Title

Highway Electrification And Automation Technologies - Regional Impacts Analysis Project: Phase II: Scenario For Advanced Highway Technologies

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Highway Electrification and Automation Technologies - Regional Impacts Analysis Project: Phase II: Scenario for Advanced Highway Technologies

Southern California Association of Governments (SCAG), California Partners for Advanced Transit and Highways (California PATH)

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Highway Electrification and Automation Technologies - Regional Impacts Analysis Project: Phase II: Scenario for Advanced Highway Technologies

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Prepared for:

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Institute of Transportation Studies
University of California at Berkeley

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FOREWORD

A variety of organizations, too numerous to list on the report cover page, provided valuable service to this project and helped lead to its successful completion.

Phase II of the project consisted of the development of the advanced highway technology system scenarios. Work was performed primarily by PATH and SCAG. In addition, PATH provided management overview, including handling administrative issues and documentation review. Systems Control Technology, Inc., a PATH contractor on a related project also provided technical support.

The following were the principal contributors from each supporting organization:

PATH: Mark Miller, Project Manager
Steven Shladover, PATH Deputy Director

SCAG: Anne Bresnock, Project Coordinator & Associate Planner
William Boyd, Project Manager
Hong Kim, Principal Planner
Teresa Wang, Senior Planner

Systems Control Technology, Inc.: Edward Lechner, Senior Engineer
Daniel Empey, Senior Engineer

A Project Advisory Group was formed at the beginning of the study to provide guidance regarding study goals/objectives, specific methodological approaches, schedule and milestone review, and overall project evaluation. The membership was comprised of individuals from academia, as well as the private and public sectors, with interest in the applications of advanced transportation technologies. The membership list is provided at the end of the report.

Funding for this project was provided by the United States Department of Transportation, Federal Highway Administration, the State of California, Business, Transportation, and Housing Agency, Department of Transportation, and the Southern California Association of Governments.

TABLE OF CONTENTS

LIST OF TABLES

TABLE OF CONTENTS (cont.)

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4.0 SCENARIO SPECIFICATION

4.1 OVERVIEW

This report completes the second phase of the Highway Electrification and Automation Technologies Regional Impacts Analysis Project, a three-year investigation of the potential regional mobility and air quality benefits that could result from implementation of advanced highway technologies in the greater Los Angeles area. Roadway electrification, highway automation, and a combination system of these advanced technologies are examined by Southern California Association of Governments (SCAG) and the PATH Program at the Institute of Transportation Studies, University of California, Berkeley.

Summary of Phase I Report

Phase I of the project covered data collection and preparation of baseline forecasts for use in assessing the regional impacts of the technologies identified above. Transportation demand and the associated air quality indicators for 2025 were forecast assuming that the aforementioned advanced technologies had not been implemented on the Southern California highway system. A brief summary of these findings follows.

The SCAG Regional Transportation Model System was employed to generate the baseline assessment of travel in 2025 for the SCAG region. Baseline estimates for total projected vehicle miles traveled (VMT), vehicle hours traveled (VHT), and vehicle hours of delay (VHD) (in 1,000s) for 2025 were given as 415,672, 15,095, and 4,904 respectively. (See Table 3.7 in the Phase I Report). Projected 2025 average speed (mph) on all facilities and freeways was estimated to be 28 and 36, respectively. Comparing these 2025 baseline figures with those reported by SCAG for 1987, the following summary statistics may be noted: (a) VMT are expected to increase by an average of 1.3% per year, (b) VHT are projected to increase by an average of 1.7% per year, (c) VHD are expected to grow by an average of 3.6% per year, and (d) average speeds are projected to decrease from 33 mph for all facilities and 43 mph on freeways to 28 mph and 36 mph, respectively. (The reader is referred to the Phase I Report for a complete discussion of these mobility performance indicators, including a disaggregation of VMT and average speed by facility type and time period, for both 1984 and the project baseline year 2025.) Overall there are dramatic decreases in average speeds, and increases in VMT due to projected population growth, jobs-housing imbalances, and individual driver behavior expected in the SCAG region for 2025.

The baseline assessment of air quality for the year 2025 was determined by use of the Direct Travel Impacts Model (DTIM). DTIM computes the amounts of emissions from and fuel utilized by motor vehicles based on

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Caltrans transportation modeling and California Air Resources Board (CARB) impact rates. The methodology contained in DTIM and its companion impact rate program, EMFAC7E, were employed, with modifications recommended by CARB for 2025, to calculate the baseline reactive organic gases (ROG), oxides of nitrogen (NOx), oxides of sulfur (SOx), carbon monoxide (CO), and particulate matter of size smaller than 10 microns in diameter (PM10) emissions shown in Table 4.1 below.

Table 4.1
Baseline Daily Emissions for SCAG Region
(tons)

	1987			2025		
	LDA	LDT	MDT	LDA	LDT	MDT
Reactive Organic Gases (ROG)	454.09	98.10	31.13	184.70	48.85	14.21
Oxides of Nitrogen (NOx)	388.42	83.91	26.63	240.79	63.69	18.52
Carbon Monoxide	3,354.02	724.61	229.97	1,216.74	321.84	93.60
Oxides of Sulfur (SOx)	18.44	3.98	1.26	24.73	6.54	1.90
Particulate Matter (PM10)	23.33	5.04	1.60	37.61	9.95	2.89

Note: LDA = Light Duty Auto, LDT = Light Duty Truck, and MDT = Medium Duty Truck.

Source: Direct Travel impacts Model, Southern California Association of Governments, Los Angeles, CA, 1990.

Comparing the 2025 baseline figures above with those reported by SCAG for 1987, the following summary statistics may be noted: (a) reduction in emissions for ROG, CO, and NOx across all vehicle types, (b) increase in emissions for SOx, and PM10 across all vehicle types, (c) aggregated over vehicle types, ROG, CO, and NOx are expected to have an emissions reduction of 57.5%, 62.1%, and 35.3% respectively, and (d) aggregated over vehicle types, SOx and PM10 are expected to have an emissions increase of 68.3% and 40.1%, respectively. The emissions reduction for ROG, CO, and NOx could result from the impact of the air

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quality management plan which places stringent controls on the sources of air pollution, and fosters retirement of the older more polluting internal combustion engine vehicle fleet. Mobile source PM10 emissions are road gravel, dust, and oily residue forced up from the road surface by continuous vehicle movement, and could increase as VMT increases. Mobile source SOx emissions are calculated as SO2 (sulfur dioxide) because almost all sulfur in gasoline is converted into SO2 during gasoline combustion. Even with controls on the sulfur content of gasoline, the growth in VMT between 1987 and that projected for 2025 could lead to the indicated increase in SOx emissions.

It is important to note that the reductions in the criteria pollutants cited above are based on the methodological assumptions contained in EMFAC7E. The revisions of EMFAC7D to EMFAC7E result from tightening the hydrocarbon standard to from 0.41 grams/mile to 0.25 grams/mile and the CO standard from 7.0 to 3.4 grams/mile, and adjustments in the speed correction factors imbedded in the emissions model, rather than from the adoption of air policy rules by the CARB board. Use of EMFAC7EP for the 2025 baseline would produce even further reductions in the criteria pollutants due to the inclusion of substantial policy rules that have been adopted by the CARB board, i.e. clean fuels and low emission vehicle measures, etc.

Thus, while urban traffic congestion and air pollution are crucial issues in most metropolitan areas, the Southern California region presents a challenge to policymakers of acute proportions. The forecasts have shown the ongoing need to develop remedies to curb these disamenities whether they be government regulations, infrastructure developments, and/or technological changes, the subject of this report.

Phase II Coverage

The Phase II report focuses on development of a modeling framework for evaluation of the impacts of the alternative advanced technologies applied to selected freeway lanes. Initially, criteria were developed for guidance in determining the configuration of the advanced technology systems so as to appropriately address air quality and/or mobility considerations. Subsequently, the advanced technology system scenarios were chosen from several alternatives based on sensitivity analyses that allowed for variability in electrified and automated network location, total network miles, and market penetration of vehicles equipped with a specific advanced technology.

With respect to roadway electrification, the principal potential benefit derived from electrifying the highways is expected to be mitigation of on-road vehicle mobile source emissions. Air quality is expected to improve through the implementation of this technology because fewer ROG, NOx, SOx, CO, and PM10 emissions should result from

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application of this advanced technology. The impact of roadway electrification on fossil fuel usage, the electric utility industry, and the regional economy are also important impacts for study purposes.

Roadway electrification is not expected to have any appreciable effect on the mobility of the region, as measured by such indicators as average speed, volume to capacity ratio, VMT, VHT, or VHD. There could be some minor deterioration in mobility levels as a result of the implementation of this technology, resulting from possible short time delays for accessing and egressing the electrified roadway. Possible secondary improvements associated with reduced air pollution, such as health care savings, and increased labor force productivity, may also be possible benefits of applying roadway electrification, but are not investigated in this study.

The primary potential benefit from automating the highways is expected to be traffic congestion mitigation. Regional mobility, again expressed in terms of the system performance indicators stated previously, is expected to improve through the implementation of this technology. Depending on the degree to which automation decreases congestion and changes in VMT, air quality benefits, i.e. fewer emissions, should also result from application of this advanced technology. The secondary improvements mentioned above could result from reduced driving time and/or reduced air pollution but were not analyzed in this report.

The combination of roadway electrification and highway automation has particular appeal in that such a system would have a greater potential to reduce air pollution and congestion than either of the advanced technologies if separately applied. Although roadway electrification has great potential with respect to air quality improvement, mobility enhancement associated with application of this technology would be non-existant. Highway automation, while increasing capacity and mobility, has only indirect air quality benefits at best. Thus, a highway system that combined both of these technologies is expected to yield the largest benefits to the urban environment. Pollution and mobility indicators cited previously will be studied to capture the impacts of the combined technology system. Additionally, the increase in capacity of the automation technology allows fewer lanes of a facility to be electrified while still handling the same volume, which improves the cost effectiveness of electrification.

For all three advanced technology designs, the scenario development process to determine the specific application of the system technology entailed specifying the location, number of lanes, and number of lane miles for the advanced technologies as well as consideration of lane separation, access and egress, and lane capacity with respect to

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the advanced technologies versus mixed flow facilities. The methodology for selecting each technology system configuration is explained in Sections 4.2 to 4.4. Problems which arose in modeling each technology given the constraints of the available transportation simulation techniques are also identified.

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4.2 ROADWAY ELECTRIFICATION

The methodology designed to create the electrified highway system scenario for subsequent impact analyses is detailed in this section. First, physical characteristic considerations for the electrified facility are summarized. Next, the sensitivity analysis utilized to determine the specific configuration for the electrified network is described. Following this explanation, alternative lane determination methodologies to specify the electrified network are reviewed. The 2025 electrified network for subsequent impacts analysis is defined and analyzed in Section 5.1.

Physical Characteristics of the Electrified Roadway Network

The characteristics of the electrified highway system that required identification for the purposes of this study included type of facility, number and location of lanes to which the roadway electrification technology would be applied, and issues of roadway-powered lane separation, access, egress, and capacity.

Freeways are the facility type chosen for application of roadway electrification technology. Given the (a) regional scope of the project, (b) tradeoff between the extent of the electrified network and assumed vehicle battery range, and (c) importance of infrastructure costs relative to total costs for this technology, investigating the impacts of roadway electrification limited to the region's vast and intricate freeway system was considered reasonable.

The 2025 SCAG regional highway network provided a base network from which electrified network subsets were chosen. Three networks ranging in size from modest to intermediate to ambitious, containing 234, 431, and 657 center-line miles respectively, were selected for the sensitivity analysis. (See Figure 7 and the detailed network location descriptions given in Appendix D).

Given the absence of a priori information regarding the size of freeway systems to which roadway electrification technology may be applied, the following criteria were utilized in selecting the links to include in the three networks. Freeway links were selected based on: (a) baseline volume to capacity ratios (V/C) greater than one, (b) proximity to SCAG regional activity centers, such as the downtown CBD or the LAX airport, (c) potential air quality improvements attributable to proven correlations between congestion and emissions, and (d) possible infrastructure advantages associated with the existing and/or planned HOV facilities.

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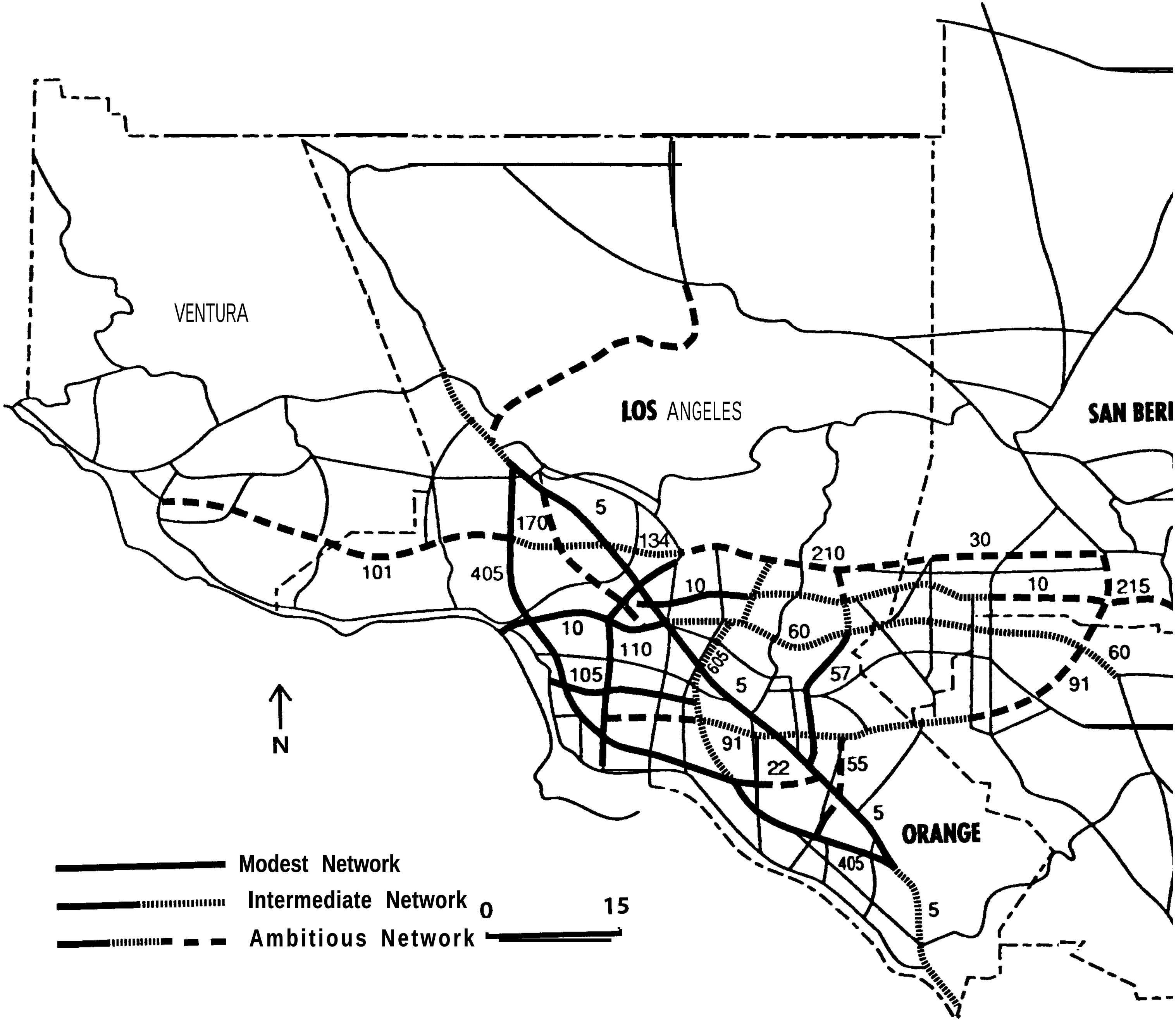

Figure 7
2025 Regional Highway Network
Roadway Powered Electric Vehicle & Automation Alternatives

The number of lanes to which the technology was applied was determined via the sensitivity analysis detailed in the next section. In general, the number of lanes in the electrified facility was assumed to be directly related to the expected market penetration of suitably equipped vehicles. Given that the number of electrified vehicles in 2025 is unknown, the sensitivity analyses considered several market penetration percentages on each network. That is, alternative percentages of VMT, and the corresponding number of trips, were assumed to be associated with roadway powered electrified vehicles and were assigned separately to each network.

Volume plots for the number of trips associated with each market penetration on each network were produced and evaluated to identify the areas of highest electric vehicle traffic volume. The number of electrified lanes specified in the freeway system was then selected to accommodate the volume of electrified trips traveling on each section of the facility, i.e. in some sections multiple lanes were required whereas on other sections one lane in each direction adequately served the estimated roadway-powered vehicle demand. The number of freeway lane miles contained in the roadway-powered facilities was determined as the product of roadway-powered facility miles and the number of roadway-powered lanes on each freeway section of the electrified network.

Roadway electrification does not require facility separation from conventional mixed-flow traffic. Any vehicle, an RPEV or a conventional internal combustion engine vehicle (ICEV), can travel on the electrified roadway. If RPEVs are not segregated from non-RPEVs, then the continuous availability of the electrified facility for those RPEVs that require it to complete their trips could be in jeopardy due to overcrowding by non-RPEVs. However, sufficient measures could be available, such as changeable message signs indicating restricted use of electrified lane(s), to insure that RPEVs are not denied access.

Maintaining separate facilities in conjunction with stringent facility misuse enforcement could help link electrified roadway costs to users if the powered roadway infrastructure is financed by user fees. However, it may be assumed that other available means, such as electronic toll collection, could be utilized for this purpose. Given these considerations regarding separation vs non-separation of lanes to which the RPEV technology could be applied, both ideas are modeled in the assignment stage of the modeling process to clarify the results of this consideration for the impacts analysis.

Special access and egress facilities, though of value in helping to maintain separate facilities by minimizing the number of facility misusers, are not modeled explicitly in this study because (a) current practice with simulating separate facilities, such as HOV lanes, does

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not include special access and egress constructions, and (b) the regional scope of this project made consideration of these issues unnecessary.

Both freeway on- and off-ramps are not modeled in this study since this level of detail was also viewed as inappropriate given the regional scope of the project. However, from a practical perspective, use of roadway power on freeway ramps could offer the benefit of increased recharging capability due to the greater cost effectiveness of inductive power transfer in the environment of a freeway ramp, i.e. slower speeds, instead of the generally higher speeds on flowing freeway lanes, permit more seconds of charging for each foot of electrified roadway and additionally may provide a power boost for vehicles accelerating to merge into flowing freeway traffic..

Automatic steering control devices, offer capacity enhancement opportunities by potentially increasing the number of lanes, without expanding existing roadway due to the narrowing of lane width. A somewhat weaker version of this technology, a lateral guidance or steering assist, is currently under investigation to help increase the efficiency of the RPEV system by helping the driver to keep the vehicle lane-centered in order to maximize the inductive transfer of roadway power, and thereby decrease vehicle costs. This steering assist system could be engineered so that the control of the vehicle would be maintained by the driver. The capacity effect of the lateral assist is not included in the modeling of the RPEV highway scenario, however for implementation purposes, it should be seriously considered.

Roadway Electrification Scenario Development

To determine the specific configuration for the electrified roadway facility, expected usage of the facility must be examined. Existing roadway electrification technology research does not contain information concerning potential and/or actual user demand. Thus, a wide range of assumptions was formulated regarding the market potential and market penetration percentages for roadway-powered vehicles.

Market potential is the number of trips (and corresponding VMT) that are possible with an RPEV, and depends on the assumed vehicle battery range and extent of the electrified network. Trip length distribution tables for both daily and AM-peak trips (and VMT) were produced for each electrified roadway network to determine the market potential for various battery range values. Tables 4.2 and 4.3 present the 2025 AM-peak trip length distribution matrices for mileage traveled on and off the electrified facility given the modest network. That is, each entry in Table 4.2, for example, indicates the number of trips with on-electrified network trip length shown by the row descriptor, and the off-network trip length given by the column heading. For example, the

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TABLE 4.2

2025 AM-PEAK **VEHICLE TRIPS** BY ON- AND OFF- **MODEST** NETWORK **TRIP** LENGTHS

TRIP LENGTH On-network/Off-network →		0-2	2-4	4-6	6-a	8-10	10-15	15-20	20-25	25-30	30-35	35-40
0		1,325,484	900,460	590,586	346,059	225,805	276,768	131.194	61.119	47,447	26.366	21,958 2,991
0-2		22,666	45,815	37,154	28,486	19,985	31.371	16.425	9,952	6.132	3.624	2,617 2,
2-4		45,755	72,683	45,103	33.076	16.767	29.648	14,600	9,666	6.106	3.772	
4-6		32,069	49.603	29,914	16.654	12,106	21,696	11.652	7,551	5,344	3.418	3,216
6-8		21,014	31,573	23,316	15,815	11,355	21.422	6.667	5,066	3,504	2,589	2,289
8-10		13,925	20,957	16,337	11,636	6,147	14.509	7,547	4,270	3,169	2,001	1.809
10-15	Section 1	25,444	28,039	25,377	18,091	11,765	21.136	II.060	8,145	5,918	2,968	2,554
15-20		9.839	11,336	11.796	5,096	6,772	12,068	6,606	4,915	3,440	2,550	1,628
20-25		2,948	3,916	5,363	2,183	4,220	7,271	4.611	2,915	2,407	1.976	1,392
25-30		649	1,134	1.965		2,246	3,560	2,068	1,296	992	1,254	797
30-35		161	283	572	922	1,066	1,161	1,504	939	911	I.107	836
35-40		28	71	180	376	737	I.203	632	658	526	464	465
40-45		0	20	61	135	334	759	559	467	364	431	394
45-50		0	4	36	75	139	396	300	221	197	lo9	124
50-55	Section 2	0	0	3	la	42	123	138	69	56	71	66
55-60		0	0	0	2	6	26	19	19	7	9	2
		1,500,182	1,165,896	767,769	490,609	323,514	444,444	218,204	137,292	66.542	55,049	42,936

TRIP LENGTH On-network/Off-network →		40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	ao+	TOTAL
0		15,538	IO.663	8,946	7,095	5,560	4,299	2917	2,388	6.770	4,039,082
0-2		2,677	2,045	1.491	1.633	1,349	1,116	963	606	2,412	239,097
2-4		1,972	1,646								
4-6		2,297	2,141	1.433 1,907	1,476 1,909	1,126 1,594	1,120 1.566	1,237 1.014	1,090 707	2,567 1,696	295,284 210.662
6-8		1,381	1.471	1,487	1,266	1,072	786	751	607	962	156,457
8-10		1,220									
10-15		2,244	1,152 1.769	1,028 1,606	1,060 1,546	1.170 614	602 909	473 6%	373 665	3.63 794 1	112,025 174,695
15-20	Section 3	I.533	1,525	1,234	I.166	1,028	749	455	409	1,355	90,579
20-25		1,153	944	649	750	662	452	290	246	1,133	48,596
25-30		576	575	538	465	439	324	254	187	642	22,364
30-35		729	598	621	480	405	336	253	171	600	14.976
35-40		457	266	314	271	207	119	124	115	460	7,695
40-45		367	171	220	183	167	80	56	49	236	5,095
45-50		151	63	95	98	66	51	36	22	245	2,574
50-55		73	36	42	45	46	52	44	31	n	1,044
55-60		5	3	0	0	0	0	0	0	0	102
		32,393	25.130	21,811	19,447	I 5,749	12,587	9,703	7,668	23,802	5,420,749

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TABLE 43

2025 AM-PEAK **VMT (IN 1000s)** BY ON- AND OFF. **MODEST** NETWORK TRIP LENGTHS

TRIP LENGTH On-network/Off-network → / ↓		0-2	2–4	4–6	6–8	8–10	10–15	15–20	20–25	25–30	30–35	35–40
0		685	2,694	2,911	2,407	2,032	3,375	2,272	1.616	1,296	920	609
0–2		63	197	231	232	203	417	303	231	173	127	115
2–4		194	432	359	331	225	456	302	245	187	133	lo6
4–6		199	399	299	223	169	375	265	lo6	173	128	136
6–8		171	318	280	222	163	420	212	150	121	101	101
8–10		139	253	230	190	147	312	200	135	116	83	64
10–15	Section 1	331	430	441	352	253	523	330	286	239	134	129
15–20		174	229	264	238	179	360	237	195	154	127	101
20–25		66	99	146	149	132	252	183	130	120	lo8	63
25–30		23	34	64	75	82	142	93	65	55	76	52
30–35		5	10	21	36	44	103	75	52	55	n	59
35–40		1	3	8	17	34	60	35	40	34	34	35
40–45		0	1	3	7	17	42	33	30	27	32	31
45–50		0	0	2	4	a	24	19	16	15	17	11
50–55	Section 2	0	0	0	2	)	8	)	5			
55–60		0	0	0	0	31	2	10 l	2	4I	6I	60
		2,052	5,098	5,259	4,484	3.71 1	6,673	4,568	3,605	2,768	2,099	1,859

TRIP LENGTH On-network/Off-network → / ↓		40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	aot	TOTAL
0		658	507	469	408	348	290	211	165	640	24,936
0–2		116	99	80	96	86	76	71	47	256	3.222
2–4		90	63	60	69	74	79	76	57	258	3.656
4–6											3,600
6–8		109	162	160	181	lo74	158	96	51	168	2,938
8–10		63	65	63	71	56	46	39	32	62	2,407
10–15		124	108	105	109	66	73	41	60	425	4,614
15–20	Section 3	92	99	86	67	62	63	27	39	155	3,002
20–25		75	66	64	60	56	41		24	135	2,015
25–30		41	43	43	40	40	31	25	20	79	I.123
30–35		55	46	53	43	39	34	27	19	lo7	955
35–40		36	22	la	26	21	13	14	13	63	534
40–45		33	15	21	la	17	9	b	6	34	363
45–50		13	4	14	10	15	6	4	4	37	215
50–55		7	0	0	5	0	6	6	0	11	96
55–60		1			0		0	0		0	a
		1,579	1,361	1,304	1,263	1.105	941	n 4	651	2,552	53,905

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number entered in the third row and first column of Table 4.2 shows that 45,755 trips travel on the electrified facility between 2-4 miles and off the facility between O-2 miles. These 45,755 trips occur in numerous origin-destination combinations throughout the highway system. Each such combination, however, possesses an on-network length of between 2-4 miles, and an off-network length of between O-2 miles. Table 4.3 gives the trip length distribution VMT associated with the AM-peak trips in an equivalent format. The 45,755 above mentioned trips represent 194,000 VMT, or an average trip length of 4.2 miles, with an average of approximately 3 miles on the electrified facility and 1 mile off the RPEV network.

The trip length distribution tables for both daily and AM-peak in terms of trips (and VMT) depict unlinked trips (and VMT) during the given time period. That is, individual trips (and VMT) are depicted, not a full day's or time period's tour of trips. In testing the sensitivity of market potential to varying battery ranges, derated battery ranges were utilized to account for the inability of the transportation model and existing regional tripmaking data to capture linked trip information. The derating factor is defined as the ratio between conventional (or total) and derated battery range, and is a function of the daily travel and recharging pattern for each vehicle. For a vehicle which makes two trips, i.e. home-to-work followed by work-to-home, with no mid-day recharging, the derating factor is two. That is, a vehicle with a 60 mile range could make two 30 mile trips without recharging. With provisions for mid-day recharging, two sixty mile trips could be made, and the derating factor would be one. Similarly, a vehicle which makes five trips of equal length with no recharging, would possess a derating factor of five, and the derated range of the vehicle would be 12 miles. Rather than choosing a specific total battery range or distribution of ranges to represent the electric vehicle population, and a distribution of derating factors, derated range was chosen as the independent variable. The derated battery ranges that were considered were 20, 30, 40, 50, and 60 miles. A deratedm range of 40 miles was chosen for the purposes of this study.

Next, the trip length distribution tables produced for each electrified network/time period combination for both trips and VMT were split into three sections, given alternative derated battery assumptions. The three sections corresponded to those trips (and VMT) with (1) total trip length less than the derated battery range, (2) total trip length greater than the derated battery range, with off-network trip length component less than derated battery range, and (3) off-network trip length greater than derated battery range. Tables 4.2 and 4.3 depict these three regions for the modest network during the AM-peak period, for a derated battery range of 40 miles. Trips in region (1) may be accomplished on battery power alone (or by an RPEV or an ICEV), while those in (2) require assistance from roadway power for a portion of the trip or could be accomplished by an ICEV, and those in (3) cannot be

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handled by a battery only or an RPEV thus requiring an ICEV for completion. All boundary lines were drawn using the midpoint of each row and column heading as the representative trip length for that cell. The boundary that separates region 3 from the balance of the table is drawn as a vertical line, indicating no net battery recharging from the roadway, i.e. the roadway electrification only supplies enough power to propel the vehicle. Such a recharge would provide additional vehicle battery energy, permitting region 3 to be slightly reduced in size since the vertical boundary line would gradually curve toward the right as the lengths of the on-network trip components grew. The change in the configuration of the three regions if net battery recharging was incorporated into the analysis was considered small enough to omit for modeling purposes. These three regions are shown on Table 4.3 for a 40 mile derated range.

The trip length distribution tables for each network/battery range combination, for both daily and AM-peak trips and VMT were analyzed to evaluate the market potential for RPEV. It was assumed that trips contained in regions (1) and (2) could be accomplished by RPEVs. Although region (1) includes trips and VMT that may be attributed to battery power-only vehicles, all of these trips (and associated VMT) have the potential to be performed by RPEVs. The extent to which RPEVs may be utilized for trips in region (1) would depend on recharging requirements and opportunities to complete the tour of daily trips, and recharging preferences with respect to traveling with a partial or full charge, effect of deep discharges on battery life, and numerous other features.

A comparison of the results for daily and AM-peak trip length distributions for each network size/battery range combination showed similar patterns for trip and VMT percentages that could be accomplished by battery power alone and roadway power. Differences between AM peak and daily percentages were small, with most corresponding table entries being equal within 1 to 2 percent. (See Tables 4.4 and 4.5). Tables 4.4 and 4.5 present the market potential percentages of daily and AM-peak trips and VMT, and the disaggregation of these percentages into battery only (BO) and roadway power (RPEV) components. A further breakdown of the trips and VMT in regions (1) and (2), the partitioned designations, is also provided. The "complete" network is the entire regional freeway system.

In general, market potential is directly related to battery range and network size. (See Figure 8, Tables 4.4, 4.5 and Appendix E). The potential trips and VMT that could be handled by battery power alone or roadway power is substantial, i.e. greater than 90% for trips, and almost 55% for VMT during the AM-peak (as well as daily) time period assuming a 20 mile derated battery range and modest network size. A derated battery range of 60 miles coupled with the complete network

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FIGURE 8: Changes in A.M. Peak Trip Market Potential over Network Size by Battery Range

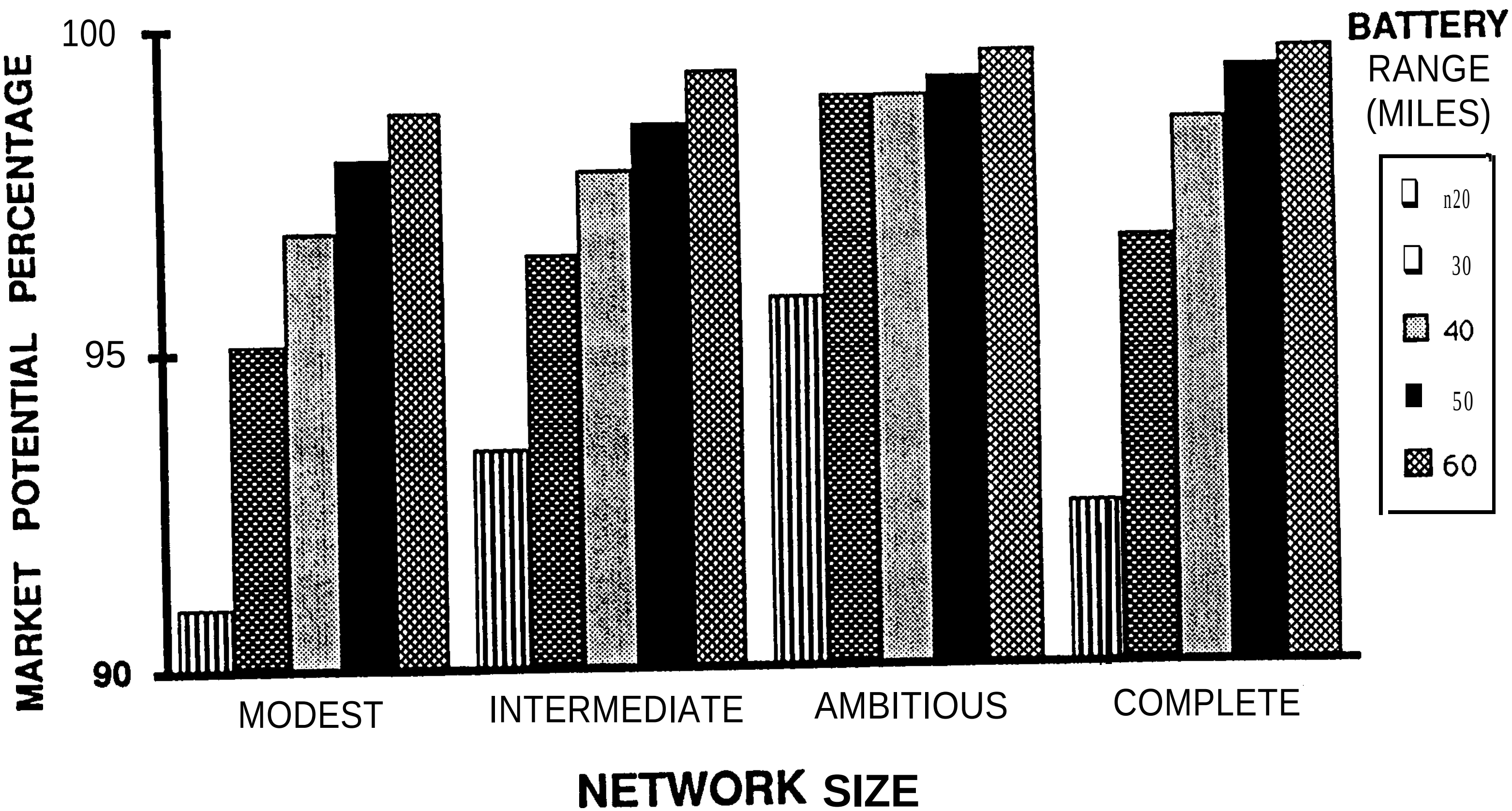

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Table 4.4
2025 RPEV Market Potential
(Daily)

MODEST NETWORK

Derated Battery Range (miles)	Percentage of All Trips (BO , RPEV)	Percentage of All Trips VMT (BO , RPEV)
20	91.9 (89.0, 2.9)	54.4 (45.3, 9.1)
30	94.9 (93.3, 1.6)	64.5 (57.4, 7.1)
40	96.6 (95.5, 1.1)	72.1 (65.8, 6.3)
50	97.6 (96.7, 0.9)	78.5 (72.3, 6.2)
60	98.4 ((97.7, 0,7)	84.2 (78.2, 6.0)

Derated Battery Range (miles)	Percentage of Partitioned Trips BO	Percentage of Partitioned Trips RPEV	Percentage of Partitioned Trips VMT BO	Percentage of Partitioned Trips VMT RPEV
20	96.8	3.2	83.2	16.8
30	98.3	1.7	89.0	11.0
40	98.9	1.1	91.2	8.8
50				
60	99.1 99.2	0.9 0.8	92.2 92.9	7.8 7.1

INTERMEDIATE NETWORK

Derated Battery Range (miles)	Percentage of All Trips (BO , RPEV)	Percentage of All Trips VMT (BO , RPEV)
20	93.9 (88.8, 5.1)	62.9 (45.0, 17.9)
30	96.2 (93.3, 2.9)	71.9 (57.4, 14.5)
40	97.5 (95.5, 2.0)	78.5 (65.9, 12.6)
50	98.3 (96.8, 1.5)	83.7 (72.5, 11.2)
60	99.0 ((97.7, 1,3)	88.5 (78.5, 10.0)

Derated Battery Range (miles)	Percentage of Partitioned Trips BO	Percentage of Partitioned Trips RPEV	Percentage of Partitioned Trips VMT BO	Percentage of Partitioned Trips VMT RPEV
20	94.5	5.5	71.5	28.5
30	96.9	3.1	79.8	20.2
40	97.9	2.1	83.9	16.1
50	98.5	1.5	86.7	13.3
60	98.7	1.3	88.7	11.3

Note: All percentages are based on daily trip length distribution tables derived from the SCAG Regional Transportation Model.

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Table 4.4 (cont.)
2025 RPEV Market Potential
(Daily)

AMBITIOUS NETWORK

Derated Battery Range (miles)	Percentage of All Trips (BO , RPEV)	Percentage of All Trips VMT (BO , RPEV)
20	96.0 (88.8, 7.2)	72.8 (44.9, 27.9)
30	97.7 (93.3, 4.4)	81.3 (57.3, 24.0)
40	98.6 (95.5, 3.1)	87.3 (65.9, 21.4)
50	99.1 (96.8, 2.3)	91.2 (72.6, 18.6)
60	99.4 (97.7, 1.7)	94.2 (78.6, 15.6)

Derated Battery Range (miles)	Percentage of Partitioned Trips BO	Percentage of Partitioned Trips RPEV	Percentage of Partitioned Trips VMT BO	Percentage of Partitioned Trips VMT RPEV
20	92.5	7.5	61.7	38.3
30	95.5	4.5	70.5	29.5
40	96.8	3.2	75.4	24.6
50	97.7	2.3	79.6	20.4
60	98.3	1.7	83.4	16.6

COMPLETE FREEWAY NETWORK

Derated Battery Range (miles)	Percentage of All Trips (BO , RPEV)	Percentage of All Trips VMT (BO , RPEV)
20	94.9 (88.9, 6.0)	70.9 (45.1, 25.8)
30	97.6 (93.4, 4.2)	81.9 (57.5, 24.4)
40	98.8 (95.5, 3.3)	89.4 (66.0, 23.4)
50	99.4 (96.8, 2.6)	94.0 (72.6, 21.4)
60	99.7 (97.7, 2.0)	96.9 (78.6, 18.3)

Derated Battery Range (miles)	Percentage of Partitioned Trips BO	Percentage of Partitioned Trips RPEV	Percentage of Partitioned Trips VMT BO	Percentage of Partitioned Trips VMT RPEV
20	93.7	6.3	63.6	36.4
30	95.7	4.3	70.2	29.8
40	96.7	3.3	73.8	26.2
50	97.4	2.6	77.2	22.8
60	98.0	2.0	81.1	18.9

Note: All percentages are based on daily trip length distribution tables derived from the SCAG Regional Transportation Model.

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Table 4.5
2025 RPEV Market Potential
(AM Peak)

MODEST NETWORK

Derated Battery Range (miles)	Percentage of AM Peak Trips (BO , RPEV)	Percentage of AM Peak Trips VMT (BO , RPEV)
20	91.0 (86.9, 4.1)	59.5 (48.2, 11.3)
30	95.1 (93.1, 2.0)	71.3 (63.5, 7.8)
40	96.9 (95.8, 1.1)	78.6 (72.9, 5.7)
50	98.0 (97.2, 0.8)	84.1 (79.3, 4.8)
60	98.7 (98.1, 0.6)	88.8 (84.5, 4.3)

Derated Battery Range (miles)	Percentage of AM Peak Partitioned Trips		Percentage of AM Peak Partitioned Trips VMT	
	BO	RPEV	BO	RPEV
20	95.5	4.5	81.0	19.0
30	97.9	2.1	89.1	10.9
50	98.9	1.1	92.7	7.3
60	99.2 99.4	0.8 0.6	94.3 95.1	4.9 5.7

INTERMEDIATE NETWORK

Derated Battery Range (miles)	Percentage of AM Peak Trips (BO , RPEV)	Percentage of AM Peak Trips VMT (BO , RPEV)
20	93.4 (86.7, 6.7)	67.9 (47.8, 20.1)
30	96.5 (93.1, 3.4)	77.7 (63.5, 14.2)
40	97.8 (95.8, 2.0)	83.6 (72.9, 10.7)
50	98.5 (97.2, 1.3)	88.1 (79.5, 8.6)
60	99.3 (98.1, 1.2)	91.9 (83.8, 8.1)

Derated Battery Range (miles)	Percentage of AM Peak Partitioned Trips		Percentage of AM Peak Partitioned Trips VMT	
	BO	RPEV	BO	RPEV
20	92.8	7.2	70.4	29.6
30	96.5	3.5	81.7	18.3
40	98.0	2.0	87.3	12.7
50	98.7	1.3	90.4	9.6
60	98.8	1.2	91.2	8.8

Note: All percentages are based on daily trip length distribution tables derived from the SCAG Regional Transportation Model.

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Table 4.5 (cont.)
2025 RPEV Market Potential
(AM Peak)

AMBITIOUS NETWORK

Derated Battery Range (miles)	Percentage of AM Peak Trips (BO , RPEV)			Percentage of AM Peak Trips VMT (BO , RPEV)		
20	95.8	(86.6,	9.2)	77.8	(47.7,	30.1)
30	98.9	(93.1,	5.8)	86.3	(63.4,	22.9)
40	98.9	(95.8,	3.1)	90.9	(73.0,	17.9)
50	99.2	(97.2,	2.0)	93.6	(79.6,	14.0)
60	99.6	(98.2,	1.4)	95.8	(84.9,	10.9)

Derated Battery Range (miles)	Percentage of AM Peak Partitioned Trips BO	RPEV	Percentage of AM Peak Partitioned Trips VMT BO	RPEV
20	90.4	9.6	61.3	38.7
30	94.1	5.9	73.5	26.5
40	96.9	3.1	80.3	19.7
50	98.0	2.0	85.0	15.0
60	98.6	1.4	88.7	11.3

COMPLETE FREEWAY NETWORK

Derated Battery Range (miles)	Percentage of AM Peak Trips (BO , RPEV)			Percentage of AM Peak Trips VMT (BO , RPEV)		
20	92.5	(86.5,	6.0)	66.4	(47.8,	18.6)
30	96.7	(93.1,	3.6)	80.5	(63.5,	17.0)
40	98.5	(95.9,	2.6)	88.8	(73.2,	15.6)
50		(97.3,		93.6		
60	99.3.	(98.2,	2.0).)	96.4	(79.7,.,	13.9).
	99.6		1.4)		(84.9.	11.5)

Derated Battery Range (miles)	Percentage of AM Peak Partitioned Trips BO	RPEV	Percentage of AM Peak Partitioned Trips VMT BO	RPEV
20	93.6	6.4	72.0	28.0
30	96.3	3.7	78.9	21.1
40	97.3	2.7	82.4	17.6
50	98.0	2.0	85.2	14.8
60	98.6	1.4	88.1	11.9

Note: All percentages are based on daily trip length distribution tables derived from the SCAG Regional Transportation Model.

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shows that approximately 100% of the trips and 97% of the VMT could be serviced with RPEVs. For a derated battery range of 40 miles and a given network size, the RPEV market potential falls between the two battery range/network size extremes given above. Approximately 97% or more of the AM-peak trips and greater than 78% of AM-peak VMT could be completed by RPEVs with a 40 mile derated battery range. For subsequent analysis purposes, the 40 mile derated battery range was selected as a conservative estimate of the likely derated battery range in 2025.

Next, alternative market penetrations, that is, the percentages of the market potential that actually use the roadway-powered facility for any portion of the trip, were first specified in terms of VMT. More specifically, 5%, 15%, and 30% market penetrations were chosen for the modest network, 5%, 15%, 30%, and 45% for the intermediate network, and 5%, 15%, 30%, 45%, and 60% for the ambitious network. For example, given the modest network, the amount of VMT that must be allocated to the roadway-powered system, given a desired 15% VMT market penetration objective, was calculated as follows:

(1) Total System VMT	=	53,905,000	
(2) Total VMT with off-network trip length at least 40 miles	=	11,530,000	(Section 3)
(3) Total market potential VMT	=	(1) - (2)	
	=	42,375,000	(Sections 1 and 2)
(4) Total VMT to be allocated	=	15% of (3)	
	=	6,356,250	

To allocate the amount of VMT calculated for each network/market penetration combination, total trip length was an important consideration since shorter trips could more easily be handled by battery power alone, whereas longer trips would be more dependent on roadway power to complete the trip. As a result, longer trips were given greater weight and shorter trips less weight in the VMT allocation procedure.

Thus, the market potential region of the trip length distribution table for each network/market penetration combination was divided into the following six categories based on total trip length:

Category 1: Off-network trips with total length less than or equal to 40 miles.

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Category 2: Trips with a combined on-network and off-network length between 0.1 miles and 10.0 miles.

Category 3: Trips with a combined on-network and off-network length between 10.1 miles and 20.0 miles.

Category 4: Trips with a combined on-network and off-network length between 20.1 miles and 30.0 miles.

Category 5: Trips with a combined on-network and off-network length between 30.1 miles and 40.0 miles.

Category 6: Trips with a combined on-network and off-network length of at least 40.1 miles with the off-network component less than or equal to 40 miles.

Tables 4.6 and 4.7 depict the 2025 AM-peak trip length distribution tables for trips and VMT on the modest network partitioned into the six categories. Next, for each network/market penetration combination, total VMT and VMT allocated to the RPEV system were calculated for each of the six categories defined above. Increasing weights were given to categories 1 through 6 respectively. Trips in category 1, those which cannot use roadway power, were assigned zero weight. Trips in category 6 were most likely to need roadway power and were assigned the highest weight, usually in the 90-95% range. The remaining guidelines for weight assignment in categories 2 through 5 were assumed: (a) to have a monotonic increase from categories 2 to 6, (b) to maintain a similar monotonically increasing shape per category across all network/market penetration combinations, and (c) to be chosen so that the sum of allocated VMT for the six categories equaled the total VMT to be allocated.

For the 15% market penetration case on the modest network, total VMT, the allocation percentages, and the allocated VMT for each of the six categories are described as follows:

Category	Total VMT	Allocation Percentage	Allocated VMT
1	21,212,000	0.0	0
2	3,767,000	0.0	0
3	5,823,000	3.9	227,100
4	5,155,000	20.0	1,031,010
5			
6	3,330,000 3,088,000	95.0 65.0	2,164,520 2,933,620
Total	42,375,000		6,356,250

The allocation percentages in the above listing utilize the assumptions given in the previous paragraph as well as the categorical weighting

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TABLE 4.6
2025 AM-PEAK VEHICLE **TRIPS** BY ON- AND **OFF-** MODEST NETWORK TRIP LENGTHS

TRIP LENGTH On-network/Off-network →		**0-2**	**2-4**	**4-6**	**6-8**	**8-10**	**10-15**	**15-20**	**20-25**	**25-30**	**30-35**	**35-40**
0	**Category 1**	1,325,484	900,460	590,586	346,059	225,805	276,768	131,194	81,119	47,447	28,386	21,558
0-2		22,666	45,815	37,154	28,486	19,985	31,371	16,425	9,952	6,132	3,824	2,991
2-4		45,755	72,683	45,103	33,078	18,787	29,848	14,800	9,668	6,108	3,772	2,617
4-6	**Category 2**	32,069	49,603	29,914	18,654	12,106	21,696	11,852	7,551	5,344	3,418	3,216
6-8		21,014	31,573	23,318	15,815	11,355	21,422	8,687	5,088	3,504	2,589	2,289
8-10		13,925	20,957	16,337	11,838	8,147	14,509	7,547	4,270	3,169	2,001	1,809
10-15		25,444	28,039	25,377	18,091	11,765	21,138	11,060	8,145	5,918	2,968	2,554
15-20	**Category 3**	9,839	11,336	11,798	9,769	6,772	12,068	6,808	4,915	3,440	2,550	1,828
20-25		2,948	3,918	5,363	5,096	4,220	7,271	4,611	2,915	2,407	1,976	1,392
25-30	**Category 4**	849	1,134	1,985	2,183	2,246	3,560	2,068	1,296	992	1,254	797
30-35		161	283	572	922	1,066	2,282	1,504	939	911	1,107	836
35-40	**Category 5**	28	71	180	378	737	1,203	632	658	526	484	465
40-45		0	20	61	135	334	759	559	467	384	431	394
45-50		0	4	38	75	139	398	300	221	197	209	124
50-55	**Category 6**	0	0	3	28	42	123	138	69	56	71	66
55-60		0	0	0	2	8	28	19	19	7	9	2
		1,500,182	**1,165,896**	787.789	490.609	323.514	**444,444**	**218,204**	**137,292**	86,542	55.049	42.938

TRIP LENGTH On-network/Off-network →	**40-45**	**45-50**	**50-55**	**55-60**	**60-65**	**65-70**	**70-75**	**75-80**	**80+**	**TOTAL**
0	1 5,538	10,683	8,946	7,095	5,580	4,299	2.917	2,388	6,770	4,039,082
0-2	2,677	2,045	1,491	1.633	1,349	1,118	963	608	2,412	239,097
2-4	1,972	1,646								
4-6	2,297	2,141	1,433 1,907	1.478 1,909	1,128 1,594	1.120 1.588	1.014 1,237	1,090 707	2,567 1,696	295,284 210,882
6-8	1.381	1.471	1,487	1,266	1,072	786	751	607	982	1 56,457
8-10	1,220									
10-15	2,244	1.152 1.789	1,028 1,606	1,060 1,546	1,170 814	602 909	473 a36	373 665	3.63 794 1	112,025 174,895
15-20	1,533	1,525	1,234	I.168	1,028	749	455	409	1.355	90.579
20-25										48,596
25-30	1.576	944	849	750	662	452	290	246	1.133	22,364
30-35	729	575 598	621 538	465 480	439 405	324 338	254 253	187 171	642 800	14,978
35-40	457	266	314	271	207	119	124	115	460	7.695
40-45	387	171	220	183	167	80	56	49	238	5,095
45-50	151	83	95	98	88	51	36	22	245	2,574
50-55	73	38	42	45	46	52	44	31	II	1,044
55-60	5	3	0	0	0	0	0	0	0	102
	32393	**25,130**	21,811	19.447	15,749	12,587	9.703	**7,668**	23,802	**5,420,749**

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TABLE 4.7

2625 AM-PEAK VMT (IN 100th) BY ON- AND OFF- MODEST NETWORK TRIP LENGTHS

TRIP LENGTH On-network/Off-network →		0-2	t-4	4-4	6-8	8-10	10-15	15-20	20-25	25-30	30-35	35-40
0	Category 1	685	2,694	2,911	2,407	2,032	3,375	2,272	1,818	1,296	920	809
0-2		63	197	231	232	203	417	303	231	173	127	115
2-4		194	432	359	331	225	458	302	245	187	133	106
4-6	Category 2	199	399	299	223	169	375	265	206	173	128	136
6-8		171	318	280	222	183	420	212	150	121	101	101
8-10		139	253	230	190	147	312	200	135	116	83	84
10-15		331	430	441	352	253	523	330	286	239	134	129
15-20	Category 3	174	229	264	238	179	360	237	195	154	127	101
20-25		66	99	146	149	132	252	183	130	120	108	83
25-30	Category 4	23	34	64	75	82	142	93	65	55	76	52
30-35		5	10	21	36	44	103	75	52	55	72	59
35-40	Category 5	1	3	8	17	34	60	35	40	34	34	35
40-45		0	1	3	7	17	42	33	30	27	32	31
45-50		0	0	2	4	8	24	19	16	15	17	11
50-55	Category 6				2		8		5			
55-60		8	8	8	0	31	2	101	2	41	61	60
		2,052	5,098	5,259	4.484	3,711	6,873	4,568	3,605	2,768	2,099	1.859

TRIP LENGTH On-network/Off-network →	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80+	TOTAL
0	658	507	469	408	348	276	211	185	640	24,936
0-2	116	99	80	96	86	79	71	47	2.5%	3,222
2-4	90	83	80	89	74		76	57	258	3.856
4-6										3,600
6-8	109	180	188	189	107	115	96	90	198	2,938
8-10	63	65	63	71	58	46	39	32	82	2407
10-15	124	108	105	109	88	73	71	60	425	4.614
15-20	92	99	86	87	82	63	41	39	155	3.002
20-25	75	66	64	60	40	41	27	24	135	2,015
25-30	41	43	43	40	39	31	25	20	79	1.123
30-35	55	48	53	43		34	27	19	107	955
35-40	36	22	28	26	21	13	14	13	63	534
40-45	33	15	21	18	17	9	6	6	34	383
45-50	13	4	IO	10	15	6	6	3	37	215
50-55	/	0	4	5	0	0	0	4	II	96
55-60	1		0	0				0	0	8
	1,579	1.361	1,304	1,263	1,105	941	774	651	2,552	53,905

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Table 4.8

TRIP MARKET PENETRATION WEIGHTS (%)
(AM PEAK)

RPEV

VMT Market Penetration Percentages	5%			**15%**			30%			45%			60%		
Network	**M**	**I**	A	**M**	I	A	**M**	I	A	**M**	I	A	**M**	I	A
Trip Length Catagory							WEIGHTS								
	0									**na**					
0	**0**	0	0	0	0	0	0	0	0	**na**	0	0	na	na	0
0.1 - 10.0		0	0	0	0	0	22.7	0	0		18.5	20.0	na	na	38.5
10.1 - 20.0	**0**	0	0	**3.9**	**0**										
20.1 - 30:o	**0**	0	**0**	**20.0**	**4.1**	0 0	65.0 50.0	45.0 25.1	30.0 9.9	na na	65.0 75.0	45.0 60.0	na na	na na	80.0 85.0
30.1 **-** 40.0	**68.6**	3902	**0**	65:0	30:0	0	80.0	70.0	60.0	na	85.0	75.0	na	na	95.0
40.1+			25.3	95.0	90.0	76.0	95.0	95.0	90.0	na	95.0	90.0	na	na	95.0

Note: a = Trips in this catagory are off-network trips **with** length less than or equal to 40 miles.
b = Trips in this catagory have a **combined** on-network and off-network length designated by the given Interval.
c = Trips in this catagory have a combined on-network and off-network length of at least 40.1 miles with their off-network component not to exceed 40 miles.

description. A full presentation of the weighting schedules associated with each network size/VMT market penetration percentage follows in Table 4.8. After determining the percentages of VMT to be assigned to each network/market penetration combination, the number of trips that would correspond to the designated VMT was specified for modeling purposes. This task was performed by first dividing each network trip length distribution table for AM-peak trips into the same categories previously described, and then computing the trips to be allocated for each network/market penetration combination based on the derived weights.

For the modest network with a 15% market penetration, the number of trips to be allocated to each category was computed as follows:

(5) Total Trips = 5,420,749

(6) Total number of trips with off-network trip length at least 40 miles = 168,290 (Section 3)

(7) Total trips in market potential region = (5) - (6)
= 5,252,459 (Sections 1 and 2)

(7a) Category 1 total (allocated) trips =	3,974,866	(0)
(7b) Category 2 total (allocated) trips =	528,823	(0)
(7c) Category 3 total (allocated) trips =	384,866	(15,010)
(7d) Category 4 total (allocated) trips =	209,666	(41,933)
(7e) Category 5 total (allocated) trips =	93,951	(61,068)
(7f) Category 6 total (allocated) trips =	60,287	(57,273)
Total	5,252,459	(175,284)

The total number of allocated trips is 175,284 representing 3.34% of the total trips in the market potential region and accounting for 15% of the associated VMT. Finally, each category trip total was allocated according to the following procedure. In the market potential region of the trip length distribution matrix, all trips in each row-column entry were grouped by associated o-d pair. For each category, the allocation percentage was randomly chosen from each of these o-d pair groupings per row-column entry.

Assignments of the trips designated to utilize the roadway-powered facility were produced based on the total number of trips required to achieve the specified market penetration. Twelve assignments and their corresponding link volume plots were prepared, one for each network size/market penetration combination, so as to pinpoint areas of

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possible congestion on the electrified facility. Careful scrutiny of the volume plots indicated that the number of electrified lanes necessary to accommodate the stipulated amount of vehicle trips was directly related to the market penetration and associated network size, and varied across electrified freeway system segments within a particular network.

Traffic volume statistics on each electrified freeway segment were compiled for each network size/market penetration combination in order to prepare lane recommendations for the electrified facility. These descriptive statistics included minimum, maximum, and average AM-peak traffic volume for each electrified network section in each network size/market penetration combination, as well as the corresponding traffic volume standard deviations. Tables illustrating these statistics appear as Appendix F of this report.

Methodologies to Specify the Number of Electrified Lanes

Three different approaches, based on maximum, average, and distributional traffic volumes, were formulated to determine the number of lanes to electrify for each network size/market penetration combination. The length of most of the freeway sections comprising each network was short enough to provide consistently larger volume counts in one direction during the AM-peak period. Three exceptions to this pattern occurred on the freeway system. The I-10, I-5, and I-405 were sufficiently longer than most freeway sections in the network. Consequently, each of these freeways was split in two parts based on scrutiny of the traffic volume patterns. The I-10 was divided at the intersection with the I-110 freeway, I-5 was split at the I-10, and the I-405 was separated at California Highway 19, adjaacent to the Long Beach airport. Assuming that higher volume readings would occur in the opposite direction during the PM-peak, the lane recommendation methodologies were formulated based on AM-peak period volume statistics.

The maximum volume approach recorded the two-hour volume on the most heavily traveled freeway link per freeway section for each network size/market penetration combination. The number of lanes required to accommodate each freeway section's maximum volume was computed by dividing this reading by 4,000, the lane capacity assumed for the RPEV technology (given an hourly capacity of 2,000). Volume on each lane was thus theoretically stipulated not to exceed capacity. For example, the maximum two-hour volume for the RPEV technology on the I-405 (N) section of the modest network with a 5% market penetration was 4,527 thus requiring 1.13 lanes. The number of lanes recommended was obtained by rounding the number of required lanes to the nearest integer. Thus, one RPEV lane was recommended for the freeway section cited previously. This method amounts to taking the volume on the most

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heavily traveled link and rounding to the nearest integral number of lanes.

The maximum volume procedure forms the basis for the <u>average</u> volume approach. That is, average traffic volumes replace maximum volumes in each step of the maximum volume methodology. An average two-hour volume of 3,633 on the northern section of the I-405 for the modest network for a 5% market penetration yields a lane requirement of 0.91 lanes and a lane recommendation of one lane. This method amounts to taking the average volume and rounding it to the nearest integer number of lanes.

The distributional volume lane specification method incorporates information from the entire range of trip volumes arriving at each freeway section link during a specified time period. Such distributional information was viewed as useful in balancing idle lane capacity against excess capacity, and as superior to the maximum and average volume approaches that may bias lane decisions toward extreme volume measurements.

The distributional volume approach was performed as follows. Trip volumes occurring in the manner stated above were assumed to be described by a Poisson distribution. Traffic volume for a particular freeway link location, X, was defined as a Poisson random variable that was assumed to be approximated by the normal distribution since the number of vehicle trips arriving at a particular freeway link location was large. For example, equations (1) and (2) below express 95% probability statements for the original Poisson variable and its normal approximation, respectively. The solution to (2)

(1) $$P(x \leq 4{,}000) = 95\%$$

(2) $$P\left(Z \leq \frac{4{,}000 - \lambda}{\sqrt{\lambda}}\right) = 95\% \text{ is } \lambda = 3{,}897,$$

where RPEV facility capacity is defined as 4,000 vehicles per lane per two-hour period, and Z is the normalized version of X. This indicates that if the mean traffic volume is 3,897, the probability that a traffic volume count at a particular freeway section link location is less than capacity is 95% for one lane. Similarly, for two, three, four, and more than four lanes, the solutions to the above equations were determined to be 7,854, 11,821, 15,793, and greater than 15,793, respectively. The listing on the top of the next page summarizes the two-hour traffic volume categories that correspond to the number of lanes suitable to avoid excess lane capacity.

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Number of Lanes	Two-Hour Traffic Volume
1	0 - 3,897
2	3,898 - 7,854
3	7,855 - 11,821
4	11,822 - 15,793
more than 4	15,794 and above

Traffic volumes for each link location on each network section were next sorted into the two-hour traffic volume categories given above. From these traffic volume tallies, the percentages of actual traffic volumes falling in each of the number of lane's categories was then computed. For example, on the modest network with a 5% market penetration on the northern section of I-405, 81.2% of the traffic volumes fell in category one, and all of the readings were accounted for in categories one and two. Therefore, 81.2% of the actual traffic volumes are less than capacity for a one lane application of the RPEV technology at least 95% of the time, and 100% are less than capacity for a two lane application of the technology at least 95% of the time.

The distributional method for lane determination as described above involves rounding to the next higher number of lanes rather than the nearest integer, and therefore does not allow for "no-RPEV lane" recommendations to be made. Thus, this method often leads to recommending more lanes than would be expected given the traffic volume, in particular, in the cases of the smaller market penetrations. A complete set of tables recording the traffic volume tallies for each number of lane category per network size/market penetration combination appear as Appendix G in this report.

In order to determine the number of recommended lanes for each RPEV facility section utilizing the traffic volumes classified in the arrangement given above, the following decision rules were applied. If at least 50% of the two-hour traffic volumes were contained in a particular number of lanes category, then the recommended number of lanes for that category was chosen. For example, on the modest network for a 15% market penetration on the 405 (S), since 54% of the traffic volumes were in lane category 3, the recommended number of lanes was 3. Further, if since zero actual traffic volumes occur in lane category 1, and 38% of the actual traffic volumes occur in lane category 2, we can conclude that 92% of the traffic volumes would be less than capacity 95% of the time for a 3 lane facility.

If no lane category contained a majority of the traffic volumes, the number of lanes determined by the average volume lane specification method was selected. For example, for a 15% market penetration on the modest network on the 10 (W), the number of lanes recommended was one based on the less than 50% volume counts in each lane category and the

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average volume lane specification. An asterisk in the lane recommendation column signifies the use of this rule. This situation is indicative of a section of highway where the volume is changing over the length of the segment. Spliting such a segment into two or even three shorter segments can be done to allow the built capacity to more closely match the demand. With shorter segments, a single lane category generally contains a majority of traffic volumes.

Upon review of the distributional lane recommendation tables it was reported that the traffic volume distribution for at least one third of the network sections for each of the twelve network/market penetration combinations contained a single category with greater than 75% of the traffic volume counts. Appendix H presents the lane recommendations formulated by all three lane determination approaches for each network size/market penetration combination.

A review of the lane recommendations generated by each of the lane determination methodologies described above was completed for each network size/market penetration combination to help specify the RPEV scenario to be used for the impacts analysis. The number of lanes recommended by the distributional approach decreased or remained the same as network size increased for a particular market penetration, and increased with market penetration for each network size. Thus, additional considerations such as capital and operating costs, technological availability, fundability, organizational feasibility, ease of implementation, construction phasing, political and social acceptance, and monitoring, and other operations issues were reviewed to assist in selecting a particular market penetration/network size combination for the RPEV scenario. These issues along with the selected roadway powered network description are presented in Section 5.1 of this report.

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4.3 HIGHWAY AUTOMATION

The methodology utilized to determine the highway automation scenario for the upcoming in-depth impact analysis is presented in this section. Physical characteristic considerations and the sensitivity analysis designed to select the configuration for the automated network are reviewed. Following these discussions, alternative lane determination methodologies used to select the automated network are summarized.

Physical Characteristics of the Automation Network

The characteristics of the automated highway system that required identification for this study included type of facility, number and location of lanes to which the automation technology would be applied, and issues of automated lane separation, access, egress, and capacity.

Freeways are the facility type chosen for application of the automation technology, as in the case of roadway electrification. Frequent and regular interruptions of traffic flow to allow access and egress from cross street traffic would render automated arterials considerably more difficult to operate and the technology for automating vehicles in the complicated, unstructured arterial environment (with pedestrians, cross-traffic, turning movements, etc.) is much more difficult to develop than for freeway use. Further, the primary benefit from automation was captured by automating freeway facilities where mobility improvements could be accomplished from higher lane capacities, accident reductions, and bottleneck elimination.

The 2025 regional highway network was again used to specify the location of the automated facility. (See Figure 7). Given the absence of a priori information regarding the size of freeway systems to which the automation technology may be applied, the three network subsets, i.e. modest, intermediate, and ambitious, defined for the roadway electrification scenario development were applied for the highway automation sensitivity analysis as well. Criteria previously stated that led to the selection of the three sub-networks are also applicable for the automation technology, especially the choice of freeway links with volume to capacity ratios greater than one.

As in the roadway electrification case, the number of lanes to which the technology could be applied was assumed to be directly related to the expected market penetration of suitably equipped vehicles. Given that the number of automated vehicles in 2025 is unknown, the sensitivity analysis modeled several market penetration percentages on each network as in the roadway electrification case. That is, alternative percentages of VMT, and the corresponding number of trips, were assumed to be performed by automated vehicles and were assigned separately to each network. Volume plots for the number of trips

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associated with each market penetration on each network were produced and evaluated to identify areas of traffic congestion. The number of automated lanes specified in the freeway system was then selected to accommodate the volume of automated trips traveling on each section of the facility, i.e. in some sections multiple lanes were required whereas on other sections one lane in each direction adequately served the estimated automation demand. The number of freeway lane miles contained in the automation facility was determined as the product of automated facility miles multiplied by the number of automated lanes on each freeway section of the automation network.

"Taking away" a lane or lanes from conventional vehicles in order to implement the automation technology on the freeway system is a difficult issue that must be addressed in practical applications of this technology. For the purposes of this study, the number of lanes modeled in the 2025 regional highway system are divided between mixed flow traffic and automated facility lanes as determined by the scenario development sensitivity analysis.

The freeway automation technology was assumed to require lane separation to ensure maximum safety. Modeling the lane/s separation for application of this technology was accomplished in a fashion similar to the current HOV procedure. Again, the number of automated trips selected depended directly on the market penetration and network size.

Special access and egress facilities and ramps are not modeled in this study because: (a) current research was not deemed- be sufficiently advanced to offer definitive choices for these system characteristics, (b) current practice with simulating separate facilities, such as HOV lanes, does not include special access and egress constructions, and (c) the regional scope of the project. For actual implementation of the automation technology, research proposals regarding construction of access and egress facilities have included Jersey barriers with openings and a transition lane, special ramps (i.e. the El Monte Busway on I-10 in Los Angeles county), and fly overs.

For modeling purposes, automation was defined as vehicles traveling in fifteen vehicle average length platoons at approximately current free flow speed limits, i.e. 55 mph, on freeways. The reader is referred to Shladover (1991) for a description of the derivation of the lane capacity estimates for an automated freeway system. Figure 9 depicts the functional relationship between lane capacity and speed for platoons of different average length. From this previous effort, it was determined that an average vehicle platoon size of fifteen vehicles traveling at 55 mph would allow lane capacity to be approximately 6,000 vehicles per lane per hour when longitudinal control automation features are utilized.

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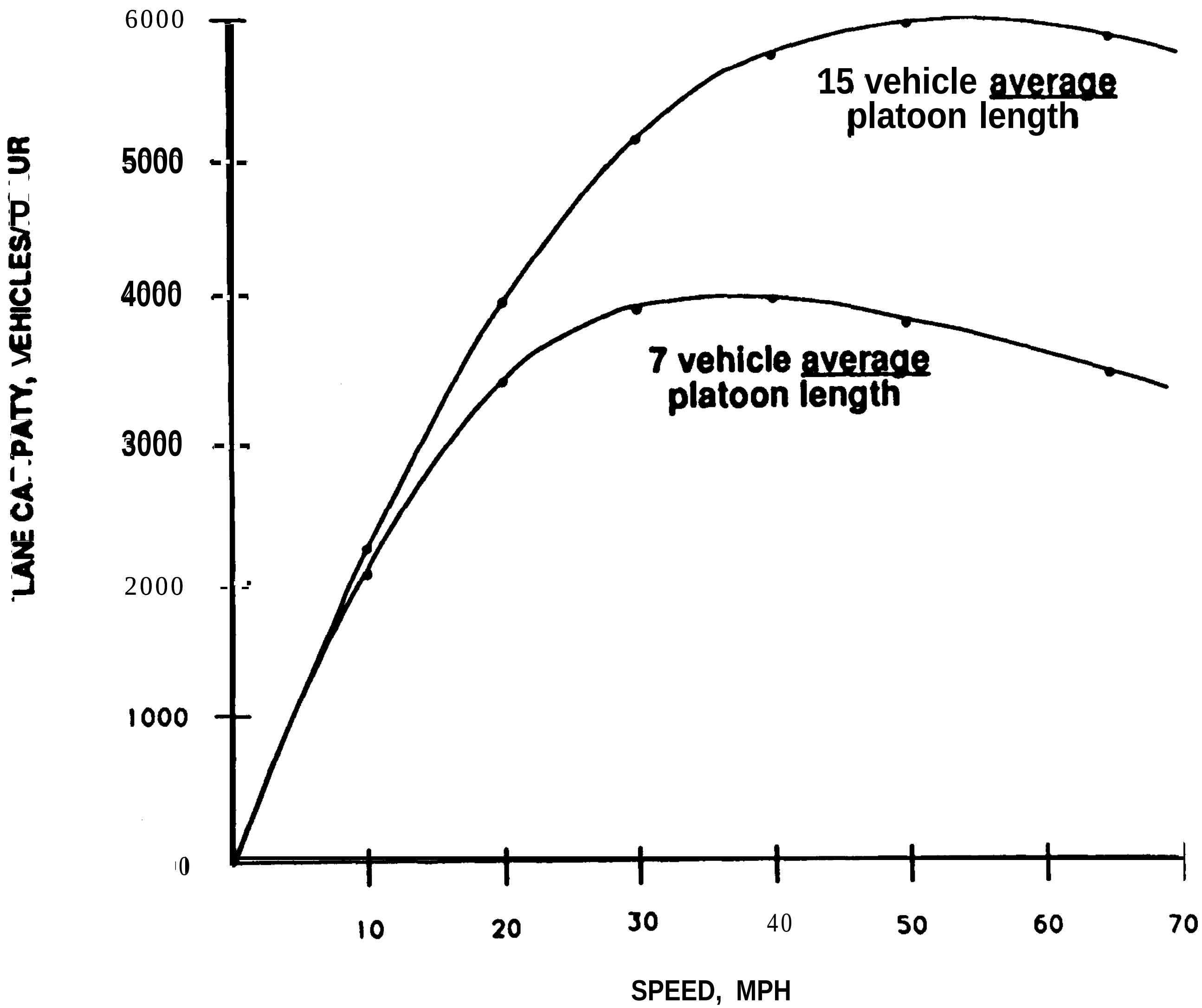

FIGURE 9

AUTOMATION LANE CAPACITY-SPEED RELATIONSHIPS

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Lateral guidance offers an additional capacity enhancement possibility by increasing the number of lanes, without expanding roadway width, due to the narrowing of lane width when automatic steering is employed. The extent to which lanes may be narrowed on automated facilities depends on the accuracy of vehicle steering mechanisms and restrictions that could be applied given vehicles of numerous widths. Shladover (1990) analyses different sets of steering control accuracy and lane restriction assumptions to derive estimates for the possible increase in the number of lanes when lateral guidance techniques are utilized on all lanes of a freeway system. These results demonstrate that it may be possible to convert three lanes of standard width, i.e. 12 feet, into four automated lanes of 8 or 9 foot width, if buses and heavy duty trucks are not permitted on the automated facility. Thus, the increased capacity benefits due to reduced lane width are more likely for light duty vehicles traveling on automated facilities that span at least three lanes. Further, when three or more automated lanes are utilized, one of these lanes may serve as a buffer lane to accommodate vehicles merging from conventional to automated lanes. The potential increase in number of lanes that could be gained from use of lateral control technology is likely to be very site dependent, based on factors such as the width of right of way available, obstacles in the right of way (bridge supports), and the means of separating automated from non-automated lanes (barriers, etc.). If a buffer lane is required when less than three lanes are automated, it may be necessary to actually decrease the number of lanes carrying traffic, regardless of whether or not automatic steering is used.

Automation Scenario Development

To determine the specific configuration for the automated facility, expected usage of the facility must be examined. Existing automation technology research as in the case of roadway electrification research does not contain information concerning potential and/or actual user demand. Thus, assumptions were formulated regarding the market potential and market penetration percentages for automated vehicles.

Market potential, that is, the number of trips (and corresponding VMT) that could utilize the automation facility, was assumed to consist of all trips (or VMT) of all lengths within the study region. Trip length distribution tables for AM-peak trips (and VMT) were thus produced for each automated network for initial design purposes in order to evaluate the technology application during peak period usage. Table 4.9 presents the 2025 AM-peak trip length distribution matrix for on and off the automated facility given an ambitious network. That is, each entry in Table 4.9 indicates the number of trips with on-automated network length shown by row descriptor, and the potential off-network trip length given by column heading. For example, the number entered in the third row and first column of Table 4.9 shows that 101,727 trips

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Table 4.9

2025 AM-PEAK VEHICLE TRIPS BY ON- AND OFF- AMBITIOUS NETWORK TRIP LENGTHS

TRIP LENGTH On-network/Off-network → ↓	0-2	2-4	4-6	6-8	8-10	10-15	15-20	20-25	25-30	30-35	35-40
0	1,323,620	848,862	472,129	234,209	121,920	113,644	43,491)	27,641	12,534	7,155	3,818
0-2	50,148	76,926	46,778	24,370	14.429	17,003	7,216	4.112	1,228	800	819
1-4	101,727	120,125	63,363	30,251	14.131	18,989	7,901	4,653	2.191	1,538	1,280
4-6	86,401	100,775	46,596	23,228	11.192	13.306	5,376	3.873	1416	1.152	832
u	64,098	72,367	29,880	17,832	9,883	11.217	6.161	3,899	2.174	2,617	1,330
8-10	53,144	53.997	52,967	15,903	8,632	11,559	9,062	2,832	2.079	1,982	911
10-15	84,729	83,567		28,804	16,175	19,304	6,165	5.513	2.619	1.614	1,311
15-20	44,981	44,996	32,252	19.171	11,135	13.893		3,840	2,363	1,387	1,072
20-25	23.430	23,180	18,803	12,519	7.998	11,268	5,375	2,860	1,803	1212	940
25-30	11,040	11,795	11.137	9,250	6,895	10,364	3,833	1,824	2,207	1,397	1,072
30-35	5.981	5,908	5,679	5,746	6,293	8,044	4,011	3,243	1,374	1.021	869
35-40	2,628	3,291	3,570	3,852	4,217	6,496	3.491		1,507	1,029	1.195
40-45	1,020	1,470	1,891	2,420	2632	5,086	2921	2.539	1,359	752	967
45-50	397	930	1,293	1,730	1.830	4,044	2,383	2,115	1,309	687	817
50-55	203	461	809	1,070	1,228	3391	1,900	1,515	1,057	568	572
55-60	106	232	426	783	946	2,480	1,825	1,449	1,092	512	628
60-65	73	161	244	m	477	1,445	1.015	737	591	361	307
65-70	U	60	124	209	m	864	789	485	449	304	255
70-75	9	27	u	85	80	410	434	332	328	m	156
75-80	4	12	21	19	13	109	139	178	194	n o	138
80+	1	4	10	12	17	87	227	275	290	403	334
	1,853,786	1,449,146	826,937	431,836	240,396	273,005	120,338	76.514	40,424	26,994	19,623

TRIP LENGTH On-network/Off-network → ↓	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75.M	80+	TOTAL
0	2.359	1,819	1,591	1,016	837	705	457	421	1,256	3,219,491
0-2	405	518	312	266	138	192	140	97	174	246,071
2-4	714	576	602	436	418	363	276	175	457	370,166
4-6	601	549	574	480	318	347	301	193	197	297,909
U	660	680	730	541	tab	604	517	360	352	2335.529
8-10	676	460	512	371	401	351	288	240	865	191,699
10-15	I,032	909	715	611	717	b21	731	475	782	312,318
15-20	780	618	555	482	519	362	293	191	373	185,428
20-25	697	384	288	273	249	236	116	105	229	111,965
25-30	744	414	463	378	329	215	172	126	274	74.704
30-35	513	297	263	211	224	188	147	97	448	49,140
								85		37,084
40-45	657	243	406	378	180	105	166	55	247	25,087
45-50	483	201	201	218	153	120	54	13	61	19,039
50-55	331	150	139	115	97	114	64	5	20	13,809
55-60	314	299	141	125	112	2.38	172	36	14	11,997
60-65	211	132	96	93	121	180	101	14	20	6.752
65-70	228	209	88	63	64	132	96	9	11	4.753
70-75	199	153	124	116	120	107	64	43	92	3.218
75-80	104	69	67	59	33	4	12	20	15	1,440
80+	262	276	225	251	154	70	57	66	129	3.150
	12,562	9316	8,392	6.192	5,990	5,394	4224	2,828	6,252	5,420,749

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could be on the automated facility between 2-4 miles and off the facility between 0-2 miles. These trips occur between numerous origin and destination pairs throughout the region. Each such origin-destination combination, however, possesses an on-network length of between 2-4 miles, and an off-network length of between 0-2 miles.

Alternative market penetrations, that is, the percentages of market potential trips that use the automated facility, for any portion of the trip, were first specified in terms of VMT. More specifically, 5%, 15%, and 30% market penetrations were chosen for the modest network, 5%, 15%, 30%, and 45% for the intermediate network, and 5%, 15%, 30%, 45%, and 60% for the ambitious network. Given a total VMT during the AM-peak period for the ambitious network of 53,930,000 (see Table 4.10), 24,268,500 VMT was calculated to be the amount of VMT that must be allocated to the vehicles that use automated system given a desired 45% VMT market penetration objective. Since 12,316,000 VMT were performed by vehicles not using the automated facility at all, 58.3% of the VMT associated with the those origins and destinations that completed part of their mileage on the freeway were allocated to the vehicles that use automated facility.

The amount of VMT to be allocated to the automated system was calculated as follows. Given the ambitious network during the AM-peak period, from Table 4.10:

Total System VMT	=	53,930,000
Total VMT for non-network trips (Row 0)	=	-12,316,000
Total VMT for on-network trips	=	41,614,000

If a 45% market penetration out of total VMT is selected, then

$$\begin{array}{r} 53{,}930{,}000 \\ \times\ .45 \\ \hline 24{,}268{,}500 \end{array}$$

is the amount of VMT that must be allocated to the automated system. That is, 58.3% of the VMT in each row entry in the trip length distribution table (excluding Row 0), will be selected to travel on the automated facility, since 24,268,500/41,614,000 = 58.3%. A full presentation of the weighting schedules associated with each network size/VMT market penetration percentage follows in Table 4.11

After determining the percentage of VMT to be allocated to each network/market penetration combination, the percentage of trips that would correspond to the designated VMT were specified for modeling purposes. For a 45% market penetration of system VMT during the AM-peak period for the ambitious network, 1,283,333 trips were assumed to utilize the automated facility to complete their journeys. This number of trips represents 58.3% of the trips traveling on the freeway system that use the automated system.

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Table 4.10

2025 AM-PEAK VMT (IN 1000s) *BY* ON- AND OFF. AMBITIOUS NETWORK TRIP **LENGTHS**

TRIP LENGTH On-network/Off-network → ↓	0-2	2-4	4-6	6-8	8-10	10-15	15-20	20-25	25-30	30-35	35-40
0	682	2,524	2,312	1,620	1,095	1,371	752	625	342	231	143
0-2	144	335	288	201	147	227	134	95	35	27	32
2-4	439	711	so4	303	lb9	290	161	118	66	54	52
4-6	537	807	464	277	157	229	120	105	53	43	35
6-8	518	m	466	249	158	215	149	114	75	103	59
8-10	524	646	418	255	156	247	174	a9	76	a2	43
10-15	1.102	1,281	919	559	349	472	268	193	107	73	65
15-20	800	915	720	468	295	413	214	153	106	69	59
20-25	529	588	516	369	252	393	212	128	90	67	56
25-30	304	360	361	320	251	412	173	130	122	84	70
30-35	195	210	213	228	261	360	199	100	82	67	61
35-40	98	133	152	171	1%	324	193	195	94	72	90
40-45	U	67	90	120	136	279	175	165	98	n	77
45-50	19	47	68	94	103	243	154	147		55	69
50-55	11	26	47	64	76	220	133	114	84	48	52
55-60	6	14	27	51	63	173	136	116	93	46	60
60-65	5	11	17	26	34	108	81	63	53	34	31
65-70	3	4	9	lb	21	69	67	U	43	30	27
70-75	0	1	5	7	1	35	13	18	20	w	17
75-80	0	0	21	21	2	109	24	31	35	25 50	44 lb
80+											
	5,961	9,404	7,596	5399	3.928	6.0%	3,571	2,776	1,805	1,347	1,157

TRIP LENGTH On-network/Off-network → ↓	40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80+	TOTAL
0										
0-2	10018	2687	8317	58 lb	52 9	46 13	33 10	33 8	12416	12,316 1.7%
2-4	32	29	33	27	28	26	21	14	42	3,118
i-b	W	W	33	30	21	25	23	lb	18	3,051
6-8	33	37								
8-10	35	26	43 32	25 35	42 W	45 27	41 23	21 30	89	3,172 3.016
10-15	56	54	46	43	54	49	62	43	79	5,875
15-20	47	40	39	36	42	31	26	18	40	4.531
20-25	45	27	22	22	21	21	11	10	25	3,404
25-30	52	31	37	32	30	21	17	13	32	2,852
30-35	38	24	22	19	21	19	15	11	54	2,200
35-40	53	31	37	36	20	15	11	10	30	1,963
40-45	45	22	26	31	19	11	8	7	32	1,504
45-50	31	19	20	23	17	14	8	1	3	1,251
50-55	37	3115	1615	1413	1113	30 14	22	5	2	955 983
55-60										
60-65	22	14	11	11	15	23	14	2	3	578
65-70	25	24	11	8	8	18	13	1	2	443
70-75	13	9	9	8	6	15	2	3	3	339
75-80	36	39	33	38	24	12	9	11	24	423 159
80+										
	813	633	602	539	4%	476	3%	265	675	53.930

Table 4.11 VMT Market Penetration Weights (X)

AUTOMATION[a]

VMT Market Penetration Percentages	5%			15%			3096			45%			60%		
hetwork	M	I	A	M	I	A	M	I		M	I	A	M	I	A
	WEIGHTS														
	9.3	7.2	6.5	27.9	21.6	19.4	55.8	43.2	38.9	na	64.9	58.3	na	na	77.i

Note: a = All selected trips are on-network trips.

The amount of trips to be allocated to the automated system was calculated as follows. Given the ambitious network during the AM-peak period, from Table 4.9

Total Trips	=	5,420,749
Total Non-Automated Network Trips	=	-3,219,491
Total Automated Network Trips	=	2,201,258

If a 45% market penetration out of total VMT is selected, then

2,201,258
x .583
1,283,333 is the number of trips allocated to the automated system. The trip allocation procedure was performed as follows. All trips in each row-column entry (except Row 0) of the trip length distribution matrix (Table 4.9) were grouped by associated o-d pair. The percentage of trips to be allocated, for example, the 58.3% of trips stated above, were randomly chosen from each of these o-d pair groupings for each of these row-column entries.

The trip allocation procedure gives equal weight to all trips being made by automated vehicles, regardless of on-network length. This study has also analyzed other technologies, in particular, roadway-powered electrification in conjunction with highway automation. In the scenario development of that technology, different weights were used, with larger weights given to trips with longer on-network components. A complete discussion of the weight derivation for the combination technology -- roadway electrification and automation technology may be found in Section 4.4. A comparison was made of the recommended number of lanes for each network size/market penetration combination for these two technologies and indicated only minor differences for each combination. A further examination of network traffic volumes was made, and consequently, all of the differences were incorporated into the final automation scenario.

Trip assignments of the origin-destination pairs designated to utilize the automated facility were produced based on the percentage of trips required to achieve the specified market penetration. A total of twelve assignments were prepared, that is, one for each network size/market penetration combination. (See Table 4.11 which presents VMT market penetration weights for these twelve cases). With respect to the previous example, 58.3% of the trips completing a portion of their journey on the freeway (all row entries except row 0 in Table 4.9) were assigned to the automation network given the selected 45% total VMT market penetration. For each network size/market combination percentage, plots of link volumes were created so as to pinpoint areas of possible congestion on the automated facility.

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Careful scrutiny of the volume plots indicated that the number of automated lanes necessary to accommodate the stipulated number of vehicle trips was directly related to the market penetration associated with particular network size, and varied across automated freeway system segments within a particular network. Descriptive statistics of traffic volume on each automated freeway segment were compiled for each network size/market penetration combination in order to prepare lane recommendations for the automated facility. These descriptive statistics included minimum, maximum, and average AM-peak traffic volumes for each automated network section in each network size/market penetration combination, as well as the corresponding traffic volume standard deviations. Tables illustrating these statistics appear in Appendix F.

Methodologies to Specify Number of Automated Lanes

The three traffic volume approaches used to determine the number of lanes to recommend for the roadway electrification scenario development were applied to each automated network size/market penetration combination. These methodologies are based on maximum, average, and distributional traffic volumes.

The number of lanes to be automated was determined for each freeway section, based on the AM-peak period. These sections are typically twenty to thirty miles in length, although some are longer. Given substantial directional flows in the study region, the flow direction indicating the highest traffic volumes was selected for further analysis. The same number of lanes were selected for automation in both directions, based on the assumption that the PM-peak hourly flows are approximately equal and opposite to AM-peak flows. (The PM-peak has more trips, VMT, etc., but is spread over a somewhat longer time period). For freeway sections possessing multiple dominant flow directions over their entire length, it was necessary to split these sections into their distinct directional flow components, i.e. I-5 and I-10 which intersect downtown Los Angeles, were each divided into two components. In addition, I-405 was split into two sections, as indicated by dominant flow directions. The same number of lanes was selected for an entire freeway section even though traffic volumes taper down in outlying areas on some sections. This results in overbuilding in the rural areas and perhaps underbuilding in the urban areas, or locations of highest demand.

The maximum volume approach selects the number of lanes based on the single link within a freeway section with the highest (maximum) volume. This volume is divided by the two-hour capacity of 12,000, the lane capacity assumed for the automation technology (given an hourly automated lane capacity of 6,000). The number of required automated

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lanes depends on the assumed hourly lane capacity, and had a different capacity been used, such as 4,000 or 8,000 vehicles, the lane recommendations would have changed. The capacity assumption used in this study was based on the work found in Shladover (1991).

Volume on each automated lane was thus restricted from exceeding capacity, i.e. V/C ratio less than or equal to one. For example, the maximum two-hour volume for the automation technology on the I-405 (N) section of the modest network with a 5% market penetration was 4,262 thus requiring 0.36 lanes. The number of lanes recommended was obtained by rounding the number of required lanes to the nearest integer. Thus, no automated lanes were recommended for that freeway section.

The maximum volume procedure forms the basis for the average volume approach. That is, average traffic volumes replace maximum volumes in each step of the maximum volume methodology. An average two-hour volume of 3,519 on the northern section of the I-405 for the modest network for a 5% market penetration yields a lane requirement of 0.29 lanes and a lane recommendation of zero lanes, for example. Appendix F contains a complete set of tables indicating the average volume recommendations for each network size/market penetration combination.

The distributional volume lane specification method incorporates information from the entire distribution of trip volumes by modeling them as a random variable described by the Poisson distribution. Number of lane breakpoints are established for 95% confidence intervals per number of lanes, and are slightly lower than the assumed capacity of 12,000 vehicles per lane for two hours, or 6,000 vehicles per lane per hour, as shown below.

Number of Lanes	Two-Hour Traffic Volume
1	0 - 11,821
2	11,822 - 23,746
3	23,744 - 35,689
4	35,690 - 47,641
more than 4	47,642 and above

A distribution of link volumes is next formed utilizing the above 2-hour volume class interval designations for each freeway section. If a majority of the link volumes generate the same recommended number of lanes, then that number of lanes is chosen. If a single lane category does not contain a majority of link volumes, then the average volume lane recommendation method is used for subsequent analysis. The distributional method rounds to the next higher integer rather than the nearer, and thus always indicates that at least one lane is automated unless no one bin contains a majority For example, if the

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traffic volume is 4,262 the distributional method will round a 0.36 lanes (4,262/12,000) to a one lane requirement. Thus, since the distributional method's rounding up prevents traffic volume from exceeding capacity, it is viewed as superior to both the maximum and average methodologies. Appendix G contains a full set of tables recording the traffic volume tallies utilized to generate the lane recommendations determined by the distributional method.

A review of the lane recommendations generated by each of the lane determination methodologies described above was completed for each network size/market penetration combination to help specify the automation scenario be used for the impacts analysis. (See Appendix H). The number of lanes recommended by the distributional approach decreased or remained the same as network size increased for a particular market penetration, and increased with market penetration for each network size. Thus, additional considerations such as capital and operating costs, technological availability, fundability, organizational feasibility, ease of implementation, construction phasing, political and social acceptance, monitoring, and other operations issues were reviewed to assist in selecting a particular market penetration/network size combination for the automation scenario. These issues along with the selected highway automation network description are given in Section 5.2 of this report.

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4.4 COMBINATION SYSTEM

The methodology employed to specify the combination system scenario for the upcoming regional impacts analysis is given in this section. The combination scenario encompasses two types of special facility lanes: (a) lanes servicing both automated RPEVs (the only RPEVs considered in the combination scenario), and (b) lanes equipped to facilitate only automated vehicles. Much of the preceding scenario development analysis in Sections 4.2 and 4.3 was utilized to form the combination system's sensitivity analysis. Thus, this section will focus on explaining any new considerations and refinements to the previously described selection processes.

Physical Characteristics of the Combination System

The combination system of advanced technologies was assumed to consist of the freeways designated in the SCAG 2025 regional highway network, or one of the previously described subsets of this freeway system. (See Figure 7). The number of lanes to which the technology was applied was selected via sensitivity analyses for each of the two special facilities explained above that comprise the combination system. This procedure will be summarized in the next section. As was the case in the roadway electrification and highway automation lane determination decisions, little guidance was available to gauge the future market penetration of the combined system technologies. Thus, as before, alternative market penetrations and their corresponding number of lane recommendations were studied as part of the sensitivity analysis to select the final combination system scenario. Volume plot analysis and freeway section descriptive statistics were evaluated for each of the twelve network size/market penetration combinations given on page 4-18 of this report.

Although roadway electrification does not in itself require facility separation from conventional mixed-flow traffic, roadway electrification combined with automation, special facility type (a), does. Thus, since automation itself (type (b)) requires a separate facility, the combination system yields three types of freeway facilities, types (a), (b), and mixed-flow. Vehicles that are not equipped with at least automation features are thus prevented from traveling on the combination system facilities. In the trip assignment stage of the modeling process a multipath assignment will be performed in order to prioritize the trips that will use each facility. The type (a) trips will be assigned first to the type (a) facility. Since the V/C ratio (due to the automation component) on the type (a) lane/s is restricted to be less than or equal to one, given a lane capacity definition of 6,000 vehicles per lane per hour, any trips that are equipped with the type (a) technologies that cannot enter the "full" type (a) lane/s will be directed to the type (b) lane/s. Next, the

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type (b) trips will be assigned to the type (b) facility lane/s. Again, should the type (b) trips needing this facility exceed the V/C=1 restriction, surplus trips will be routed to type (a) lane/s, if excess capacity exists, or to the mixed flow lanes. The remaining trips, those not equipped with either type (a) or (b) technology/s, will be assigned to the mixed-flow lanes only.

As in the roadway electrification and highway automation cases, special access and egress facilities are not modeled in this study. In addition, both freeway on- and off-ramps are not modeled given the regional scope of the project. Lateral assist capacity enhancements are possible with respect to both type (a) and type (b) technologies, but were not modeled in the study. The reader is referred to the previously described practical considerations regarding these physical characteristics of the combination advanced technology system.

Combination System Scenario Development

The combination system scenario development process is two-fold given the two special facilities that are contained in the system design. Information from other sources concerning potential and/or actual user demand and market penetration was absent for the combination system. For the type (a), roadway electrification and highway automation, component of the combination system, the trip length distribution analysis given in Section 4.2 was utilized to define the market potential trips and VMT as well as corresponding market penetration sensitivity analysis regarding trips and VMT. Careful review of the twelve network size/market penetration assignments and their correlated link volume plots enabled determination of the number of lanes to which the combination system technology would be applied. Analysis of the volume plots and descriptive statistics assumed a two-hour lane capacity of 12,000 due to the automation component. The reader is referred to Appendices F, G, and H for a complete set of tables, entitled Combination, which refer to the type (a) facility descriptive statistics and lane recommendations.

The methodology utilized to select the type (b), or automation only, component of the combination system follows the detailed analysis previously identified in Section 4.3. Analysis of the volume plots and descriptive statistics for each network size/market penetration combination were thus compared. To determine, however, if the additional trip length considerations assumed in the type (a) facility analysis (which essentially provides that longer trips be more likely to use the facility than shorter trips) yielded lane reconunendations that were different from those produced from studying type (b) statistics, a comparison of the lane recommendations for each network size/market penetration combination for type (a) and type (b) facilities was performed. This comparison indicated that most of the

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lane recommendations were similar, if not identical. The comparison was pursued to satisfy concerns raised by some project advisors who asserted that longer trips were more likely to use the special facility, type (b), even though battery range was not a limiting factor as in type (a). The reader is referred to the Automation tables in Appendices F, G, and H for a complete set of the descriptive statistics and lane recommendations that were utilized for the type (b) facility component of the combination system's development.

A review of the lane recommendations generated by each of the lane determination methodologies for facility types (a) and (b) was performed for each network size/market penetration combination to specify the combination scenario to be selected for the regional impacts analysis. As noted in the roadway electrification and automation scenario cases, the number of lanes recommended by the distributional approach decreased or remained the same as network size increased for a particular market penetration, and rose with market penetration for each network size. The additional considerations given in Sections 4.2 and 4.3 to assist in picking the particular network size/market penetration combination/s for the combination scenario were also deemed essential for the final combination scenario definition. These issues as well as the chosen combination scenario for further impacts analysis development are given in Section 5.3 of this report.

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5.0 SCENARIO SELECTION AND PRELIMINARY ANALYSIS

The networks detailed in Sections 5.1 - 5.3 are the result of the sensitivity analyses previously presented in Sections 4.2 - 4.4, substantive comments on that analysis by SCAG/PATH staff and Project Advisory Group (PAG) members, and a review of the following scenario development considerations: preliminary capital and operating costs (where available), technological availability, fundability, organizational feasibility, ease of implementation, construction phasing, operations issues, social and political acceptance, and monitoring. In each specific scenario section we review the considerations previously stated first. Next, each final technology scenario is defined, depicted, and summarized.

5.1 ROADWAY ELECTRIFICATION

Capital and Operating Costs

Given the prototype stage of development of RPEV technology, little information on the costs of this technology are currently available. Further, considerations of any costs associated with this technology will depend on the size of the implemented project in order to realize as yet unknown, economies of scale that may be possible through mass production. Since only a few demonstration projects are planned at present, practical experience is lacking to provide data sufficient to properly evaluate potential economies of scale.

A study by Nesbitt, Sperling, and Deluchi (1990) has, however, offered comprehensive preliminary cost information for private RPEV costs. The authors note that the RPEV system encompasses several efficiency/cost trade-offs that stem from design changes within the system. For example, the amount of electric roadway installation is inversely related to battery size and correlated initial vehicle cost. If an extensive roadway infrastructure network is utilized, then battery size can be reduced thus lowering an individual's cost of using the RPEV system. Another trade-off would arise from decreasing the air gap between the roadway and pick-up cores which would require a heavier, and more costly suspension system for the pick-up inductor, thus increasing initial vehicle cost. Numerous additional technical/design trade-offs are investigated in this report which indicate that caution should be applied to usage of the preliminary cost information for purposes other than initial evaluation. Further, the private cost estimates that are given are only a partial effort toward provision of a complete social cost analysis of this technology.

For illustrative purposes, the private capital and operating costs of a RPEV system are given below in 1987 cents per mile. Numerous assumptions have been detailed in the Nesbitt, Sperling, and DeLuchi

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paper to support the low and high cost estimates. Importantly the set of assumptions contained in each scenario depend on complex technical relationships that together produce the cost figures. For example, several types of technical efficiencies are imbedded in the produced figures which in turn depend on the overall design of system infrastructure and subsequent electric vehicle configuration that will be operated on that infrastructure.

Capital Costs		Cents/Mile Results
Low	High	
10.69	18.93	Initial vehicle cost
1.49	4.52	Batteries
0.78	6.00	Cost of electric roadway installation (per mile)
Operating Costs		**Cents/Mile Results**
1.21	2.31	Total electricity cost for given operating mode
7.35	9.48	Insurance
2.42	4.12	Maintenance
0.53	0.62	Replacement tires
1.27	1.27	Parking and tolls
0.28	0.34	Registration
0.57	0.86	Fuel tax
0.19	0.19	Accessories
0.016	0.049	Cost of additional electric roadway maintenance (as compared to conventional)
26.80	48.69	Total Private Cost, Cents/Mile

Based on the Nesbitt, Sperling, and DeLuchi life cycle cost analysis, the RPEV system's private cost ranges from 29.80 to 48.69 cents/mile. This compares favorably with their estimate of approximately 29.53 to 36.74 cents/mile for their baseline gasoline vehicle. Importantly, an assumption of electric roadway cost of $1 to $2 million per lane mile, incorporated in the above analysis, is viewed by some experts as too low. A revised upper limit of $4 million per lane mile may be more appropriate for the electric roadway. Further, other sources stipulate refinements for several of the cost categories above but were not incorporated in this cost summary due to the stage of completion of these figures. Appendix L offers some of these additional cost estimates (also in a preliminary form) which will be reviewed more fully prior to the regional and individual economic impacts analysis in the Phase III Report.

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Technological Availability

The roadway powered electric vehicle (RPEV) technology has been under development since 1976. It consists of buried cables in the roadway, which carry an electric current that produces a strong electromagnetic field. Energy is transferred to an inductive pickup device on the electric vehicle via the magnetic field.

The technology has been tested in static and dynamic modes at the University of California, Berkeley, Richmond Field Station since 1987. A 400 foot electrified roadway was developed to test the inductive coupling technology. An electric bus, originally fabricated for the Santa Barbara Electric Bus Project, has been equipped with an inductive pickup device and on-board controller (OBC). The OBC controls the amount of energy transferred to the vehicle and converts it from alternating current (AC) to direct current (DC) which is used to power the traction motor and/or charge the on-board battery. The bus has undergone dynamic testing over the past three years. The initial round of testing resulted in redesign of the inductor technology to substantially minimize acoustic noise and electromagnetic field strength problems. The more recent testing was on a G-Van which was modified to accommodate new design parameters.

The redesigned roadway and pickup technology has undergone testing during the first half of 1991. The results of the testing have been favorable and the technology is being extended to an ongoing evaluation effort as a part of the Playa Vista RPEV project in Los Angeles. Plans are underway to build a test facility at Playa Vista, a development several miles north of Los Angeles International Airport, in 1992 and to further demonstrate the technical feasibility of the RPEV concept. (The specifics of this demonstration program will be discussed in the Phase III Report).

All studies to date on the RPEV technology have demonstrated its technical viability. If currently planned studies are carried to fruition, the technology should be available for widespread application in the late 1990s or early 2000s, with small scale demonstrations much earlier.

Fundability

Funding for application of the RPEV technology must involve ongoing public and private sector cooperation. A public/private sector effort is underway to fund the Playa Vista project. This involves utilization of Federal, State and Local public transportation and energy funds; and, private funding from utilities and developers. This effort will move toward the demonstration of the technology with different vehicle types and roadway environments.

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Funding for the RPEV scenario being studied would require a coordinated public and private effort as well. Construction funds for the roadway inductor system could be provided wholly or partly from government transportation funds (federal, state and local). Electric utility revenue based funding could be utilized as well. Private funding would be required for building and/or adapting electric vehicles with the inductive coupling technology. Government support for electric vehicle development and purchase is also possible, and may be more likely in areas with major air quality problems, such as the South Coast Air Basin.

Organizational Feasibility

Organizational feasibility of the RPEV scenario requires that the following questions be addressed: who would construct, own and operate the RPEV system; and, can an effective system be developed to capture the ongoing costs for operating the RPEV system as well as paying for some portion of the capital costs.

Construction of the RPEV scenario would be on the state highway system, which is under the jurisdiction of the California Department of Transportation (Caltrans). Under normal conditions Caltrans would supervise construction of the roadway inductor system. This would involve concrete cutting, debris removal, installation of roadway inductor segments, cabling, and surface coating. The electric utility would normally be responsible for providing electricity to power conditioner units spaced along the routes which are being electrified; and, maintaining the process for determining electric use and cost to users. Alternatively, the electric utility or another governmental agency could construct and operate the RPEV system, under contract with Caltrans.

Operation of the RPEV system involves the development of a mechanism for allocating the ongoing costs, primarily electric energy. Devices would be installed on the electric vehicles to record inductive coupled energy use and a process established to recover these costs through a standard utility billing mechanism. Depending on the manner of cost allocation for construction of the roadway inductor, these costs could be amortized with ongoing operations costs (including electric use) by the electric utility.

Ease of Implementation

Implementation of the RPEV scenario requires that it be viewed in relation to the other scenarios. All things considered, the RPEV

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scenario may be harder to implement than the automation scenario and easier than the combination scenario. Although they are comparable on the whole, with different advantages and disadvantages, costs, fundability, construction phasing, operational considerations, and social and political acceptability would, when taken together, support this finding. If the automation scenario includes building (or expanding existing) ramps, this assumption is probably incorrect. Also, liability problems are likely to be more severe with the automation scenario than the RPEV scenario.

Construction Phasing

One of the critical questions regarding the RPEV scenario involves the determination of "how can the technology be implemented with minimum disruption and at minimum cost, while receiving the greatest benefit from the technology". The answer to this complex question requires an understanding of the construction techniques to be utilized in placing the roadway inductor.

Current plans for the Playa Vista project involve the installation of 10 foot prefabricated "modules" in channels which have been cut into the roadway. Once a decision has been made to build an RPEV system of the magnitude set forth in the scenario, it is expected that economies of scale will allow for the prefabrication of the roadway modules at location(s) near the site to minimize transportation costs. Discussions with knowledgeable construction professionals indicate that this is expected.

Minimizing disruption to the freeway system while the RPEV system is being constructed should be no more a challenge in a highly developed urban area than ongoing lane resurfacing projects. Construction will be necessary for the roadway inductor and the power distribution system. Caltrans and their contractors have developed techniques for minimizing disruption, such as: construction during off-peak periods, especially during late evening hours; extensive use of telecommunications to publicize construction activities and alternative travel routes; and, use of concrete safety barricades and lane merging techniques to minimize space required for construction. Opportunities exist for piggybacking RPEV construction onto periodic resurfacing projects. Given that for most segments of the RPEV scenario, installation of the technology in one or two lanes is called for, operation of the remaining lanes would still be possible. Assuming that these techniques are implemented, it is believed that an acceptable level of disruption can be tolerated, given the commensurate public benefit of the RPEV technology.

Operations Issues

Annual operations costs for the RPEV scenario are detailed in the "Capital and Operating Costs" presented earlier in this section. These

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costs could be borne by the RPEV user (as assumed by the Nesbitt, Sperling, DeLuchi study) in large part through utility rate charges, which, depending on the mechanism utilized to finance construction of the system, could be factored through the electric utility, but not necessarily included in the utility rate base. Alternatively, these costs could be borne by the driving public through road use taxes.

Operating costs involve an ongoing long term commitment to maintaining the RPEV system. This will require maintenance of the roadway inductor, the electrical distribution system within the right-of-way (including power conditioners), and the roadway surface over the conductor. Depending on the constructing and operating mechanism chosen by the highway agency (Caltrans), these costs could be integrated with the ongoing operating and maintenance costs for the highway system.

Operationally, the roadway inductor could be switched on automatically by a sensing device when an RPEV was over the roadway. This would help minimize system energy losses. Furthermore, it would also reduce operating costs. Additional research and testing is needed to determine the technical and operational feasibility of this approach.

Social Acceptance

Social acceptance of the RPEV technology may require acceptance of the electric vehicle (EV) by the driving public or RPEVs may come to have more widespread public acceptance than battery-only EVs. However by the time RPEV technology becomes as widespread as contemplated in the RPEV scenario, most of the following social acceptance issues pertaining to electric vehicles should be addressed and satisfied. For example, (1) Will the electric vehicle be marketed or priced (vehicle, purchase cost, operating and maintenance costs) as a cost effective alternative to the internal combustion vehicle (ICV)? (2) Will a publicly acceptable static charging system be implemented and in place to support the EV? (3) Given that fleet EVs will likely be the first in widespread use, how will their experiences be translated so as to help convince the general public to buy and use EVs? (4) Will the EV be an effective substitute to an ICV for multi-vehicle owning family units, and if so, will EVs meet the public's short and intermediate daily travel needs, given some practical battery range limitations? and, (5) Will acceptable EVs be designed and built, given personal preference characteristics of the driving public? Answering these, and other EV related social acceptance questions is beyond the scope of this study, but will need to be addressed to the satisfaction of the driving public.

Public acceptance of RPEV technology will require that some additional questions be addressed: (1) Will the public adapt their longer distance driving within the metropolitan area to optimally utilize

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the RPEV network? (2) Will the RPEV users accept their proportionate share (user charges) of the electricity costs? (3) Will the general public accept the direct costs of constructing and operating the RPEV system, as well as the indicrect costs of inconvenience and time delay associated with constructing the RPEV facility, or will these costs have to be fully borne by the RPEV user? The following discussion addresses these questions.

The RPEV network has been designed to maximize the year 2025 forecasted vehicle trips that can be accommodated by RPEVs. Multiple daily trips over portions of the RPEV network, which in the aggregate exceed the EV battery range limitations, will be beneficial as well. These factors should help to improve the social acceptance of RPEV technology.

The RPEV users acceptance of their proportionate share of ongoing electric costs for using the RPEV system will depend on the magnitude of the costs in relation to perceived benefits. This is a judgment question, with no clear answer. RPEV online charging will occur at various times of the day depending on driving characteristics, with predominant use occurring during the AM- and PM-peak driving periods. Electricity costs during these periods would normally be higher than during off-peak late evening hours (the period when most static charging of EVs would preferably occur). This should not be a big problem, as costs are likely to be less than gasoline costs for internal combustion vehicles (ICVs).

Importantly, driving habit changes of the public as they adapt to the new technology is a social acceptance issue that remains to be addressed. Such an adaptation would certainly benefit from proper training as well as development of the necessary servicing and infrastructure requirements needed to accommodate the new technology. Any large scale introduction of EVs or RPEVs should be preceded by public education and training programs. A cooperative effort of the vehicle manufacturers, electric utilities and public transportation planning and implementing agencies will be necessary to facilitate public acceptance and use of the technology.

<u>Political Acceptance</u>

Political acceptability of the RPEV scenario can best be gauged through the review of the results of prototype demonstration project(s) in the metropolitan area. Continuing testing of the RPEV technology is underway at Richmond Field Station. Visits by local elected officials to this and the Playa Vista test site could help facilitate political acceptance.

Local officials will need to see the benefits of RPEV technology in relationship to other alternatives, including doing nothing.

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Furthermore, they will need to review RPEV opportunities in light of forthcoming EV developments, namely California Air Resources Board regulations which call for the introduction of 20,000 zero emission vehicles (ZEVs) by year 2000.

Regional and county transportation and air quality planning bodies should be utilized to bring local elected officials on board and educate them and their constituencies on the benefits of RPEV technology. Sufficient mechanisms exist in Southern California to make this a reality.

Monitorinq

Given the introduction of the new technology, an effective pre- and post-monitoring program is essential. The program should be designed to collect transportation systems utilization data; socio-economic data; public acceptance levels; and, projected and actual capital and operations costs. It should be carried out by an impartial body, not by the constructor and/or operator of the system. Full public, elected official and news media input should be sought in designing and executing the monitoring program.

Success of the RPEV scenario can best be gauged by periodically measuring the number of users and by examining indicator statistics,such as improved air quality that can be traced to the implementation of RPEV technology. Construction of the RPEV system should be staged over a period of time and ongoing monitoring data should provide the means of evaluating the success or failure of the technology. Decision points should be pre-established so that actions can be taken by the appropriate officials to all a halt to the program, should it prove ineffective in meeting any agreed to program objectives. If an RPEV program ultimately fails, the highway system could continue to function with little if any noticeable change in traffic operations.

Roadway Electrification Scenario

Having reviewed the above information, reviewer comments, and sensitivity analysis statistics, the roadway electrification (or RPEV) scenario was chosen to be of modest size (with a few modifications to the modest network in Figure 7) assuming a 15% market penetration. The smaller network size was selected due to the high proportion of roadway infrastructure costs relative to other costs. The electrified system selected for 2025 was a slightly expanded version of the modest network given reviewer comments concerning some sections of high vehicle demand that were not fully captured in the original modest configuration. The freeway sections added to the original modest network are: (a) I-10 from I-605 to I-15, (b) US-101 from California Highway 23 to I-405, and (c) California Highway 91 from California Highway 57 to

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I-15. Based on volume plot analysis and the corresponding descriptive statistics for these freeway sections, two lanes were chosen in each direction for each of the network additions. Please refer to Figure 10, Table 5.1, and Appendix I for a visual depiction and mileage description of the revised modest network, or RPEV scenario network. The total number of lane miles, counting both directional flows, is 1,240.

Table 5.1

RPEV
Number of Lane Recommendations
(Revised Modest Network with 15% Market Penetration)

	Recommended Number of Lanes by Volume Method		
Freeway Sections	Maximum	Average	Distributional
405 (N)	3	2	2
405 (S)	4	2	3
5 (N)	3	2	2
5 (S)	All	All	All**
110	2	1	1
10 (W)	2	1	1*
10 (E)	2	2	2
105	2	1	2
57	2	2	2
91	2	2	2
101	2	2	2

* = Indicated that the average volume method was used to determine the lane recommendation. This substitution of method occurs when none of the lane recommendation categories in the distributional method procedure contain 50% of the traffic volume counts.

** = Although the distributional method indicated traffic volumes of sufficient size to justify an all lane application of the technology, the project staff limited the modeled recommendation to three lanes.

The 15% RPEV market penetration was viewed as plausible for study purposes given 2010 California Energy Commission electric vehicle market penetration estimates ranging from 2% to 28%. Other estimates of electric vehicle market penetration range from 0% with a "naturally occurring" market penetration (without government regulation stimulus) to 30% if government mandates, i.e. by AQMD and CARB, to replace the current vehicle fleet with zero emission vehicles (ZEVs) are aggressively employed by 2010.

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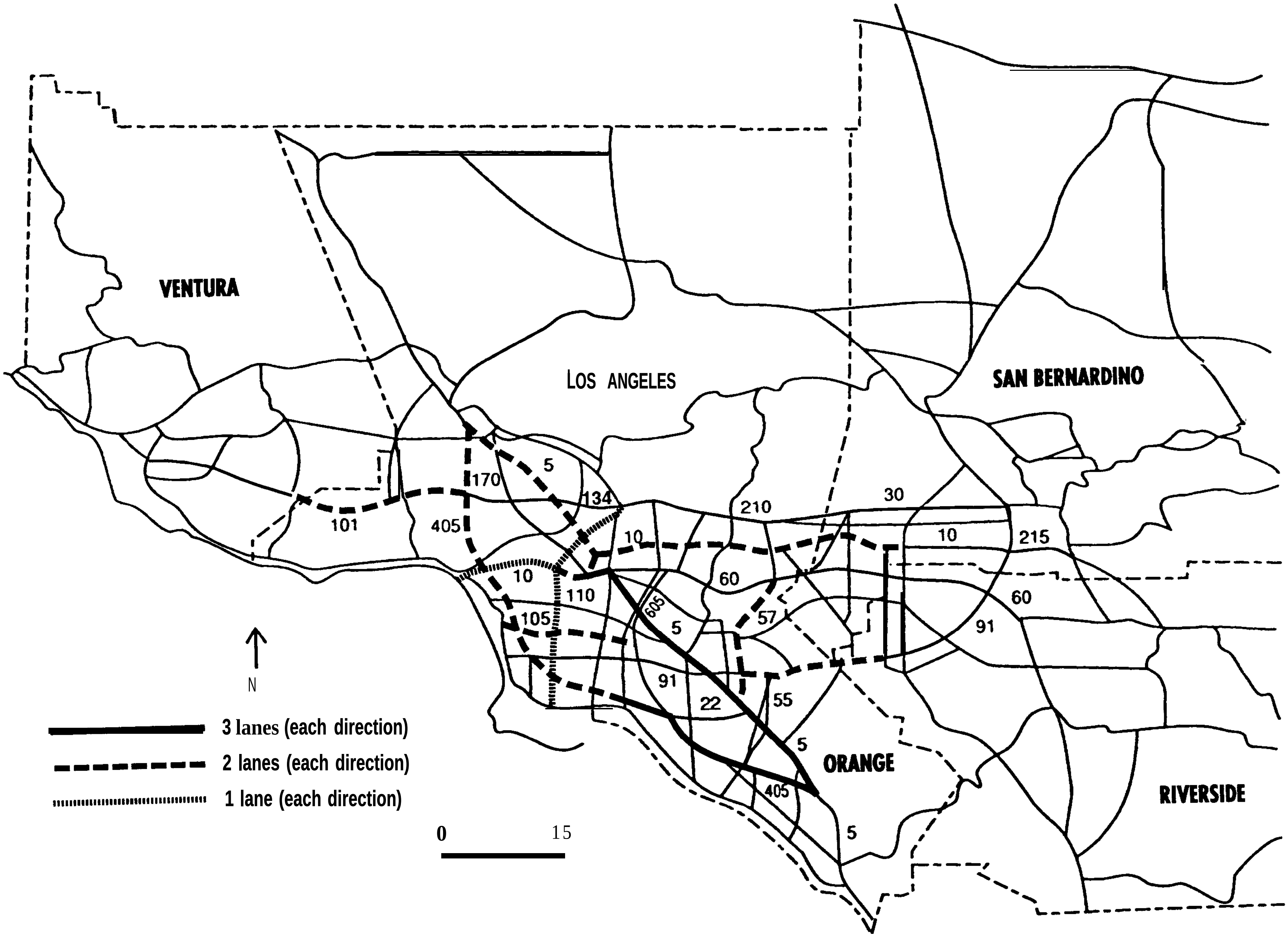

Figure 10
RPEV Scenario
2025 Regional Highway Network

The additions of the I-10, US-91 and US-101 freeway sections to the original modest network produced modifications to the trip length distribution tables (Tables 4.2 and 4.3) given in section 4.1 of this report. The revised trip length distribution tables that reflect the final RPEV network configuration are Tables 5.2 and 5.3. Given the new trip length distribution information the following calculations replace those found on pages 4-18, 4-19 and 4-23 of this report and were utilized in all subsequent modeling analyses. Please refer to tables 5.2 to review the information referred to as Sections 1 - 3 and Table 5.3 for the data utilized in Categories 1 - 6.

For the final RPEV network, the amount of VMT to be allocated to the roadway-powered system, given a desired 15% VMT market penetration objective, was computed as follows:

(1) Total System VMT	=	53,908,000	
(2) Total VMT with off-network trip length at least 40 miles	=	9,692,000	(Section 3)
(3) Total market potential VMT	=	(1) - (2)	
	=	44,216,000	(Sections 1 and 2)
(4) Total VMT to be allocated	=	15% of (3)	
	=	6,632,400	

For the 15% market penetration case on the final RPEV network, total VMT, the allocation percentages, and the allocated VMT for each of the six categories described on pages 4-18 and 4-19 of this report are detailed as follows:

Category	Total VMT	Allocation Percentage	Allocated VMT
1	17,868,000	0.0	0
2	4,458,000	0.0	0
3	6,822,000	7.1	482,700
4	6,222,000	10.0	622,200
5	4,049,000	30.0	1,214,700
6	4,792,000	90.0	4,312,800
Total	44,216,000		6,632,400

Following the procedure given in Section 4.1, the number of trips to be allocated to the final RPEV network for each of the six categories given above was calculated as follows:

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Table 5.2
2025 AM-PEAK VMT (IN 1000S) BY ON- AND OFF- RPEV NETWORK LENGTHS

TRIP LENGTH On-network/Off-network ↓ →		0-2	2-4	4-6	6-8	8-10	10-15	15-20	20-25	25-30	30-35	35-40
0	(Category 1)	685	2.661	2,770	2,225	1,779	2,776	1,735	1,307	875	586	469
0-2		75	249	271	272	244	502	351	221	140	104	99
2-4		229	520	445	395	305	596	426	315	213	158	107
4-6	(Category 2)	226	468	347	248	181	424	312	227	174	127	132
6-8		192	364	335	257	218	509	274	187	131	109	93
8-10		161	294	263	204	158	353	242	157	129	95	72
10-15	Section 1	377	518	497	381	286	608	401	320	210	137	113
15-20	(Category 3)	204	301	334	277	212	476	359	300	235	189	144
20-25		83	137	196	185	156	311	280	223	198	200	169
25-30	(Category 4)	29	56	100	111	106	203	146	119	98	121	90
30-35		8	21	44	61	71	153	112	93	96	110	88
35-40	(Category 5)	2	7	20	34	53	108	80	91	84	79	72
40-45		0	2	7	16	2s	71	55	56	41	51	52
45-50		0	1	3	7	12	37	35	32	29	26	26
50-55		0	0	1	3	4	17	18	15	16	11	11
55-60	Section 2	0	0	0	1	1	5	5	6	8	6	6
60-65	(Category 6)	0	0	0	1	1	2	1	2	2	1	3
65-70		0	0	0	0	0	1	0	0	1	1	1
70-75		0	0	0	0	0	3	2		1	1	1
75-80		0	0	0	0	0	0	1	1	2	2	4
		2,272	5,600	5,634	4.679	3.813	7.154	4,836	3.673	2.688	2.117	1.752

TRIP LENGTH On-network/Off-network ↓ →		40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80+	TOTAL
0		370	269	258	208	179	158	111	105	394	19.922
0-2		72	62	58	54	46	44	35	27	94	3,022
2-4		87	80	74	83	64	65	62	49	222	4.497
4-6		105	112	110	114	108	116	93	85	138	3.846
6-8		57	63	78	69	61	51	50	44	79	3.219
8-10		60	55	59	68	55	44	37	32	74	2,610
10-15		90	64	67	55	38	39	36	24	103	4.364
15-20		116	110	102	93	86	71	50	44	179	3.881
20-25		138	116	107	91	76	60	34	35	218	3.014
25-30		n	79	65	59	55	46	33	22	63	1.685
30-35	Section 3	81	61	62	48	52	41	29	22	78	1.333
35-40		65	42	46	40	32	24	26	24	92	1,021
40-45		52	29	36	26	27	19	12	10	37	631
45-50		25	23	23	22	18	13	12	12	70	427
50-55		10	9	10	10	7	4	3	3	4	154
55-60		6	6	4	6	7	7	6	7	42	129
60-65		2	3	3	6	7	8	8	6	38	93
65-70		1	1	1	0	2	0	0	0	0	9
70-75		1	2	0	1	2	0	0	0	0	16
75-80		4	6	3	3	4	2	1	1	0	35
		1,420	1.191	1.168	1,057	926	812	636	551	1,931	53.908

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Table 5.3
2825 AM-PEAK VEHICLE TRIPS BY ON- AND OFF- *RPEV* NETWORK TRIP LENGTHS

TRIP LENGTH On-network/Off-network →		0-2	2-4	4-6	u	8-10	10-15	15-U	20-25	25-30	30-35	35-40
0	(Category 1)	1,325,484	890,746	562,563	320,163	197,889	228,524	100,508	58.242	32,056	18,111	12,497
o-2		26.446	57.682	44,131	33.416	24,161	37,751	19,075	9,560	4,990	3.139	2,580
2-4		53,627	87,654	567,085	39,731	25,559	39.241	21,003	12,486	7.016	4,488	2,654
4-6	(Category 2)	36,360	58,078	34,814	20,752	12,947	24,459	14,011	8,310	5,344	3,393	3,114
U		23,582	36,247	28,017	18,365	13,627	26,057	11,222	6,367	3,802	2,781	2,126
8-10		16,085	24,477	18,709	12,697	8,735	16,433	9,161	4,984	3,514	2,300	1,552
10-15	Section 1	29,011	33,746	28,539	19,615	13,260	24,541	13,403	9,115	5,237	3,038	2,261
15-20	(Category 3)	11,498	14,844	14,919	11,380	8,018	15,911	10,283	7,508	5,197	3.114	2,601
20-25		3,687	5,425	7,176	6,295	4,984	8,932	7,001	4,947	3.951	3,619	2,794
25-30	(Category 4)	1,045	1,856	3,102	3,224	2,902	5,097	3,290	2,387	1.794	2,025	1,393
30-35		264	589	1,185	1,539	1,721	3,414	2,255	1,693	1,595	1,697	1,264
35-40	(Category 5)	49	172	468	770	1.146	2.167	1.445	1,504	1,286	1.120	962
40-45		5	52	149	326	494	1,292	913	-862	676	686	648
45-50		0	14	65	136	219	625	533	463	392	323	307
50-55		0	2	13	55	65	254	264	201	199	127	118
55-60	Section 2	0	0	5	13	21	65	61	76	96	64	64
u-65	(Category 6)	0	0	2	9	7	29	16	20	19	13	26
65-70		0	0	0	0	2	14	4	1	8	9	6
n75		0	0	0	0	1	31	25	14	12	14	8
75-80		0	0	0	0	0	2	10	14	15	19	32
		1,527,143	1,211,584	799,942	488,486	315,758	454.839	214,463	128,754	77,199	50.740	37,007

TRIP LENGTH On-network/Off-network →		40-45	45-50	50-55	55-60	60-65	65-70	70-75	75-80	80+	TOTAL
0		8,756	5,660	4.934	3,629	2,868	2.345	1535	1.351	4.150	3,782,011
0-2		1.675	1,283	1,084	916	734	644	477	344	-935	271,023
2-4		1.910	1,586	1,340	1379	984	926	822	614	2,232	361,337
4-6		2,213	2,129	1.913	1,825	1,602	1592	1.197	1,026	1,415	236.494
6-8		1.150	1.154	1.319	1,073	881	683	631	518	784	180.386
8-10		1,177	975	951	1,015	767	581	450	364	720	125.647
10-15		1,624	1,069	1,022	789	509	480	417	265	893	188,834
15-20		1,925	1,687	1,448	1,244	1,081	834	5 5 2	460	1,565	116,129
20-25		2,112	1,637	1,421	1.130	892	664	360	349	1,752	69,128
25-30		1.107	1.063	821	694	607	488	326	210	558	33,989
30-35	Section 3	1,078	758	728	535	547	407	279	202	622	22,372
35-40		820	497	506	419	313	225	234	211	687	15,001
40-45		616	320	380	256	258	i n	103	85	273	8,571
45-50		278	237	232	206	167	114	98	97	469	4.975
se-55		101	93	96	a	57	35	21	24	31	1.843
55-60		60	56	39	54	55	55	48	51	m	1,160
60-65		22	26	24	50	52	59	61	46	242	723
65-70		5	10	9	3	14	2	0	0	0	87
70-75		12	16	1	7	16	1	0	0	0	158
75-80		37	u	26	25	31	14	6	4	2	281
		26.678	20.300	18,294	15,336	12,435	10.326	7,617	6.221	17,607	5,420,749

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(5) Total Trips	=	5,420,749
(6) Total number of trips with off-network trip length at least 40 miles	=	134,814 (Section 3)
(7) Total trips in market potential region	=	(5) - (6)
	=	5,285,935 (Sections 1 and 2)

(7a) Category 1 total (allocated) trips =	3,746,783	(0)
(7b) Category 2 total (allocated) trips =	628,099	(0)
(7c) Category 3 total (allocated) trips =	452,877	(32,154)
(7d) Category 4 total (allocated) trips =	253,447	(25,345)
(7e) Category 5 total (allocated) trips =	113,908	(34,172)
(7f) Category 6 total (allocated) trips =	90,821	(81,739)
Total	5,285,935	(173,410)

The total number of trips to be allocated to the RPEV facility is 173,410 representing 3.28% of the total trips in the market potential region and accounting for 15% of the associated VMT. The allocation of these trips to the final RPEV network described in Table 5.1 and depicted in Figure 10 was performed in the manner described on page 4-23.

A review of the RPEV trip assignment by project staff led to a few adjustments in the number of lanes chosen on some freeway segments. The primary reason for these RPEV facility adjustments was the noticeable traffic changes that occurred on certain long freeway sections, i.e a noticeable tapering of traffic volume at the southern end of the 405, or the eastern section of the 10 (E). Secondly, the RPEV technology does not require that the V/C ratio on a given freeway segment must be less than or equal to one. Since the distributional method's lane recommendations had been utilized for scenario design purposes and, as stated previously, tends to round up the number of recommended lanes to the next highest integer number of lanes, crosschecks of the lane recommendations with model output from the trip assignment were further scrutinized. Of particular concern to the project team was overbuilding the number of RPEV lanes given the high infrastructure cost associated with the RPEV technology. The specific adjustments to Figure 10 (and all corresponding RPEV network descriptions) will appear in the HE&A Project's Phase III Report.

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5.2 HIGHWAY AUTOMATION

Capital and Operating Costs

At this time cost data is under review for this technology. The Phase III report will present review of the available cost information assumed for the regional and individual economic impacts analysis of full system automation.

Technological Availability

The automated highway system technology utilized in this scenario includes both lateral guidance and longitudinal control features. Lateral guidance, or automatic steering, allows vehicles to maintain their position relative to the center of the lane. It could, for example, consist of magnetic lane markers and on-board vehicle sensing systems to enable the vehicles to maintain their position relative to lane center. Longitudinal control features are assumed to include: obstacle detection, automatic braking, headway keeping, and communication devices among vehicles and between the vehicles and a highway network control facility. This latter feature assumes vehicles traveling in a group or "platoon" of about 15 vehicles.

Automated highway system technology has been under development since the late 1950s by various public institutions and private parties, both in the US and overseas. A good comprehensive synopsis of technology developments is contained in the "Advanced Vehicle Control Systems Section" of IEEE Transactions on Vehicular Technology (1991). Articles by Fenton, Bender, and Shladover et al, detail the general availability of automated highway systems (AHS) technology which form the basis of this analysis. Further discussions on the availability of the technology are contained in the Mobility 2000 "Advanced Vehicle Control Systems Final Working Group Report" (1990). This report presents a comprehensive strategy for development and deployment of the various lateral and longitudinal control technologies assumed to be available by 2025. Development would continue through the 1990s and into the 2000s. Deployment would begin in the early 2000s, with all components considered in this study fully deployed by 2025.

Automatic lateral and longitudinal control, according to the Mobility 2000 study, would undergo further research and development about 2000 and operational testing through 2005, with deployment continuing thereafter.

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An experiment with longitudinal control is underway by PATH in the San Diego area on the I-15 reversible lanes (when these lanes are not being used by the public). This study will test the concept of "platooning" in a realistic laboratory environment.

Fundability

Funding for AHS technology applications, as with RPEV, must involve both public and private sector cooperation. Mobility 2000 has estimated a cost of about $2.5 billion nationwide to fund research, development and operational test programs that will ensure development of AHS technology by 2010. Efforts are underway to include funding for continuing AHS studies as part of Intelligent Vehicle Highway System (IVHS) language in currently developing federal transportation legislation. Federal support for AHS technology development and implementation is critical. Continuing private sector efforts by the automobile, communications and related industries are needed in support of public efforts, including those by educational and research institutions. Work is underway by the recently formed Intelligent Vehicle Highway Society of America to coordinate funding of research, development and testing of AHS systems.

Funding for the AHS scenario would require a significant commitment of federal, state and local government transportation funds, for construction and operation of the system. Once the automation technology have become proven, funding for deployment in the Los Angeles area could proceed through established highway funding channels.

(Detailed discussion of the fundability of the AHS scenario must flow from the quantification of capital and operating costs which will be pursued in the Phase III report).

Organizational Feasibility

Organizational feasibility of the AHS scenario needs to address the same basic questions of construction, ownership, liability, operation and effectiveness as the RPEV scenario.

Caltrans is the logical candidate to construct and operate the AHS infrastructure as it is the owner of the highway network detailed in the AHS scenario. They would be responsible for design, installation and operation of the infrastructure components of the AHS technology. Due to the strong communications interface, a major role could be played by a local or national telecommunications provider, like GTE, Pac Bell or a similar vendor. This role could range from installation of a system owned and operated by Caltrans, to a contractual or franchise arrangement between Caltrans and the telecommunications

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provider, whereby the provider would own, install and operate the infrastructure system in a manner similar to a local cable TV system. It should be noted that much of any "system" is on the vehicles, and only part is on the ground.

Another approach for construction and operation of the AHS scenario would involve the formation of a regional authority, similar to those being formed to build and operate toll roads in Southern California. The approach being utilized along the Rt. 91 corridor provides a possible model for application of AHS technology on an existing state highway facility.

Operation of the AHS would need to address the issue of quantifying and paying for ongoing costs. One scenario would have these costs viewed as "public benefit costs", and thus be borne by Caltrans, and funded as part of the annual state highway operations and maintenance program. An alternative would be to have them borne by the direct users of the automated roadways, through user charges recovered by the telecommunication supplier, using recording devices in or outside the vehicles (somewhat similar to the method used to recover mobile cellular phone system costs). Another approach could involve electronic toll collection via automated vehicle identification (AVI) technology. The local authority approach, to funding and operation, would have the highway user bearing the costs (this would likely require the designation of separated automation only lanes with toll collection facilities which are necessary for safety purposes).

Ease of Implementation

The AHS scenario may be easier to implement than the RPEV scenario, because minimal disruption of the roadway would be required. Construction of the AHS scenario would involve installation of magnetic markers or some other technology for lateral guidance within the roadway and along the right-of-way or in the median (or possibly lane) dividers. Installation of these communications devices would involve significantly less disruption than the RPEV infrastructure. Roadway magnetic marker installation may involve minimal construction effort, depending on design and vehicle interface. Physical barriers may be necessary to segregate automated from non-automated lanes, and possibly separate ramps as well which would greatly increase both the cost and disruption during construction.

The exact nature of separation of automated lanes from mixed flow lanes is only now being researched. To ease the impact of congestion shifts from the freeway to the off-ramps and adjacent arterials extra construction (restriping of lanes at best) of added lanes may be necessary which could add to disruption.

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Construction Phasing

Since mixed flow traffic is excluded from automated lanes, an immediate and permanent takeaway problem exists. If relatively few vehicles are equipped withg the automation hardware, as will surely be true during initial operation of the facility, congestion will be worse not better.

As noted previously, minimal construction would be required within the pavement surface. The telecommunication construction activity along the right-of-way or median should have only a minimal disruptive effect, in the same manner that other activities within this area (like installation of the roadway emergency call box system). Phasing the installation of AHS would need to occur in a manner so that significant segments of the system would be operational and functional in a coordinated manner, to minimize user confusion.

Operations Issues

Three major operations issues have been identified to date in the research on AHS technology: "platoon" functioning and systems integration; legal/institutional barriers to AHS deployment: and, functioning of an operations cost recovery mechanism.

The platooning aspects of highway automation have been investigated by Mobility 2000 (1990) and various U.C. Berkeley researchers, most recently Varaiya and Shladover (1991). Research to date suggests that lane-changing maneuvers by platoons not be permitted in an AHS environment. Rather, platoons would operate in a dedicated automated lane. Continuing research needs to address the following questions related to platooning: (1) Can a car-to-car headway spacing control system be developed and tested that will allow the platooning concept to function effectively? (2) Can vehicle speed control and platoon entrance diagnostics be developed and tested as well? (3) Can a wide diversity of drivers function comfortably in a controlled platoon environment? (4) Will flyovers or other special merging lanes be required? (5) How will drivers function in the event of vehicle failure or unusual occurrences? (6) How will drivers give up and regain manual control of their vehicles when they enter and leave the automated operating mode? and (7) How will use of automated lanes effect the functional capacity on other links of the system?

Perhaps the biggest obstacle to deployment of AHS technology may be the institutional barriers inherent in our legal system. The current climate of automobile damage litigation poses both an opportunity to see significant benefits accrue from automation due to reduced accident frequency, and the inevitability of accidents due to equipment malfunctions, system design deficiencies and human factor design deficiencies. Studies by the National Safety Council indicate that almost 90 percent of all automobile accidents are caused by driver

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error. Platooning may result in fewer accidents: (a) a decrease in the frequency of accidents, (b) a decrease in the average number of casualities per accident, (c) a decrease in the average severity of an accident if a casualty occurs, and (d) a possible increase in the number of casualties per accident.

On the other hand, the challenges of a new technology will present a different series of problems or challenges to address legal/institutional concerns. New approaches will be needed to limit liability to the automated system developers and suppliers, public transportation system operators, and the driving public. This is particularly significant if the platoon concept proves operational, as system failure could affect a number of closely spaced vehicles. The following study approaches have been suggested by Mobility 2000 to help overcome potential legal/institutional barriers: (1) federally or state subsidized liability insurance, (2) narrower definitions of negligence, (3) limitations on compensatory and punitive damage awards, (4) limitations on what constitutes joint liability, and; (5) improved training within the legal system for the challenges faced by new automation technologies.

The efficient functioning of the AHS cost recovery system has been dealt with previously in the "Fundability" section. Depending on the approach taken to recover operations costs, the integration of a cost recovery mechanism is a matter requiring further study.

Social Acceptance

An important, perhaps the most important, aspect of the automated highway will be its level of acceptance by the driving public. If the human side of AHS technology and operations is not clearly understood and considered by all elements of the public, it will not receive the social acceptance needed to make it a viable option to today's driver operated and controlled vehicle. Clearly the automated vehicle will change the way that drivers perceive their environment and make operations decisions, especially when functioning in a platoon with other closely spaced vehicles. The following acceptance factors will need to be addressed in the development of AHS education and training programs: (1) perceived levels of driver convenience, (2) change in felt level of enjoyment in driving, versus a sense of riding in an automated vehicle, (3) ability of the driver to understand and use the automated vehicle control systems (extent to which vehicle is user friendly), (4) sense of loss of personal freedom to "do your own thing", and (5) operators perceived risk of platoon driving. Some of these factors may be positive rather than negative.

The ability to process information in complex driving systems, varies from driver to driver. The degree to which AHS technology helps the vehicle/driver interface is critical to its acceptance. Design and operational testing of the AHS will need to focus on the

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perception/response characteristics of various drivers and their interrelationships.

Further research is needed to address the potential problems and solutions of different sub-groups of the driving public in an AHS environment. The following sub-groups will require special consideration: elderly drivers, physically impaired or handicapped, alcohol or drug users, illiterate or mentally incompetent, and high accident risk groups, like young males.

As with the RPEV, AHS users will need to accept the added initial vehicle costs and any direct or indirect assessment of ongoing operations costs. Social acceptance is integrally tied to acceptance of the costs associated with owning and operating an automated vehicle.

Political Acceptance

Political acceptance of the automation scenario may be a more complex challenge than the RPEV scenario. It may require a higher level of public acceptance because it involves a higher level of driver adaptation, which further complicates the process of political acceptance. Political acceptance will ultimately hinge on public acceptance.

Once the automation concepts have been more fully developed and tested in the laboratory/university, development of a demonstration project(s) in the Los Angeles area or at Caltrans' proposed new test facility is/are essential. Convincing local transportation and air quality planning bodies of the viability of automation technology must precede any consideration of a specific automation network.

Inter-jurisdictional coordination required to implement the automation scenario will likely be more difficult than the RPEV scenario because of a larger network configuration and the higher level of technical complexity of the system. The regional and county transportation planning agencies and Caltrans will need to work closely with local cities and counties to 'explain and seek public support for the automation program because of its potential to significantly increase freeway capacity which could have a strong influence on traffic on local streets.

Monitoring

The monitoring program necessary to make the automation scenario a success would need to be similar in many ways to that for the RPEV scenario. It would need to have a more fully developed social acceptance component.

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Close monitoring of demonstration programs and communicating results to local officials and the general public would be crucial for integration of the technology into the regional transportation system. This monitoring effort, in addition to concentrating on evaluating system reliability, should also focus on public acceptance.

Highway Automation Scenario

After review of the information presented above, reviewer comments, and sensitivity analysis statistics, the automation scenario was chosen to be of ambitious size (see Figure 7) assuming a 45% market penetration. The larger network size was configured to be of sufficient size to capture a healthy application of this technology. Vehicle costs of automation were asserted to compose a larger proportion of total system automation costs than for other technologies such as RPEV, given the limitation of the preliminary cost figures.

The automated system is depicted in Figure 11 and further detailed in Appendix J. Based on reviewer comments it was assumed in the revised analysis that short freeway trips, i.e. trips with an on-network trip length of less than or equal to 4.0 miles would not utilize the automated facility. This assumption alters the previous statistical analysis of the trip length distribution tables for the automated network found in Section 4.3 (Tables 4.9 and 4.10). The revised analysis is as follows based on the divisions of the trip length distribution tables for the automated network given as Tables 5.4 and 5.5.

The amount of VMT to be allocated to the automated system was calculated for the AM-peak period, from Table 5.5 as:

Total System VMT	=	53,930,000
Total VMT for non-network trips (Rows 0, O-2, 2-4)	=	- 17,230,000
Total VMT for on-network trips	=	36,700,000

If a 45% market penetration out of total VMT is selected, then

53,930,000
X .45
24,268,500 is the amount of VMT that must be allocated to the automated system. That is, 66.1% of the VMT in each row entry in the trip distribution table (excluding Rows 0, O-2, and 2-4), will be selected to travel on the automated facility, since 24,268,500/36,700,000 = 66.1%. For a 45% market penetration of system VMT during the AM-peak period for the automation network, 1,047,699 trips were assumed to utilize the automated facility to complete their journeys.

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Table 5.4
2.25 AM-PEAK VEHICLE TRIPS BY ON- AND OFF- AMBITIOUS NETWORK TRIP LENGTHS

TRIP LENGTH On-network/Off-network ↓ →	0-2	2-4	4-6	6-8	8-10	10-15	15-20	20-25	25-30	30-35	35-40
0	1323.620	848,862	472,129	234,209	121.920	113,644	43.498	27,641	12.534	7,155	3.818
0-2	50,148	76.926	46,778	24,370	14.429	17,003	7216	4,112	1,228	800	819
2-4	101,727	120,125	63.363	30,25 I	14,131	18,989	7,901	4.653	2,191	1,538	1,280
4-6	86,401	100,775	46,596	23,228	II,192	13,308	3,376	3,873	I,616	1,152	832
6-8	64,098	72,367	38,901	17,832	9,883	11,217	6,161	3,899	2,174	2,617	1,330
8-10	53,144	53,997	29,880	15.903	8,632	Ii.559	6.616	2,832	2,079	1.982	911
10-15	84,729	83,567	52,967	28.804	16,175	19.304	9.062	5,513	2,679	I.614	1,311
I C Y	44.981	44,996	32.252	19,171	11.135	13.893	6.165	3,840	2,363	1.387	I,072
20-25	23,430	23,180	18,803	12,519	1,998	II.268	5375	2,860	1,803	I.212	940
25-30	11,040	11,795	11,137	9,250	6,895	IO.364	3,833	2,599	2,207	I.397	1.072
30-35	5,981	5,908	5,679	5.746	6,293	8,044	4,011	1,824	I.374	1,021	869
35-40	2,628	3291	3.570	3.852	4.217	6.4%	3,491	3.243	1,507	1,029	1.195
40-45	1,020	1,470	1.891	2.420	2,632	5,086	2,921	2,539	1,359	752	967
45-50	397	930	1,293	I.730	1,830	4,044	2,383	2.115	1,309	687	817
50-55	203	461	809	1.070	1,228	3.391	1,900	1,515	I.057	568	572
55-60	106	232	426	783	946	2.480	1.825	1,449	1.092	512	628
60-65	73	161	244	373	477	I.445	1,015	737	591	361	307
65-70	u	60	124	209	273	864	789	485	449	304	255
70-75	9	27	64	85	13	410	434	332	194	273	1%
75-80	4	12	21	19	17	109	139	178	290	230	138
80+	1	4	10	12		87	2.2-l	275		403	334
	1,853,786	1,449,146	826.937	431,836	240.3%	273.005	120338	76,514	40.424	26,994	19.623

TRIP LENGTH On-network/Off-network ↓ →	40-45	48-5-w	50-55	55-60	60-65	65-70	70-75	75-80	80+	TOTAL
0	2.359	I.819	I.591	I.016	837	705	457	421	1,256	3,219,491
0-2	405	518	312	266	138	192	140	97	174	246,071
2-4	714	576	602	436	418	363	276	175	457	370.166
4-6	601	549	574	480	318	347	301	193	197	297.909
6-8	660	680	730	541	606	604	517	360	352	235,529
8-10	676	460	512	371	401	351	288	240	865	191.699
10-15	1,032	909	715	611	717	621	731	475	182	312.318
15-20	780	618	555	482	519	362	293	191	373	185,428
m-25	697	384	288	273	249	236	116	105	229	111,965
28-M	744	414	463	378	329	215	172	126	274	74.104
30-35	513	297	263	211	224	188	147	9-l	448	49.140
35-40	657	360	406	378	200	140	103	85	236	37.084
40-45	532	243	293	309	180	105	66	55	247	25,087
45-50	483	201	201	218	153	120	54	13	61	19,039
50-55	331	150	139	115	97	114	64	5	20	13,809
55-60	374	299	148	125	112	238	172	36	14	11,997
be-65	211	132	96	93	121	180	101	14	20	6.752
65-70	228	209	88	63	64	132	96	9	II	4,753
70-75	199	153	124	116	120	107	64	45	92	3,218
75-80	104	69	67	59	33	4	12	20	15	I,440
80+	262	276	225	251	154	IO	57	66	129	3,150
	12.562	9.316	8,392	6.792	5,990	5,394	4224	2.828	6,252	5,420,749

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Table 5.5
2625 AM-PMK VMT (IN 1000s) ON ON- AND OFF-AMBITIOUS NETWORK TRIP LENGTHS

On-network/Off-network →	0-2	2-4	4-6	6-8	8-10	10-15	15-20	20-25	25-30	30-35	35-40
0	682	2,524	2312	1,620	1.095	1371	752	625	342	231	143
0-2	144	335	288	201	147	227	134	95	35	27	32
2-4	439	711	504	303	169	290	161	118	66	54	52
4-6	537	807	464	277	157	229	120	105	53	43	35
6-8	518	723	466	249	158	215	149	114	75	103	59
8-10	524	646	418	255	1%	247	174	89	76	82	43
10-15	1,102	1.281	919	559	349	472	268	193	107	73	65
15-20	800	915	720	468	295	413	214	153	106	69	59
20-25	529	588	516	369	252	393	212	128	90	67	56
25-30	304	360	361	320	251	412	173	130	122	84	70
30-35	195	210	213	228	261	360	199	100	82	67	61
35-40	98	133	152	171	1%	324	193	195	98	72	90
40-45	44	67	90	120	136	279	175	165	94	57	n
45-50	19	47	68	94	103	243	154	147	98	55	69
50-55	11	26	47	64	76	220	133	114	84	48	52
55-60	6	14	27	51	63	173	136	116	93	46	60
60-65	5	11	17	26	34	108	81	63	53	34	31
65-70	3	4	9	16	21	69	67	44	43	30	27
70-75	0	1	5	7	I	35	13	18	33	25	17
75-80	0	0	21	21	2	109	24	31	2035	50	4416
80+											
	5,961	9,404	7,596	5,399	3.928	6.098	3.571	2.776	1,805	1.347	1,157

TRIP LENGTH

On-network/Off-network →	40-45	45-w	50-55	55-60	60-65	65-70	70-75	75-80	80+	TOTAL
0	100	87	83	58	52	48	33	33	124	12.316
0-2	18	26	17	16	9	13	10	8	16	1.7%
2-4	32	29	33	27	28	26	21	14	42	3.118
4-6	29	29	33	30	21	25	23	16	18	3,051
6-8	33	37	43	35	42	45	41	30	33	3,172
8-10	35	26	32	25	29	n	23	21	a9	3.016
10-15	56	54	39	43	54	49	62	43	79	5,875
15-20	47	40	22	36	42	31	26	18	40	4,531
										3,404
20-25	52	27	37	32	30	21	17	19	32	2,852
30-35	3.8	24	22	19	21	19	15	11	54	2,200
35-40	53	31	37	36	20	15	11	10	30	1,963
40-45	45	22	28	31	19	11	8	7	32	1,504
45-50	43	19	20	23	17	14	6	2	8	1,251
50-55	31	15	15	13	11	14	8	1	3	983
55-a	37	31	16	14	13	30	22	5	2	955
60-65	22	14	11	11	15	23	14	2	3	578
65-70	25	24	11	8	8	18	13	1	2	443
PO-75	23	18	16	15	16	15	9	7	15	339
75-80	13	9	9	8	6		2	3		159
80+	36	39	33	38	24	12	9	11	2:	423
	813	633	602	539	498	476	3%	265	675	53.930

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Table 5.6 below illustrates the lane recommendations formulated by the three lane determination approaches given in Section 4.3 for the ambitious network assuming a 45% market penetration. The total number of lane miles in the automation scenario network, summing both directions is 2,165.

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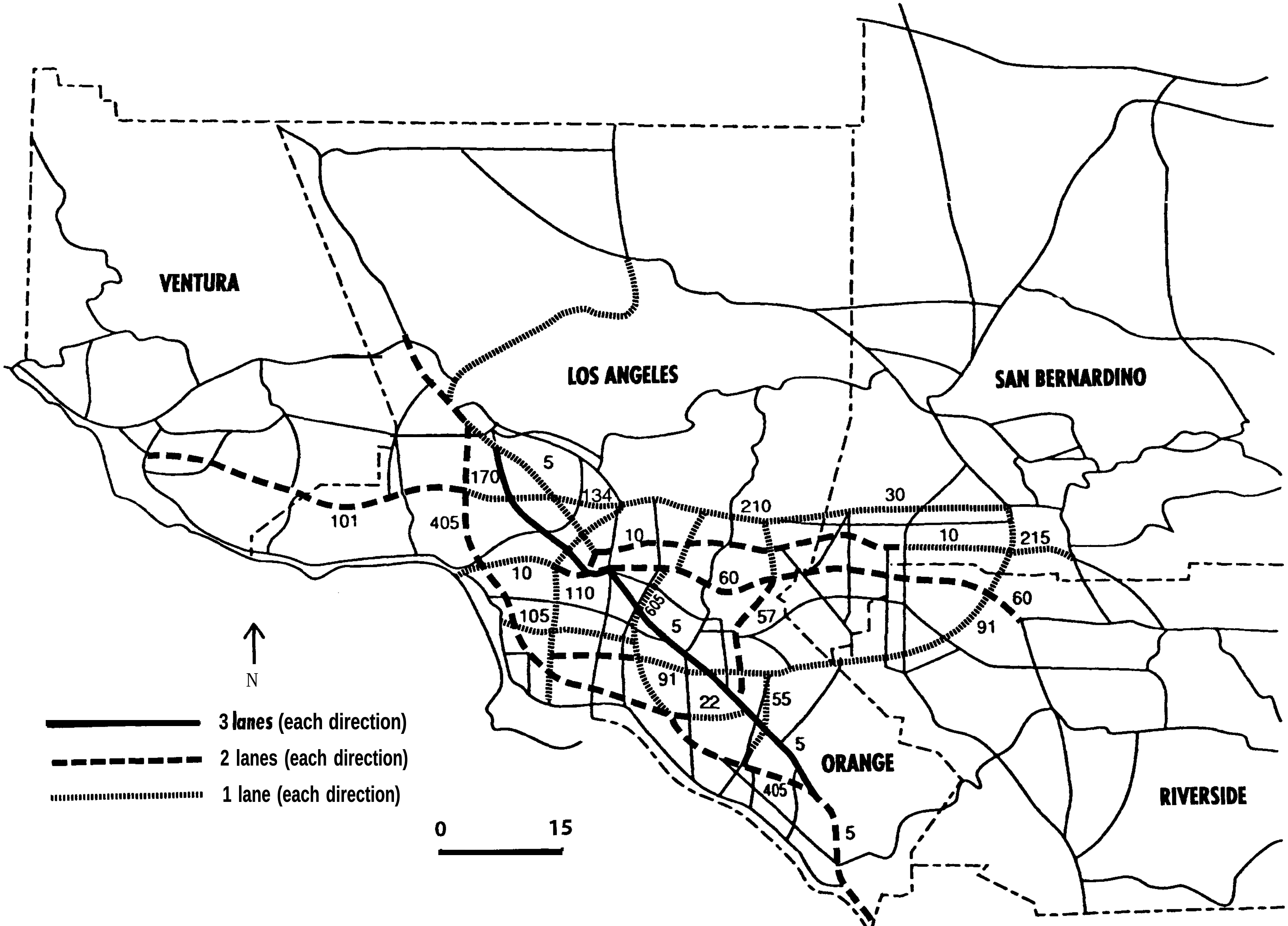

Figure 11
Automation Scenario
2025 Regional Highway Network

Table 5.6

AUTOMATION

Number of Lane Recommendations
(Ambitious Network with 45% Market Penetration)

Freeway Section	Recommended Number of Lanes by Volume Method: Maximum	Average	Distributional
Modest Sections			
405 (N)	3	2	2
405 (S)	3	1	2
5 (N)	3	1	1
5 (S)	4	2	3
110	1	1	1
10 (W)	2	1	1*
10 (E)	2	2	2
105	2	1	2
57	2	1	2
Intermediate Additions			
605	2	1	1
91	2	2	2
10	2	2	2
57	1	1	1
101/134	2	1	1
5 (N)	3	2	2*
5 (S)	2	1	2
60	2	1	2
Ambitious Additions			
10	1	1	1
91/215	1	1	1
101	3	2	2*
215	1	0	1
55	2	1	1*
210	1	1	1
91	1	1	2
14	3	2	2
101/170	3	2	2*
22	1	1	1

* = Indicates that the average volume method was used for the number of lanes recommendation.

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5.3 COMBINATION SYSTEM

Capital and Operating Costs

The combined system capital and operating costs will be formulated in the Phase III report.

Technological Availability

The combination network scenario includes both the RPEV and automation technologies. The scenario assumes one or two lanes in each direction of automation and RPEV treatment, dependent on demand considerations. It also assumes that for some segments one or two automation only lanes in each direction will be developed.

Technology availability for the combination scenario should parallel the respective discussions for RPEV and Automation. This would mean that they would be available for application by 2025.

An issue with regard to the combination scenario is that the magnetic markers (if this technology is utilized) would not be compatible with the use of the RPEV roadway inductor. A different approach to lateral stabilization would be needed for the lanes where both technologies are applied. The RPEV roadway inductor creates a distinctively shaped magnetic field which could be (and in fact already has been) used as a lateral position reference. In this case, a dual sensor would be used, one for use over electrified segments of roadway and the other over non-electrified links. A system would have to be developed to automatically switch between these two sensors.

The magnetic field created as a result of roadway electrification could serve as its own reference system (with sensors on-board the vehicle to help steering control). Further research and testing is necessary to determine if this is a practical approach.

Fundability

The discussion under the RPEV and automation scenarios applies equally to the combination scenario. The combination scenario is the most extensive of the three networks, with 2,218 lane miles; versus 2,165 lane miles for automation; and, 1,240 lane miles for RPEV.

Further discussion of the fundability of the combination scenario will be incorporated in the Phase III Report.

Organizational Feasibility

With the complexity of the combination scenario, it would be appropriate if construction and operation of the RPEV/automation and

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automation only lanes were the responsibility of the State Highway Agency (Caltrans). This will involve close cooperation with the electric utility, who would handle recovery of ongoing electric use charges. It would also require coordination with the telecommunications company that might be responsible for the automation system.

Ease of Implementation

The combination scenario would be the hardest to implement of the three scenarios, because of its extensive nature and complexity, but the benefits would be the greatest, to justify the implementation.

Construction Phasing

This scenario will require a high level of coordination in the phasing of construction. Construction of both automation only and RPEV/automation lanes on a given side of a freeway segment should not be done at the same time as such a procedure would maximize disruption by taking perhaps three of a four lane facility out of use at one time. Construction of the RPEV lane(s), with automation treatment may, if technically feasible, take place in the lanes(s) adjacent to the center median of the freeway. The automation only lanes(s) may be next to the RPEV/automation facility. These questions of lane location clearly require further study before answers are defined.

Construction of the combination scenario should be easier (fewer RPEV lane miles, but almost certainly more complexity) than the RPEV scenario and harder than the automation scenario. The combination scenario has 882 lane miles of RPEV treatment, whereas the RPEV scenario has 1,240 lane miles. Even with the automation improvements to the RPEV scenario, it will still not be as complex a construction endeavor as the complete RPEV scenario.

Operations Issues

Operations costs for this scenario are presented in the "Capital and Operating Costs" section. Cost related to operational issues have been addressed in the discussions of the other two scenarios. The mechanism for cost recovery would likely be a melding of the options discussed previously. With the merging of two technologies, the cost recovery method would therefore be more complex, but this shouldn't be terribly complicated.

Melding the RPEV and automation concepts in a given freeway segment presents a major operations challenge. Conceptually, the RPEV/automation lanes (closest to the center median) and the automation only lanes (adjacent to the RPEV/automation lanes) would be restricted

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to vehicles which could only use the automation technology. Present thinking is that automated lanes in general must be restricted to automated vehicles for safety reasons.

The platoon functioning and integration issues discussed under the automation scenario would need to be addressed, prior to embarking on a combination approach. Appropriate lane identification would also be necessary to avoid driver confusion, and to clearly distinguish which lane(s) could be used by the automated RPEVs and automation only vehicles, as opposed to those which were non-automated.
High occupancy vehicle (HOV) lanes are currently functioning or will be operational on many of the freeway segments by 2025. Decisions will need to be made on the relationship of these facilities to the RPEV and automation operations. In some instances it may be necessary to convert HOV lanes to either one or both of the technologies.

The legal/institutional issues, noted under the automation scenario, would apply equally to the combination scenario.

Social Acceptance

The public's acceptance of the combination scenario will need to address all the issues discussed under the RPEV and automation scenarios. As the scenario incorporates both automation only lanes and RPEV/automation lanes, getting the public to understand, distinguish between and use these facilities (this may not be a concern under full automation), will require a coordinated effort by all involved. This necessitates public involvement in the planning, construction and initial operations phases of project development. It will also require a clearly understandable education effort, including: appropriate signage; distinguishing lane markings; public radio and TV announcements; and, print media resources.

Of the three scenarios, the combination will present the biggest challenge to public acceptance. This results from its level of complexity in relation to the other scenarios. It does, however, present the most comprehensive solution to meeting the mobility and air quality challenges. Once the generic social acceptance issues facing the two technologies are dealt with, the combination scenario may be the most favored by the public. This would result from the scenario's ability to meet diverse needs of the greatest number of potential users.

Political Acceptance

Political acceptance of this scenario is hard to judge. On one hand, it incorporates the best technical features of both technologies and will probably be the most cost-effective of the three. On the other,

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it is the most complex scenario for the driving public to understand and use. Sorting out these questions will require a well coordinated effort by Caltrans, municipal and county government, various public/private organizations, and the general public.

Monitoring

The monitoring effort for this scenario, of necessity, would need to be more complex than the other two scenarios individually. It would need to incorporate the same basic elements as the RPEV and automation scenarios.

Traffic flow on the automation lanes and the RPEV/automation lanes needs to be closely monitored to assure that they are being used to the maximum, and to determine if changes are needed.

Combination System Scenario

The combination system scenario contains the two special facilities that were described in Section 4.4. After studying all of the relevant inputs to the scenario development process a revised intermediate network with: (a) a 15% of total VMT RPEV and automation assumption for facility type (a), and (b) a 30% of total VMT automation only assumption for facility type (b) were employed. The revised intermediate network is illustrated in Figure 12 and incorporated the addition of the 101 freeway from California Highway 23 to the I-405. A full description of the mileage contained in the combination system network is given in Appendix K. The total number of freeway lane miles contained in the combination scenario network is 2,218.28. Table 5.7 gives the alternative lane recommendations that were used to select the specific configuration for this network. The distributional lane determination method recommendations were followed as they were in the previous scenario developments.

The choice of network size and market penetrations for the combination are influenced by the decisions made in choosing the RPEV and automation scenario networks. The 15% market penetration imbedded in facility (a)'s lane determination rests on the assumption given in Section 5.1. A total of 45% of the vehicles will be equipped with automation technology -- the separate assumptions of 15% facility type (a) and 30% facility type (b) market penetrations -- in the combination scenario. Importantly, the assumed market penetrations were instrumental in designing the combination system. Alternative market penetrations, higher and lower than the designated percentages, may be utilized in the trip assignment phase of the modeling process to study the results that such changes will have on the impacts analysis.

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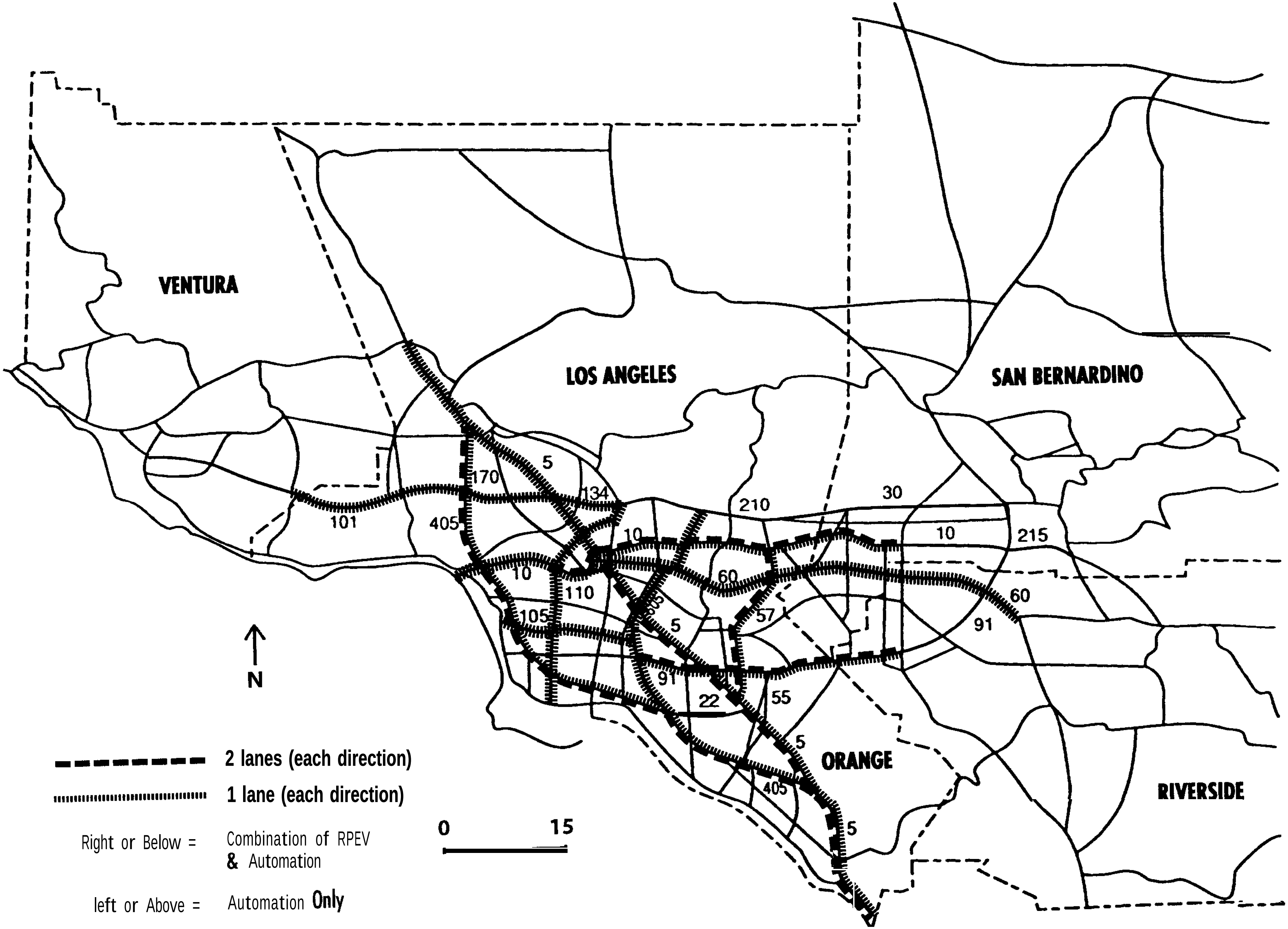

Figure 12
Combination Scenario
2025 Regional Highway Network

Table 5.7

COMBINATION

Type A Facility

Number of Lane Recommendations
(Revised Intermediate Network with 15% Market Penetration of RPEV and Automation Technologies)

Freeway Section	Recommended Number of Lanes by Volume Method Maximum	Average	Distributional
Modest Sections			
405 (N)	1	1	1
405 (S)	1	1	1
5 (N)	1	0	1
5 (S)	2	1	2
110	0	0	1
10 (W)	1	0	1
10 (E)	1	1	1
105	1	0	1
57	0	0	1
101	1	1	1
Intermediate Sections			
605	1	0	1
91	1	1	1
10	1	1	1
57	0	0	1
101/134	0	0	1
5 (N)	1	1	1
5 (S)	1	1	1
60	1	1	1

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Table 5.7 **(cont)**

COMBINATION

Type B Facility

Number of Lane **Recommendations**
(Revised Intermediate Network with 30% Automation Market Penetration)

Freeway Section	Recommended Number of Lanes by Volume Method: Maximum	Average	Distributional
Modest Sections			
405 (N)	2	1	2
405 (S)	2	1	1
5 (N)	2	1	1
5 (S)	2	2	2
110	1	1	1
10 (W)	1	1	1
10 (E)	1	1	2
105	1	1	1
57	1	1	1
101	1	1	1
Intermediate Sections			
605	1	1	1
91	2	1	2
10	2	1	2
57	0	0	1
101/134	1	1	1
5 (N)	2	1	1
5 (S)	1	1	1
60	1	1	1

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Appendix D

Description of Network Locations

Description of Network Locations

The three networks detailed below will be utilized for all three of the scenarios in the Highway Electrification and Automation project. The number of miles associated with each section is an approximation of the number of miles for one lane in one direction on that section. The 1988 Traffic Volumes on the California State Highway System (Sacramento: State of California, 1988) was utilized for determining the number of miles. This calculation is given for information purposes and should not be interpreted to suggest that our decision is to use only one lane in one direction on each section of the network. The number of lanes that will be utilized for the impact evaluation was determined through the sensitivity analysis.

Modest Network

The modest network appears as the green markings on the 2025 Regional Highway Network map that is attached.

Freeway Section	Description of Freeway Section	Number of Miles (One lane, One direction)
405	From 5N intersection in SF valley to 5S intersection below Irvine	72
5	From 405N intersection in SF valley to 405S intersection below Irvine	64
110	Between the 1 and the intersection of the 101/134/210	29
10	Between the 4th/5th St. Exit (in Santa Monica) and the 605	32
105	Between the 1 and the 605	18
57	Between the 5 and the 60	19
	Total	234

Description of Network Locations (cont.)

Intenediate Network

The intermediate network appears as the green and blue markings on the 2025 Regional Highway Network map that is attached. Therefore, the freeway sections detailed below are to be added to the modest network.

Freeway Section	Description of Freeway Section	Number of Miles (One lane, One direction)
605	Between the 405 and the 210	28
91	Between the 605 and the 15	31
10	Between the 605 and the 15	26
57	Between the 60 and the 10	3
101/134	Between the 405 and the intersection of the 210/110	19
5	Between 5/405N intersection and the 126	12
5	Between 5/405S intersection and San Clemente	18
60	Between 5 and the 215 intersection in Box Springs	60
	Subtotal	197 (Added)
	Plus Modest Network Miles	234
	Total	431

Description of Network Locations (cont.)

Ambitious Network

The ambitious network apprears as the green plus blue plus red markings on the 2025 Regional Highway Network map that is attached. Therefore, the freeway sections detailed below are to be added to the intermediate network.

Freeway Section	Description of Freeway Section	Number of Miles (One lane, One direction)
10	Between the 15 and Redlands	21
91/215	Between the 15 and the 10	20
101	Between the 118 and the 405	44
215	Between the 10 and the 30	4
55	Between the 405 and the 91	11
210	From the intersection of the 134/110 to the 10 and from 57 to 215	56
91	Between the 110 and the 605	10
14	From the 5 to Palmdale	30
101	From the 5 (downtown) to the intersection of the 5/170/101 in SF Valley	17
22	Between the 405 and the 5	13
	Subtotal	226 (Added)
	Plus Intermediate Network Miles	431
	Total	657

Appendix E

2025 Trip and VMT Market Potential (%)

Daily and AM Peak

2025 RPEV Market Potential

MODEST NETWORK

Derated Battery Range (miles)	Percentage of All Trips	Percentage of All Trips VMT
20	91.9	54.4
30	94.9	64.5
50	96.6	72.1
60	97.6 98.4	84.2 78.5

INTERMEDIATE NETWORK

Derated Battery Range (miles)	Percentage of All Trips	Percentage of All Trips VMT
20	93.9	62.9
30	96.2	71.9
40	97.5	78.5
50	98.3	83.7
60	99.0	88.5

AMBITIOUS NETWORK

Derated Battery Range (miles)	Percentage of All Trips	Percentage of All Trips VMT
20	96.0	72.8
30	97.7	81.3
40	98.6	87.3
50	99.1	91.2
60	99.4	94.2

COMPLETE NETWORK

Derated Battery Range (miles)	Percentage of All Trips	Percentage of All Trips VMT
20	94.9	70.9
30	97.6	81.9
40	98.8	89.4
50	99.4	94.0
60	99.7	96.9

Note: All percentages are based on daily trip length distribution tables derived from the SCAG Regional Transportation Model.

2025 RPEV Market Potential

MODEST NETWORK

Derated Battery Range (miles)	Percentage of AM Peak Trips	Percentage of AM Peak Trips VMT
20	91.0	59.5
30	95.1	71.3
40	96.9	78.6
50	98.0	84.1
60	98.7	88.8

INTERMEDIATE NETWORK

Derated Battery Range (miles)	Percentage of AM Peak Trips	Percentage of AM Peak Trips VMT
20	93.4	67.9
30	96.5	77.7
40	97.8	83.6
50	98.5	88.1
60	99.3	91.9

AMBITIOUS NETWORK

Derated Battery Range (miles)	Percentage of AM Peak Trips	Percentage of AM Peak Trips VMT
20	95.8	77.8
30	98.9	86.3
40	99.9	90.9
50	99.2	93.6
60	99.6	95.8

COMPLETE NETWORK

Derated Battery Range (miles)	Percentage of AM Peak Trips	Percentage of AM Peak Trips VMT
20	92.5	66.4
30	96.7	80.5
40	98.5	88.8
50	99.3	93.6
60	99.6	96.4

Note: All percentages are based on daily trip length distribution tables derived from the SCAG Regional Transportation Model.

2025 Regional Transportation Model

Market Potential
RPEV and BO Percentages of ALL TRIPS

RPEV

Battery Range	Network			
	Modest	Intermediate	Ambitious	Complete
20	2.9	5.1	7.2	6.0
30	1.6	2.9	4.4	4.2
40	1.1	2.0	3.1	3.3
50	0.9	1.5	2.3	2.6
60	0.7	1.3	1.7	2.0

BO

Battery Range	Network			
	Modest	Intermediate	Ambitious	Complete
20	89.0	88.8	88.8	80.9
30	93.3	93.3	93.3	93.4
40	95.5	95.5	95.5	95.5
50	96.7	96.8	96.8	96.8
60	97.7	97.7	97.7	97.7

Market Potential
RPEV and BO Percentages of PARTITIONED TRIPS

RPEV

Battery Range	Network			
	Modest	Intermediate	Ambitious	Complete
20	3.2	5.5	7.5	6.3
30	1.7	3.1	4.5	4.3
40	1.1	2.1	3.2	3.3
50	0.9	1.5	2.3	2.6
60	0.8	1.3	1.7	2.0

BO

Battery Range	Network			
	Modest	Intermediate	Ambitious	Complete
20	96.8	94.5	92.5	93.7
30	98.3	96.9	95.5	95.7
40	98.9	97.9	96.8	96.7
50	99.1	98.5	97.7	97.4
60	99.2	98.7	98.3	98.0

Note: All percentages are based on daily trip length distribution tables derived from the SCAG Regional Transportation Model.

2025 Regional Transportation Model

Market Potential
RPEV and BO Percentages of ALL TRIPS VMT

RPEV

Battery Range	Network Modest	Intermediate	Ambitious	Complete
20	9.1	17.9	27.9	25.8
30	7.1	14.5	24.0	24.4
40	6.3	12.6	21.4	23.4
50	6.2	11.2	18.6	21.4
60	6.0	10.0	15.6	18.3

BO

Battery Range	Network Modest	Intermediate	Ambitious	Complete
20	45.3	45.0	44.9	45.1
30	57.4	57.4	57.3	57.5
40	65.8	65.9	65.9	66.0
50	72.3	72.5	72.6	72.6
60	78.2	78.5	78.6	78.6

Market Potential
RPEV and BO Percentages of PARTITIONED TRIPS VMT

, RPEV

Battery Range	Network Modest	Intermediate	Ambitious	Complete
20	16.8	28.5	38.3	36.4
30	11.0	20.2	29.5	29.8
40	8.8	16.1	24.6	26.2
50	7.8	13.3	20.4	22.8
60	7.1	11.3	16.6	18.9

BO

Battery Range	Network Modest	Intermediate	Ambitious	Complete
20	83.2	71.5	61.7	63.6
30	89.0	79.8	70.5	70.2
40	91.2	83.9	75.4	73.8
50	92.2	86.7	79.6	77.2
60	92.9	88.7	83.4	81.1

Note: All percentages are based on daily trip length distribution tables derived from the SCAG Regional Transportation Model.

2025 Regional Transportation Model

Market Potential
RPEV and BO Percentages of AM PEAK TRIPS

RPEV

Battery Range	Network: Modest	Intermediate	Ambitious	Complete
20	4.1	6.7	9.2	6.0
30	2.0	3.4	5.8	3.6
40	1.1	2.0	3.1	2.6
50	0.8	1.3	2.0	2.0
60	0.6	1.2	1.4	1.4

BO

Battery Range	Network: Modest	Intermediate	Ambitious	Complete
20	86.9	86.7	86.6	86.5
30	93.1	93.1	93.1	93.1
40	95.8	95.8	95.8	95.9
50	97.2	97.2	97.2	97.3
60	98.1	98.1	98.2	98.2

Market Potential
RPEV and BO Percentages of PARTITIONED AM PEAK TRIPS

RPEV

Battery Range	Network: Modest	Intermediate	Ambitious	Complete
20	4.5	7.2	9.6	6.4
30	2.1	3.5	5.9	3.7
40	1.1	2.0	3.1	2.7
50	0.8	1.3	2.0	2.0
60	0.6	1.2	1.4	1.4

BO

Battery Range	Network: Modest	Intermediate	Ambitious	Complete
20	95.5	92.8	90.4	93.6
30	97.9	96.5	94.1	96.3
40	98.9	98.0	96.9	97.3
50	99.2	98.7	98.0	98.0
60	99.4	98.8	98.6	98.6

Note: All percentages are based on daily trip length distribution tables derived from the SCAG Regional Transportation Model.

2025 Regional Transportation Model

Market Potential
RPEV and BO Percentages of AM PEAK TRIPS VMT

RPEV

Battery Range	Network Modest	Intermediate	Ambitious	Complete
20	11.3	20.1	30.1	18.6
30	7.8	14.2	22.9	17.0
40	5.7	10.7	17.9	15.6
50	4.8	8.6	14.0	13.9
60	4.3	8.1	10.9	11.5

BO

Battery Range	Network Modest	Intermediate	Ambitious	Complete
20	48.2	47.8	47.7	47.8
30	63.5	63.5	63.4	63.5
40	72.9	72.9	73.0	73.2
50	79.3	79.5	79.6	79.7
60	84.5	83.8	84.9	84.9

Market Potential
RPEV and BO Percentages of PARTITIONED AM PEAK TRIPS VMT

RPEV

Battery Range	Network Modest	Intermediate	Ambitious	Complete
20	19.0	29.6	38.7	28.0
30	10.9	18.3	26.5	21.1
40	7.3	12.7	19.7	17.6
50	5.7	9.6	15.0	14.8
60	4.9	8.8	11.3	11.9

BO

Battery Range	Network Modest	Intermediate	Ambitious	Complete
20	81.0	70.4	61.3	72.0
30	89.1	81.7	73.5	78.9
40	92.7	87.3	80.3	82.4
50	94.3	90.4	85.0	85.2
60	95.1	91.2	88.7	88.1

Note: All percentages are based on daily trip length distribution tables derived from the SCAG Regional Transportation Model.

Appendix F

Maximum and Average Volume

Lane Recommendations

Appendix F
Maximum and Average Volume Lane Recommendations

The source given below was utilized for the maximum, average, and distributional lane determination methods. Notes 1 through 6 apply to the maximum, average, and distributional methods although the numerical superscripts were not repeated in Appendices G and H. The reader should note that superscripts 1 through 6 explain freeway section description qualifications that were employed throughout all three lane determination processes. Notes 7 through 10 apply to the tables in Appendix F exclusively.

Source: AM Peak, 2-Hour, 2025 Traffic Volume Plots, SCAG Regional Transportation Model, Modest Network with 5%, 15%, and 30% market penetrations, Intermediate Network with 5%, 15%, 30%, and 45% market penetrations, and Ambitious Network with 5%, 15%, 30%, 45%, and 60% market penetrations.

Notes:
1 = From 5N intersection in SF valley to 105.
2 = From 105 to the 5S intersection south of Irvine.
3 = From 405N intersection in SF valley to approximately halfway between 110 and 10.
4 = From approximately halfway between 110 and 10 to the 405S intersection south of of Irvine.
5 = From 1 to 110 intersection.
6 = From 110 intersection to 605.
7 = Based on two-hour capacity of 4,000 for RPEV technology and 12,000 for automation and combination technologies.
8 = based on lane recommendation table given in text.
9 = Minimum two-hour hour volumes appear below all maximum two-hour volumes.
10 = Standard deviation of two-hour volumes appear below all two-hour volumes.

Modest Network

Market Penetration = 5 %

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
405 (N)'	4,527 178 [9]	1.13	1	3,633 592 [10]	0.91	1
405 (S) [2]	5,674 66	1.42	1	3,280 1,128	0.82	1
5 (N) [3]	3,651 260	0.96	1	1,569 1,032	0.39	0
5 (S) [4]	11,141 1,204	2.79	3	8,795 1,860	2.20	1
110	646 24	0.16	0	286 182	0.07	0
10 (W) [5]	3,063 456	0.77	1	1,610 877	0.40	0
10. (E) [6]	2,035 450	0.51	1	1,943 52	0.49	0
105	1,905 64	0.48	0	1,225 411	0.31	0
57	1,808 729	0.45	0	1,534 230	0.38	0

Modest Network

Market Penetration = 15 %

Freeway Section	Maximum Volume (2Hr.)	#of Lanes Required [7]	#of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
405(N)'	13,501 696	3.38	3	9,622 2,328	2.41	2
405 (S) [2]	16,569 408	4.14	4	8,486 3,564	2.12	2
5 (N) [3]	12,886 851	3.22	3	5,456 3,735	1.36	1
5 (S) [4]	26,115 2,876	6.53	All	18,462 4,276	4.61	All
110	5,435 2,718	2.00	2	2,409 736	0.60	1
10 (W) [5]	8,521 1,367	2.31	2	4,611 2,426	1.15	1
10 (E) [6]	7,674 1,671	1.92	2	7,463 202	1.87	2
105	7,504 293	1.88	2	4,964 1,617	1.24	1
57	8,494 3,148	2.12	2	6,954 1,307	1.74	0

Modest Network

Market Penetration ≈30 %

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
405 (N)'	24,863 1,794	6.22	All	19,728 3,803	4.93	All
405 (S) [2]	30,847 1,761	7.71	All	17,302 4,833	4.33	4
5 (N) [3]	24,686 1,569	6.17	All	11,476 5,035	2.87	3
5 (S) [4]	45,141 5,179	11.29	All	29,843 8,369	7.46	All
110	13,676 2,402	3.42	3	8,253 2,657	2.06	2
10 (W) [5]	13,637 3,230	3.41	3	10,752 2,054	2.69	3
10 (E) [6]	20,140 4,304	5.04	All	17,312 1,379	4.33	4
105	16,477 4,351	4.12	4	12,060 2,677	3.02	3
57	19,061 6,111	4.77	All	14,961 3,054	3.74	4

intermediate Network

Market Penetration= 5 %

Modest Network Sections

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
405(N)[1]	2,893	0.72	1	2,280	0.57	1
	255[9]			353[10]		
405 (S)[2]	3,888	0.97	1	2,018	0.51	1
	30			976		
5 (N)[3]	3,316	0.83	1	1,227	0.31	0
	306			837		
5 (S)[4]	6,813	1.70	2	5,681	1.42	1
	1,233			1,115		
110	526	0.13	0	235	0.06	0
	12			196		
10 (W)[5]	2,751	0.69	1	1,360	0.34	0
	347			891		
10 (E)[6]	3,464	0.87	1	3,070	0.77	1
	511			213		
105	2,353	0.59	1	1,382	0.35	0
	49			562		
57	1,188	0.30	0	986	0.25	0
	555			168		

Intermediate Network

Market Penetration = 5 %

Intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended'	Average Volume (2 Hr.)	#of Lanes Required [7]	#of Lanes Recommended [8]
605	2,155 102 [9]	0.54	1	1,234 760 [10]	0.31	0
91	4,084 273	1.02	1	3,384 622	0.85	1
10	5,415 223	1.35	1	3,947 1,353	0.99	1
57	625 279	0.16	0	620 8	0.15	0
101/134	1,175 185	0.29	0	725 390	0.18	0
5 (N)	4,404 428	1.10	1	2,633 1,559	0.66	1
5 (S)	3,281 943	0.82	1	2,312 516	0.58	1
60	3,213 245	0.80	1	2,450 551	0.61	1

Intermediate Network

Market Penetration = 15%

Modest Network Sections

Freeway Section	Maximum Volume (2Hr.)	#of Lanes Required [7]	# of Lanes Recommended*	Average Volume (2 Hr.)	# of Lanes Required [7]	#of Lanes Recommended [8]
405(N)[1]	9,240	2.31	2	7,375	1.84	2
	743			1,267		
405(S)[2]	12,030	3.01	3	7,155	1.79	2
	165			2,185		
5(N)[3]	10,380	2.60	3	4,316	1.08	1
	941			2,722		
5(S)[4]	19,445	4.86	Ail	16,311	4.08	4
	3,287			1,161		
110	2,221	0.56	1	1,209	0.30	0
	283			604		
10(W)[5]	7,726	1.93	2	3,899	0.97	1
	1,034			2,355		
10(E)[6]	9,639	2.41	2	8,634	2.16	2
	1,548			538		
105	7,252	1.81	2	4,388	1.10	1
	161			1,762		
57	5,014	1.25	1	4,131	1.03	1
	2,104			747		

Intermediate Network

Market Penetration = 15%

Intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Reauired [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
605	6,442 431[9]	1.61	2	3,979 2,325"	0.99	1
91	11,149 890	2.79	3	9,607 1,564	2.40	2
10	14,521 663	3.63	4	10,794 3,567	2.70	3
57	2,488 1,087	0.62	1	2,472 23	0.62	1
101/134	4,274 804	1.07	1	2,603 1,360	0.65	1
5 (N)	13,357 1,234	3.34	3	7,825 4,855	1.96	2
5 (S)	9,659 2,443	2.41	2	6,754 1,524	1.69	2
60	9,051 715	2.26	2	6,886 1,322	1.72	2

Intermediate Network

Market Penetration = 30 %

Modest Network Sections

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	#of Lanes Required [7]	#of Lanes Recommended [8]
405(N)'	19,728 (1,517)[9]	4.93	Ail	15,728 2,968[10]	3.93	4
405(S)[2]	24,402 1,077	6.10	Ail	13,228 3,619	3.31	3
5 (N)[3]	20,387 1,752	5.10	All	10,147 5,299	2.54	3
5 (S)[4]	30,687 4,964	7.67	Ail	24,108 6,226	6.03	Ail
110	8,437 1,348	2.11	2	5,132 1,665	1.28	1
10 (W)[5]	15,385 2,262	3.85	4	8,224 4,427	2.06	2
10 (E)[6]	16,731 3,271	4.18	4	16,084 639	4.02	4
105	14,928 689	3.73	4	9,845 3,151	2.46	2
57	13,559 4,886	3.39	3	10,965 2,121	2.74	3

Intermediate Network

Market Penetration = 30%

Intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required[7]	# of Lanes Recommended@	Average Volume (2 Hr.)	#of Lanes Required[7]	#of Lanes Recommended[8]
605	15,594 1,592[9]	3.90	4	9,045 4,492[10]	2.26	2
91	20,336 1,739	5.08	All	16,018 2,299	4.00	4
10	22,280 1,882	5.57	All	16,558 5,233	4.14	4
57	7,012 3,412	1.75	2	6,204 704	1.55	2
101/134	12,070 2,795	3.02	3	6,799 3,950	1.70	2
5 (N)	22,871 2,105	5.72	Al!	13,129 8,419	3.28	3
5 (S)	21,745 3,421	5.44	All	12,436 4.231	3.11	3
60	16,385 1,457	4.10	4	12,210 1,974	3.05	3

RPEV

Intermediate Network

Market Penetration = 45%

Modest Network Sections

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required[7]	#of Lanes Recommended'	Average Volume (2 Hr.)	#of Lanes Required'	#of Lanes Recommended[8]
405(N)'	28,475 2,377	7.12	All	21,367 6,296	5.34	All
405 (S)[2]	35,713 2,286	a.93	All	19,639 5,292	4.91	All
5 (N)[3]	29,728 2,321	7.43	All	14,362 6,140	3.59	4
5 (S)[4]	41,969 6,795	10.49	All	32,817 a,932	a.20	All
110	16,300 2,762	4.08	4	8,683 3,330	2.17	2
10 (W)[5]	23,623 3,746	5.91	All	12,012 2,623	3.00	3
10 (E)[6]	25,528 5,371	6.38	All	23,816 1,517	5.95	All
105	22,720 4,766	5.66	All	14,859 3,638	3.71	4
57	21,821 7,079	5.46	All	17,202 3,515	4.30	4

Intermediate Network

Market Penetration = 45 %

Intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Reaulred [7]	# of Lanes Recommended*	Average Volume (2 Hr.)	#of Lanes Required[7]	#of Lanes Recommended[8]
605	23,920 3,039[9]	5.98	All	13,892 6,139[10]	3.47	3
91	28,410 2,457	7.10	All	21,502 3,509	5.38	All
10	30,364 3,568	7.59	All	21,945 6,546	5.49	All
57	8,738 5,936	2.18	2	a,579 225	2.14	2
101/134	20,700 5,141	5.18	All	10,990 6,442	2.75	3
5 (N)	29,510 2.857	7.38	All	16,858 10,903	4.21	4
5 (S)	33,108 4,300	8.28	All	17,566 6,968	4.39	4
60	23,259 2,129	5.81	All	16,418 3,891	4.10	4

Ambitious Network

Market Penetration = 5 %

	Modest Network Sections					
Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
405(N)'	3,952 337 [9]	0.99	1	3,086 528 [10]	0.77	1
405 (S) [2]	2,712 21	0.68	1	1,447 595	0.36	0
5 (N) [3]	4,167 279	1.04	1	1,397 1,331	0.35	0
5 (S) [4]	5,033 961	1.26	1	4,064 a20	1.02	1
110	597 30	0.15	0	290 146	0.07	0
10 (W) [5]	1,914 274	0.48	0	1,082 583	0.27	0
10 (E) [6]	2,826 544	0.71	1	2,527 145	0.63	1
105	1,606 36	0.40	0	a74 361	0.22	0
57	889 377	0.22	0	732 128	0.18	0

Ambitious Network Market Penetration = 5 %

Intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	#of Lanes Recommended [8]	Average Volume (2 Hr.)	#of Lanes Required [7]	#of Lanes Recommended*
605	1,505	0.38	0	885	0.22	0
	79[9]			506 [10]		
91	3,064	0.77	1	2,496	0.62	1
	199			489		
10	4,256	1.06	1	3,359	0.84	1
	329			902		
57	445	0.11	0	442	0.11	0
	191			4		
1011134	3,089	0.77	1	1,586	0.40	0
	360			1,124		
5 (N)	6,714	1.68	2	3,684	0.92	1
	428			2,810		
5 (S)	2,225	0.56	1	1,584	0.40	0
	779			337		
60	2,328	0.58	1	1,745	0.44	0
	193			438		

Ambitious Network Market Penetration ≈ 5 %

Ambitious Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required[7]	# of Lanes Recommended[8]	Average Volume (2 Hr.)	#of Lanes Required'	#of Lanes Recommended[8]
10	1,869 296[9]	0.47	0	1,383 248[10]	0.35	0
91/215	2,708 248	0.68	1	1,786 718	0.45	0
101	5,017 629	1.25	1	3,566 1.437	0.89	1
215	463 42	0.12	0	324 176	0.08	0
55	934 45	0.23	0	490 331	0.12	1
210	1,954 89	0.49	0	1,275 362	0.32	0
91	985 89	0.25	0	803 362	0.20	0
14	5,806 326	1.45	1	4,067 1,091	1.02	1
101	4,926 546	1.23	1	3,814 879	0.95	1
22	724 80	0.18	0	688 30	0.17	0

Ambitious Network

Market Penetration = 15 %

Modest Network Sections

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	#of Lanes Recommended'	Average Volume (2 Hr.)	#of Lanes Required [7]	#of Lanes Recommended [8]
405 (N) [1]	11,861 993 [9]	2.97	3	8,614 2,044 [10]	2.15	2
405 (S) [2]	8,166 69	2.04	2	4,394 1,827	1.10	1
5 (N) [3]	12,561 889	3.14	3	4,090 3,965	1.02	1
5 (S) [4]	13,820 2.925	3.46	3	11,982 2,755	3.00	3
110	1,702 91	0.43	0	642 484	0.16	0
10 (W) [5]	5,817 807	1.45	1	3,520 436	0.88	1
10 (E) [6]	7,949 1,630	1.99	2	7,705 436	1.93	2
105	4,849 115	1.21	1	2,815 1,177	0.70	1
57	2,606 1,117	0.65	1	2,156 356	0.54	1

Ambitious Network

Market Penetration = 15 %

Intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
605	4,487 262[9]	1.12	1	2,733 1,539 [10]	0.68	1
91	9,169 591	2.29	2	7,520 1,440	1.66	2
10	12,757 975	3.19	3	9,914 2,735	2.48	2
57	1,361 582	0.34	0	1,352 13	0.34	0
1011134	9,337 1,072	2.33	2	4,656 3,333	1.16	1
5 (N)	20,161 1.341	5.04	Ali	10,174 8,444	2.54	3
5 (S)	6,641 2,258	1.66	2	4,745 1,005	1.19	1
60	7,191 552	1.80	2	5,294 1,340	1.32	1

Ambitious Network

Market Penetration = 15%

Ambitious Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required[7]	# of Lanes Recommended[8]	Average Volume (2 Hr.)	# of Lanes Required[7]	#of Lanes Recommended*
10	5,609 852[9]	1.40	1	4,148 723[10]	1.04	1
91/215	8,360 742	2.09	2	5,225 2,191	1.31	1
101	15,080 1,878	3.77	4	11,166 4,274	2.79	3
215	1,356 118	0.34	0	943 524	0.24	0
55	2,543 244	0.64	1	1,328 914	0.33	0
210	5,919 246	1.48	1	3,961 1,130	0.99	1
91	3,012 308	0.75	1	2,401 282	0.60	1
14	16,847 1,043	4.21	4	11,310 4,035	2.83	3
101	14,827 1,478	3.71	4	11,301 2,505	2.83	3
22	2,200 270	0.55	1	2,077 103	0.52	1

Ambitious Network

Market Penetration = 30%

Modest Network Sections

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required[7]	# of Lanes Recommended[8]	Average Volume (2 Hr.)	# of Lanes Required[7]	# of Lanes Recommended[8]
405(N)[1]	22,940 1,770[9]	5.74	All	16,695 3,995[10]	4.17	4
405(S)[2]	19,890 623	4.97	All	10,336 3,508	2.58	3
5(N)[3]	23,626 2,169	5.91	All	8,570 6,221	2.14	2
5(S)[4]	30,635 4,853	7.66	All	7,210 2,601	1.80	2
110	5,103 868	1.28	1	3,461 1,188	0.87	1
10 (W)[5]	12,542 2,052	3.14	3	7,084 3,548	1.77	2
10 (E)[6]	15,728 3,235	3.93	4	14,952 604	3.74	4
105	11,795 453	2.95	3	7,417 2,491	1.85	2
57	10,529 3,898	2.63	3	8,374 1,636	2.09	2

Ambitious Network

Market Penetration = 30%

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	Intermediate Network Additions to Modest			
			#of Lanes Recommended*	Average Volume (2 Hr.)	#of Lanes Required [7]	#of Lanes Recommended*
605	12,247 1,139[9]	3.06	3	7,158 3,637"	1.79	2
91	16,518 1,809	4.13	4	14,044 1,970	3.51	4
10	21,585 1,995	5.40	All	16,862 4,440	4.22	4
57	4,730 2,523	1.18	1	4,623 151	1.16	1
101/134	17,207 2,808	4.30	4	8,389 5,596	2.10	2
5(N)	32,862 2,371	8.22	All	17,011 13,429	4.25	4
5(S)	16,865 3,434	4.22	All	9,969 3,098	2.49	4
60	13,661 1,219	3.42	3	10,482 1,889	2.62	3

Ambitious Network

Market Penetration = 30%

Ambitlous Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	#of Lanes Recommended[8]	Average Volume (2 Hr.)	#of Lanes Required'	#of Lanes Recommended[8]
10	9,741	2.44	2	7,502	1.88	2
	1,625[9]			1,252[10]		
911215	12,970	3.24	3	7,892	1.97	2
	2,821			2,530		
101	27,052	6.76	All	16,718	4.18	4
	3,558			8,130		
215	2,932	0.73	1	2,027	0.51	1
	510			1,119		
55	11,560	2.89	3	5,376	1.34	1
	1,906			3,208		
210	10,941	2.74	3	7,213	1.80	2
	709			2,303		
91	7,814	1.95	2	6,399	1.60	2
	1,847			754		
14	26,080	6.52	All	16,586	4.15	4
	1,575			6,268		
101	29,373	7.34	All	21,492	5.37	All
	2,832			5,755		
22	6,141	1.54	2	5,922	1.48	1
	1,471			161		

Ambitious **Network** | Market Penetration = 45%

			Modest **Network Sections**			
Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	#of Lanes Required [7]	#of Lanes Recommended [8]
405 (N)[1]	31,107 2,575’	7.78	All	24,696 4,177[10]	6.17	All
405(S)[2]	30,466 1,727	7.62	All	16,740 5,145	4.19	4
5 (N)[3]	32,772 3,030	8.19	All	13,692 832	3.42	3
5(S)[4]	45,337 6,623	11.33	All	29,554 7,548	7.39	All
110	13,037 2,344	3.26	3	7,587 2,523	1.90	2
10(W)[5]	20,251 3,435	5.06	All	10,100 1,939	2.52	3
10(E)[6]	24,327 5,201	6.08	All	22,089 1,105	5.52	All
105	18,275 4,713	4.57	All	12,202 4,625	3.05	3
57	18,330 5,961	4.58	All	14,446 2,974	3.61	4

Ambitious Network

Market Penetration= 45%

Intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
605	20,193 2,431[9]	5.05	All	11,390 5,300[10]	2.85	3
91	25,217 2,334	6.30	All	19,218 2,891	4.80	All
10	28,684 3,633	7.17	All	21,638 5,014	5.41	All
57	7,713 4,874	1.93	2	7,546 236	1.89	2
1011134	24,839 5,082	6.21	All	13,094 8,539	3.27	3
5(N)	39,110 3,062	9.78	All	20,525 15,773	5.13	All
5(S)	27,545 4,326	6.89	All	15,189 5,637	3.80	4
60(S)	18,921 1,859	4.73	All	14,805 2,649	3.70	4

Ambitious Network

Market Penetration = 45 %

Ambitious Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	#of lanes Recommended [8]	Average Volume (2 Hr.)	#of Lanes Required [7]	#of Lanes Recommended*
10	13,689 2,346'	3.42	3	11,155 1,823[10]	2.79	3
91/215	15,621 4.930	3.91	4	11,291 2,531	2.82	3
101	36,962 4,598	9.24	All	21,292 10,640	5.32	All
215	7,078 1,391	1.77	2	4,462 1,824	1.12	1
55	22,705 4,819	5.68	All	11,782 8,006	2.95	3
210	15,961 1,132	3.99	4	9,937 3,675	2.48	2
91	14,133 4,226	3.53	4	11,305 1,546	2.83	3
14	30,404 1,636	7.60	All	18,432 7,878	4.61	All
101	38,115 4,482	9.53	All	28,108 7,012	7.03	All
22	10,468 3,337	2.62	3	9,937 387	2.48	2

Ambitious Network Market Penetration = 60%

	Modest Network Sections					
Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
405 (N)[1]	39,384 3,405[9]	9.85	All	31,599 5,521[10]	7.90	All
405 (S)[2]	40,603 2,791	10.15	All	22,553 6,066	5.64	All
5 (N)[3]	42,105 3,619	10.53	All	18,290 9,602	4.57	All
5 (S)[4]	59,918 8,456	14.98	All	38,284 11,027	9.57	All
110	20,876 3,599	5.22	All	11,066 3,984	2.77	4
10 (W)[5]	27,924 4,803	6.98	All	15,855 3,531	3.96	4
10 (E)[6]	31,238 7,164	7.81	All	27,883 3,867	6.97	All
105	26,412 6,030	6.60	All	19,287 5,055	4.82	All
57	25,685 9,176	6.42	All	19,071 3,785	4.77	All

Ambitious Network

Market Penetration = 60%

Intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required[7]	# of Lanes Recommended[8]	Average Volume (2 Hr.)	# of Lanes Required[7]	# of Lanes Recommended[8]
605	27,881 3,778[9]	6.97	All	15,895 6,771[10]	3.97	4
91	33,118 2,992	8.28	All	24,132 4,207	6.03	All
10	36,310 5,017	9.08	All	27,034 6,890	6.76	All
57	9,902 7,125	2.48	2	9,702 283	2.43	2
101/134	32,840 7.505	8.21	All	18,561 11,463	4.64	All
5(N)	46,265 3,812	11.57	All	24,458 18.524	6.11	All
5(S)	37,878 5,359	9.47	All	20,288 8,345	5.07	All
60	28,037 2,461	7.01	All	19,455 3,898	4.86	All

Ambitious Network

Market Penetration = 60 %

Ambitious Network Additions to Modest Network

Freeway Section	Maximum volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended'	Average Volume (2 Hr.)	#of Lanes Required'	#of Lanes Recommended [8]
10	17,893	4.47	4	14,091	3.52	4
	3,068 [9]			2,636 [10]		
91/215	19,691	4.92	All	14,745	3.69	4
	6,919			2,483		
101	42,985	10.75	All	23,200	5.80	All
	5,700			12,128		
215	10,926	2.73	3	7,514	1.88	2
	2,234			2,340		
55	39,190	9.80	All	22,323	5.58	All
	8,087			11,068		
210	21,891	5.47	All	16.441	4.11	4
	1,452			5,183		
91	20,297	5.07	All	16,441	4.11	4
	6,521			2,466		
14	35,533	8.88	All	20,571	5.14	All
	1,734			9,641		
101	49,645	12.41	All	38,002	9.50	All
	6,077			9,589		
22	14,680	3.67	4	13,853	3.46	3
	5,119			613		

Modest Network

Market **Penetration** = 5%

Freeway Section	Maximum Volume (2Hr.)	#of Lanes **Required** [7]	#of Lanes Recommended'	Average **Volume (2 Hr.)**	#of Lanes Required [7]	#of Lanes Recommended'
405 (N)'	4,262 406	0.36	0	3,519 563	0.29	0
405 **(S)** [2]	4,575 340	0.38	0	2,715 747	0.23	0
5 (N) [3]	4,997 453	0.42	0	2,436 1,311	0.20	0
5 **(S)** [4]	8,371 1,771	0.70	1	4,825 1,636	0.40	0
110	3,088 435	0.26	0	1,811 1,381	0.15	0
10 **(W)** [5]	3,432 690	0.29	0	2,075 570	0.17	0
lb **(E)** [6]	3,846 934	0.32	0	3,573 287	0.30	0
105	3,201 326	0.27	0	2,280 445	0.19	0
57	3,083 889	0.26	0	2,287 517	0.19	0

Modest Network

Market Penetration= 15%

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended'	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
405 (N)'	12,763 1,228	1.06	1	10,353 1,577	0.86	1
405 (S) [2]	14,329 993	1.19	1	8,071 2,264	0.67	1
5 (N) [3]	14,947 1,395	1.25	1	4,825 4,304	0.40	0
5 (S) [4]	25,088 3,457	2.09	2	13,956 4,829	1.16	1
110	9,151 1,372	0.76	1	4,674 1,871	0.39	0
10 (W) [5]	10,341 1,916	0.87	1	6,187 1,682	0.52	1
10 (E) [6]	12,649 2,730	1.05	1	10,738 859	0.89	1
105	9,601 980	0.80	1	6,852 1,245	0.57	1
57	9,293 2,680	0.77	1	7,081 1,612	0.59	1

Modest Network

Market Penetration = 30 %

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
405 (N)'	25,520 2,431	2.13	2	20,982 3,329	1.75	2
405 (S) [2]	28,581 2,204	2.38	2	16,567 4,657	1.38	1
5 (N) [3]	29,881 2,806	2.49	2	12,922 6,765	1.08	1
5 (S) [4]	50,188 6,925	4.18	4	29,202 12,565	2.43	2
110	18,301 2,766	1.53	2	9,817 3,919	0.02	1
10 (W) [5]	20,700 3,846	1.73	2	12,370 1,709	1.03	1
10 (E) [6]	25,324 5,527	2.11	2	21,306 1,709	1.78	2
105	17,582 4,813	1.47	1	13,382 2,714	1.11	1
57	18,579 5,348	1.55	2	13,568 . 3,080	1.13	1

Automation

intermediate Network

Market Penetration = 5%

Modest Network Sections

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required'	#of Lanes Recommended [8]
405 (N)[1]	3,273 339 [9]	0.27	0	2,645 417 [10]	0.22	0
405(S)[2]	3,653 270	0.30	0	2,097 659	0.17	0
5(N)[3]	3,881 341	0.32	0	1,689 905	0.14	0
5(S)[4]	6,507 922	0.54	1	3,845 1,316	0.32	0
110	2,082 403	0.17	0	1,241 462	0.10	0
10(W)[5]	2,760 1,034	0.23	0	1,575 434	0.13	0
10 (E)[6]	3,263 724	0.27	0	2,759 230	0.23	0
105	2,430 253	0.20	0	1,742 337	0.15	0
57	2,397 681	0.20	0	1,825 416	0.15	0

Intermediate Network

Market Penetration = 5%

Intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Reauired [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
605	2,632 394[9]	0.22	0	1,560 619[10]	0.13	0
91	3,002 277	0.25	0	2,252 383	0.19	0
10	3,101 469	0.26	0	2,392 628	0.20	0
57	866 661	0.07	0	723 54	0.06	0
101/134	2,980 753	0.25	0	1,961 1,007	0.16	0
5(N)	3,826 404	0.32	0	2,085 1,465	0.17	0
5(S)	3,315 436	0.28	0	1,794 516	0.15	0
60	2,628 229	0.22	0	1,740 373	0.15	0

Automation

Intermediate Network

Market Penetration = 15%

Modest Network Sections

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended[8]	Average Volume (2 Hr.)	#of Lanes Required [7]	#of Lanes Recommended[8]
405 (N)[1]	9,897 932[9]	0.82	1	8,080 1,180"	0.67	1
405(S)[2]	11,070 787	0.92	1	6,463 1,779	0.54	1
5(N)[3]	11,545 1,078	0.96	0	4,855 1,921	0.40	0
5(S)[4]	19,417 2,700	1.62	2	10,123 3,456	0.84	1
110	3,931 1,387	0.33	0	3,931 1,387	0.33	0
10(W)[5]	4,782 1,299	0.40	0	4,782 1,299	0.40	0
10	8,298 697	0.69	1	8,298 697	0.69	1
105	5,199 1,065	0.43	0	5,199 1,065	0.43	0
57	5,342 1,188	0.45	0	5,342 1,188	0.45	0

Market Penetration = 15%

Intermediate Network Additions to Modest Network

Freewav Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	#of Lanes Recommended [8]	Average Volume (2 Hr.)	#of Lanes Required [7]	#of Lanes Recommended'
605	7,938 1,099 [9]	0.66	1	4,761 1,822"	0.40	0
91	9,100 829	0.76	1	6,759 1,156	0.56	1
10	10,040 1,436	0.84	1	7,185 1,966	0.60	1
57	2,600 661	0.22	0	2,345 332	0.20	0
101/134	8,943 2,157	0.75	1	5,389 3,036	0.45	0
5(N)	11,500 1,590	0.96	1	6,264 4,398	0.52	0
5(S)	9,951 1,460	0.83	1	5,385 2.137	0.45	0
60	6,645 664	0.55	1	5,210 1,167	0.43	0

Automation

intermediate Network

Market Penetration = 30%

Modest Network Sections

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required[7]	# of Lanes Recommended[8]	Average Volume (2 Hr.)	# of Lanes Required[7]	# of Lanes Recommended[8]
405(N)[1]	19,774 1,855'	1.65	2	16,502 2,590[10]	1.38	1
405(S)[2]	22,123 1,588	1.84	2	12,476 3,331	1.04	1
5(N)[3]	23,091 2,152	1.92	2	9,869 4,987	0.82	1
5(S)[4]	22,123 1,588	1.84	2	20,819 7,402	1.73	2
110	14,145 2,143	1.18	1	7,299 2,786	0.61	1
10(W)[5]	16,076 3,021	1.34	1	9,096 4,205	0.76	1
10(E)[6]	17,724 4,252	1.48	1	16,594 1,146	1.38	0
105	13,577 3,753	1.13	1	10,462 1,887	0.87	1
57	14,395 4,165	1.20	1	10,723 2,389	0.89	1

Intermediate Network

Market Penetration = 30%

Intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	#of Lanes Required [7]	#of Lanes Recommended'
605	15,813 2,186'	1.32	1	9,276 3,392 [10]	0.77	1
91	17,975 1.686	1.50	2	13,265 2,298	1.11	1
10	20,017 2,871	1.67	2	14,758 3,372	1.23	1
57	5,189 4,090	0.43	0	5,058 185	0.42	0
101/134	17,925 4,529	1.49	1	10,281 5,984	0.86	1
5(N)	22,974 2,513	1.91	2	12,513 8,784	1.04	1
5 (S)	17,756 2,864	1.48	1	10,075 3,507	0.84	1
60	15,793 1,318	1.32	1	10,613 2,323	0.88	1

Automation

Intermediate Network

Market Penetration = 45%

Modest Network Sections

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Limes Recommended [8]
405(N)[1]	26,744 2,825[9]	2.23	2	21,603 9,107[10]	1.80	2
405(S)[2]	33,252 2,346	2.77	3	18,675 5,355	1.56	2
5(N)[3]	34,764 3,242	2.90	3	15,003 9,348	1.25	2
5(S)[4]	39,847 8,065	3.32	3	33,148 10,915	2.76	3
110	21,286 3,222	1.77	2	10,429 4,081	0.87	1
10(W)[5]	24,147 4,473	2.01	2	14,750 4,019	1.23	1
10 (E)[6]	26,608 6,378	2.22	2	24,723 1,861	2.06	2
105	20,380 2,289	1.70	2	15,896 3,134	1.32	1
57	21,647 6,225	1.80	2	16,111 3,598	1.34	1

Automation

Intermediate Network

Market Penetration = **45%**

Intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	#of Lanes Recommended*	Average Volume (2 Hr.)	#of Lanes Required'	#of Lanes Recommended'
605	23,698 3,249 [9]	1.97	2	13,360 5,244"	1.11	1
91	27,343 2,542	2.28	2	19,900 3,567	1.66	2
10	30,103 4,325	2.51	3	22,412 4,891	1.87	2
57	7,798 7,401	0.65	1	7,600 281	0.63	1
101/134	26,922 6,518	2.24	2	14,863 8,861	1.24	1
5(N)	34,563 3.676	2.88	3	18,826 13,231	1.57	2
5(S)	29,899 4,341	2.49	2	16,388 6,631	1.37	1
60	23,704 2,011	1.98	2	15,596 3,518	1.30	1

Automation

Ambitious Network

Market Penetration = 5%

Modest Network Sections

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
405 (N)[1]	3,953 337[9]	0.33	0	2,815 710[10]	0.23	0
405(S)[2]	2,712 21	0.23	0	1,421 659	0.12	0
5(N)[3]	4,187 279	0.35	0	1,385 905	0.12	0
5(S)[4]	5,033 961	0.42	0	4,117 743	0.34	0
110	536 30	0.04	0	208 156	0.02	0
10(W)[5]	1,914 270	0.16	0	1,219 534	0.10	0
10 (E)[6]	2,826 544	0.24	0	2,534 118	0.21	0
105	1,608 36	0.13	0	911 395	0.07	0
57	869 377	0.07	0	727 122	0.06	0

Automation

Ambitious Network

Market Penetration = **5%**

Intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
605	1,505 79 [9]	0.13	0	840 513 [10]	0.07	0
91	3,064 199	0.26	0	2,491 497	0.21	0
10	4,228 329	0.35	0	3,338 873	0.28	0
57	577 191	0.05	0	467 43	0.04	0
101/134	3,089 360	0.26	0	1,587 1,125	0.13	0
5(N)	6,698 428	0.56	0	3,386 2,811	0.28	0
5(S)	2,225 758	0.19	0	1,584 337	0.13	0
60	2,355 193	0.20	0	1,722 430	0.14	0

Automation

Ambitious Network

Market Penetration = 5%

Ambitious Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	#of Lanes Recommended [8]	Average Volume (2 Hr.)	#of Lanes Required [7]	#of Lanes Recommended*
10	1,869 296 [9]	0.16	0	1,384 241 [10]	0.12	0
91/215	2,788 248	0.23	0	1,730 686	0.14	0
101	5,017 629	0.42	0	3,711 1,421	0.31	0
215	463 42	0.04	0	324 176	0.03	0
55	934 45	0.08	0	524 360	0.04	0
210	1,954 89	0.16	0	1,318 340	0.11	0
91	985 95	0.08	0	795 91	0.07	0
14	5,606 326	0.47	0	4,067 1,090	0.34	0
101	4,898 505	0.41	0	3,731 780	0.31	0
22	675 80	0.06	0	687 32	0.06	0

Automation

Ambitious Network

Market Penetration = 15%

Modest Network Sections

Freeway Section	Maximum Volume (2Hr.)	#of Lanes Required 7	#of Limes Recommended*	Average Volume (2 Hr.)	#of Lanes Required 7	#of Lanes Recommended*
405(N)[1]	11,914 993[9]	0.99	1	8,913 2,050"	0.74	1
405(S)[2]	8,166 69	0.68	1	4,205 2,024	0.35	0
5(N)[3]	12,581 953	1.05	1	4,177 4,135	0.35	0
5(S)[4]	15,125 2,925	1.26	1	12,194 2,590	1.02	1
110	1,702 87	0.14	0	636 442	0.05	0
10(W)[5]	5,817 807	0.48	G	3,246 1,681	0.27	0
10(E)[6]	8,510 1,630	0.71	1	7,627 596	0.64	1
105	4,849 115	0.40	0	3,037 1,267	0.25	0
57	2,606 1,117	0.22	0	2,156 356	0.18	0

Ambitious Network

Market Penetration = 15%

Intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended'	Average Volume (2 Hr.)	# of Lanes Required'	# of Lanes Recommended*
605	4,575 262[9]	0.38	0	2,583 1,553[10]	0.22	0
91	9,169 591	0.76	1	7,445 1,460	0.62	1
10	12,757 967	1.06	1	9,575 2,723	0.80	1
57	1,571 571	0.13	0	1,425 127	0.12	0
101/134	9,337 1,072	0.78	1	4,835 3,357	0.40	0
5(N)	20,161 1,341	1.68	2	10,174 8,444	0.85	1
5(S)	6,641 2,285	0.55	1	4,745 1,005	0.40	0
60	7,191 552	0.60	1	5,124 1,318	0.43	0

Ambitious Network

Market Penetration = 15%

Ambitious Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	#of Lanes Required [7]	#of Lanes Recommended'	Average Volume (2 Hr.)	#of Lanes Required [7]	#of Lanes Recommended'
10	5,609 852 [9]	0.47	0	4,148 723 [10]	0.35	0
91/215	8,360 742	0.70	1	4,887 2,083	0.41	0
101	15,080 1.878	1.26	1	11,405 4,262	0.95	1
215	1,356 118	0.11	1	943 524	0.08	1
55	2,753 141	0.23	0	1,330 913	0.11	0
210	5,919 246	0.49	0	3,988 1,078	0.33	0
91	3,012 308	0.25	0	2,401 282	0.20	0
14	16,847 1,043	1.40	1	12,488 3,211	1.04	1
101	11,835 1.614	0.99	1	11,604 2,506	0.97	1
22	2,200 270	0.18	0	2,077 103	0.17	0

Automation

Ambitious Network

Market Penetration = 30%

Modest Network Sections

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Reauired [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	#of Lanes Required [7]	#of Lanes Recommended*
405(N)[1]	22,940 17,070[9]	1.91	2	17,175 3,587"	1.43	1
405(S)[2]	19,890 623	1.66	2	9,892 3,732	0.82	1
5(N)[3]	23,626 2,169	1.97	2	8,866 6,743	0.74	1
5(S)[4]	30,665 4,853	2.56	3	20,969 5.960	1.75	2
110	5,898 860	0.49	0	3,444 1,142	0.29	0
10(W)[5]	12,543 2,051	1.05	1	7,010 3,530	0.58	1
10(E)[6]	15,237 3,235	1.27	1	14,791 578	1.23	1
105	11,735 450	0.98	1	6,979 2,339	0.58	1
57	10,529 3,898	0.88	1	8,342 1,556	0.70	1

Automation

Ambitious Network Market Penetration = 30%

Intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	#of Lanes Required [7]	# of Lanes Recommended*	Average Volume (2 Hr.)	#of Lanes Required'	#of Lanes Recommended*
605	12,247 1,139[9]	1.02	1	6,701 3,634"	0.56	1
91	17,636 1,722	1.47	1	14,137 2,074	1.18	1
10	21,546 1,995	1.80	2	16,350 4,576	1.36	1
57	4,730 2,523	0.39	0	4,673 81	0.39	0
101/134	17,207 2,703	1.43	1	9,885 6,291	0.82	1
5(N)	32,862 2,371	2.74	3	17,011 13,429	1.42	1
5(S)	16,865 3,434	1.41	1	10,743 2,998	0.90	1
60	12,837 1,219	1.07	1	10,409 1,780	0.87	1

Automation

Ambitious Network

Market Penetration = 45%

Freeway Section	Modest Network Sections: Maximum Volume (2Hr.)	# of Lanes Required [7]	# of lanes Recommended [8]	Average Volume (2 Hr.)	# of Limes Required [7]	# of Lanes Recommended [8]
405 (N)[1]	31,107 2,575 [9]	2.59	3	22,260 7,605 [10]	1.86	2
405(S)[2]	30,466 1,727	2.54	3	16,477 6,136	1.37	1
5(N)[3]	32,744 3,030	2.73	3	13,883 8,184	1.16	1
5(S)[4]	45,337 6,623	3.78	4	29,367 7,472	2.45	2
110	12,667 2,225	1.06	1	7,353 2,044	0.61	1
10(W)[5]	20,251 3,438	1.69	2	10,081 2,024	1.84	1
10 (E)[6]	24,327 5,201	2.03	2	21,959 963	1.83	2
105	18,275 1,031	1.52	2	12,077 2,861	1.01	1
57	18,341 5,961	1.53	2	13,899 2,843	1.16	1

Automation

Ambitious Network

Market Penetration =45%

Intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
605	20,193 2,491 [9]	1.68	2	11,278 5,234"	0.94	1
91	25,232 2,542	2.10	2	19,175 3,567	1.60	2
10	28,798 3,564	2.40	2	22,166 5,003	1.85	2
57	7,379 4,874	0.61	1	7,247 187	0.60	1
1011134	24,839 4,082	2.07	2	13,975 8,771	1.16	1
5 (N)	39,110 3,062	3.26	3	20,525 15.773	1.71	2
5 (S)	27,545 4,328	2.30	2	15,342 5,837	1.28	1
60	20,903 1,859	1.74	2	14,610 2,550	1.22	1

Ambitious Network

Market Penetration = 45%

Ambitious Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	#of Lanes Recommended [8]	Average Volume (2 Hr.)	#of Lanes Required'	#of Lanes Recommended*
10	13,689	1.14	1	10,791	0.90	1
	2,346[9]			1,979[10]		
911215	15,621	1.30	1	11,057	0.92	1
	4,930			2,218		
101	36,962	3.08	3	20,688	1.72	2
	4,598			10,255		
215	7,078	0.59	1	5,578	0.46	0
	984			387		
55	22,705	1.89	2	10,790	0.90	1
	4,819			4,866		
210	15,961	1.33	1	9,737	0.81	1
	1,132			3,644		
91	14,133	1.18	1	11,365	0.95	1
	4,226			1,587		
14	30,404	2.53	3	17,928	1.49	1
	1,636			7,873		
101	38,115	3.18	3	30,273	2.52	3
	4,482			7,449		
22	10,316	0.86	1	9,937	0.83	1
	3,337			387		

Automation

Ambitious Network

Market Penetration = 60%

	Modest Network Sections					
Freeway Section	**Maximum Volume (2Hr.)**	**# of Lanes Required [7]**	**# of Lanes Recommended [8]**	**Average Volume (2 Hr.)**	**# of Lanes Required [7]**	**# of Lanes Recommended [8]**
405(N)'	39,384 3,405 [9]	3.28	3	32,315 5,284 [10]	2.69	3
405(S)[2]	40,922 2,781	3.41	3	23,852 6,102	1.99	2
5(N)[3]	42,105 3,619	3.51	4	18,952 10.031	1.58	2
5(S)[4]	59,918 8,456	4.99	All	37,695 11,391	3.14	3
110	20,874 3,494	1.74	2	11,425 4,379	0.95	0
10(W)[5]	27,927 4,803	2.33	2	15,429 3,871	1.29	1
10 (E)[6]	31,238 7,164	2.60	3	28,994 1,785	2.42	2
105	24,619 6,556	2.05	2	17,817 4,573	1.48	1
57	25,685 7,993	2.14	2	19,231 4,034	1.60	2

Automation

Ambitious Network

Market Penetration = 60%

Intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Reauired [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	#of Lanes Required'	#of Lanes Recommended*
605	27,881 3,778'	2.32	2	17,012 6,964 [10]	1.42	1
91	33,118 199	2.76	3	23,633 5,908	1.97	2
10	36,310 5,017	3.03	3	27,534 6,787	2.29	2
57	9,902 7,125	0.83	1	9,702 283	0.81	1
1011134	32,840 7,505	2.74	3	17,480 11,075	1.46	1
5(N)	46,265 3,861	3.86	4	22,062 17,928	1.84	2
5(S)	37,878 5,259	3.16	3	20,288 8,345	1.69	2
60	28,037 2,343	2.34	2	18,365 3,107	1.53	2

Automation

Ambitious Network

Market Penetration = 60%

Ambitious Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Reauired [7]	#of Lanes Recommended [8]	Average Volume (2 Hr.)	#of Lanes Required'	#of Lanes Recommended [8]
10	17,893	1.49	1	14,092	1.17	1
	3.0689			2,638[10]		
91/215	19,691	1.64	2	14,445	1.20	1
	6,919			2,338		
101	47,160	3.93	4	24,511	2.04	2
	5,484			12.691		
215	10,926	0.91	1	6,206	0.52	1
	1,370			3,794		
55	34,411	2.87	3	21,759	1.81	2
	7,559			10.667		
210	21,891	1.82	2	12,293	1.02	1
	1,462			5,141		
91	20,297	1.69	2	16,609	1.38	1
	6,521			2,244		
14	35,533	2.96	3	19,987	1.67	2
	1,784			9,602		
101	49,645	4.14	4	36,336	3.03	3
	5,912			9,158		
22	14,680	1.22	1	13,753	1.15	1
	5,119			818		

Combination

Modest Network

Market Penetration = 5%

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
405 (N) [1]	4,527	0.37	0	3,633	0.30	0
	178 [9]			592 [10]		
405 (S) [2]	5,674	1.47	0	3,280	0.27	0
	66			1,128		
5 (N) [3]	3,851	0.32	0	1,569	0.13	0
	260			1,032		
5 (S) [4]	11,141	0.93	1	8,795	0.73	1
	1,204			1,860		
110	646	0.05	0	286	0.02	0
	24			182		
10 (W) [5]	3,063	0.25	0	1,610	0.13	0
	456			877		
10 (E) [6]	2,035	0.17	0	1,943	0.16	0
	450			52		
105	1,905	0.16	0	1,225	0.10	0
	64			411		
57	1,808	0.15	0	1,534	0.13	0
	729			230		

Combination

Modest Network

Market Penetration = 15%

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
405 (N)'	13,501	1.12	1	9,622	0.80	1
	696			2,328		
405 (S) [2]	16,569	1.38	1	8,486	0.71	1
	408			3,564		
5 (N) [3]	12,886	1.07	1	5,456	0.45	0
	851			3,735		
5 (S) [4]	26,115	2.18	2	18,462	1.54	2
	2,876			4,276		
110	5,435	0.45	0	2,409	0.20	0
				736		
10 (W) [5]	8,521	0.71	1	4,611	0.38	0
	1,367			2,426		
10 (E) [6]	7,674	0.64	1	7,463	0.62	1
	1,671			202		
105	7,504	0.63	1	4,964	0.41	0
	293			1,617		
57	8,494	0.71	1	6,954	0.58	1
	3,148			1,307		

Combination

Modest Network

Market Penetration = 30%

Freeway Section	Maximum Volume (2Hr.)	#of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required'	#of Lanes Recommended*
405 (N)'	24,863 1,794	2.07	2	19,728 3,803	1.64	2
405 (S) [2]	30,847 1,761	2.57	3	17,302 4,833	1.44	1
5 (N) [3]	24,686 1,569	2.06	2	11,476 5,035	0.96	1
5 (S) [4]	45,141 5,179	3.76	4	29,843 8,369	2.49	2
110	13,676 2,402	1.14	1	8,253 2,657	0.69	1
10 (W) [5]	13,637 3,230	1.14	1	10,752 2,054	0.90	1
1.0 (E) [6]	20,140 4,304	1.68	2	17,312 1.379	1.44	1
105	16,477 4,351	1.37	1	12,060 2,677	1.00	1
57	19,061 6,111	1.59	2	14,961 3,054	1.25	1

Combination

intermediate Network

Market Penetration = 5 %

Modest Network Sections

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required'	# of Lanes Recommended*
405(N)'	2,893	0.24	0	2,280	0.19	0
	255 [9]			353 [10]		
405 (S)[2]	3,888	0.32	0	2,018	0.17	0
	30			976		
5 (N)[3]	3,316	0.28	0	1,227	0.10	0
	306			837		
5 (S)[4]	6,813	0.57	1	5,681	0.47	0
	1,233			1,115		
110	526	0.04	0	235	0.02	0
	12			196		
10 (W)[5]	2,751	0.23	0	1,360	0.11	0
	347			891		
10 (E)[6]	3,464	0.29	0	3,070	0.26	0
	511			213		
105	2,353	0.20	0	1,382	0.12	0
	49			562		
57	1,188	0.10	0	986	0.08	0
	555			168		

Combination

Intermediate Network

Market Penetration = 5%

intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
605	2,155 102	0.18	0	1,234 760	0.10	0
91	4,084 273	0.34	0	3,384 622	0.28	0
10	5,415 223	0.45	0	3,947 1,353	0.33	0
57	625 279	0.05	0	620 8	0.05	0
101/134	1,175 185	0.10	0	725 390	0.06	0
5	4,404 428	0.37	0	2,633 1,559	0.22	0
5	3,281 943	0.27	0	2,312 516	0.19	0
60	3,213 245	0.27	0	2,450 551	0.20	0

Combination

Intermediate Network Market Penetration = 15%

Modest Network Sections

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required'	# of Lanes Recommended [8]
405 (N)[1]	9,240 743	0.77	1	7,375 1,267	0.61	1
405(S)[2]	12,030 165	1.00	1	7,155 2,185	0.60	1
5(N)[3]	10,380 941	0.87	1	4,316 2,722	0.36	0
5(S)[4]	19,445 3,287	1.62	2	16,311 1,161	1.36	1
110	2,221 283	0.19	1	1,209 604	0.10	0
10(W)[5]	7,726 1,034	0.64	1	3,899 2,355	0.32	0
10 (E)[6]	9,639 1,548	0.80	1	8,634 538	0.72	1
105	7,252 161	0.60	1	4,388 1,762	0.37	0
57	5,014 2,104	0.42	0	4,131 747	0.34	0

Combination

intermediate Network

Market Penetration -15%

Intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	#of Lanes Recommended*	Average Volume (2 Hr.)	#of Lanes Required [7]	#of Lanes Recommended [8]
605	6,442 431 [9]	0.54	1	3,979 2,325"	0.33	0
91	11,149 890	0.93	1	9,607 1,564	0.80	1
10	14,521 663	1.21	1	10,794 3,567	0.90	1
57	2,488 1,087	0.21	0	2,472 23	0.21	0
101/134	4,274 804	0.36	0	2,603 1,360	0.22	0
5 (N)	13,357 1,234	1.11	1	7,825 4,855	0.65	1
5 (S)	9,659 2,443	0.80	1	6,754 1,524	0.56	1
60	9,051 715	0.75	1	6,886 1,322	0.57	1

Combination

Intermediate Network

Market Penetration = 30 %

Modest Network Sections

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	#of Lanes Recommended*	Average Volume (2 Hr.)	# of Lanes Required'	# of Lanes Recommended [8]
405(N)'	19,728 (1,517) [9]	1.64	2	15,728 2,968 [10]	1.31	1
405 (S)[2]	24,402 1,077	2.03	2	13,228 3,619	1.10	1
5 (N)[3]	20,387 1,752	1.70	2	10,147 5,299	0.85	1
5 (S)[4]	30,687 4,964	2.56	3	24,108 6,226	2.01	2
110	8,437 1,348	0.70	1	5,132 1,665	0.43	0
10 (W)[5]	15,385 2,262	1.28	1	8,224 4,427	0.69	1
1 o (E)[6]	16,731 3,271	1.39	1	16,084 639	1.34	1
105	14,928 689	1.24	1	9,845 3,151	0.82	1
57	13,559 4,886	1.13	1	10,965 2,121	0.91	1

Combination

Intermediate Network Market Penetration ≈ 30%

Intermediate Network Additions to Modest Network

Freeway Section	**Maximum Volume (2Hr.)**	**# of Lanes** Required [7]	#of Lanes Recommended [8]	Average **Volume (2** Hr.)	#of Lanes Required'	#of Lanes Recommended@
605	15,594 1,592[9]	1.30	1	9,045 4,492[10]	0.75	1
91	20,336 1,739	1.69	2	16,018 2,299	1.33	1
10	22,280 1,882	1.86	2	16,558 5,233	1.38	1
57	7,012 3,412	0.58	1	6,204 704	0.52	1
101/134	12,070 2,795	1.01	1	6,799 3,950	0.57	1
5 (N)	22,871 2,105	1.91	2l	13,129 8,419	1.09	1
5 (S)	21,745 3,421	1.81	2	12,436 4,231	1.04	1
60	16,385 1,457	1.37	1	12,210 1,974	1.02	1

Combination

Intermediate Network

Market Penetration = 45%

	Modest Network Sections					
Freeway Section	**Maximum Volume (2Hr.)**	**# of Lanes Required [7]**	#of Lanes **Recommended [8]**	Average **Volume (2 Hr.)**	**#of Lanes** Required[7]	**#of Lanes** Recommended*
405(N)'	28,475 2,377	2.37	2	21,367 6,296	1.78	2
405 (S)[2]	35,713 2,286	2.98	3	19,639 5,292	1.64	2
5 (N)[3]	29,728 2,321	2.48	2	14,362 6,140	1.20	1
5 (S)[4]	41,969 6,795	3.50	4	32,817 8,932	2.73	3
110	16,300 2,762	1.36	1	8,683 3,330	0.72	1
10 (W)[5]	23,623 3,746	1.97	2	12,012 2,623	1.00	1
10 (E)[6]	25,528 5,371	2.13	2	23,816 1,517	1.98	2
105	22,720 4,788	1.89	2	14,859 3,638	1.24	1
57	21,821 7,079	1.82	2	17,202 3,515	1.43	1

Combination

Intermediate Network Market Penetration = 45%

Intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required'	# of Lanes Recommended'
605	23,920 3,039 [9]	1.99	2	13,892 6,139"	1.16	1
91	28,410 2,457	2.37	2	21,502 3,509	1.79	2
10	30,364 3,568	2.53	3	21,945 6,546	1.83	2
57	8,738 5,936	0.73	1	8,579 225	0.71	1
101/134	20,700 5,141	1.73	2	10,990 6,442	0.92	1
5 (N)	29,510 2,857	2.46	2	16,858 10,903	1.40	1
5 (S)	33,108 4,300	2.76	3	17,566 6,968	1.46	1
60	23,259 2,129	1.94	2	16,418 3,891	1.37	1

Combination

Ambitious Network

Market Penetration = 5%

Modest Network Sections

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Voiume(2 Hr.)	#of Lanes Required [7]	#of Lanes Recommended [8]
405(N)'	3,952 337[9]	0.33	0	3,086 528[10]	0.26	0
405 (S)[2]	2,712 21	0.23	0	1,447 595	0.12	0
5 (N)[3]	4,167 279	0.35	0	1,397 1,331	0.12	0
5 (S)[4]	5,033 961	0.42	0	4,064 820	0.34	0
110	597 30	0.05	0	290 146	0.02	0
10 (W)[5]	1,914 274	0.16	0	1,082 583	0.09	0
10 (E)[6]	2,826 544	0.24	1	2,527 145	0.21	0
105	1,606 36	0.13	1	874 361	0.07	0
57	889 377	0.07	0	732 128	0.06	0

Combination

Ambitious Network Market Penetration = 5%

Intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended[8]	Average Volume (2 Hr.)	#of Lanes Required'	#of Lanes Recommended*
605	1,505 79 [9]	0.13	0	885 506 [10]	0.07	0
91	3,064 199	0.26	0	2,496 489	0.21	0
10	4,256 329	0.35	0	3,359 902	0.28	0
57	445 191	0.04	0	442 4	0.04	0
101/134	3,089 360	0.26	0	1,586 1,124	0.13	0
5(N)	6,714 428	0.56	1	3,684 2,810	0.31	0
5 (S)	2,225 779	0.19	0	1,584 337	0.13	0
60	2,328 193	0.19	0	1,745 438	0.15	0

Combination

Ambitious Network Market Penetration = 5 %

Ambitious Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required'	# of Lanes Recommended [8]
10	1,869 296"	0.16	0	1,383 248[10]	0.12	0
91/215	2,708 248	0.23	0	1,786 718	0.15	0
101	5,017 629	0.42	0	3,566 1,437	0.30	0
215	463 42	0.04	0	324 176	0.03	0
55	934 45	0.08	0	490 331	0.04	0
210	1,954 89	0.16	0	1,275 362	0.11	0
91	985 89	0.08	0	803 362	0.07	0
14	5,806 326	0.48	0	4,067 1,091	0.34	0
101	4,926 546	0.41	0	3,814 879	0.32	0
22	724 80	0.06	0	688 30	0.06	0

Combination

Ambitious Network

Market Penetration = 15%

Freeway Section	Modest Network Sections					
	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	#of Lanes Required [7]	#of Lanes Recommended'
405(N)[1]	11,861 993 [9]	0.99	1	8,614 2,044 [10]	0.72	1
405(S)[2]	8,166 69	0.68	1	4,394 1,827	0.37	0
5(N)[3]	12,561 889	1.05	1	4,090 3,965	0.34	0
5(S)[4]	13,820 2,925	1.15	1	11,982 2,755	1.00	1
110	1,702 91	0.14	0	642 494	0.05	0
10(W)[5]	5,817 807	0.48	0	3,520 1,777	0.29	0
10(E)[6]	7,949 1,630	0.66	1	7,705 436	0.64	1
105	4,849 115	0.40	0	2,815 1,177	0.23	0
57	2,606 1,117	0.22	0	2,156 356	0.18	0

Combination

Ambitious Network

Market Penetration = 15%

Intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	#of Lanes Recommended'	Average Volume (2 Hr.)	#of Lanes Required [7]	#of Lanes Recommended [8]
605	4,487 262 [9]	0.37	0	2,733 1,539 [10]	0.23	0
91	9,169 591	0.76	1	7,520 1,440	0.63	1
10	12,757 975	1.06	1	9,914 2,735	0.83	1
57	1,361 582	0.11	0	1,352 13	0.11	0
1011134	9,337 1,072	0.78	1	4,656 3,333	0.39	0
5 (N)	20,161 1,341	1.68	2	10,174 8.444	0.85	1
5 (S)	6,641 2,258	0.55	1	4,745 1,005	0.40	0
60	7,191 552	0.60	1	5,294 1,340	0.44	0

Combination

Ambitious Network

Market Penetration = 15%

Ambitious Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended*	Average Volume (2 Hr.)	#of Lanes Required'	#of Lanes Recommended*
10	5,609 852[9]	0.47	0	4,148 723[10]	0.35	0
91/215	8,360 742	0.70	1	5,225 2,191	0.44	0
101	15,080 1,878	1.26	1	11,166 4,274	0.93	1
215	1,356 118	0.11	0	943 524	0.08	0
55	2,543 244	0.21	0	1,328 914	0.11	0
210	5,919 246	0.49	0	3,961 1,130	0.33	0
91	3,012 308	0.25	0	2,401 282	0.20	0
14	16,847 1,043	1.40	1	11,310 4,035	0.94	1
101	14,827 1,478	1.24	1	11,301 2,505	0.94	1
22	2,200 270	0.18	0	2,077 103	0.17	0

Combination

Ambitious Network

Market Penetration = 30%

Modest Network Sections

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
405 (N)[1]	22,940 1,770 [9]	1.91	2	16,695 3,995[10]	1.39	1
405 (S)[2]	19,890 623	1.66	2	10,336 3,508	0.86	1
5 (N)[3]	23,626 2,169	1.97	2	8,570 6,221	0.71	1
5 (S)[4]	30,635 4,853	2.55	3	7,210 2,601	0.60	1
110	5,103 868	0.43	0	3,461 1,188	0.29	0
10 (W)[5]	12,542 2,052	1.05	1	7,084 3,548	0.59	1
10 (E)[6]	15,728 3,235	1.31	1	3,548 604	1.25	1
105	11,795 453	0.98	1	7,417 2,491	0.62	1
57	10,529 3,898	0.88	1	8,374 1,636	0.70	1

Combination

Ambitious Network Market Penetration = 30%

Intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	#of Lanes Required'	#of Lanes Recommended'
605	12,247	1.02	1	7,158	0.60	1
	1,139[9]			3,637"		
91	16,518	1.38	1	14,044	1.17	1
	1,809			1,970		
10	21,585	1.80	2	16,862	1.41	1
	1,995			4,440		
57	4,730	0.39	0	4,623	0.39	0
	2,523			151		
101/134	17,207	1.43	1	8,389	0.70	1
	2,808			5,956		
5 (N)	32,862	2.74	3	17,011	1.42	1
	2,371			13,429		
5 (S)	16,865	1.41	1	9,969	0.83	1
	3,434			3,098		
60	16,661	1.14	1	10,482	0.87	1
	1,219			1,889		

Combination

Ambitious Network

Market Penetration = 30%

Ambitious Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	#of Lanes Recommended*	Average Volume (2 Hr.)	#of Lanes Required [7]	#of Lanes Recommended [8]
10	9,741 1,625[9]	0.81	1	7,502 1,252[10]	0.63	1
91/215	12,970 2,821	1.08	1	7,892 2,530	0.66	1
101	27,052 3,558	2.25	2	16,718 8,130	1.39	1
215	2,932 510	0.24	0	2,027 1,119	0.17	0
55	11,560 1,906	0.96	1	5,376 3.208	0.45	0
210	10,941 709	0.91	1	7,213 2,303	0.60	1
91	7,814 1,847	0.65	1	6,399 754	0.53	1
14	26,080 1,575	2.17	2	16,586 6,268	1.38	1
101	29,373 2,832	2.45	2	21,492 5,755	1.79	2
22	6,141 1,471	0.51	1	5,922 161	0.49	0

Combination

Ambitious Network

Market Penetration = 45 %

Freeway Section	Modest Network Sections Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
405(N)'	31,107 2,575	2.59	3	24,696 4,177	2.06	2
405 (S) [2]	30,466 1,727	2.54	3	16,740 5,145	1.40	1
5 (N) [3]	32,772 3,030	2.73	3	13,692 832	1.14	1
5 (S) [4]	45,337 6,623	3.78	4	29,554 7,548	2.46	2
110	13,037 2,344	1.09	1	7,587 2,523	0.63	1
10 (W) [5]	20,251 3,435	1.69	2	10,100 1,939	0.84	1
10 (E) [6]	24,327 5,201	2.03	2	22,089 1,105	1.64	2
105	18,275 4.713	1.52	2	12,202 4,625	1.02	1
57	18,330 5,961	1.53	2	14,448 2,974	1.20	1

Combination

Ambitious Network

Market Penetration = 45 %

Intermediate Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
605	20,193 2,431[9]	1.68	2	11,390 5,300[10]	0.95	2
91	25,217 2,334	2.10	2	19,218 2,891	1.60	2
10	28,684 3,633	2.39	2	21,638 5,014	1.80	2
57	7,713 4,874	0.64	1	7,546 236	0.63	1
101/134	24,839 5,082	2.07	2	13,094 8,539	1.09	1
5 (N)	39,110 3,062	3.26	3	20,525 15,773	1.71	2
5 (S)	27,545 4,326	2.30	2	15,189 5,637	1.27	1
60	18,921 1,859	1.58	2	14,805 2,649	1.23	1

Combination

Ambitious Network Market Penetration **=45%**

Ambitious Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended*	Average Volume (2 Hr.)	#of Lanes Required'	#of Lanes Recommended [8]
10	13,689	1.14	1	11,155	0.93	1
	2,346'			1,823[10]		
91/215	15,621	1.30	1	11,291	0.94	1
	4,930			2,531		
101	36,962	3.08	3	21,292	1.77	2
	4,598			10,640		
215	7,078	0.59	1	4,462	0.37	0
	1,391			1,824		
55	22,705	1.89	2	11,782	0.98	1
	4,819			8,006		
210	15,961	1.33	1	9,937	0.83	1
	1,132			3,675		
91	14,133	1.18	1	11,305	0.94	1
	4,226			1,546		
14	30,404	2.53	3	18,432	1.54	2
	1,636			7,878		
101	38,115	3.18	3	28,108	2.34	2
	4,482			7,012		
22	10,468	0.87	1	9,937	0.83	1
	3,337			387		

Combination

Ambitious Network

Market Penetration = 60 %

Modest Network Sections

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
405(N)[1]	39,384 3,405	3.28	3	31,599 5,521	2.63	3
405 (S)[2]	40,603 2,791	3.38	3	22,553 6,066	1.88	2
5 (N)[3]	42,105 3,619	3.51	4	18,290 9,602	1.52	2
5 (S)[4]	59,918 8,456	4.99	All	38,284 11,027	3.19	3
110	20,876 3,599	1.74	2	11,066 3,984	0.92	1
10 (W)[5]	27,924 4,803	2.33	2	15,855 3,531	1.32	1
10 (E)[6]	31,238 7,164	2.60	3	27,883 3,867	2.32	2
105	26,412 6,030	2.20	2	19,287 5,055	1.61	2
57	25,685	2.14	2	19,071	1.59	2

Combination

Ambitious Network

Market Penetration = 60 %

Intermediate Network Addititons to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]
605	27,881	2.32	2	15,895	1.32	4
	3,778 [9]			6,771 [10]		
91	33,118	2.76	3	24,132	2.01	2
	2,992			4,207		
10	36,310	3.03	3	27,034	2.25	2
	5,017			6,890		
57	9,902	0.83	1	9,702	0.81	1
	7,125			283		
1011134	32,840	2.74	3	18,561	1.55	2
	7,505			11,463		
5 (N)	46,265	3.86	4	24,458	2.04	2
	3,812			18,524		
5 (S)	37,878	3.16	3	20,288	1.69	2
	5,359			8,345		
60	28,037	2.34	2	19,455	1.62	2
	2,461			3,898		

Combination

Ambitious Network Market Penetration = 60%

Ambitious Network Additions to Modest Network

Freeway Section	Maximum Volume (2Hr.)	# of Lanes Required [7]	# of Lanes Recommended [8]	Average Volume (2 Hr.)	# of Lanes Required [7]	#of Lanes Recommended*
10	17,893 3,068	1.49	1	14,091 2,636	1.17	1
91/215	19,691 6,919	1.64	2	14,745 2,483	1.23	1
101	42,985 5,700	3.58	4	23,200 12,128	1.93	2
215	10,926 2,234	0.91	1	7,514 2,340	0.63	1
55	39,190 8,087	3.27	3	22,323 11,068	1.86	2
210	21,891 1,452	1.82	2	16.441 5,183	1.07	1
91	20,297 6,521	1.69	2	16,441 2,466	1.37	1
14	35,533 1,734	2.96	3	20,571 9,641	1.71	2
101	49,645 6,077	4.14	4	38,002 9,589	3.17	3
22	14,680 5,119	1.22	1	13,853 613	1.15	1

Appendix G

Distributional Volume

Lane Recommendations

RPEV

Modest Network — Market Penetration = 5%

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)	81.2	18.8				1
405 (S)	66.0	34.0				1
5 (N)	100.0					1
5 (S)	8.2	22.4	69.4			1
110	100.0					1
10 (W)	100.0					1
10 (E)	100.0					1
105	100.0					1
57	100.0					1

Modest Network — Market Penetration = 15%

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)	11.1	70.4	18.5			2
405 (S)		38.0	54.0	4.0	4.0	3
5 (N)	29.2	50.0	8.3	12.5		2
5 (S)	6.4	12.8			80.0	All
110	100.0					1
10 (W)	36.8	47.4	15.8			1"
10 (E)		100.0				2
105	19.2	80.8				2
57	57.1	42.9				2

Modest Network — Market Penetration = 30%

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)		4.3			95.7	All
405 (S)			2.2	48.9	48.9	4
5 (N)		10.5	57.9	21.1	10.5	3
5 (S)			7.0	4.6	88.4	All
110		50.0	42.3	7.7		2
10 (W)	18.8	25.0	12.4	25.0	18.8	3*
10 (E)				7.7	92.3	All
105			68.8	12.5	18.7	3
57			14.2	42.9	42.9	4*

Intermediate Network — Market Penetration = 5%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)	100.0					1
405 (S)	100.0					1
5 (N)	100.0					1
5 (S)	13.6	86.4				2
110	100.0					1
10 (W)	100.0					1
10 (E)	100.0					1
105	100.0					1
57	100.0					

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605	100.0					1
91	87.1	12.9				1
10	37.9	62.1				2
57	100.0					1
101/134	100.0					1
5 (N)	63.6	36.4				1
5 (S)	100.0					1
60	100.0					1

Intermediate Network | Market Penetration = 15%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)		75.9	24.1			2
405 (S)	16.7	66.7	16.7			2
5 (N)	79.2	8.3	12.5			1
5 (S)		10.0	2.5	30.0	57.5	All
110	100.0					1
10 (W)	41.2	58.8				2
10 (E)		5.6	94.4			3
105	55.6	44.4				1
57	50.0	50.0				1

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605	46.7	53.3				2
91		25.8	74.2			3
10		30.0	23.3	46.7		3*
57	100.0					1
101/134	68.4	31.6				1
5 (N)	20.0	40.0		40.0		2*
5 (S)		85.7	14.3			2
60		63.2	36.8			2

Intermediate Network

Market Penetration = 30%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)			11.5	65.4	23.1	4
405 (S)			29.2	8.3	12.5	4
5 (N)		79.2		10.6	12.5	2
5 (S)					89.4	All
110	18.5	74.1	7.4			2
10 (W)	25.0	25.0	12.4	18.8	18.8	2*
10 (E)				25.0	75.0	All
105		24.0	56.0	20.0		3
57		60.0	60.0			3

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605			55.6	44.4		2
91				56.2	43.8	4
10			25.0	10.7	64.3	All
57		100.0				2
101/134	37.5	25.0	6.3	31.2		2*
5 (N)	20.0	10.0	30.0		40.0	3*
5 (S)		14.3	42.8	28.6	14.3	3*
60		1.9	54.7	35.8	7.6	3

Intermediate Network

Market Penetration = 45%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)				8.0	92.0	All
405 (S)				22.9	77.1	All
5 (N)			52.0	28.0	20.0	3
5 (S)					100.0	All
110	4.0	32.0	36.0	20.0	8.0	2*
10 (W)	7.1	14.3	28.6	7.1	42.9	3*
10 (E)					100.0	All
105			13.1	47.8	39.1	4*
57				50.0	50.0	4

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605		25.9	25.9		48.2	3*
91					100.0	All
10			10.0	16.7	73.3	All
57		100.0				2
101/134		55.6	11.1		33.3	2
5 (N)		20.0	20.0	20.0	40.0	4*
5 (S)			21.4	28.6	50.0	All
60				48.2	51.8	All

RPEV

Ambitious Network — Market Penetration = 5%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)	86.2	13.8				1
405 (S)	100.0					1
5 (N)	84.0	16.0				1
5 (S)	21.7	78.3				2
110	100.0					1
10 (W)	100.0					1
10 (E)	100.0					1
105	100.0					1
57	100.0					1

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605	100.0					1
91	100.0					1
10	56.7	43.3				1
57	100.0					1
101/134	100.0					1
5 (N)	60.0	40.0				1
5 (S)	100.0					1
60	100.0					1

Ambitious Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
10	100.0					1
91/215	100.0					1
101	43.3	56.7				2
215	100.0					1
55	100.0					1
210	100.0					1
91	100.0					1
14	56.2	43.8				1
101	50.0	50.0				1
22	100.0					1

Ambitious Network — Market Penetration = 15%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)	4.0	44.0	52.0			3
405 (S)	34.0	62.0	4.0			2
5 (N)	75.0		8.3	16.7		1
5 (S)		13.3	8.9	77.8		4
110	100.0					1
10 (W)	42.9	57.1				2
10 (E)		68.8	31.2			2
105	75.0	25.0				1
57	100.0					1

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605	51.7	48.3				1
91		40.6	59.4			3
10		34.5	24.1	41.4		2
57	100.0					1
101/134	64.7		35.3			1
5 (N)	30.0	30.0		40.0		3*
5 (S)	21.4	78.6				2
60	15.8	84.2				2

Ambitious Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
10	38.9	61.1				2
91/215	26.3	52.6	21.1			2
101	87.1	12.9				1
215	100.0					1
55	100.0					1
210	46.8	53.2				2
91	100.0					1
14			56.3	18.7	25.0	3
101			55.0	45.0		3
22	100.0					1

Ambitious Network — Market Penetration = 30%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)			11.5	44.3	46.2	4'
405 (S)		23.8	42.9	26.2	7.1	3"
5 (N)	12.5	66.7			20.8	2
5 (S)			8.7	4.3	87.0	2
110	54.1	45.9				1
10 (W)	23.5	29.4	35.3	11.8		2*
10 (E)					100.0	4
105		81.0	19.0			2
57		57.1	42.9			2

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605	37.9	13.8	41.4	6.9		2*
91			16.7	60.0	23.3	4
10			26.7	10.0	63.3	All
57		100.0				2
101/134		66.7			33.3	2
5 (N)	20.0	10.0	30.0		40.0	4*
5 (S)		25.0	58.3		16.7	3
60		7.5	73.6	18.9		

Ambitious Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
10		72.2	27.8			2
91/215		52.9	29.4	17.7		2
101		16.1	16.1	9.7	58.1	All
215	100.0					1
55	40.0	30.0	30.0			1*
210	2.2	48.9	48.9			2*
91		100.0				2
14			25.0	37.5	37.5	4*
101					100.0	All
22		100.0				2

Ambitious Network | Market Penetration = 45%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)					100.0	All
405 (S)			6.2	46.9	46.9	4*
5 (N)		23.1	46.1	7.7	23.1	3*
5 (S)				4.9	95.1	All
110 (W)		45.4	36.4	18.2		2*
10 (E)		17.6	47.1	23.5	100.0 11.8	3*
						All
105			52.4	23.8	23.8	3
57			30.8	30.8	38.4	4

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605		42.3	7.7		50.0	All
91					100.0	All
10				29.6	70.4	All
57						2
101/134		100.0 61.1	5.6		33.3	2
5 (N)		20.0	20.0	20.0	40.0	All*
5 (S)		7.7	15.4	46.1	30.8	4*
60				64.7	35.3	4

Ambitious Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
10						3
91/215		5.5	66.7 58.8	27.8 41.2		3
101		3.2	22.6	9.7	64.5	All
215	37.5	62.5				2
55		27.3	36.3	9.1	27.3	3*
210		48.9	12.8	38.3		2*
91			46.2	53.8		4
14			25.0	37.5	37.5	All*
101					100.0	All
22			100.0			3

RPEV

Ambitious Network | Market Penetration = 60%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)					100.0	All
405 (S)				2.2	97.8	All
5 (N)			15.4	46.1	38.5	All*
5 (S)					100.0	All
110		12.9	35.5	32.3	19.3	4*
10 (W)		18.7	18.7	6.3	56.3	All
10 (E)					100.0	All
105				15.8	84.2	All
57				7.7	92.3	All

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605			40.7	11.1	48.2	4*
91					100.0	All
10				10.7	89.3	All
57			100.0			3
101/134			57.9	10.5	31.6	3
5 (N)		20.0	10.0	30.0	40.0	All*
5 (S)			14.3	14.3	71.4	All
60				19.6	80.4	All

Ambitious Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
10			29.4	41.2	29.4	4*
91/215			7.2	57.1	35.7	4
101			25.9	11.1	63.0	All
215	25.0		75.0			3
55			10.0	30.0	60.0	All
210		33.3	15.6	15.6	35.5	4*
91				41.7	58.3	All
14			25.0	31.3	43.7	All*
101					100.0	All
22				100.0		4

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Modest Network — Market Penetration = 5%

Freeway Sections	Distribution of Flume Counts (%) 1	2		4	5	# of Lanes Recommended
405 (N)	100.0					1
405 (S)	100.0					1
5 (N)	100.0					1
5 (S)	100.0					1
110	100.0					1
10 (W)	100.0					1
10 (E)	100.0					1
105	100.0					1
57	100.0					1

Modest Network — Market Penetration = 15%

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)	84.6	15.4				1
405 (S)	94.1	5.9				1
5 (N)	90.9	9.1				1
5 (S)	26.2	64.3	9.5			2
110	100.0					1
10 (W)	100.0					1
10 (E)	100.0					1
'105	100.0					1
57	100.0					1

Modest Network — Market Penetration = 30%

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)	84.0	16.0				1
405 (S)	9.1	90.9				2
5 (N)	63.7	22.7	13.6			1
5 (S)	27.9	62.8			9.3	2
110	73.3	26.7				1
10 (W)	35.3	64.7				2
10 (E)		83.3	16.7			2
105	13.0	87.0				2
57	35.7	64.3				2

Automation

Intermediate Network

Market Penetration = 5%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%)	# of Lanes Recommended
405 (N)	100.0	1
405 (S)	100.0	1
5 (N)	100.0	1
5 (S)	100.0	1
110	100.0	1
10 (W)	100.0	1
10 (E)	100.0	1
105	100.0	1
57	100.0	1

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%)	# of Lanes Recommended
605	100.0	1
91	100.0	1
10	100.0	1
57	100.0	1
101/134	100.0	1
5 (N)	100.0	1
5 (S)	100.0	1
60	100.0	1

Automation

Intermediate Network

Market Penetration = 15%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)	100.0					1
405 (S)						1
5 (N)	100.0 100.0					1
5 (S)	71.7	23.8				1
110	100.0					1
10 (W)	100.0					1
10 (E)	100.0					1
105	100.0					1
57	100.0					1

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605	100.0					1
91	100.0					1
10	100.0					1
57	100.0					1
101/134	100.0					1
5 (N)	100.0					1
5 (S)	100.0					1
60	100.0					1

Automation

Intermediate Network

Market Penetration = 30%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)	12.5	87.5				2
405 (S)	53.8	46.2				1
5 (N)	72.7	27.3				1
5 (S)	9.1	61.4	22.7	6.8		2
110	80.1	19.9				1
10 (W)	52.6	47.4				1
10 (E)		100.0				2
105	79.2	20.8				1
57	57.1	42.9				1

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605	57.1	42.9				1
91	20.7	79.3				2
10	27.6	72.4				2
57						1
101/134	100.0 57.1	42.9				1
5 (N)	60.0	40.0				1
5 (S)	76.9	23.1				1
60	79.6	20.4				1

Automation

Intermediate Network

Market Penetration = 45%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)						2
405 (S)		90.6 55.6	44.4 9.4			2
5 (N)	44.0	42.0	12.0			2*
5 (S)		13.9	79.1	7.0		3
110	57.1	42.9				1
10 (W)	47.1	47.1	5.8			1*
10 (E)		43.4	56.3			3
105	16.7	83.3				2
57	7.1	92.9				2

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605	42.9	57.1				2
91	93.3	6.7				1
10	6.9	55.2	37.9			2
57	100.0					1
101/134	66.7		33.3			1
5 (N)	50.0	10.0	40.0			1
5 (S)	28.6	57.1	14.3			2
60	3.6	96.4				2

Automation

Ambitious Network

Market Penetration = 5%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)	100.0					1
405 (S)	100.0					1
5 (N)						1
5 (S)	100.0 100.0					1
110	100.0					1
10 (W)	100.0					1
10 (E)	100.0					1
105	100.0					1
57	100.0					1

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605	100.0					1
91	100.0					1
10	100.0					1
57	100.0					1
101/134	100.0					1
5 (N)	100.0					1
5 (S)	100.0					1
60	100.0					1

Ambitious Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
10	100.0					1
91/215	100.0					1
101	100.0					1
215	100.0					1
55	100.0					1
210	100.0					1
91	100.0					1
14	100.0					1
101	100.0					1
22	100.0					1

Automation

Ambitious Network

Market Penetration = 15%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)	90.0	10.0				1
405 (S)	100.0					1
5 (N)	80.9	11.1				1
5 (S)	21.3	78.7				2
110	100.0					1
10 (W)	100.0					1
10 (E)	100.0					1
105	100.0					1
57	100.0					1

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605	100.0					1
91	100.0					1
10	56.7	43.3				1
57	100.0					1
101/134	100.0					1
5 (N)	60.0	40.0				1
5 (S)	100.0					1
60	100.0					1

Ambitious Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
10						1
91/215	100.0	100.0				1
101	41.9	58.1				2
215	100.0					1
55	100.0					1
210	100.0					1
91	100.0					1
14	56.3	43.7				1
101	47.6	52.4				2
22	100.0					1

Automation

Ambitious Network

Market Penetration = 30%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)		100.0				2
405 (S)	68.5	31.5				1
5 (N)	80.8	19.2				1
5 (S)	8.5	55.3	36.2			2
110	100.0					1
10 (W)	83.3	16.7				1
10 (E)	100.0					1
105	100.0					1
57	100.0					1

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605	100.0					1
91	16.1	83.9				2
10	25.8	74.2				2
57	100.0					1
101/134	68.4	31.6				1
5 (N)	60.0		40.0			1
5 (S)	71.4	28.6				1
60	87.8	12.2				1

Ambitious Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
10						1
91/215	100.0 83.3	16.7				1
101	32.3	32.3	35.4			2”
215	100.0					1
55	100.0					1
210	100.0					1
91	100.0					1
14	25.0	50.0	25.0			2
101		73.7	26.3			2
22	100.0					1

Ambitious Network | Market Penetration = 45%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)		60.0	40.0			2
405 (S)		94.0	6.0			2
5 (N)	66.6	16.7	16.7			1
5 (S)		15.9	84.1			3
110	81.1	18.9				1
10 (W)	50.0	50.0				1
10 (E)		100.0				2
105	47.8	52.2				2
57	28.6	71.4				2

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605	51.9	48.1				1
91		93.9	6.1			2
10		59.3	40.7			2
57						1
101/134	100.0	68.4	31.6			1
5 (N)	40.0	20.0		40.0		2*
5 (S)	28.6	57.1	14.3			2
60	7.1	92.9				2

Ambitious Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
10	72.2	27.8				1
91/215	61.1	38.9				1
101	26.7	16.7	46.6	10.0		2*
215	100.0					1
55	46.2	46.2	7.6			1*
210	59.12	40.9				1
91	42.9	57.1				2
14	25.0	50.0	25.0			2
101		33.3	42.9	23.8		3*
22	100.0					1

Automation

Ambitious Network

Market Penetration = 60%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)		7.7	76.9	15.4		3
405 (S)		70.8	25.0	4.2		2
5 (N)	15.8	84.2				2
5 (S)		9.1	27.3	56.8	6.8	4
110	50.0	50.0				1
10 (W)		70.0	30.0			2
10 (E)			100.0			3
105		87.0	13.0			2
57		71.4	28.6			2

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605	40.7	48.2	11.1			1
91		53.6	46.4			2
10		35.7	57.1	7.2		3
57	100.0					1
101/134	55.6	11.1	33.3			1
5 (N)	30.0	30.0	40.0			2*
5 (S)	14.3	57.1	21.4	7.2		2
60		77.8	22.2			2

Ambitious Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
10	27.8	72.2				2
91/215	5.9	94.1				2
101	22.6	19.3	25.8	32.3		2*
215	100.0					1
55	10.0	50.0	40.0			2
210	51.1	46.8	2.1			1
91		100.0				2
14	25.0	37.5	37.5			2”
101				66.7	33.3	4
22		100.0				2

COMBINATION

Modest Network

Market Penetration = 5%

Freeway Sections	Distribution of Volume Count; (%) 1	2	3	4	# of Lanes Recommended
405 (N)	100.0				1
405 (S)	100.0				1
5 (N)	100.0				1
5 (S)	100.0				1
110	100.0				1
10 (W)	100.0				1
10 (E)	100.0				1
105	100.0				1
57	100.0				1

Modest Network

Market Penetration = 15%

Freeway Sections	Distribution of Volume Count; (%) 1	2	3	4	# of Lanes Recommended
405 (N)	80.6	19.4			1
405 (S)	93.1	6.9			1
5 (N)	87.0	13.0			1
5 (S)	12.8	80.8	6.4		2
110	100.0				1
10 (W)	100.0				1
10 (E)	100.0				1
105	100.0				1
57	100.0				1

Modest Network

Market Penetration = 30%

Freeway Sections	Distribution of Volume Count; (%) 1	2	3	4	# of Lanes Recommended
405 (N)	84.0	16.0			1
405 (S)	9.1	90.9			2
5 (N)	63.7	22.7	13.6		1
5 (S)	27.9	62.8		9.3	2
110	73.3	26.7			1
10 (W)	35.3	64.7			2
10 (E)		83.3	16.7		2
105	13.0	87.0			2
57	35.7	64.3			2

Combination

Intermediate Network

Market Penetration = 5%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)	100.0					1
405 (S)	100.0					1
5 (N)	100.0'					1
5 (S)	100.0					1
110	100.0					1
10 (W)	100.0					1
10 (E)	100.0					1
105	100.0					1
57	100.0					1

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (5%) 1	2	3	4	# of Lanes Recommended
605	100.0				1
91	100.0				1
10	100.0				1
57	100.0				1
101/134	100.0				1
5 (N)	100.0				1
5 (S)	100.0				1
60	100.0				1

Combination

Market Penetration = 15%

Modest Network

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)	100.0					1
405 (S)	100.0,					1
5 (N)	100.0					1
5 (S)	12.8	87.2				2
110	100.0					1
10 (W)	100.0					1
10 (E)	100.0					1
105	100.0					1
57	100.0					1

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605	100.0					1
91	100.0					1
10	51.5	48.5				1
57	100.0					1
101/134	100.0					1
5 (N)	60.0	40.0				1
5 (S)	100.0					1
60	100.0					1

Combination

Intermediate Network Market Penetration = 30%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)		100.0				2
405 (S)	40.7	55.6	3.7			2
5 (N)	76.9	23.1				1
5 (S)		28.3	71.7			3
110	100.0					1
10 (W)	64.7	35.3				1
10 (E)		100.0				2
105	80.0	20.0				1
57	57.1	42.9				1

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605	50.0	50.0				1
91		100.0				2
10	25.8	74.2				2
57	100.0					1
101/134	66.7	33.3				1
5 (N)	60.0	40.0				1
5 (S)	35.7	64.3				2
60	59.6	40.4				1

Combination

Intermediate Network

Market Penetration = 45%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)		82.1	17.9	,		2
			8.0			2
405 (N)		92.0	14.3			1
5 (S)	53.6 20.0 32.1		46.5	39.5		3*
110	52.8	47.2				1
10 (W)	50.0	50.0				1
10 (E)	53.8	46.2				1
105	13.0	87.0				2
57		100.0				2

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605	50.0	50.0				1
91		77.8	22.2			2
10	12.9	45.2	41.9			2*
57	100.0					1
101/134	66.7	33.3				1
5 (N)	40.0	20.0	40.0			1*
5 (S)	20.0	66.7	13.3			2
60		100.0				2

Combination

Ambitious Network

Market Penetration = 5%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)	100.0					1
405 (S)						1
5 (N)	100.0 100.0					1
5 (S)	100.0					1
110	100.0					1
10 (W)	100.0					1
10 (E)	100.0					1
105	100.0					1
57	100.0					1

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605	100.0					1
91	100.0					1
10	100.0					1
57						1
101/134	100.0 100.0					
5 (N)	100.0					1
5 (S)	100.0					1
60	100.0					1

Ambitious Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
10						1
91/215	100.0 100.0					1
101	100.0					1
215	100.0					1
55	100.0					1
210	100.0					1
91	100.0					1
14						1
101	100.0 100.0					1
22	100.0					1

Combination

Ambitious Network

Market Penetration = 15%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)	100.0					1
405 (S)						1
5 (N)	100.0 83.3 16.7					1
5 (S)	22.2	77.8				2
110	100.0					1
1 0 (W)	100.0					1
10 (E)	100.0					1
105	100.0					1
57	100.0					1

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605	100.0					1
10	100.0					1
57	100.0 58.6 41.4					1
						1
101/134	100.0					1
5 (N)	60.0	40.0				1
5 (S)	100.0					1
60	100.0					1

Ambitious Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
10						1
91/215	100.0 100.0					1
101	100.0					1
215	100.0					1
55	100.0					1
210	100.0					1
91	100.0					1
14						1
101	75.0 55.0 25.0 45.0					1
22	100.0					1

Combination

Ambitious Network

Market Penetration = 30%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)	11.5	88.5				2
405 (S)	74.1	25.9				1
5 (N)						1
5 (S)	81.5 / 9.8	18.5 / 53.7	36.6			2
110	100.0					1
10 (W)	88.2	11.8				1
10 (E)		100.0				2
105	100.0					1
57	100.0					1

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605	93.1	6.9				1
91	16.7	83.3				2
10	26.7	73.3				2
57	100.0					1
101/134	66.7	33.3				1
5 (N)	60.0		40.0			1
5 (S)	83.3	16.7				1
60	81.1	18.9				1

Ambitious Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
10	100.0					1
91/215	82.4	17.6				1
101	32.3	35.4	32.3			1”
215	100.0					1
55	100.0					1
210	100.0					1
91	100.0					1
14	25.0	50.0	25.0			1*
101		81.3	18.7			2
22	100.0					1

Combination

Ambitious Network

Market Penetration = 45%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)						2
405 (S)	6.1	83.7 65.2	34.8 10.2			2
5 (N)	73.1	15.4	11.5	,		1
5 (S)		7.7	69.2	23.1		3
110	81.8	18.2				1
10 (W)	64.7	35.3				1
10 (E)		92.3	7.7			2
105	52.4	47.6				1
57	30.8	69.2				2

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605	50.0	50.0				1
			6.9			2
91 10		93.1 63.0	37.0			2
57	100.0					1
101/134	66.7		33.3			1
5 (N)	40.0	20.0		40.0		2*
5 (S)	23.1	61.5	15.4			2
60		100.0				2

Ambitious Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
10						1
91/215	72.2 58.8	27.8 41.2				1
101	25.8	16.1	45.2	12.9		2 ’
215	100.0					1
55	63.6	36.4				1
210	61.7	38.3				1
91	46.2	53.8				2
14	25.0	50.0	25.0			2
101		35.3	41.2	23.5		2*
22	100.0					1

Combination

Ambitious Network

Market Penetration = 60%

Modest Network Sections

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
405 (N)						3
405 (S)		68.2 8.3	75.0 27.3	16.7 4.5		2
5 (N)	15.4	57.7	11.5	15,. 5		2
5 (S)		9.5	35.7	38.1	16.7	3*
110 (W)	48.4	51.6				2
10 (E)	37.5'	43.8	100.0 18.7			1*
						3
105		68.4	31.6			2
57		69.2	30.8			2

Intermediate Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
605	40.7	40.7	18.6			1*
91		48.3	51.7			3
10		28.6	64.3	7.1		3
57	100.0					1
101/134	57.9	10.5	31.6			1
5 (N)						2*
5 (S)	30.0 14.3	30.0 57.1	40.0 21.4	7.2		2
60		76.5	23.5			2

Ambitious Network Additions to Modest Network

Freeway Sections	Distribution of Volume Counts (%) 1	2	3	4	5	# of Lanes Recommended
10	29.4	70.6				2
91/215	7.1	92.9				2
101	25.9	33.4	29.6	11.1		2*
215	100.0					1
55	10.0	40.0	50.0			3
210	48.9	51.1				2
91		100.0				2
14	25.0	37.5	37.5			2*
101			64.7	35.3		3
22		100.0				2

Appendix H

Number of Lanes Recommended

Alternative Approaches

RPEV

Intermediate Network

Market Penetration = 5%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
405 (N)	1	1	1
405 (S)	1	1	1
5 (N)	1	0	1
5 (S)	2	1	2
110	0	0	1
10 (W)	1	0	1
10 (E)	1	1	1
105	1	0	1
57	0	0	1

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
605	1	0	1
91	1	1	1
10	1	1	2
57	0	0	1
101/134	0	0	1
5 (N)	1	1	1
5 (S)	1	1	1
60	1	1	1

Intermediate Network | Market Penetration = 15%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
405 (N)	2	2	1
405 (S)	3	2	2
5 (N)	3	1	1
5 (S)	All	4	All
110	1	0	1
10 (W)	2	1	2
10 (E)	2	2	3
105	2	1	1
57	1	1	1

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
605	2	1	2
91	3	2	3
10	4	3	3*
57	1	1	1
101/134	1	1	1
5 (N)	3	2	2*
5 (S)	2	2	2
60	2	2	2

RPEV

Intermediate Network

Market Penetration = 30%

Modest Network Sections

Freeway Section	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
405 (N)	All	4	4
405 (S)	All	3	4
5 (N)	All	3	2
5 (S)	All	All	All
110	2	1	2
10 (W)	4	2	2*
10 (E)	4	4	All
105	4	2	3
57	3	3	3

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
605	4	2	2
91	All	4	4
10	All	4	All
57	2	2	2
101/134	3	2	2*
5 (N)	All	3	3*
5 (S)	All	3	3*
60	4	3	3

RPEV

Intermediate Network

Market Penetration = 45%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method		
	Maximum	Average	Distributional
405 (N)	All	All	All
405 (S)	All	All	All
5 (N)	All	4	3
5 (S)	All	All	All
110	4	2	2*
10 (W)	All	3	3"
10 (E)	All	All	All
105	All	4	4*
57	All	4	4*

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method		
	Maximum	Average	Distributional
605	All	3	3*
91	All	All	All
10	All	All	All
57	2	2	3
101/134	All	3	2
5 (N)	All	4	4*
5 (S)	All	4	All
60	All	4	All

RPEV

Market Penetration = 5%

Ambitious Network

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
405 (N)	1	1	1
405 (S)	1	0	1
5 (N)	1	0	1
5 (S)	1	1	2
110	0	0	1
10 (W)	0	0	1
10 (E)	1	1	1
105	0	0	1
57	0	0	1

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method: Maxiumum	Average	Distributional
605	0	0	1
91	1	1	1
10	1	1	1
57	0	0	1
101/134	1	0	1
5 (N)	2	1	1
5 (S)	1	0	1
60	1	0	1

Ambitious Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
10	0	0	1
91/215	1	0	1
101	1	1	2
215	0	0	1
55	0	1	1
210	0	0	1
91	0	0	1
14	1	1	1
101	1	1	1*
22	0	0	1

RPEV

Ambitious Network — Market Penetration = 15%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
405 (N)	3	2	3
405 (S)	3	1	2
5 (N)	3	31	41
5 (S)			
110	0	0	1
10 (W)	1	1	2
10 (E)	2	1	2
105	1	1	1
57	1		1

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
605	1	1	1
91	2	2	3
10	3	2	2*
57	0	1	1
101/134	2	3	1
5 (N)	All		3'
5 (S)	2	1	2
60	2	1	2

Ambitious Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
10	1	1	2
91/215	2	1	2
101	4	3	1
215	0	0	1
55	1	0	1
210	1	1	2
91	1	1	1
14	4	3	2
101	4	3	3
22	1	1	1

RPEV

Ambitious Network — Market Penetration = 30%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
405 (N)	All	4	4*
405 (S)	All	3	3*
5	All	2	2
5 I:]	All	2	All
110	1	1	1
10 (W)	3	2	2*
10 (E)	4	4	4
105	3	2	2
57	3	2	2

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
605	3	2	2*
91	4	4	4
10	All	4	All
57	1	1	2
101/134	4	2	2
5 (N)	All	4	4*
5 (S)	4	2	3
60	3	3	3

Ambitious Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
10			
91/215	23	22	22
101	All	4	All
215	1	1	1
15	3	1	1*
210	3	2	2*
91	2	2	2
14	All	4	4*
101	All	All	All
22	2	1	2

RPEV

Ambitious Network — Market Penetration = 45%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
405 (N)	All	All	All
405 (S)	All	4	4*
5 (N)	All	3	3*
5 (S)	All	All	All
110	3	2	2*
10 (W)	All	3	3*
10 (E)	All	All	All
105	All	3	3
57	All	4	4*

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
605	All	3	All
91	All	All	All
10	All	All	All
57	2	2	2
101/134	All	3	2
5 (N)	All	All	All*
5 (S)	All	4	4*
60	All	4	4

Ambitious Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
10	3	3	3
91/215	4	3	3
101	All	All	All
215	2	1	2
55	All	3	3”
210	4	2	2”
91	4	3	3*
14	All	All	All*
101	All	All	All
22	3	2	3

RPEV

Ambitious Network

Market Penetration = 60%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
405 (N)	All	All	All
405 (S)	All	All	All
5 (N)	All	All	All*
5 (S)	All	All	All
110	All	3	3*
10 (W)	All	4	All
10 (E)	All	All	All
105	All	All	All
57	All	All	All

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
605	All	4	4*
91	All	All	All
10	All	All	All
57	2	2	3
101/134	All	All	3
5 (N)	All	All	All*
5 (S)	All	All	All
60	All	All	All

Ambitious Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
10	4	4	4*
91/215	All	4	3
101	All	All	All
215	3	2	3
55	All	All	All
210	All	3	3*
91	All	4	All
14	All	All	All*
101	All	All	All
22	4	3	4

Automation

Intermediate Network

Market Penetration = 5%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method		
	Maximum	Average	Distributional
405 (N)	0	0	1
405 (S)	0	0	1
5 (N)	0	0	1
5 (S)	1	0	1
110	0	0	1
10 (W)	0	0	1
10 (E)	0	0	1
105	0	0	1
57	0	0	1

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method		
	Maximum	Average	Distributional
605	0	0	1
91	0	0	1
10	0	0	1
57	0	0	1
101/134	0	0	1
5 (N)	0	0	1
5 (S)	0	0	1
60	0	0	1

Intermediate Network

Market Penetration = 15%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method		
	Maximum	Average	Distributional
405 (N)	1	1	1
405 (S)	1	1	1
5 (N)		0	1
5 (S)	12	1	1
110	0	0	1
10 (W)	0	0	1
10 (E)	1	1	1
105	0	0	1
57	0	0	1

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method		
	Maximum	Average	Distributional
605	1	0	1
91	1	1	1
10	1	1	1
57	0	0	1
101/134	1	0	1
5 (N)	1	0	1
5 (S)	1	0	1
60	1	0	1

Automation

Intermediate Network

Market Penetration = 30%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
405 (N)	2	1	2
405 (S)	2	1	1
5 (N)	2	1	1
5 (S)	2	2	2
110	1	1	1
10 (W)	1	1	1
10 (E)	1	1	2
105	1	1	1
57	1	1	1

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
605	1	1	1
91	2	1	2
10	2	1	2
57	0	0	1
101/134	1	1	1
5 (N)	2	1	1
5 (S)	1	1	1
60	1	1	1

Automation

Intermediate Network

Market Penetration = 45%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
405 (N)	2	2	2
405 (S)	3	2	2
5 (N)	3	2	2*
5 (S)	3	3	3
110	2	1	1
10 (W)	2	1	1*
10 (E)	2	1	3
105	2	1	2
57	2		2

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
605	2	1	2
91	2	2	1
10	3	2	2
57	1	1	1
101/134	2	1	1
5 (N)	3	2	1
5 (S)	2	1	2
60	2	1	2

Automation

Ambitious Network — Market Penetration = 5%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
405 (N)	0	0	1
405 (S)	0	0	1
			1
5 (S)	0	0	1
			1
110 (W)	0	0	1
10 (E)	0	0	1
105	0	0	1
57	0	0	1

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
605	0	0	1
91	0	0	1
10			1
57	0	0	
101/134	00	00	11
5 (N)	0	0	1
5 (S)	0	0	1
60	0	0	1

Ambitious Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
10			
91/215	00	00	11
101	0	0	1
215	0	0	1
55	0	0	1
210	0	0	1
14	0	0	1
101	00	00	1
			1
22	0	0	1

Automation

Ambitious Network

Market Penetration = 15%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
405 (N)	1	1	1
405 (S)		0	1
5 (N)	1	0	1
5 (S)	1	1	2
110	0	0	1
10 (W)	0	0	1
10 (E)	1	1	1
105	0	0	1
57	0	0	1

Intenediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
605	0	0	1
	1		1
910	1	1	1
57	0	0	1
101/134	1	0	1
5 (N)			
5 (S)	21	01	11
60	1	0	1

Ambitious Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
10	0	0	1
91/215	1	0	1
101	1	1	1
215	1	1	1
55	0	0	1
210	0	0	1
91	0	0	1
14	1	1	1
101	1	1	2
22	0	0	1

Automation

Ambitious Network

Market Penetration = 30%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
405 (N)	2	1	2
405 (N)	2	1	1
5 (S)	23	21	21
110	0	0	1
10 (W)	1	1	1
10 (E)	1	1	1
105	1	1	1
57	1	1	1

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
	1	1	
605	1	1	1
91			2
10	2	1	2
57	0	0	1
101/134	1	1	1
5 (N)	3	1	1
5 (S)	1	1	1
60	1	1	1

Ambitious Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
10			
91/215	11	11	11
101	2	2	2*
215	0	0	1
55	1	1	1
210	1	1	1
91	1	1	1
14	2	1	2
101	2	2	2
22	1	0	1

Automation

Ambitious Network

Market Penetration = 45%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
405 (N)	3	2	2
405 (S)	3	1	2
5 (N)	3	1	1
5 (S)	4	2	3
110	1	1	1
10 (W)	2	1	1*
10 (E)	2	2	2
105	2	1	2
57	2	1	2

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
605	2	1	1
91	2	2	1
57	2	2	1
101/134	11	1	1
		1	1
5 (N)	3	2	2*
5 (S)	2	1	2
60	2	1	2

Ambitious Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
10	1	1	1
91/215	1	1	1
101	3	2	2*
215	1	0	1
55	2	1	1*
210	1	1	1
91	1	1	2
14	3	1	2
101	3	3	3*
22	1	1	1

Automation

Ambitious Network	Market Penetration = 60%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
405 (N)	3	3	3
405 (S)			
5 (N)	34	22	22
5 (S)	All	3	4
110	2	0	1*
10 (W)	2	1	1*
10 (E)	3	2	2*
			2
105/103	2	1/2	2

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
	2		
605	3	1	1*
91		2	2
10	3	2	3
57	1	1	1
101/134	3	1	1
5 (N)	4	2	2*
5 (S)	3	2	2
60	2	2	2

Ambitious Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
10			
91/215	21	11	22
101	4	2	2*
215	1	1	1
55	3	2	2
210	2	1	1*
91	2	1	2
14	3	2	2*
101	4	3	4
22	1	1	2

Combination

Intermediate Network

Market Penetration = 5%

Modest Network Sections

Freeway Sections	# of Lanes **Recommended** by Volume Method Maximum	Average	Distributional
405 (N)	0	0	1
405 (S)	0	0	1
5 (N)	0	0	1
5 (S)	1		1
110	0	0	1
10 (W)	0	0	1
10 (E)	0	0	1
105	0	0	1
57	0	0	1

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes **Recommended** by Volume Method Maximum	Average	Distributional
605	0	0	1
91	0	0	1
10	0	0	1
57	0	0	1
101/134	0	0	1
			1
5 (S)	0	0	1
60	0	0	1

Combination

Intermediate Network — Market Penetration = 15%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
405 (N)	1	1	1
405 (S)	1	1	1
5 (N)	1	0	1
5 (S)	2	1	2
110	0	0	1
10 (W)	1	0	1
10 (E)	1	1	1
105	1	0	1
57	0	0	1

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
605	1	1	1
91	1	1	1
10			1
57	0	0	1
101/134	0	0	
5 (N)	1		1
5 (S)	1	1	1
60	1	1	1

Combination

Intermediate Network

Market Penetration = 30%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
405 (N)	2	1	2
405 (S)	2	1	2
5 (N)	2	1	1
5 (S)	3	2	3
110	1	0	1
10 (W)	1	1	1
10 (E)	1	1	2
105	1	1	1
57	1	1	1

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
605	1	1	1*
91	2	1	2
10	2	1	2
57	1	1	1
101/134	1	1	1
5 (N)	2	1	1
5 (S)	2	1	2
60	1	1	1

Combination

Intermediate Network

Market Penetration = 45%

Modest Network Sections

Freeway Sections	# of Lanes Recormnended by Volume Method Maximum	Average	Distributional
405 (N)	2	2	2
405 (S)	3	2	2
5 (N)	2	1	1
5 (S)	4	3	3*
110	1	1	1
10 (W)	2	1	1'
10 (E)	2	2	1
105	2	1	2
57	2	1	2

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
605	2	1	1*
91	2	2	2
10	3	2	2*
57	1	1	1
101/134	2	1	1
5 (N)	2	1	1*
5 (S)	3	1	2
60	2	1	2

Combination

Ambitious Network

Market Penetration = 5%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
405 (S)	0	0	1
5 (N)	0	0	1
5 (S)	0	0	1
110	0	0	1
10 (W)	0	0	1
10 (E)	0	0	1
105	0	0	1
57	0	0	1

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
605	0	0	1
91	0	0	1
10	0	0	1
57	0	0	1
101/134	0	0	1
5 (N)	1	0	1
5 (S)	0	0	1
60	0	0	1

Ambitious Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
10	0	0	1
91/215	0	0	1
101	0	0	1
215	0	0	1
55	0	0	1
210	0	0	1
91	0	0	1
14	0	0	1
101	0	0	1
22	0	0	1

Combination

Ambitious Network

Market Penetration = 15%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
405 (N)	1	1	1
405 (S)	1	0	1
5 (N)	1	0	1
5 (S)	1	1	2
110	0	0	1
10 (W)	0	0	1
10 (E)	1	1	1
105	0	0	1
57	0	0	1

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
605	0	0	1
91	1	1	1
10	1	1	1
57	0	0	1
101/134	1	0	1
5 (N)	2	1	1
5 (S)	1	0	1
60	1	0	1

Ambitious Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
10	0	0	1
91/215	1	0	1
101	1	1	1
215	0	0	1
55	0	0	1
210	0	0	1
			1
91 14	0 1	0 1	1
101	1	1	1
22	0	0	1

Combination

Ambitious Network — Market Penetration = 30%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
405 (N)	2	1	2
405 (N)	2	1	1
5 (S)	23	11	21
110	0	0	1
10 (W)	1	1	1
10 (E)	1	1	1
105	1	1	1
57	1	1	1

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
		1	
605	1	1	1
91	1		2
10	2	1	2
57	0	0	1
101/134	1	1	1
5 (N)	3	1	1
5 (S)	1	1	1
60	1	1	1

Ambitious Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
10			1
91/215	1	11	1
101	2	1	1*
215	0	0	1
55	1	0	1
			1
290 91	1	1	1
14	2	1	2
101	2	2	1
22	1	0	1

Combination

Ambitious Network

Market Penetration = 45%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
405 (N)	3	2	2
405 (S)	3	1	2
5 (N)	3	1	1
5 (S)	4	2	3
110	1	1	1
10 (W)	2	1	1
10 (E)	2	2	2
105	2	1	1
57	2	1	2

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
605	2	1	1*
91	2	2	2
10	2	2	2
57	1	1	1
101/134	2	1	1
5 (N)	3	2	2*
5 (S)	2	1	2
60	2	1	2

Ambitious Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method: Maximum	Average	Distributional
10	1	1	1
91/215	3	11	1
101			2*
215	1	0	i
55	2	1	1
210	1	1	1
91	1	1	2
14	3	2	2
101	3	2	2*
22	1	1	1

Combination

Ambitious Network

Market Penetration = 60%

Modest Network Sections

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
405 (N)	3	3	3*
405 (S)	3	2	2
5 (N)	4	2	2
5 (S)	All	3	3*
110	2	1	2
10 (W)	2	1	1*
10 (E)	3	2	3
105	2	2	2
57	2	2	2

Intermediate Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
605	2	1	1*
91	3	2	3
10	3	2	3
57	1	1	1
101/134	3	2	1
5 (N)	4	2	2*
5 (S)	3	2	2
60	2	2	2

Ambitious Network Additions to Modest Network

Freeway Sections	# of Lanes Recommended by Volume Method Maximum	Average	Distributional
10	1	1	2
91/215	2	1	2
101	4	2	2*
215	1	1	1
55	3	2	3
		1	2
210 / 91	2 / 2	1	2
14	3	2	2*
101	4	3	3
22	1	1	2

Appendix I

RPEV Scenario Description

RPEV Scenario Network

The network detailed below is the RPEV scenario network for the Highway Electrification and Automation project. For each freeway section the number of lane miles for one lane, one direction as well as total lane miles (number of lanes multiplied by the miles per lane) are indicated. The number of lanes on each freeway section was determined via the distributional lane selection methodology for a 15% RPEV market penetration on the modest network. Additions to the modest network were incorporated in the RPEV scenario network based on scrutiny of the alternative lane recommendations for each market penetration and network size, and comments received from project staff and the Project Advisory Group (PAG). The additions are: (a) the 10 (E) fromw the 605 to the 15, (b) the 101 from the 23 to the 405, and (c) the 91 from the 57 to the 15.

In the RPEV scenario network map that is attached, the number of lanes in each direction to which the technology will be applied is given as green for three lanes, blue for two lanes and red for one lane. Also attached is a detailed description of the specific freeway sections to which the RPEV technology will be applied. The number of lane miles (1 lane, 1 direction), number of lanes (1 direction), and the total number of lane miles are presented for each of the selected RPEV freeway sections.

The RPEV lanes are modeled as a separate facility from the remaining mixed flow lanes in the analysis. In the trip assignment phase of the modeling process RPEV trips are given priority to use the RPEV lane/s. Two trip assignments are modeled for the RPEV scenario. First, the RPEVs are given exclusive usage of the RPEV facility to complete their AM peak travel provided that such travel occurs on the freeway sections that have been equipped with the roadway power. In this assignment ICEVs are assigned to only the remaining mixed flow lanes of the freeway sections equipped with roadway power.

Since the RPEV technology does not preclude ICEVs from traveling on the roadway powered facility, in thesecond model assignment it is assumed that both RPEVs and ICEVs may use the powered roadway. In this assignment the RPEV trips are assigned first to the highway system and the remaining trips are assigned second. Such prioritization was required for the available modeling procedure. Loading all trips regardless of technology classification would be preferable since such a procedure would more accurately portray actual driving patterns.

RPEV SCENARIO NETWORK

a

Total # Freeway Section	Description of Freeway Section	# of Lane Miles (1 lane, 1 dir.)	# of Lanes (1 dir.)	Lane Miles (2 dirs.)
405 (N)	Los Angeles, Jct. Rte. 5, Golden State Freeway to Long Beach, Jct. Rte. 19 Interchange	45.32	2	181.28
405 (S)	Long Beach, Jct. Rte. 19 Interchange to Jct. Rte. 5, San Diego Freeway	27.27	3	163.62
5 (N)	Sylmar, Jct. Rte. 405, San Diego Freeway to Los Angeles, Jct. Rte. 10, San Bernardino Freeway	23.15	2	92.60
5 (S)	Los Angeles, Jct. Rtes. 10, 60, and 101, East Los Angeles Interchange to Jct. Rte. 405, Begin Santa Ana Freeway	39.55	3	237.30
110	Pasadena, Jct. Rte. 248, Colorado Boulevard, to Wilmington, Jct. Rte. 1, Pacific Coast Highway Interchange	29.09	1	58.18
10 (W)	Santa Monica, Jct. Rtes. 1 and 2, Lincoln Boulevard, via Santa Monica Freeway to Los Angeles, Jct. Rte. 110, Harbor Freeway	12.68	1	25.36
10 (E)	Los Angeles, Jct. Rte. 110, Harbor Freeway to Jct. Rte. 15	43.37	2	173.48
105	Westchester, Jct. Rte. 1, Lincoln Boulevard to Norwalk, Jct. Rte. 605, San Gabriel River Freeway	18.81	2	75.24
57	Jct. Rtes. 5 and 22, Santa Ana/ Garden Grove Freeways to Diamond Bar, South Jct. 60, Pomona Freeway	16.24	2	64.96
101	Thousand Oaks, Jct. Rte. 23 South, Westlake Boulevard Interchange to Sherman Oaks, Jct. Rte. 405, San Diego Freeway	21.72	2	86.88

RPEV SCENARIO NETWORK (cont.)

Freeway Section	Description of Freeway Section	# of Lane Miles[a] (1 lane, 1 dir.)	# of Lanes (1 dir.)	Total # Lane Miles (2 dirs.)
91	Anaheim, Jct. Rte. 57, Orange Freeway to Jct. Rte. 15	20.33	2	81.32
Total RPEV Scenario Network Lane Miles				1,240.22

a = Source for number of lane miles is 1988 Traffic Volumes on the California State Highway System (Sacramento: State of California, 1988).

Appendix J

Automation Scenario Description

Automation Scenario Network

The network detailed below is the automation scenario network for the Highway Electrification and Automation project. For each freeway section the number of lane miles for one lane, one direction as well as total lane miles (number of lanes multiplied by the miles per lane) are indicated. The number of lanes on each freeway section was determined via the distributional lane selection methodology for a 45% automation market penetration on the ambitious network.

In the automation scenario network that is attached, the number of lanes in each direction to which the technology will be applied is given as green for three lanes, blue for two lanes, and red for one lane. The automation lanes are a separate facility from the remaining mixed flow lanes in this analysis.

For the trip assignment four model runs are examined. First, for the 45% automation market penetration, the automated trips are assigned after first loading the mixed flow trips to the highway system. Next, the same procedure was followed with additional access/egress ramps added to the 2025 highway system to determine if these additional facilities would smooth the traffic flow transitioning from automated lanes to major arterials. The procedure previously described was also performed for a 30% automation market penetration on the ambitious network with and without the addition of the special facility access/egress ramps to investigate the impacts that such changes would have on the degree of congestion throughout the overall 2025 highway 'system.

AUTOMATION SCENARIO NETWORK

Freeway Section	Description of Freeway Section	# of Lane Miles[a] (1 lane, 1 dir.)	# of Lanes (1 dir.)	Total # Lane Miles (2 dirs.)
405 (N)	Los Angeles, Jct. Rte. 5, Golden State Freeway to Long Beach, Jct. Rte. 19 Interchange	45.32	2	181.28
405 (S)	Long Beach, Jct. Rte. 19 Interchange to Jct. Rte. 5, San Diego Freeway	27.27	2	109.08
5 (N)	Santa Clarita, Jct. Rte. 126 West to Sylmar, Jct. Rte. 405, San Diego Freeway	13.88	2	55.52
5 (N)	Sylmar, Jct. Rte. 405, San Diego Freeway to Los Angeles, Jct. Rte. 10, San Bernardino Freeway	23.15	1	46.30
5 (S)	Los Angeles, Jct. Rtes. 10, 60, 101, East Los Angeles Interchange; Begin Golden State Freeway to Jct. Rte. 405, Begin Santa Ana Freeway	39.55	3	237.30
5 (S)	Jct. Rte. 405, Begin Santa Ana Freeway to San Diego-Orange County Line at Christianitos Road Interchange	21.30	2	85.20
110	Pasadena, Jct. Rte. 248, Colorado Boulevard to Wilmington, Jct. Rte. 1, Pacific Coast Highway Interchange	29.09	1	58.18
10 (W)	Santa Monica, Jct. Rtes. 1 and 2, Lincoln Boulevard, via Santa Monica Freeway to Los Angeles, Jct. 110, Harbor Freeway	12.68	1	25.36
10 (E)	Los Angeles, Jct. Rte. 110, Harbor Freeway to Jct. Rte. 15	43.37	2	173.48
10 (E)	Jct. Rte. 15 to Redlands, Jct. Rte. 38 North, Orange Street Interchange	20.96	1	41.92
105	Westchester, Jct. Rte. 1, Lincoln Boulevard to Norwalk, Jct. Rte. 605, San Gabriel Freeway	18.81	1	37.62

AUTOMATION SCENARIO NETWORK (cont.)

Freeway Section	Description of Freeway Section	# of Lane Miles[a] (1 lane, 1 dir.)	# of Lanes (1 dir.)	Total # Lane Miles 2 dirs.)
17	Jct. Rtes. 5 and 22, Santa Ana/ Garden Grove Freeways to Pomona, Jct. Rte. 10 East, Jct. Rte. 210 North	19.44	2	77.76
101	Oxnard, Jct. Rte. 232, Vineyard Ave. Interchange to Sherman Oaks, Jct. Rte. 405, San Diego Freeway	43.02	2	172.08
101/134	Sherman oaks, Jct. Rte. 405, San Diego Freeway to Pasadena, Jct. Rte. 210, Jct. Rte. 710 South	13.34	1	26.68
101	East Los Angeles Interchange, Jct. Rtes. 5, 10, and 60, Begin Route via Santa Ana Freeway to North Hollywood, Jct. Rtes. 134 and 170, Ventura/Hollywood Freeways	11.75	2	47.00
170	Jcts. Rtes. 101 and 134, Begin Hollywood Freeway Extension to Jct. Rte. 5, Golden State Freeway	6.05	2	24.20
91	Los Angeles, Jct. Rte. 110, Harbor Freeway to Jct. Rte. 15	40.84	2	163.36
91	Jct. Rte. 15 to Riverside, Jct. Rte. 60, Jct. Rte. 215 North, Riverside/Escondido Freeway Interchange	14.12	1	28.24
215	Riverside, Jct. Rtes. 60 and 91 West Riverside/Escondido Freeway to San Bernardino, Jct. Rte. 30, Highland Avenue Interchange	11.42	1	22.84
605	Irwindale, Jct. Rte. 210, Foothill Freeway to Orange-Los Angeles County Line	26.00	1	52.00
60	East Los Angeles Interchange, Jct. Rte. 10, Begin Pomona Freeway to Box Springs South Jct. Rte. 215	50.73	2	202.92

AUTOMATION SCENARIO NETWORK (cont.)

Freeway Section	Description of Freeway Section	# of Lane Miles[a] (1 lane, 1 dir.)	# of Lanes ((1 dir.)	Total # Lane Miles 2 dirs.)
55	Jct. Rte. 405, San Diego Freeway to Jct. Rte. 91, Riverside Freeway	11.84	1	23.68
210	Pasadena, Jct. Rte. 710 South, Jct. Rte. 134 West to Jct. Rte. 10 Freeway, Jct. Rte. 57 South, Jct. Rte. 71 Southeast	23.56	1	47.12
30	Glendora, Jct. Rte. 210 Foothill Freeway to San Bernardino, Jct. Rte. 215, barstow Freeway	33.18	1	66.36
14	Los Angeles, Jct. Rte. 5, Golden State Freeway, Begin Antelope Valley Freeway to Palmdale, Jct. Rte. 138, Palmdale Boulevard	35.01	2	140.04
22	East Jct. Rte. 405, San Diego Freeway at Bolsa Chica Road, Resume Garden Grove Freeway to Santa Ana, Jct. Rtes. 5, 22 and 57; Santa Ana/Orange Freeways	9.82	1	19.64
Total Automation Scenario Network Lane Miles				**2,165.16**

a = Source for number of lane miles is 1988 Traffic Volumes on the California State Highway System (Sacraments: State of California, 1988).

Appendix K

Combination Scenario Description

Combination Scenario Network

The network detailed below is the combination scenario network for the Highway Electrification and Automation project. For each freeway section the number of lane miles for one lane, one direction as well as total lane miles (number of lanes multiplied by the miles per lane) are indicated. The number of lanes on each freeway section was determined via the distributional lane selection methodology for: (a) a 15% automated RPEV market penetration on the intermediate network, and (b) a 30% automation only market penetration on the intermediate network. One addition to the intermediate network was incorporated in the combination network based on scrutiny of the alternative lane recommendations for each market penetration and network size, and comments received from project staff and the Project Advisory Group (PAG). The freeway section added to the intermediate network is the 101 from the 23 to the 405.

In the combination scenario network that is attached, the number of lanes in each direction to which the technology/s will be applied is given as blue for two lanes and red for one lane. Note that the color appearing to the right or below a freeway section indicates the RPEV and automation number of lanes whereas the color appearing to the left or above a freeway section indicates the automation only number of lanes to which the technology/s will be applied. The RPEV and automation lanes are a separate facility, automation only lanes are a separate facility, and the remaining lanes are mixed flow in the analysis.

'In the trip assignment phase of the modeling process automated RPEV trips will be given priority to use the lane equipped with both RPEV and automation technologies. Any trips that can not be facilitated by the RPEV/automation lane will be allowed to enter the automation only lanes with those trips assigned to the automation only special facility lane/s. If any excess capacity should exist on the RPEV/automation lane and if there are any automation only trips that can not be serviced by the automation only lanes, these trips will be allowed to enter the RPEV/automation lane so long as the V/C ratio does not exceed one on this lane. All remaining trips will be handled by the mixed flow lanes.

COMBINATION SCENARIO NETWORK

Freeway Section	Description of Freeway Section	# of Lane Miles[a] (1 lane, 1 dir.)	# of Lanes (1 dir.)	Total # Lane Miles dirs.)
405 (N)	Los Angeles, Jct. Rte. 5, Golden State Freeway to Long Beach, Jct. Rte. 19 Interchange	45.32	1[b] 2[c]	90.64[b] 181.28[c]
405 (S)	Long Beach, Jct. Rte. 19 Interchange to Jct. Rte. 5, San Diego Freeway	27.27	1 2	54.54 109.08
5 (N)	Santa Clarita, Jct. Rte. 126 West to Los Angeles, Jct. Rte. 10, San	37.03	1	74.06 74.06
5 (S)	Los Angeles, Jct. Rtes. 10, 60 and 101, East Los Angeles Interchange to San Diego-Orange County Line in Christianitos Road Interchange	60.85	1 2	121.70 243.40
110	Pasadena, Jct. Rte. 248, Colorado Boulevard to Wilmington, Jct. Rte. 1, Pacific Coast Highway Interchange	29.09	1 1	58.18 58.18
10 (W)	Santa Monica, Jct. Rtes. 1 and 2, Lincoln Boulevard, via Santa Monica Freeway to Los Angeles, Jct. 110, Harbor Freeway	12.68	1 1	25.36 25.36
10 (E)	Los Angeles, Jct. Rte. 110, Harbor Freeway to Jct. Rte. 15	43.37	1 2	86.74 173.48
105	Westchester, Jct. Rte. 1 Lincoln Boulevard to Norwalk, Jct. Rte. 605, San Gabriel River Freeway	18.81	1 1	37.62 37.62
57	Jct. Rtes. 5 and 22, Santa Ana/ garden grove Freeways to Pomona,	19.44	1 2	38.88 76.76
101/134	Thousand Oaks, Jct. Rte. 23 South, Westlake Boulevard Interchange to Pasadena, Jct. Rte. 210, Jct. Rte. 701 South	40.48	1 1	80.96 80.96

COMBINATION SCENARIO NETWORK (cont.)

Freeway Section	Description of Freeway Section	# of Lane Miles (1 lane, 1 dir.)[a]	# of Lanes (1 dir.)	Total # Lane Miles dirs.)
91	Cerritos, Jct. Rte. 605, San Gabriel River Freeway to Jct. Rte. 15	30.25	1[b] 2[c]	60.50[b], 121.00
605	Irwindale, Jct. Rte. 210, Foothill Freeway to Orange-Los Angeles County	26.00	1 1	52.00 52.00
60	East Los Angeles Interchange, Jct. Rte. 10, Begin Pomona Freeway to 80x Springs South Jct. Rte. 215	50.73	1 1	101.46 101.46

Total RPEV/Automation Lane Miles	882.64
Total Automation Only Lane Miles	1,335.64
Total Combination Scenario Network Lane Miles	2,218.28

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a = Source for number of lane miles is 1988 Traffic Volumes on the California Highway System (Sacramento: State of California, 1988).

b = Number appearing in top position in these columns indicate the number of lanes and total number of lane miles (2 dir.) to which both RPEV and automation technologies will be applied.

c = Number appearing in bottom position in these columns indicate the number of lanes and total number of lane miles (2 dir.) to which only the automation technology will be applied.

Appendix L

Roadway Electrification Prototype System Costs

RPEV PROTOTYPE SYSTEM COSTS

These costs include costs of purchasing and operating an electric vehicle on an electric powered roadway, and the infrastructure costs of building and maintaining this roadway. The primary sources of information are the Nesbitt, Sperling, and DeLuchi (1990), The California Energy Commission's AB 234 reports (1989a, 1989b), the Systems Control Technology reports (1983, 1984), and the report of the AQMD Transporation Fuel Use and Availability Subgroup of the AQMD Energy Working Group (1990). These sourcess were used in the following cost summary.

The following information is provided to generate a preliminary set of capital and operating costs for the RPEV system. Capital costs are stated in dollars and operating costs are given in cents per mile following the reported information. Importantly, size of the roadway electrification facility will create an inversely related cost ramification on electric roadway cost versus individual vehicle operating costs. This crucial relationship is not fully captured in these preliminary cost figures. Also note that the Nesbitt, Sperling and DeLuchi paper assumes "... that users of the electric roadway bear the full cost of roadway installation. A one-time user fee could be collected or an annual fee could be collected based on electric roadway-powered vehicle mileage." (p. 17, 1990) This assumption thus supports the author's reporting of private RPEV costs.

CAPITAL COSTS

1. Initial Vehicle Cost -- EV with AC powertrain and onboard charger (not including battery, pick-up inductor, and onboard controller)

	LOW	HIGH
Nesbitt, Sperling, DeLuchi	**$11,500**	$12,500
AQMD Fuel Use and Availability Subgroup:		
G-Van*	$19,500	To be provided
TEVan*	18,300	
G-Van**	25,800	
TEVan**	28,000	

(Note: Vehicle price used should be cross-checked with the Electric Vehicle Task Force " most frequently quoted price" for a basic battery included G-Van of $34,500.)

* = Assuming full production of 30,000 - 100,000 vehicles.
** = Assuming limited production of 3,000 - 30,000 vehicles.

Note: The vehicle life stated in the Nesbitt, Sperling, DeLuchi paper for the RPEV is 25% to 100% longer than that of an ICE vehicle. Given their assumptions regarding vehicle life (see pp. 14-15, and 19) these percentages would indicate a range for RPEV life of 15 to 24 years. In the upcoming AQMD Fuel Use and Availability Subgroup report the life of an electric vehicle is given as 5 years.

2. Pick-up Inductor -- Approximately $2,000 for an auto with the range cited as given by Nesbitt, Sperling, and DeLuchi. The life of this component is not stated. (Assume that the vehicle is approximately 8 feet long.)

LOW	HIGH
$200/ft	$400/ft

3. Onboard Controller -- includes onboard control computer (OBCC) and rectifier unit. Range cited as given by Nesbitt, Sperling, and Deluchi. The life of this component is not stated.

LOW	HIGH
$500	$1,500

4. Battery Cost -- dependent on numerous factors as explained in Nesbitt, Sperling, DeLuchi (See p. 13 for their specific assumptions).

	LOW	HIGH
Nesbitt, Sperling, DeLuchi	$3,032.43	$5,262.51
AQMD Fuel Use and Availability Subgroup:		
G-Van*	$7,000	To be provided
TEVan*	6,000	

G-Van**	7,300
TEVan**	6,500

* = Assuming full production of 30,000 - 100,000 vehicles.
** = Assuming limited production of 3,000 - 30,000 vehicles.

5. Electric Roadway Cost -- includes cost and installation of the distribution network for getting electricity from the utility substation to the roadway, cost and installation of the power conditioners, and the cost and installation of the roadway inductors into an existing road.

	LOW	HIGH
Nesbitt, Sperling, DeLuchi	$1,000,000 per lane mile	$2,000,000 per lane mile

Note: The expected life in this calculation is 40 years.

An assumption has to be made regarding the number of miles of automated lanes in order to complete this portion of the capital costs.

From the Draft Phase I Report of SCAG's Highway Electrification and Automation Project the following information may be utilized to assist in estimating the number of automated lanes and arterial miles for the SCAG region.

	1984	2025
Number of Freeway Lane Miles	6,950	10,810
Arterial Miles	6,000	6,200

6. Cost of Residential Infrastructure Needed for RPEV -- includes the cost of equipping a home with branch circuitry, high-ampere outlets, safety equipment and load management necessary to recharge the electric vehicle. The minimum estimate given is based on the cost to equip a new house. The maximum estimate is the cost to retrofit an existing house. The recharging station is assumed to have a life of 20 to 40 years.

	LOW	HIGH
Nesbitt, Sperling, DeLuchi	$425	$640

OPERATING COSTS

The operating costs for the RPEV as given by Nesbitt, Sperling, DeLuchi would include fuel, maintenance and repair, tire and fluid replacement and insurance. The assumptions presented by these authors are contained on pp. 16-17 of their paper. The operating costs are given in cents per mile as are the operating costs available thus far from the AQMD Subgroup report. The work to convert these cents per mile operating costs to dollars with comments on operating cost changes over time is continuing at this time. It is not a simple matter to take the cents per mile information and multiply by the number of miles. Nesbitt, Sperling and DeLuchi state that annual cost and annual mileage are-necessary to convert cents per mile to total dollars per each catagory.

	LOW	HIGH
1) License and Registration		
Nesbitt, Sperling, DeLuchi	.80	1.31
AQMD Fuel Use and Availability Subgroup:		
G-Van*	.02	To be provided
TEVan*	.02	
G-Van**	.02	
TEVan**	.03	

* = Assuming full production of 30,000 - 100,000 vehicles.
** = Assuming limited production of 3,000 - 30,000 vehicles.

Note: Comparable figures from AB 234 range from 1.9 to 2.4 cents per mile from the low estimate and 3.7 to 4.8 cents/mile for the high estimate. The low estimate is based on a 20,000 mi/year set of vehicle type scenarios while the high estimate is based on a 10,000 mi/year set of vehicle type scenarios. In general, the operating costs in cents/mi decrease with more mileage/year. This explanation of low and high operating costs applies to all ensuing cost categories.

2) Insurance	LOW	HIGH
Nesbitt, Sperling, DeLuchi	4.96	6.83
AQMD Fuel Use and Availability Subgroup:		

G-Van*	.06	To be provided
TEVan*	.05	
G-Van**	.06	
TEVan**	.06	

* = Assuming full production of 30,000 - 100,000 vehicles.
** = Assuming limited prduction of 3,000 -30,000 vehicles.

Note: The Nesbitt, Sperling, Deluchi estimates assume that collision insurance is carried for five years for the low figure and ten years for the high figure while comprehensive insurance is carried for life of the vehicle. In addition, the comparable figures from the AB 234 report are 4.2 cents/mile for the low estimate and 8.4 cents/mile for the high estimate.

3) Fuel, or Total Electricity Cost -- a function of cost of electricity, fuel economy of the vehicle, the fuel tax, total accumulated mileage, and the percentage of that mileage the vehicle is operated on the roadway and during peak-electricity generating periods. Additional assumptions regarding calculation of the nesbitt, Sperling and DeLuchi figures are contained on pages 17 and 21 of their report.

	LOW	HIGH
Nesbitt, Sperling, DeLuchi	1.59	3.21
AQMD Fuel Use and Availability Subgroup		
G-Van*	.06	To be provided
TEVan*	.03	
G-Van**	.06	
TEVan**	.03	

* = Assuming full production of 30,000 - 100,000 vehicles.
** = Assuming limited production of 3,000 - 30,000 vehicles.

Note: Comparable figures from the AB 234 report range from 3.1 to 3.7 cents per mile for both the low and the high cost estimate categories.

4) Maintenance -- The assumptions imbedded in the Nesbitt, Sperling and DeLuchi estimates are explained on pages 16-17 of their report.

	LOW	HIGH
Nesbitt, Sperling, DeLuchi	1.00	2.00
AQMD Fuel Use and Availability Subgroup:		
G-Van*	.07	To be provided
TEVan*	.07	
G-Van**	.08	
TEVan	.07	

Note: Comparable figures from AB 234 range from 4.8 to 5.1 cents per mile for both the low estimate and high cost estimate categories.

5) Storage/Dispensing Equipment -- The AB 234 gives a low estimate of .OO cents/mile and a high estimate of .067 cents/mile for this category. The other sources do not contain information for this operating cost.

6) Cost of Additional Roadway Maintenance -- The Nesbitt, Sperling and DeLuchi paper qives a low estimate of .OO cents/mile and a high of .01 cents per mile for this operating cost. No other sources provide estimates for this cost category.

7) Accessories Cost -- The Nesbitt, Sperling, and DeLuchi paper is the only source that provides any information for this cost category. The figure given is .21 cents per mile (no range of costs is given for this category).

8) Parkinq and Tolls -- The Nesbitt, Sperling, and DeLuchi paper is the only source that provides any information for this cost category. The figure given is .96 cents/mile (no range of costs is given for this category).

Also, note that this operating cost allocates the capital cost of building the electrified roadway to the users of the roadway. This assumption allows all of the costs of the measure to fall into the private cost category.

9) Replacement Tires -- The Nesbitt, Sperling, and DeLuchi paper is the only source that provides any information for this cost category. -The cost range is from .47 per mile to 8.56 per mile

NOTE: The cost information above is a first estimate for the categories given. The Nesbitt, Sperling, and DeLuchi paper is currently undergoing a cost revision. The AQMD's Transportation Fuel Use and Availability Subgroup report has only recently begun to finalize the information on costs associated with the alternative fuel vehicles under study (which includes EV's). The AB 234 Report (CEC) provides only information on EV's.

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Mr. Roland J. Risser, Pacific Gas and Electric Company
Mr. Howard R. Ross, Ross Industries, Inc.
Mr. Ed Rowe, Los Angeles Department of Transportation
Mr. Richard N. Schweinberg, Southern California Edison Company
Mr. Earl Shirley, California Department of Transportation
Mr. Jim Sims, Commuter Transportation Services
Mr. John Slifco, Office of Congressman Howard Berman
Mr. Hideo Sugita, Riverside County Transportation Commission
Mr. Edward Vine, California Institute for Energy Efficiency
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