinkCol: integer;
      scale: real;    {scaling factor for contour map)
      1, lenUnit, adjust: real;
      linkSpacing: array[1..MAXGROUPLINKS] of integer;
      outfile: text;

   begin
      assign(outfile,contourFile);
      rewrite(outfile);

      {determine scale factor)
          case dataType of
           1:  scale:: 16.09;   {1.609 km/mile divided by 10 for speed}
           2:  scale:= 10.0;    {vehicles/mile factored by 10 for density)
           3:  scale:= 1.0;     (use density, but don't scale for queues}
      end;
```

```
writeln;
write('Adjusting total length....');
adjust:=1.0;
repeat
   l:=0.0;
   linkCol:=0;
   for i:=1 to outputLinkNum[0] do
      l:=l+linkData[outputLinkNum[i]].linkLen;
   lenUnit:= PRINTWIDTH/l;
   for i:=1 to outputLinkNum[0] do begin
       linkSpacing[i]:=trunc(linkData[outputLinkNum[i]].linkLen
              * lenUnit + adjust);
       if linkSpacing[i] < 1 then linkSpacing[i]:=1
   end;
   for i:=1 to outputLinkNum[0] do
      linkCol:=linkCol+linkSpacing[i];
   adjust:=adjust - 0.05;
   if linkCol < 200 then adjust:=adjust + 0.055;
until (linkCol=200);
writeln('Total length was ',linkCol);

{fill in output data}
case dataType of
     1: centerString(outfile,'SPEED CONTOUR MAP');
     2: centerString(outfile, 'DENSITY CONTOUR MAP');
     3: centerString(outfile,'QUEUEING DIAGRAM');
end;
centerString(outfile,simulationName);
centerString(outfile,groupNames[groupNum]);

linkCol:=1;
linkNum:=1;
for map:=1 to 2 do begin
   if map=2 then offset:=linkCol-1;    (save amount previously printed]
   origStart:=linkNum;
   origLinkNum:=linkNum;
   origLinkCol:=linkCol;
   writeln(outfile,' Time');
   write(outfile, 'Slice ');
   j:=0;
   for i:=1 to 100 do write(outfile,'.');
   writeln(outfile);
   for i:=1 to numTimeSlices do begin
       linkCol:=origLinkCol;
       linkNum:=origLinkNum;
       write(outfile,i:5,'.');
       for j:=1 to 100 do begin
          if linkCol > linkSpacing[linkNum] then begin
             linkCol:=1;
             linkNum:=linkNum + 1;
          end;
          if linkNum <= outputLinkNum[0] then begin
             case dataType of 1,2:
               if (outputData[linkNum,i] > 0.0) and
                  (outputData[linkNum,i]/scale < 10.0) then
                write(outfile,trunc(outputData[linkNum,i]/scale))
               else write(outfile,'*');
                              3:
               if (outputData[linkNum,i]) > 71*1.609  {Vc in veh/miles}
               then write(outfile,'*')
               else write(outfile,' ');
             end; (case)
          end;
          linkCol:=linkCol + 1;
       end;
       writeln(outfile,'.');
   end;
```

```
        write(outfile,'       ');
        for i:=1 to 100 do write(outfile,'.');
        writeln(outfile);
        (draw linear map of link numbers)
        write(outfile,'       ');
        if map=2 then
           for i:=1 to linkSpacing[origStart]-offset do write(outfile,' ');
        for i:=origStart + map - 1 to linkNum  do begin
            write(outfile,'^');
             for j:=1 to linkSpacing[i] - 1 do write(outfile,' ');
        end;
        writeln(outfile);

        write(outfile, 'link #');
        if map=2 then
           for i:=1 to linkSpacing[origStart]-offset do write(outfile,' ');
        for i:=origStart + map - 1 to linkNum  do begin
              write(outfile,trunc(linkData[outputLinkNum[i]].linkNum/1000));
               for j:=2 to linkSpacing[i] do write(outfile,' ');
        end;
        writeln(outfile);

        write(outfile,'       ');
        if map=2 then
           for i:=1 to linkSpacing[origStart]-offset do write(outfile,' ');
        for i:=origStart + map - 1 to linkNum  do begin
              write(outfile,trunc((linkData[outputLinkNum[i]].linkNum  -
                    trunc(linkData[outputLinkNum[i]].linkNum/1000)*1000)/100));
               for j:=2 to linkSpacing[i] do write(outfile,' ');
        end;
        writeln(outfile);

        write(outfile,'       ');
        if map=2 then
           for i:=1 to linkSpacing[origStart]-offset do write(outfile,' ');
        for i:=origStart + map - 1 to linkNum  do begin
              write(outfile,trunc((linkData[outputLinkNum[i]].linkNum
                   - trunc(linkData[outputLinkNum[i]].linkNum/100)*100)/10));
               for j:=2 to linkSpacing[i] do write(outfile,' ');
        end;
        writeln(outfile);

        write(outfile,'       ');
        if map=2 then
           for i:=1 to linkSpacing[origStart]-offset do write(outfile,' ');
        for i:=origStart + map - 1 to linkNum  do begin
              write(outfile,trunc(linkData[outputLinkNum[i]].linkNum
                   - trunc(linkData[outputLinkNum[i]].linkNum/10)*10));
               for j:=2 to linkSpacing[i] do write(outfile,' ');
        end;

        writeln(outfile);
        writeln(outfile);

     end;  {for..do}

     writeln(outfile,'     Institute of Transportation Studies');
     writeln(outfile,'     University of California, Berkeley');
     writeln(outfile,'     INTOMAN report (1994)');
     close(outfile);
     writeln;
     write('Output file was successfully saved as ',contourFile);
     write('.  Hit return to continue.');
     readln;
  end; (procedure)
{**************************************************************************}
```

```
Procedure writeSummaryStats(outputData: outputArray; linkData: linkArray;
                              groupNum: integer);
{computes and writes total mainline vehicle miles)

var
  l,i: integer;
  numTimeSlices: integer;
  infile,outfile: text;
  totVehMiles,subVehMiles: real;
link:integer;

begin
   numTimeSlices:=linkData[-1].linkNum;
   assign(outfile,summaryFile);
   rewrite(outfile);
   centerString(outfile,'TRAFFIC STATISTICS SUMMARY');
   centerString(outfile,simulationName);
   centerString(outfile,groupNames[groupNum]);
   writeln(outfile);
   totVehMiles:=0.0;
   for i:=1 to numTimeSlices do begin
       subVehMiles:=0.0;
       link:=0;
       for l:=1 to linkData[0].linkNum do
           if linkData[l].linkGroup = groupNum then begin
              link:=link+1;
              totVehMiles:=totVehMiles +
                    linkData[l].linkLen*outputData[outputLinkNum[link]][i]/
                    (3600/timeSliceSize);
              subVehMiles:=subVehMiles +
                    linkData[l].linkLen*outputData[outputLinkNum[link]][i]/
                    (3600/timeSliceSize);
           end;
       writeln(outfile,'Time slice ',i:2,': ',subVehMiles/1.609:7:0,' vehicle-miles.');
   end;
   writeln(outfile,'Total: ',totVehMiles/1.609:10:0,' vehicle-miles');
   close(outfile);

   write('Output file was successfully saved as ',summaryFile);
   write('.  Hit return to continue. ');
   readln;
end;
{****************************************************************************}


Procedure writeLinkStats(outputData: outputArray; linkData: linkArray;
                           dataType: integer);
(provides summary statistics for a link type)

var
   i,j,k,l: integer;
   numTimeSlices: integer;
   outfile: text;

begin
   numTimeSlices:=linkData[-1].linkNum;
   assign(outfile,flowFile);
   rewrite(outfile);
   centerString(outfile,'TRAFFIC STATISTICS SUMMARY');
   centerString(outfile,'Time-Space Series of');
   centerString(outfile,'FLOW data (in vehicles/hour/roadway)');
   centerString(outfile,simulationName);
   centerString(outfile,groupNames[groupNum]);
   writeln(outfile);
   writeln(outfile,'           Time Slice');
   write(outfile, 'Link   ');
   for i:=1 to numTimeSlices do write(outfile,i:6);
   writeln(outfile);
   write(outfile,'-------');
```

```
   for i:=1 to numTimeSlices do write(outfile,'------');
   writeln(outfile);
   for j:=1 to outputLinkNum[0] do begin
        write(outfile,outputLinkNum[j]:4,'   ');
        for k:=1 to numTimeSlices do write(outfile,
                   outputData[j][k]:6:0);
        writeln(outfile);
   end;
   writeln(outfile);
   close(outfile);

   write('Output file was successfully saved as ',flowFile);
   write('.  Hit return to continue. ');
   readln;
end;
{*************************************************************************}


Function getGroupNum(linkData: linkArray): integer;
(gets a valid group number from the user)

var
   i: integer;
begin
   writeln;
   writeln('Please select a group number from the following: ');
   writeln;
   for i:=1 to linkData[0].linkGroup do
      writeln(i:2,') ',groupNames[i]);
   writeln;
   write('Your choice: ');
   getGroupNum:= getValidInt(1,linkData[0].linkGroup);
end;
{************************************************************************}

Procedure assignFileNames(var fileset: fileSetRec; start: integer);

var
     i,j: integer;

begin
     if start<>1 then
     repeat
        i:=fileSet.currentNumber;
        ClrScr;
        writeln('                          INTEGRATION Output Manager');
        writeln('           Institute for Transportation Studies - UC Berkeley');
        writeln('                            Assign File Names Screen');
        writeln;
        writeln('AVAILABLE FILESETS:');
        for j:=1 to fileSet.totalNumber do
           writeln(j:2,') ',fileSet.fileSetData[j].fileSetName);
        writeln;
        writeln(' Current set #',i,': ',fileSet.fileSetData[i].fileSetName);
        write  ('        version: ');
        if fileSet.fileSetData[i].oldVersion = 'y' then
          writeln(' INTEGRATION v1.5a or earlier')
        else writeln(' INTEGRATION v1.5b or later');
        writeln('      link file: ',fileSet.fileSetData[i].lf:15,
                         valid file: ',fileSet.fileSetData[i].vf:15);
        writeln(' output file 10: ',fileSet.fileSetData[i].o12:15,
                      output file 12: ',fileSet.fileSetData[i].o12:15);
        writeln('   contour file: ',fileSet.fileSetData[i].cf:15,
                           flow file: ',fileSet.fileSetData[i].ff:15);
        writeln('   summary file: ',fileSet.fileSetData[i].sf:15);
        writeln;
        write('New fileset (or 0 to end): ');
        j:=getValidInt(0,fileset.totalNumber);
        if j>0 then fileSet.currentNumber:=j;
```

```
     until (j=0);

     i:=fileSet.currentNumber;
     linkFile:=fileSet.fileSetData[i].lf;
     validFile:=fileSet.fileSetData[i].vf;
     outputFile10:=fileSet.fileSetData[i].o10;
     outputFile12:=fileSet.fileSetData[i .o12;
     contourFile:=fileSet.fileSetData[i] cf;
     flowFile:=fileSet.fileSetData[i].ff;
     summaryFile:=fileSet.fileSetData[i].sf;
     oldVersionData:=fileSet.fileSetData[i].oldVersion;
     simulationName:=fileSet.fileSetData[i].fileSetName;
end;
-------------------------------------    ********************************}


function mainMenu: integer;
[displays the main menu)

var
     i: integer;

begin
     ClrScr;
     writeln;
     writeln('                         INTEGRATION Output Manager');
     writeln('           Institute for Transportation Studies - UC Berkeley');
     writeln('                                Main Menu');
     i:=fileSet.currentNumber;
     writeln('______________________________________________________________________________');
     writeln;
     writeln('  Current Files: ',fileSet.fileSetData[i].fileSetName);
     write  ('        version: ');
     if fileSet.fileSetData[i].oldVersion = 'y' then
          writeln(' INTEGRATION v1.5a or earlier')
     else writeln(' INTEGRATION v1.5b or later');
     writeln;
     writeln('      link file: ',fileSet.fileSetData[i].lf:15,
                              valid file: ',fileSet.fileSetData[i].vf:15);
     writeln(' output file 10: ',fileSet.fileSetData[i].o12:15,
                          output file 12: ',fileSet.fileSetData[i].o12:15);
     writeln('   contour file: ',fileSet.fileSetData[i].cf:15,
                               flow file: ',fileSet.fileSetData[i].ff:15);
     writeln('   summary file: ',fileSet.fileSetData[i].sf:15);
     writeln('______________________________________________________________________________');
     writeln;
     writeln('                   1)  Contour Maps');
     writeln('                   2)  Statistics by Link or Link Type');
     writeln('                   3)  Summary statistics');
     writeln('                   4)  Change file names');
     writeln('                   0)  Quit the program');
     writeln;
     write('                     Enter your choice: ');
     mainMenu:=getValidInt(0,4);
end;
****************************************************************************}
```

```
function contourMapMenu: integer;
{displays the contour map menu)

begin
     ClrScr;
     writeln;
     writeln('                       INTEGRATION Output Manager');
     writeln('            Institute for Transportation Studies - UC Berkeley');
     writeln('                            Contour Map Menu');
     writeln;
     writeln('                    1)  Speed Contours');
     writeln('                    2)  Density Contours');
     writeln('                    3)  Queueing Diagram');
     writeln('                    0)  Quit this menu');
     writeln;
     write('                    Enter your choice: ');
     contourMapMenu:=getValidInt(0,3);
end;
{**************************************************************************}

function linkStatsMenu: integer;
{displays the link stats menu}

begin
     ClrScr;
     writeln;
     writeln('                       INTEGRATION Output Manager');
     writeln('            Institute for Transportation studies - UC Berkeley');
     writeln('                          Link Statistics Menu');
     writeln;
     writeln('                    1)  Time-Space Series of Link Volumes');
     writeln('                    0)  Quit this menu');
     writeln;
     write('                    Enter your choice: ');
     linkStatsMenu:=getValidInt(0,1);
end;
{**************************************************************************}


Procedure readFileSet(var fileset: fileSetRec);
(gets the current file set data from the disk)

var
      infile: text;
      i: integer;

begin
      assign(infile,'intoman.fil');
      reset(infile);
      readln(infile,fileSet.totalNumber);
      readln(infile,fileSet.currentNumber);
      for i:=1 to fileSet.totalNumber do begin
          readln(infile,fileSet.fileSetData[i].fileSetName);
          readln(infile,fileSet.fileSetData[i].oldVersion);
          readln(infile,fileSet.fileSetData[i].lf);
          readln(infile,fileSet.fileSetData[i].vf);
          readln(infile,fileSet.fileSetData[i].o10);
          readln(infile,fileSet.fileSetData[i].o12);
          readln(infile,fileSet.fileSetData[i].cf);
          readln(infile,fileSet.fileSetData[i].ff);
          readln(infile,fileSet.fileSetData[i].sf);
      end;
      close(infile);
end;
{**************************************************************************}
```

```
begin (main)
      readFileSet(fileSet);
      assignFileNames(fileSet,1);
      repeat (main menu loop}
         menuItem:=mainMenu;

         if (menuItem = 1) then repeat
            subMenuItem:=contourMapMenu;
            if (subMenuItem>0) then begin
               readLinkData(linkData);
               if (linkData[0].linkNum > 0) then
               case subMenuItem of
                  1: begin
                     groupNum:= getGroupNum(linkData);
                     readOutputData(outputData,numTimeSlices,linkData,
                                    groupNum,TRAVELTIME);
                     readOutputData(moreOutputData,numTimeSlices,linkData,
                                    groupNum,FLOW);
                     findSpeedData(outputData,moreOutputData,linkData,
                                   numTimeSlices);
                  end;
                  2,3: begin
                     groupNum:=getGroupNum(linkData);
                     readLinkStatistics(outputData,linkData,groupNum,DENSITY);
                     findDensityData(outputData,linkData);
                     numTimeSlices:=linkData[-1].linkNum;
                  end:
               end;
               if (linkData[0].linkNum > 0) then
                   writeContourToFile(outputData,numTimeSlices,linkData,
                                      groupNum,subMenuItem);
            end;
         until (subMenuItem=0);

         if (menuItem = 2) then repeat
            subMenuItem:=linkStatsMenu;
            if (subMenuItem > 0) then begin
               readLinkData(linkData);
               if (linkData[0].linkNum > 0) then begin
                 case subMenuItem of
                    1:   begin
                           groupNum:=getGroupNum(linkData);
                           readLinkStatistics(outputData,linkData,groupNum,FLOW);
                    end;
                 end; {case]
                 if (linkData[0].linkNum > 0) then
                    writeLinkStats(outputData,linkData,dataType);
               end;
            end;
         until (subMenuItem=0);

         if (menuItem = 3) then begin
            readLinkData(linkData);
            groupNum:=getGroupNum(linkData);
            readLinkStatistics(outputData,linkData,groupNum,FLOW);
            writeSummaryStats(outputData,linkData,groupNum);
         end;

         if (menuItem = 4) then
            assignFileNames(fileSet,0);

      until (menuItem=0);
end.  {main program)
```

Appendix 5: Derivations for Speed/Flow Comparisons

The graph presented in Figure 6 in the main text shows the theoretical traffic flow relationship for the INTEGRATION and FREQ models. For the graph, the volume/capacity (v/c) ratio is shown as a function of vehicle speeds. However, the fundamental speed-flow equations for FREQ are given in terms of vehicle speeds as a function of the v/c ratio. For INTEGRATION, these relations are in terms of four other variables: speed at capacity (v_c), free flow speed (v_f), jam density (k_j), and roadway capacity (C). It was necessary to convert all of these functions to a standard function y=f(x), where y is the v/c ratio and x is the vehicle speed. This is straightforward to do using standard traffic flow equations, but the details of the mathematics were left to this appendix.

Section 2 lists the three equations used in FREQ for the speed-flow relationship. These are presented again here in terms of x (the vehicle speed) and y (the v/c ratio) for the empirical 65 mph curve:

undersaturated:

$x = 63 - 8.421y$	$y = [0, 0.95)$	{1}
$x = 14856.2y - 7823.6\,y^2 - 6997.4$	$y = (0.95, 13$	{2}

oversaturated:

$x = 20y^2 + 8y$	$y = [0,1]$	{3}

Since these equations are already in terms of x and y, no substitution is needed. However, they must be rearranged in the form y = f(x). The first step is to find the values of x (the speeds) where the curves shift. At y = 0.95 (near capacity), x is 55 mph. Then, just at capacity, speeds will be approximately 35 mph. The oversaturated portion of the curve is valid from x = 0 to 28 mph. For speeds from 28 to 35 mph, the v/c ratio will be 1.0.

For Eq.{1}:

$$x = 63 - 8.421y$$
$$8.421y = 63 - x$$
$$y = \frac{63 - x}{8.421}$$

For Eq.{2}:

$$x = 14856.2y - 7823.6\,y^2 - 6997.4$$
$$\frac{-x}{7823.6} = y^2 - 1.8989y + 0.89440$$
$$\frac{-x}{7823.6} - 0.89440 = y^2 - 1.8989y$$

completing the square:

$$\frac{-x}{7823.6} - 0.89440 + 0.90146 = y^2 - 1.8989y + 0.90146$$

$$\frac{-x}{7823.6} + 0.0070553 = (y - 0.94945)^2$$

$$y = \sqrt{0.0070553 - \frac{x}{7823.6}} + 0.90146$$

For Eq.{3):

$$x = 20y^2 + 8y$$

$$0.05x = y^2 + 0.4y$$

$$0.05x + 0.04 = y^2 + 0.4y + 0.04$$

$$0.05x + 0.04 = (y + 0.2)'$$

$$y = \sqrt{0.05x + 0.04} - 0.2$$

Therefore, the complete set of equations describing the v/c ratio (y) **as** a function of vehicle speed **(x)** in FREQ are:

$y = (63 - x) / 8.421$	$x = (55,63)$
$y = \sqrt{0.0070553 - \frac{x}{7823.6}} + 0.90146$	$x = (36,54)$
$y = 1.0$	$x = (28,35)$
$y = \sqrt{0.05x + 0.04} - 0.2$	$x = (0, 27)$

For the INTEGRATION model, only one model is used, but it is described in terms of other parameters. These are discussed in some detail below.

In the INTEGRATION model, the traffic flow (q) along a roadway can be described **as** a function of vehicle speed (called **x** here). This equation can be derived from fundamental traffic flow equations [Van Aerde 1993b].

$$q = \frac{x}{c, + \frac{c_2}{v_f - x} + v \cdot c_3}$$

The constants c_1, c_2, and c_3 can be described in terms of the four parameters specified in the model by the user: speed at capacity (v_c), free flow speed (v_f), jam density (k_j), and roadway capacity (C). By dividing q (the flow) by **C** (the capacity), the v/c variable can be obtained (which is called **x** here). Therefore it is possible to describe y (the v/c ratio) as **a** function of **x** (speed) in terms of user-specified parameters in INTEGRATION:

$$y = \frac{x}{C \cdot \left(c_1 + \frac{c_2}{v_f - x} + v \cdot c_3 \right)}$$

where

$$c_1 = k \cdot c_2$$

$$c_2 = \frac{1}{k_1} + \frac{1}{k + \frac{1}{v_f}}$$

$$c_3 = \frac{-c_1 + \frac{v_c}{C} + \frac{c_2}{v_f - v_c}}{v_c}$$

and

$$k = \frac{2v_c - v_f}{(v_f - v_c)^2}$$

An alternate formulation that was not used for the simulations described in this report but could be further investigated involves using the other model available in INTEGRATION, which is based on the Bureau of Public Roads travel time function. This can be described in **terms** of four parameters: speed at capacity (v_c), density (k), jam density (k_j), and the Erst and second derivatives of vehicle speeds at capacity (the "A" and "B" parameters in the travel time function.

For undersaturated conditions, INTEGRATION uses the standard Bureau of Public Roads travel time function. It is given by:

$$t = t_f \cdot (1 + A \cdot (\tfrac{v}{c})^B)$$

where t is the travel time for a given section at a specific v/c ratio, t_f is the travel time for that section at free flow, and A and B are constant parameters. Travel times can be converted to speeds by taking the reciprocal of time and multiplymg by a constant distance d. Converting to the x,y notation used above gives:

$$x = \frac{v_f}{1 + Ay^B}$$

where v_f is the free flow speed (another constant parameter). **This** equation will give speeds ranging from v_f (when v/c is 0.0) to $v_f/(1+A)$ when v/c = 1.0. Now, converting to y = f(x) form:

$$\frac{v_f}{x} = 1 + Ay^B$$

$$\frac{v_f - x}{Ax} = y^E$$

$$\ln\left(\frac{v_f - x}{Ax}\right) = B \cdot \ln y$$

$$y = e^{\ln\left(\frac{v_f - x}{Ax}\right)/B}$$

For oversaturated conditions, the problem is somewhat more complicated. Under congestion, INTEGRATION uses a derivation of Greenshield's equation:

$$v = 2v_c \cdot \left(1 - \frac{k}{k_j}\right)$$

where k is the density of traffic on the roadway at a given v/c ratio, k_j is the density at total congestion (jam density, where v/c = 0.0), and v_c is the speed at maximum capacity. The first conversion needed is to find expressions for the density ratio (k/k_j) in terms of y (the v/c ratio).

First, an expression for jam density will be found. At v/c = 1.0, let the density equal some value k_c. At this v/c ratio, the flow will simply be the capacity of the roadway, C. Then, the fundamental relation q = kv (flow equals the product of density and velocity) is rewritten as

$$C = k_c v_c \qquad \{4\}$$

Earlier, it **was** shown that the speed at capacity, $v_c = v_f/(1+A)$. Also, for Greenshield's equation, the jam density is twice the density at capacity: $k_j = 2k_f$. Therefore, Eq.{4} becomes:

$$C = \frac{k_j v_f}{2(1+A)}$$

$$k_j = \frac{2C(1+A)}{v_f} \qquad \{5\}$$

Now, a linear expression for **k** (density) in terms of C (the capacity) can be divided by Eq.{5} to eliminate the unknown C variable. Using q = kv and dividing by C gives:

$$\frac{q}{C} = \frac{kv}{C}$$

q/C is the v/c ratio (which is called y here) and v is the speed (called x) so:

$$y = \frac{xk}{C}$$

$$k = \frac{yC}{x} \qquad \{6\}$$

Dividing (6} by (5} gives:

$$\frac{k}{k_j} = \frac{v_f y}{2(1+A)x}$$

Substituting into Greenshield'sequation gives:

$$v = 2v_c(1-\frac{k}{k_j})$$

$$x = 2v_c(1-\frac{k}{k_j})$$

$$x = 2v_c(1-\frac{v_f y}{2x(1+A)})$$

$$x = \frac{2v_f}{1+A}\cdot(1-\frac{v_f y}{2x(1+A)})$$

$$x\left(\frac{1+A}{2v_f}\right) = 1-\frac{v_f y}{2x(1+A)}$$

$$\frac{v_f y}{2x(1+A)} = 1-\frac{x(1+A)}{2v_f}$$

$$v_f y = 2x(1+A)-\frac{x^2(1+A)'}{v_f}$$

$$y = \frac{2x(1+A)}{v_f}-\frac{x^2(1+A)'}{v_f^2}$$

Therefore, the complete set of **equations describing the v/c ratio (y) as** a **function of vehicle speed (x) in INTEGRATION are:**

$$y = \frac{2x(1+A)}{v_f}-\frac{x^2(1+A)^2}{v_f^2} \qquad x = (0, \frac{v_f}{1+A})$$

$$y = e^{\ln\left(\frac{v_f - x}{Ax}\right)/B} \qquad x = (\frac{v_f}{1+A}, v_f)$$

where v_f is the free flow **speed.**

Appendix 6: Caltrans Ramp Metering Plans

Listed below are the ramp metering plans from Caltrans. Note that these plans are from 1993 (before the Northridge Earthquake), so they are not necessarily still valid. However, these were the plans that were coded into the baseline simulations of the Santa Monica Freeway. The eastbound and westbound ramps are given separately. In each case, the morning and afternoon timing plans are given; the signal time listed for each period is the phase length for the ramp meter. The metering rate can be determined by dividing 3600 by the phase length. For example, a phase length of 6 seconds will yield a metering rate of 600 vehicles/hour.

Eastbound Freeway Ramps

	time	phase length	time	phase length
Overland	6:30 to 9:30 A.M.	6.6 seconds	2:00 to 3:30 P.M.	4 seconds
	9:30 to 10:00 A.M.	4 seconds	3:30 to 6:30 P.M.	5.5 seconds
			6:30 to 7:00 P.M.	4 seconds
Manning	6:30 to 7:00 A.M.	6 seconds	2:00 to 3:30 P.M.	4 seconds
	7:00 to 8:00 A.M.	12 seconds	3:30 to 4:00 P.M.	6 seconds
	800 to 8:15 A.M.	10 seconds	4:00 to 6:30 P.M.	8.6 seconds
	8:15 to 9:00 A.M.	8.6 seconds	6:30 to 7:00 P.M.	4 seconds
	9:00 to 9:30 A.M.	6 seconds		
	9:30 to 10:00 A.M.	4 seconds		
Nat'l/Robrtsn	6:30 to 7:00 A.M.	7.5 seconds	2:00 to 3:30 P.M.	4 seconds
	7:00 to 9:00 A.M.	12 seconds	3:30 to 5:30 P.M.	4.6 seconds
	9:00 to 9:30 A.M.	7.6 seconds	5:30 to 6:30 P.M.	6 seconds
	9:30 to 10:00 A.M.	4 seconds	6:30 to 7:00 P.M.	4 seconds
La Cienega	6:30 to 7:00 A.M.	10 seconds	2:00 to 3:30 P.M.	4 seconds
	7:00 to 8:45 A.M.	15 seconds	3:30 to 4:00 P.M.	10 seconds
	8:45 to 9:00 A.M.	10 seconds	4:00 to 5:00 P.M.	15 seconds
	9:00 to 9:30 A.M.	7.5 seconds	5:00 to 6:30 P.M.	12 seconds
	9:30 to 10:00 A.M.	4 seconds	6:30 to 7:00 P.M.	4 seconds
Venice	6:30 to 7:00 A.M.	10 seconds	2:00 to 3:30 P.M.	4 seconds
	7:00 to 8:45 A.M.	15 seconds	3:30 to 4:30 P.M.	10 seconds
	8:45 to 9:15 A.M.	10 seconds	4:30 to 5:15 P.M.	8.6 seconds
	9:15 to 9:30 A.M.	7.5 seconds	5:15 to 6:30 P.M.	10 seconds
	9:30 to 10:00 A.M.	4 seconds	6:30 to 7:00 P.M.	4 seconds

	time	phase length	time	phase length
Washington	6:30 to 7:00 A.M.	4 seconds	2:00 to 7:00 P.M.	4 seconds
	7:00 to 7:45 A.M.	5 seconds		
	7:45 to 9:00 A.M.	6 seconds		
	9:00 to 10:00 A.M.	4 seconds		
SB La Brea	6:30 to 7:00 A.M.	5 seconds	2:00 to 3:30 P.M.	4 seconds
	7:00 to 8:30 A.M.	10 seconds	3:30 to 4:00 P.M.	6 seconds
	8:30 to 9:00 A.M.	8.6 seconds	4:00 to 5:00 P.M.	8.6 seconds
	9:00 to 9:30 A.M.	5 seconds	5:00 to 6:30 P.M.	6 seconds
	9:30 to 10:00 A.M.	4 seconds	6:30 to 7:00 P.M.	4 seconds
NB La Brea	6:30 to 7:00 A.M.	6 seconds	2:00 to 3:30 P.M.	4 seconds
	7:00 to 9:00 A.M.	8.6 seconds	3:30 to 4: 15 P.M.	7.5 seconds
	9:00 to 9:30 A.M.	6 seconds	4:15 to 6:30 P.M.	8.6 seconds
	9:30 to 10:00 A.M.	4 seconds	6:30 to 7:00 P.M.	4 seconds
Crenshaw	6:30 to 7:00 A.M.	6 seconds	2:00 to 3:30 P.M.	4 seconds
	7:00 to 7:15 A.M.	6.5 seconds	3:30 to 4:15 P.M.	6 seconds
	7:15 to 8:15 A.M.	7 seconds	4:15 to 6:30 P.M.	7.5 seconds
	8:15 to 9:00 A.M.	8.6 seconds	6:30 to 7:00 P.M.	4 seconds
	9:00 to 9:30 A.M.	6 seconds		
	9:30 to 10:00 A.M.	4 seconds		
Arlington	6:30 to 8:00 A.M.	6 seconds	2:00 to 3:30 P.M.	4 seconds
	8:00 to 9:00 A.M.	8.6 seconds	3:30 to 6:30 P.M.	17 seconds
	9:00 to 9:30 A.M.	6 seconds	6:30 to 7:00 P.M.	4 seconds
	9:30 to 10:00 A.M.	4 seconds		
Western	6:30 to 7:00 A.M.	5 seconds	2:00 to 3:30 P.M.	4 seconds
	7:00 to 8:30 A.M.	7.5 seconds	3:30 to 5:45 P.M.	10 seconds
	8:30 to 9:15 A.M.	10 seconds	5:45 to 6:30 P.M.	8.6 seconds
	9:15 to 9:30 A.M.	5 seconds	6:30 to 7:00 P.M.	4 seconds
	9:30 to 10:00 A.M.	4 seconds		
Normandie	6:30 to 7:00 A.M.	7.5 seconds	2:00 to 3:30 P.M.	4 seconds
	7:00 to 9:15 A.M.	8.6 seconds	3:30 to 7:00 P.M.	8.6 seconds
	9:15 to 9:30 A.M.	7.5 seconds		
	9:30 to 10:00 A.M.	4 seconds		

	time	phase length	time	phase length
Vermont	6:30 to 9:30 A.M.	6 seconds	2:00 to 3:30 P.M.	4 seconds
	9:30 to 10:00 A.M.	4 seconds	3:30 to 6:30 P.M.	8.6 seconds
			6:30 to 7:00 P.M.	4 seconds
Hoover	6:30 to 9:00 A.M.	10 seconds	2:00 to 3:30 P.M.	4 seconds
	9:00 to 9:30 A.M.	6 seconds	3:30 to 6:30 P.M.	7.5 seconds
	9:30 to 10:00 A.M.	4 seconds	6:30 to 7:00 P.M.	4 seconds

Westbound Freeway Ramps

	time	phase length	time	phase length
Hoover	6:30 to 8:15 A.M.	6.6 seconds	2:30 to 3:30 P.M.	4 seconds
	8:15 to 9:00 A.M.	12 seconds	3:30 to 6:15 P.M.	10 seconds
	9:00 to 10:00 A.M.	4 seconds	6:15 to 6:30 P.M.	4 seconds
Vermont	6:30 to 9:00 A.M.	10 seconds	2:30 to 3:30 P.M.	10 seconds
	9:00 to 10:00 A.M.	8.6 seconds	3:30 to 6:30 P.M.	15 seconds
Normandie	6:30 to 8:00 A.M.	6 seconds	2:30 to 3:30 P.M.	4 seconds
	9:00 to 9:00 A.M.	8.6 seconds	3:30 to 5:00 P.M.	12 seconds
	9:00 to 10:00 A.M.	4 seconds	5:00 to 6:30 P.M.	15 seconds
Western	6:30 to 8:00 A.M.	7.5 seconds	2:30 to 3:30 P.M.	4 seconds
	8:00 to 8:45 A.M.	10 seconds	3:30 to 4:00 P.M.	8.6 seconds
	8:45 to 9:00 A.M.	5 seconds	4:00 to 4:30 P.M.	12 seconds
	9:00 to 10:00 A.M.	4 seconds	4:30 to 6:00 P.M.	15 seconds
			6:00 to 6:30 P.M.	8.6 seconds
Arlington	6:30 to 9:00 A.M.	12 seconds	2:30 to 4:45 P.M.	10 seconds
	9:00 to 10:00 A.M.	4 seconds	4:45 to 5:45 P.M.	12 seconds
			4:45 to 6:30 P.M.	10 seconds
Crenshaw	6:30 to 7:15 A.M.	10 seconds	2:30 to 3:30 P.M.	4 seconds
	7:15 to 9:00 A.M.	7.5 seconds	3:30 to 3:45 P.M.	10 seconds
	9:00 to 10:00 A.M.	4 seconds	3:45 to 4:30 P.M.	12 seconds
			4:30 to 6:15 P.M.	15 seconds
			6:15 to 6:30 P.M.	10 seconds

	time	phase length	time	phase length
NB La Brea	6:30 to 8:30 A.M.	8.6 seconds	2:30 to 3:30 P.M.	4 seconds
	8:30 to 9:00 A.M.	6.6 seconds	3:30 to 3:45 P.M.	8.6 seconds
	9:00 to 10:00 A.M.	4 seconds	3:45 to 5:15 P.M.	10 seconds
			5:15 to 5:45 P.M.	8.6 seconds
			5:45 to 6:30 P.M.	12 seconds
SB La Brea	6:30 to 9:00 A.M.	7.5 seconds	2:30 to 3:30 P.M.	4 seconds
	9:00 to 10:00 A.M.	4 seconds	3:30 to 5:00 P.M.	10 seconds
			5:00 to 6:30 P.M.	12 seconds
Fairfax	6:30 to 7:15 A.M.	10 seconds	2:30 to 3:30 P.M.	4 seconds
	7:15 to 8:15 A.M.	6.6 seconds	3:30 to 4:00 P.M.	7.5 seconds
	9:15 to 9:00 A.M.	10 seconds	4:00 to 6:30 P.M.	10 seconds
	9:00 to 10:00 A.M.	4 seconds		
La Cienega	6:30 to 10:00 A.M.	4 seconds	2:30 to 6:30 P.M.	4 seconds
Robertson	6:30 to 7:15 A.M.	12 seconds	2:30 to 3:30 P.M.	4 seconds
	7:15 to 9:00 A.M.	6.6 seconds	3:30 to 6:30 P.M.	6 seconds
	9:00 to 10:00 A.M.	4 seconds		
Overland	6:30 to 7:15 A.M.	8.6 seconds	2:30 to 3:30 P.M.	4 seconds
	7:15 to 9:00 A.M.	5.4 seconds	3:30 to 6:30 P.M.	6 seconds
	9:00 to 10:00 A.M.	4 seconds		

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