Title
Evaluation of the Fuel-Efficient Traffic Signal Management (FETSIM) Program: 1983-1993

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ABSTRACT

This report presents the findings from the evaluation of a statewide initiative to retime traffic signals to produce more energy-efficient traffic flow: California's Fuel-Efficient Traffic Signal Management (FETSIM) Program. During the 11 years of the Program, over 160 cities and counties have retimed a total of 12,245 signals under grants from the FETSIM Program, in 334 projects. Improved timings have reduced vehicular delays by 14 percent in project areas; stops have been decreased by 13 percent. Overall travel times through these systems have dropped by 7 percent and fuel consumption has been cut by 8 percent. The reduction in fuel expenditures alone has produced annual savings of $85.1 million for California motorists--more than 5 times the total cost of the FETSIM Program. Reduced vehicular wear and tear and faster travel times added as much as $189.3 million annually in user benefits. Other benefits include reduction of air pollution emissions, traffic safety improvements, and better operating conditions for public transit vehicles. The Program also strengthened the capabilities of local traffic engineering staff, and has built better data bases for future traffic studies in participating communities.

The FETSIM Program was carefully designed to offer local agencies the tools, know-how and financial assistance necessary for improving the timing of traffic signal systems. Grants have been awarded for all aspects of retiming, including the costs of data collection, development of timing plans, implementation and field evaluation. Training and technical assistance in advanced methods for achieving optimal signal timing has been provided to the staff and consultants of the participating agencies. A number of research and development activities in support of the Program have produced improved analysis tools for traffic signal management that are used by practicing engineers nationwide.

The FETSIM Program has served as a model for several statewide signal management programs across the country. It has received recognition as a major success, not only in California but nationally. In 1985, the California Energy Commission and the California Department of Transportation received the Institute of Transportation Engineers' Transportation Energy Conservation Award for the Program.

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The FETSIM program was made possible with the efforts of many individuals and their contributions is gratefully acknowledged:

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The late Frederick Wagner

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Finally, I would like to express my appreciation to the many local traffic engineers and their consultants who through their participation and efforts made the FETSIM Program one of the most effective the State of California has ever offered.

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CHAPTER 1

INTRODUCTION

California's transportation system is the state's biggest energy user, consuming about 48 percent of the total energy supply from all sources. In 1990, more than 21 billion gallons of fuel were needed for transportation, and gasoline consumption alone accounts for 55 percent of the transportation fuel use (CEC, 1991.) Since transportation relies on petroleum for most of its energy, it is the least flexible sector of the state economy in responding to oil supply disruptions or price increases.

Cars and trucks are the state's most important means of transportation for both passengers and freight. Even though vehicle fuel economy has increased substantially over the past decade, increases in driving and truck traffic also have continued apace. This fact--coupled with the public's continued desire for go-anywhere, go-anytime mobility--makes it critical to pursue strategies for greater fuel efficiency.

Travel on urban signalized streets accounts for over 30 percent of the total fuel consumption on California's roadways (Figure 1.1). A significant amount of this fuel is burned up each year during stops and delays at traffic lights. In the widely spaced signal systems prevalent in suburban areas, about one-third of the fuel is lost in stop-and-go driving and idling (Figure 1.2). In downtowns, where signals are closer together, fully 43 percent of the fuel is consumed in stops and delays (Caltrans, 1984).

While many stops at signals must occur so that cross-traffic and pedestrians can travel safely, many others are unnecessary, or unnecessarily long. Improved traffic signal management can reduce this waste significantly. Stops and delays can be reduced by more systematic allocation of green time among the conflicting traffic movements. Synchronizing traffic signals along arterials or in a network, and optimizing the signal settings, result in smoother traffic flows, reducing idling and stopping. This, in turn, reduces fuel use, saves motorists travel time, diminishes wear and tear on vehicles, and cuts vehicular emissions. In a demonstration project in the city of Garden Grove sponsored by the California Energy Commission the retiming of 70 signals produced annual savings of 500,000 gallons of fuel (Wagner, 1982.) Similar results were obtained in federally sponsored demonstrations elsewhere in the country (FHWA, 1982).

The implementation of improved signal timing plans requires a carefully organized set of steps:

- *Field surveillance to identify traffic operations problems and special considerations such as transit movements and pedestrian flows*
- *Detailed data collection to measure intersection characteristics and traffic patterns*
- *Development of timing plans to minimize stops, delays, and fuel consumption*
- *Installation and fine tuning of the improved timing plans*

FIGURE 1.1 CALIFORNIA HIGHWAY FUEL CONSUMPTION

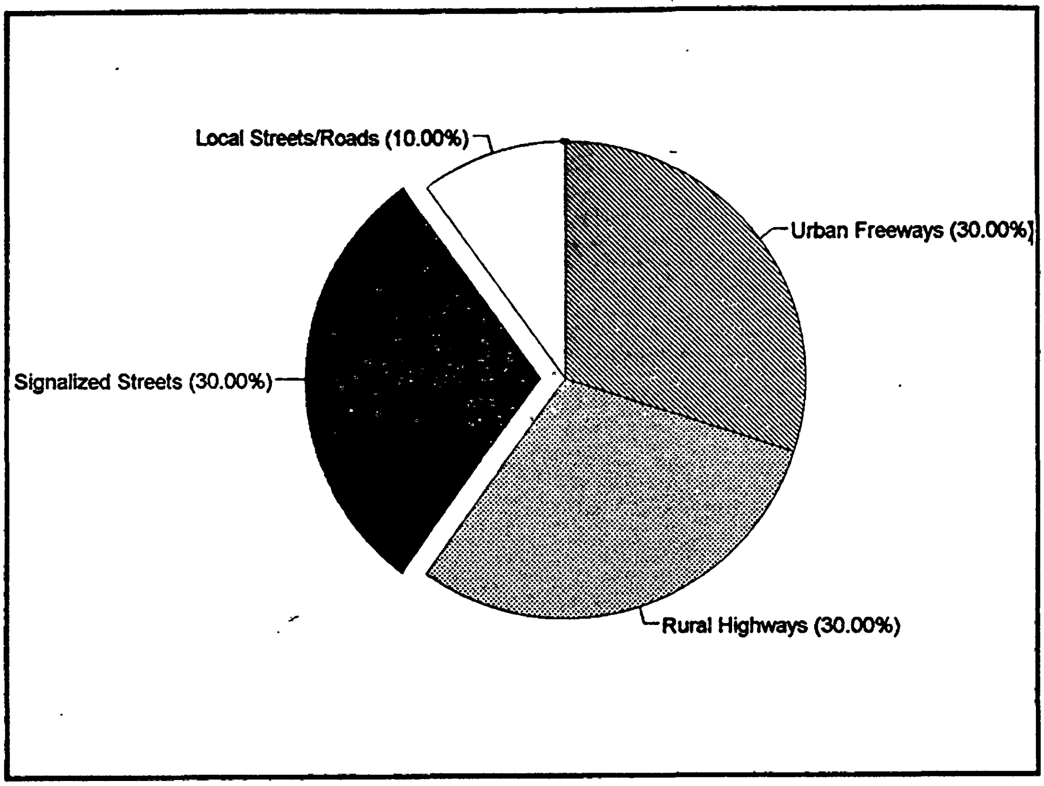
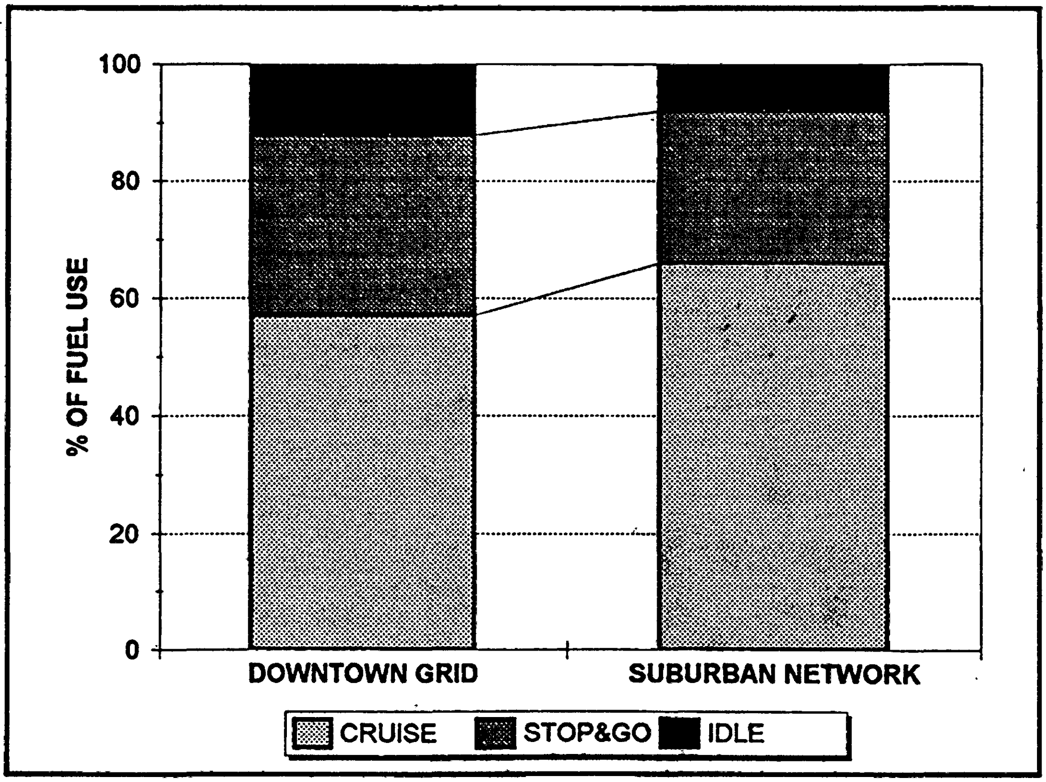


FIGURE 1.2 FUEL USE ON SIGNALIZED STREETS



Unfortunately, tight budgets and the daily pressures of work make it difficult or impossible for many city and county traffic engineers to undertake the necessary efforts on their own. Furthermore, many cities report a shortage of staff trained in the state-of-the-art methods for signal timing. Thus for the majority of California cities, signal timing improvements simply have not been given attention despite the fact that the costs of such improvements would be recaptured in fuel savings alone within a few months. Without outside assistance, most local agencies have been unable to produce these benefits to the public.

It was to address this gap between promise and performance that the Fuel-Efficient Traffic Signal Management (FETSIM) Program was developed. The Program was designed to address both the financial and the staffing problems faced by local agencies; it provided funds for signal retiming, as well as staff and consultant training in traffic management and fuel efficiency.

This report presents a summary and evaluation of the FETSIM Program's eleven funding cycles (1983-1993). In the following Chapter, the program's objectives and design are outlined and its training, technical assistance, research and evaluation activities are described. Chapter 3 presents the findings from the evaluation of the project results based on model results and field studies. The final Chapter summarizes the findings from the program evaluation, and presents recommendations on ongoing and future activities in traffic signal management. Appendix A lists all the agencies that participated in the Program. Information on the characteristics of project areas and estimated improvements per each grant cycle are included in Appendix B. Results from "before" and "after" field studies in selected cities are presented in Appendix C. Appendix D lists the consultants involved in the FETSIM program, and Appendix E lists the publications produced in support of the FETSIM Program.

CHAPTER 2

THE FUEL EFFICIENT TRAFFIC SIGNAL MANAGEMENT PROGRAM

2.1 Program Objectives and Design

The FETSIM Program began in 1982, after three years of research and testing. The Program's primary objective was to reduce stops, delays and fuel consumption through the implementation of more effective signal timing plans. A second objective of the Program was to enhance the capability of local traffic engineers to continue to manage their traffic signals effectively.

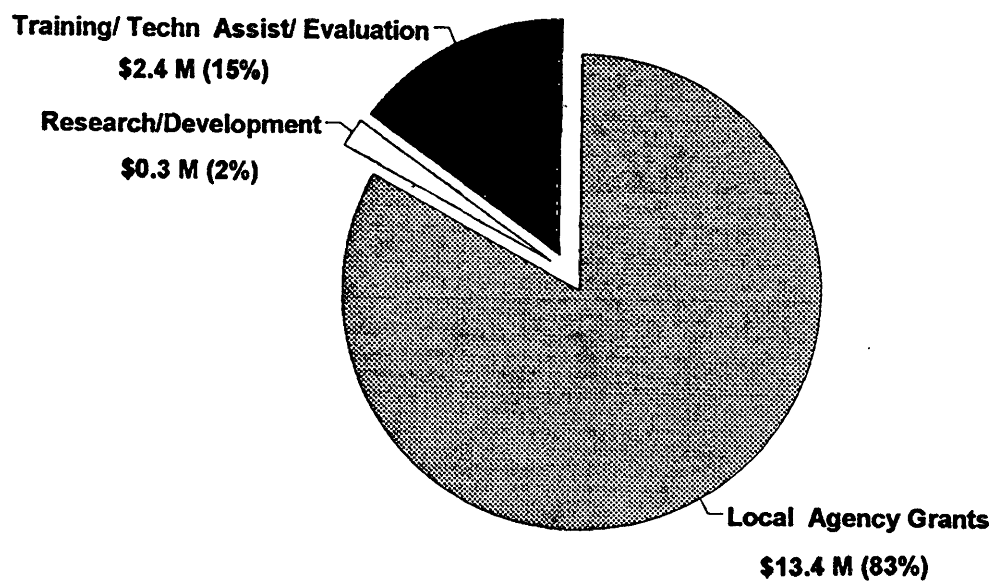
The FETSIM Program was carefully designed to provide local agencies with the tools, know-how, and financial assistance necessary for efficient signal timing. Beginning in 1983, grants have been available to local agencies to fund all aspects of optimal signal timing: data collection and processing, timing plan development, implementation, and field evaluation. The program also has funded training and technical assistance for local agency staff in the design and implementation of improved timing plans, as well as research and development activities in support of these efforts.

The Program was originally administered by the California Energy Commission; it was transferred to the California Department of Transportation (Caltrans) in late 1983. A total of $16.1 million was approved by the California State Legislature for the FETSIM program; $13.7 million from the petroleum violation escrow account (PVEA), managed by the US Department of Energy through the California Energy Commission, and $2.4 million from the State Motor Vehicle account (1983 grant cycle.) Over $13.4 million (83 percent of the total funds) were spent on local agency grants (Figure 2.1), training, technical assistance and program evaluation account for 15 percent of the costs, and 2 percent spent on research and software development in support of the Program.

Grants were made available to cities or counties through annual program cycles. The selection of projects was based on the network characteristics, traffic patterns, capabilities of the traffic signal equipment, and expertise and commitment of local staff to efficient signal management. Local agencies must not have construction planned either on streets or major land development. Local agencies have been permitted to participate in more than one funding cycle if they have had additional signal systems in need of retiming.

Project activities in each program cycle lasted about a year. The local agency staff was required to attend the training workshops, submit interim study products and prepare a final report documenting the implementation of the new timings and the traffic flow improvements. Grantees may pay in-house staff salaries under the program, or may elect to contract with consultants.

FIGURE 2.1 FETSIM PROGRAM EXPENDITURES



Several steps were taken to encourage local agencies to participate in the Program. A simple application form and a straightforward grant award process. Pre-application meetings were held in several cities across the State to explain the purposes of the program and to instruct local agencies on application procedures. Furthermore, the CEC/Caltrans worked with local engineering organizations and public works groups to publicize the availability of grants and encourage applications.

Several changes to the FETSIM Program design have been made based on suggestions by participants or otherwise identified through the ongoing evaluations to increase the participation and the quality of the projects. Those included: i) relaxation of eligibility criteria to permit applications from local agencies with small but complex signal systems, ii) task-and cost-based budgeting instead of the flat $1,100 amount per signal guideline (1983-85 grant cycles) to reduce funding inequities and inefficiencies, iii) task-based reporting and payments to encourage on-time performance and to enable closer project monitoring, and iv) tighter controls over consultant subcontracts to minimize problems due to consultants' over-commitments to too many projects. Cities were also encouraged to provide matching funds and/or in-kind contributions as a way of emphasizing the need for local involvement.

2.2 The FETSIM Grant Program

A total of 163 local agencies participated in the FETSIM program in 334 projects retiming 12,245 signals at a total cost of $13.4 million, or $1,091 per signal (Table 2.1). Appendix A lists the agencies participated in the program, along with the number of grants received, number of signals retimed and the amount of total grant awarded. FETSIM grants were awarded for signal retiming and hardware improvement projects:

TABLE 2.1 THE FETSIM GRANT PROGRAM

Year	# Grants*	# Intersections Retimed	Awards($)
1983	41	1559	$1,707,073
1984	22	937	$919,233
1985	18	701	$682,876
1986	31	1151	$1,144,353
1987	24	870	$1,071,298
1988	28	1014	$1,320,030
1989	30	898	$1,337,489
1990	30	1063	$1,310,388
1991	38	1371	$1,481,816
1992	39	1330	$1,182,732
1993	33	1351	$1,207,800
Totals	**334**	**12245**	**$13,365,088**

* *163 different local agencies participated*

Hardware demonstration projects: Since 1987 grant funds have been awarded for "demonstration projects" to upgrade signal systems through the purchase of signal equipment or control systems software. In addition to the equipment funds, funds were provided for signal retiming. The design of the "hardware demonstration" component of the FETSIM program was based on a statewide survey of signal equipment and hardware needs (Kuntemeyer, 1987), and estimated benefits and costs based on simulation results and field evaluation of three demonstration projects (Skabardonis, 1988). A total of 39 demonstration projects were conducted involving 536 signalized intersections at a total cost of about $1.6 million or $3,105 per signal (Table 2.2). These projects account for about 12 percent of all the projects and 4 percent of all the signals in the FETSIM program. Most of the hardware improvements involved replacement of signal controllers, and installation of time-based coordination units to allow previously uncoordinated signals to function as a coordinated system.

TABLE 2.2 HARDWARE DEMONSTRATION PROJECTS

Year	# Grants	# Intersections Retimed	Awards($)
1987	3	37	$148,451
1988	6	67	$307,305
1989	9	123	$489,291
1990	7	131	$330,759
1991	8	85	$190,060
1992	6	93	$198,239
Totals	**39**	**536**	**$1,664,105**

Repeat projects: Funding was also provided for retiming systems previously timed through the program, to maintain efficient signal operations on agencies unable to maintain signal timings on their own, due to continuing staff and financial resource constraints. These grants were awarded provided that a five year period has elapsed since the original grant application, and subject to availability of funds after the allocation of grants to the first time participants in each grant cycle. About 900 signals in 30 projects were "repeat" grants. The funding level for repeat projects was less than a new project, because several of the required data were already available.

2.2.1 Local Agency Participation

A total of 154 California cities and nine counties participated in the FETSIM program. Most of the participants were located in the urbanized Bay Area, Los Angeles, San Diego and Orange counties (Table 2.3). Fifty-two percent of the local agencies participated in the Program one time. Most of them had up to 50 traffic signals in systems that were retimed in a single grant project. About 24 percent of the agencies participated in two grant cycles, and 12 percent, mostly larger cities, in three grant cycles. The city of Los Angeles participated in all the eleven FETSIM grant cycles.

Table 2.4 shows the distribution of participating cities by population category. About 80 percent of the projects and 90 percent of the traffic signals retimed were in cities with more than 50,000 residents. Comparison with recent census information indicate that the FETSIM participating agencies account for more than 90 percent of all California cities with higher that 50,000 population.

The low participation rate of smaller agencies, particularly with population of less than 30,000 is because most of those cities have only very few signals (less than 5 intersections) in systems.

TABLE 2.3 PROGRAM PARTICIPATION BY COUNTY

#	County	# Local Agencies	No. of Projects	No of Signals
1	Alameda	10	25	581
2	Contra Costa	8	12	292
3	Fresno	3	7	306
4	Humboldt	1	1	17
5	Kern	1	5	145
6	Kings	1	1	21
7	Los Angeles	49	105	5614
8	Marin	3	4	104
9	Monterey	3	5	84
10	Napa	1	2	30
11	Orange	16	36	1110
12	Placer	1	2	21
13	Riverside	7	12	202
14	Sacramento	2	6	286
15	San Bernardino	7	11	244
16	San Diego	13	33	1313
17	San Francisco	1	6	561
18	San Joaquin	3	6	169
19	San Louis Obispo	2	2	43
20	San Mateo	5	11	154
21	Santa Barbara	3	5	238
22	Santa Clara	8	14	372
23	Santa Cruz	2	3	30
24	Shasta	1	1	26
25	Solano	2	2	35
26	Sonoma	3	3	44
27	Stanislaus	2	4	65
28	Ventura	4	9	130
29	Yolo	1	1	8
Totals		**163**	**334**	**12245**

TABLE 2.4 DISTRIBUTION OF PARTICIPATING CITIES (By Population Category)

Population Category	No of Cities	(%)	No of Projects	(%)	No of Signals	(%)
Less than 20,000	8	5	8	2	88	1
20,000-29,999	8	5	12	4	159	1
30,000-49,999	41	27	51	16	902	7
50,000-79,999	41	27	69	21	1457	12
80,000-119,999	29	19	78	24	2109	17
120,000-199,999	16	10	46	14	1637	14
200,000-500,000	7	5	32	10	1522	13
Greater than 500,000	4	3	29	9	4199	35
Totals	**154**	**100**	**325**	**100**	**12073**	**100**

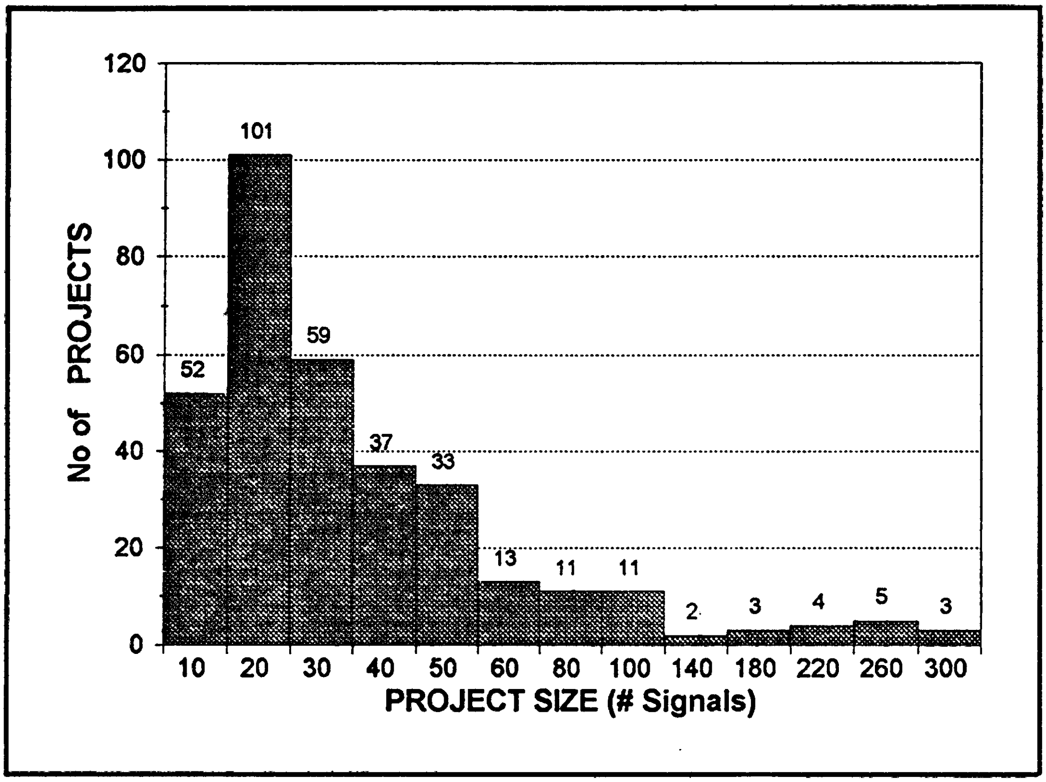
The California Energy Commission and Caltrans had originally estimated that there are about 20,000 traffic signals in the State. Of these signals about 4,000 are isolated. Thus, the FETSIM program has retimed about 80 percent of the eligible signals under local jurisdiction in the State.

Non-participation stemmed from several causes: Caltrans ownership of signals; signals only at in small systems (2-3 signals); shortage of appropriately trained staff at the local level, equipment that is not capable of coordinated operation; and in a few cases, satisfaction with current timing plans. Difficulties in coordinating across political boundaries also have been cited as reasons for not participating in FETSIM.

2.2.2 Characteristics of Project areas

The average grant project under the FETSIM program included 37 signalized intersections; fifty percent of the projects had up to 25 signals (Figure 2.2). Only 17 projects (5 percent of the total) involved more than 100 intersections most of

FIGURE 2.2 DISTRIBUTION OF RETIMING PROJECTS



them in the city of Los Angeles. About 17 percent of the projects had less than 10 signals, most of them hardware demonstrations. About 63 percent of the total systems retimed were single or crossing arterials with a total of 5,364 (44 percent) traffic signals (Figure 2.3.) Several signal systems were retimed under a single grant in many participating agencies. Table 2.5 shows the number of systems per network configuration, and the type of signal control (pretimed, or traffic actuated) for each grant cycle. The average size of arterial systems retimed was 15 signals, and the average size of grid systems was 51 signals.

Signal systems' hardware ranged from electromechanical fixed-time controllers to state-of the art central control systems. Sixty-six percent of all the signals were traffic actuated; on single arterial systems 90 percent of the signals had actuated controllers. A significant proportion of pretimed signals still use electromechanical controllers especially in the downtown areas of the larger cities. Coordination was mostly provided through hardwire interconnect, with phone lines used in about 5 percent of the signal systems. A significant proportion of the arterial systems are using on-street masters with time-based coordination units.

FIGURE 2.3 CHARACTERISTICS OF FETSIM PROJECTS

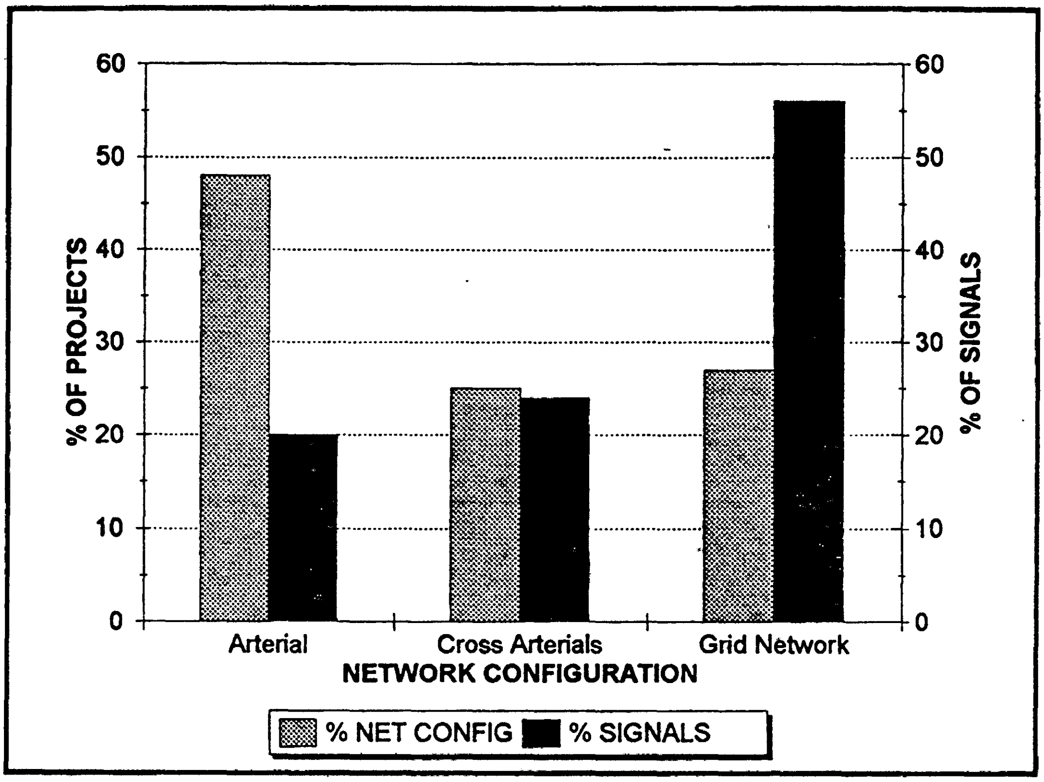


TABLE 2.5 SIGNAL SYSTEM CONFIGURATION AND TYPE OF CONTROL

Year	Single Arterial				Crossing Arterials				Grid Network			
	N	P	A	#INT	N	P	A	#INT	N	P	A	#INT
1983	12	15	87	102	12	20	272	292	28	684	481	1165
1984	7	0	63	63	12	62	204	266	11	453	155	608
1985	17	69	140	209	4	2	85	87	8	167	238	405
1986	25	74	221	295	8	33	124	157	14	428	271	699
1987	26	32	226	258	2	0	50	50	10	480	82	562
1988	26	78	200	278	9	2	232	234	9	176	326	502
1989	19	6	180	186	14	73	243	316	6	137	259	396
1990	17	3	144	147	13	12	206	218	15	221	477	698
1991	33	0	371	371	19	0	381	381	8	307	312	619
1992	24	0	195	195	17	9	374	383	14	382	370	752
1993	35	4	329	333	16	59	484	543	13	138	337	475
Totals	241	281	2156	2437	126	272	2655	2927	136	3573	3308	6881

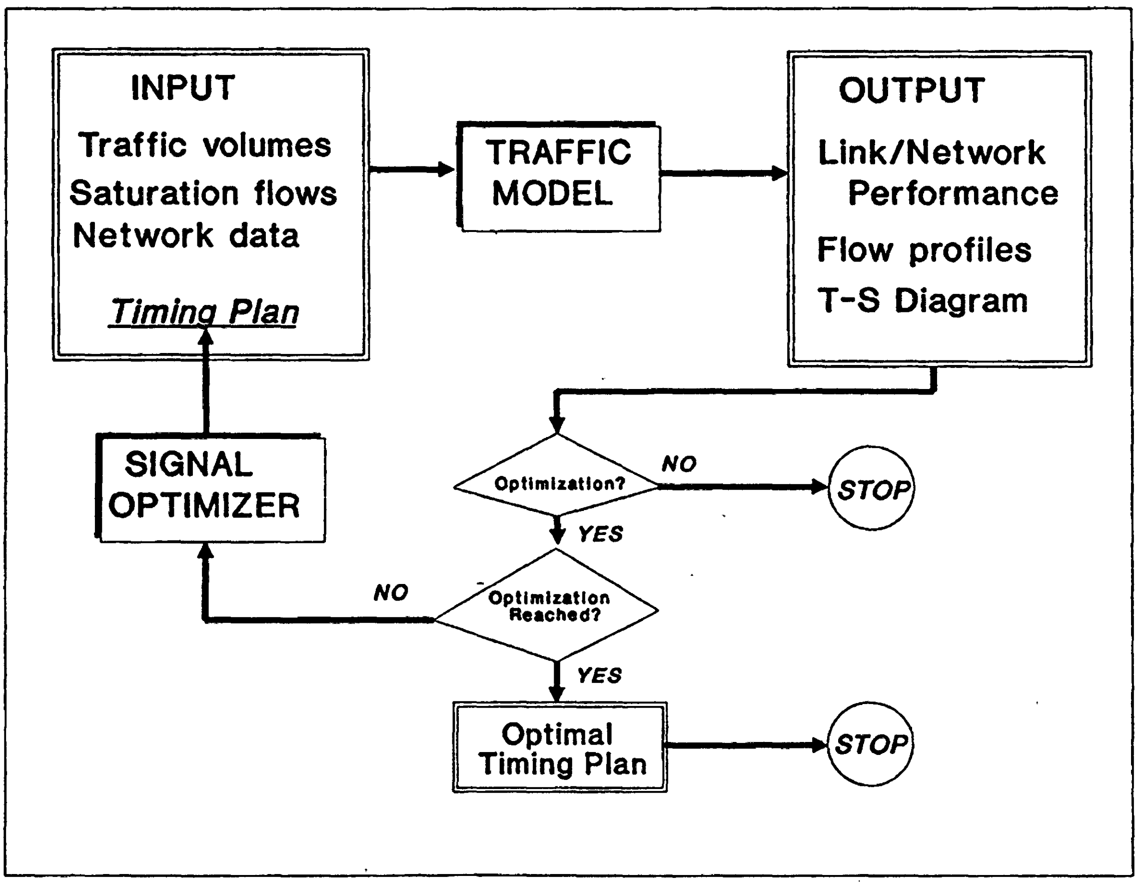
N: number of systems in each network configuration
P: number of pretimed signals
A: number of traffic actuated signals
#INT: total number of signals in each network configuration

2.3 Analysis Techniques

The TRANSYT (TRAffic Network StudY Tool) computer model has been used for optimizing signal settings and for analyzing the resulting traffic impacts (Robertson, 1967). Originally developed in England, the TRANSYT model has been applied extensively throughout the world, and several versions of the model have been produced. TRANSYT was selected because it is capable of handling complicated networks, it has been thoroughly field-tested, and it directly produces estimates of delay, stops, and fuel consumption to determine the savings from signal retiming. The publicly available TRANSYT-7F version of the model (Wallace, 1983) was used in the FETSIM Program.

TRANSYT (Figure 2.4) includes a macroscopic (platoon-based) deterministic model which simulates existing conditions along signalized arterials or grid networks and estimates degree of saturation, travel time, delay, stops, fuel consumption, queue lengths and other performance measures. Use of TRANSYT requires coding the network into links and nodes, and data on turning movements, saturation flows, speeds, and existing signal settings. The model outputs are compared to observed conditions (normally travel times, delays and queue lengths) and the input data and model parameters are adjusted until the model reasonably represents actual operations. TRANSYT then is used to optimize the timing plans (cycle length, splits and offsets).

FIGURE 2.4 OVERVIEW OF THE TRANSYT MODEL



The alternative plans are evaluated using the stop, delay, and fuel consumption estimates, and the best one is implemented in the field. Following implementation, minor adjustments to the timings (fine-tuning) often are performed in the field. The estimation of benefits is based on the model estimates and "before" and "after" field studies.

Other signal timing techniques have been used on several FETSIM projects in conjunction with the TRANSYT model. For example, the PASSER-II-90 (Progression Analysis Signal System Evaluation Routine) model (Chang, 1990) was used on arterials to determine the sequence of phases before the final TRANSYT optimization of splits and offsets.

2.4 The Training Program

The objectives of the FETSIM training activities were to encourage local commitments to signal retiming and to enable participating traffic engineers and their consultants to use state-of-the-art signal timing techniques. Basic knowledge of traffic signal timing was assumed, but no previous experience in computer use or fuel-efficient traffic management was required. The training was conducted in a series of workshops designed to provide step-by-step guidance through lectures and laboratories in the following topics:

- *Principles of fuel-efficient traffic signal management*
- *Planning and organization of an effective traffic signal management project*
- *Efficient methods of data collection*
- *Principles and application of TRANSYT and other state-of-the-art computer-based traffic signal timing methods*
- *Field study procedures*
- *Implementation of improved timing plans, and continued maintenance of effective signal operation*

Originally two series of workshops were offered: "orientation" workshops at the beginning of the grant cycle, to assist local agencies in the planning and organization of their projects and to familiarize participants with TRANSYT's data collection, coding, simulation and calibration requirements. The "implementation" workshops, five months later, covered signal timing optimization techniques, procedures for installing and fine tuning improved timings, and methods for field studies. Based on the experience gained in the first three grant cycles in 1983-85, the training program was modified to provide more direct training and guidance to participants for each major phase of the project. Three series of training workshops have been conducted in each grant cycle:

- *"Orientation" workshops*: study design and organization, principles of the TRANSYT model, data collection requirements and techniques, input data coding

- *"Calibration" workshops*: TRANSYT model application and calibration
- *"Implementation" workshops*: timing optimization with TRANSYT and other models, implementation and fine-tuning improved timing plans, field evaluation

Since the development of the QUICK-7F pre-processor in 1990, which greatly facilitates the TRANSYT input coding and application, two series of workshops were offered with hands-on experience on personal computers: the "simulation" workshop covering the materials in the previous orientation and calibration workshops, and the optimization ("implementation") workshop. The FETSIM workshops content, scheduling and course materials have been used in several other programs throughout the country and have been incorporated in the documentation of the TRANSYT model.

A final workshop was also held at the conclusion of each grant cycle where the local agencies presented their results, and guest lecturers discussed ongoing research in traffic signal management. An important purpose of this final "Users" workshop was to allow participants an opportunity to comment on the benefits and costs of the program from the local agency perspective, and suggest ways for improvement.

2.5 Technical Assistance

Local agencies also have been provided technical assistance during project design and implementation. This assistance has ranged from advice on data collection techniques and evaluation approaches, to help in setting up and running the TRANSYT model, and interpreting the model outputs. Centers established in Northern and Southern California have coordinated these efforts. Local agencies which did not have in-house computing facilities have been provided access to computers through the two centers.

The Institute of Transportation Studies at Berkeley operated the Northern Technical Assistance Center for the first five years of the FETSIM Program. Dowling Associates in Oakland provided technical assistance since 1988. The Southern Technical Assistance Center was staffed by Caltrans District 7 in 1983, and by the Southern California Association of Governments (SCAG) in the 1984 and 1985 funding cycles. Since 1986, technical assistance was provided by HRA Associates in Irvine. In each grant cycle, participating agencies were visited at least twice by the centers' technical assistance teams, who examined each project area, answered technical questions, and assessed progress. Ongoing telephone contact was used to assure that the agencies' projects proceeded on schedule and to discuss any technical problems that may have arisen. Additionally from 1983 to 1987, a bi-monthly newsletter, the FETSIM Bulletin, was mailed to all participants as a way to distribute information on the schedule of events and transmit technical advice.

2.6 Research and Development

Several research and development activities were carried out by ITS and other organizations in support of the FETSIM Program. These activities ranged from enhancement of the TRANSYT model, to the development of software and improved methods for data management, to improved signal timing procedures, to market studies and surveys of traffic signal equipment needs. The findings from those studies have been described in journal articles and research/technical reports and presented to major professional meetings. Appendix E lists the publications documenting the work carried out by ITS. These studies are briefly described below:

FETSIM Program Design/Implementation (1983-1987): ITS assisted Caltrans in assessing the need for future FETSIM grant cycles and in identifying new directions for the FETSIM Program. A survey was conducted to obtain accurate estimate of signal equipment needs and interest at the local level. A parallel study investigated the potential benefits from improved signal hardware through simulation and evaluation of three demonstration projects. The findings from these efforts were used in the development of the hardware demonstration component of the FETSIM program.

Data Management Procedures (1983-1985): Software was developed on laptop microcomputers for data collection on saturation flows, turning movement counts, platoon dispersion, as well as travel time and delay from floating car runs. Also, software was developed to facilitate the input coding for TRANSYT and to view selected model results on the computer screen. Guidelines were also developed for designing and conducting statistically valid "before" and "after" studies.

Guidelines for Improving Signal Timing (1984-1986): Research was performed on improved methods for signal timing using computer models, and the findings were presented in a guidebook including step-by-step procedures on i) TRANSYT model calibration, ii) signal timing for signals with actuated controllers, iii) concurrent use of computer models. Most of the findings were incorporated into the FHWA documentation on TRANSYT-7F, and the FETSIM training materials. Also, a major FHWA study on traffic signal progression was originated from this research (Skabardonis, 1988). Another study demonstrated the use of TRANSYT in evaluating the impacts of new development projects.

Enhancements to the TRANSYT-7F model (1987-1988): the TRANSYT model was modified to internally calculate the green times for actuated signals and provide outputs to assist the implementation of signal settings on actuated controllers. The software enhancements and documentation was incorporated into the nationally supported TRANSYT model beginning with Release 6.

Software for Model Calibration (1988): A prototype microcomputer program was developed by UC Irvine to assist users in the calibration of the TRANSYT model. The program compares the model results with user supplied field measurements, and suggests model parameters values to obtain realistic performance measures.

The QUICK-7F Pre-processor (1989-1993): an interactive computer program developed by DKS Associates to enter, store and manipulate input data for the TRANSYT model (DKS, 1994). Data are entered via on-screen data forms and the program automatically determines the link/node scheme, performs error checking and generates the input file required by the TRANSYT model. The main features of the QUICK-7F preprocessor are shown below:

KEY CHARACTERISTICS OF THE QUICK-7F PREPROCESSOR

1. Graphically oriented data input screens
2. Extensive multi-level on-line help
3. Hotkeys to move and manipulate data quickly
4. Pop-up Choice lists for field data options
5. Data input error checking
6. Extensive use of defaults and internal calculated values
7. Imports turning movement counts from an ASCII file
8. Imports TRANSYT model calculated splits and offsets
9. Automatic generation of TRANSYT input files for user defined subsystems

QUICK-7F can accommodate up to 999 intersections with any level of geometric complexity, and supports all the options and features in the TRANSYT model. Unlike other model pre-processors, QUICK-7F is a database that allows users to conveniently store all the field data on the intersection and network characteristics, allows previously entered data to be copied and edited, and automatically generates input files for any combination of the network and traffic conditions, e.g., users may define a portion of the network and analyze the traffic conditions with TRANSYT using midday peak flows with the pm peak timing plans. The software has been extensively tested by FETSIM participants, who reported that the program significantly reduced the time and effort to perform TRANSYT analysis. QUICK-7F is currently available nationwide through the McTrans center for microcomputers at the University of Florida.

CHAPTER 3

EVALUATION OF THE PROGRAM

Evaluations have been carried out on both individual signal retiming projects and the program as a whole. In each grant cycle, the transportation benefits obtained through local projects, reductions in travel time, delay, number of stops, and fuel use, have been estimated by the local participants, and have been presented in their final reports. ITS has reviewed these reports as well as model printouts, and prepared evaluations of the 1983 through 1987 grant cycles, making adjustments to reported results as necessary to account for oversaturated intersections, field study results, and other factors. The evaluations have been documented in several publications (Appendix E.)

Participants also have provided evaluations of each training session, commenting on teaching, course coverage, workbooks and handouts, and the extent to which they have absorbed the course material. The findings of these evaluations have been used to refine subsequent training activities and to direct technical assistance to the jurisdictions most needing it. Finally, surveys and interviews with both participants and non-participants have been used to assess the overall program design. These findings, coupled with the experience gained by Caltrans and the technical assistance staff, have been used to continually refine the application process, the program eligibility criteria, and the training and technical assistance elements of the program.

3.1 Transportation Benefits

The improvements in traffic performance and fuel consumption for the eleven years of the FETSIM Program were estimated based on the evaluations carried out by ITS for the 1983 through 1987 grant cycles, and the information provided by the technical assistance teams on project results for the 1988 through 1993 grant cycles.

3.1.1 TRANSYT Model Estimates

Table 3.1 shows the average TRANSYT estimated improvements in the measures of effectiveness for each grant cycle. The savings from the individual projects in each grant cycle are included in Appendix B. The values in Table 3.1 represent the average percentage changes for an eleven-hour weekday, unless specific volume adjustment factors were available from the individual cities. Results from the participating agencies in each funding cycle show that in nearly every case, the program has produced major transportation benefits. Based on TRANSYT outputs from all the funding cycles, a FETSIM retiming project produced an average of 12.5 percent reduction in stops throughout the day, 13.8 percent reduction in delays, 7.7 percent drop in travel time, and 7.8 percent decline in fuel use.

TABLE 3.1 TRANSYT-7F ESTIMATED SAVINGS (%)*

GRANT CYCLE	# OF GRANTS	# OF SIGNALS	TRAVEL TIME	DELAY	STOPS	FUEL
1983	29	1100	8.6	17.5	17.2	9.6
1984	16	768	6.5	13.6	12.9	8.0
1985	11	507	4.7	10.5	14.7	7.0
1986	27	996	7.9	12.0	11.2	6.7
1987	14	725	7.6	12.4	11.1	7.3
1988	15	732	5.7	9.0	9.2	6.4
1989	14	546	6.2	10.9	11.9	6.4
1990	9	473	7.2	12.3	7.0	7.3
1991	14	348	10.9	18.5	11.2	10.0
1992	8	93	10.9	18.3	11.9	7.4
1993	6	413	9.0	17.4	14.4	10.3
Total:	163	6701				
Average change(%)			**7.7**	**13.8**	**12.5**	**7.8**

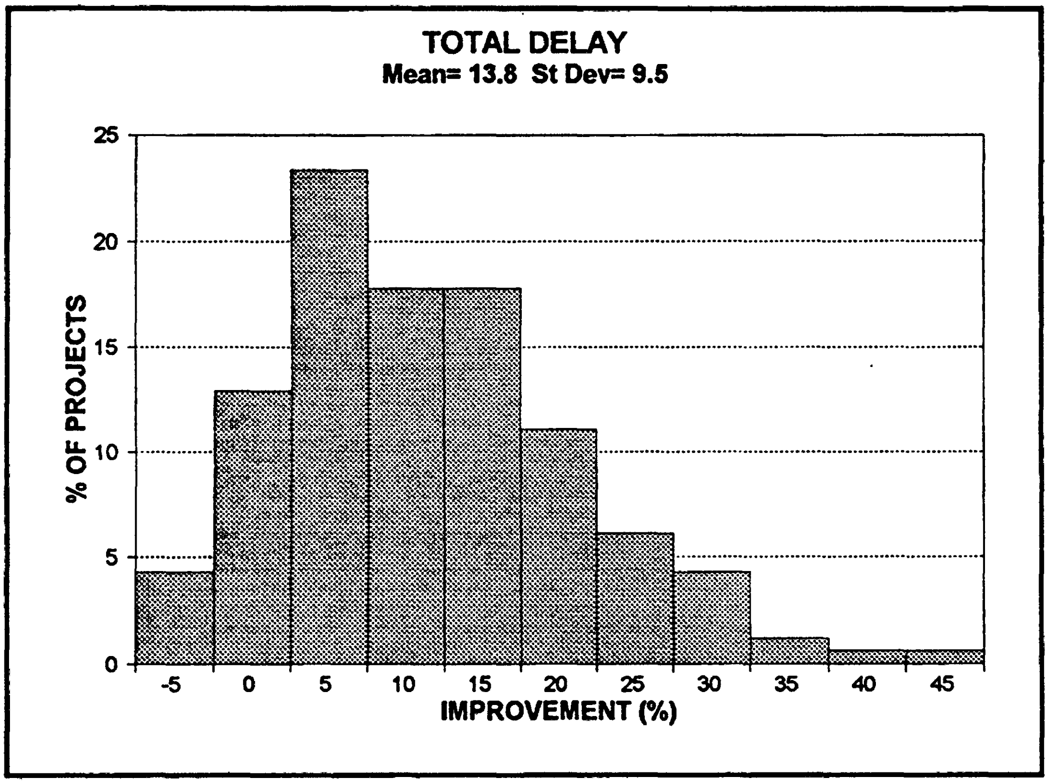
* *average daily percentage changes*

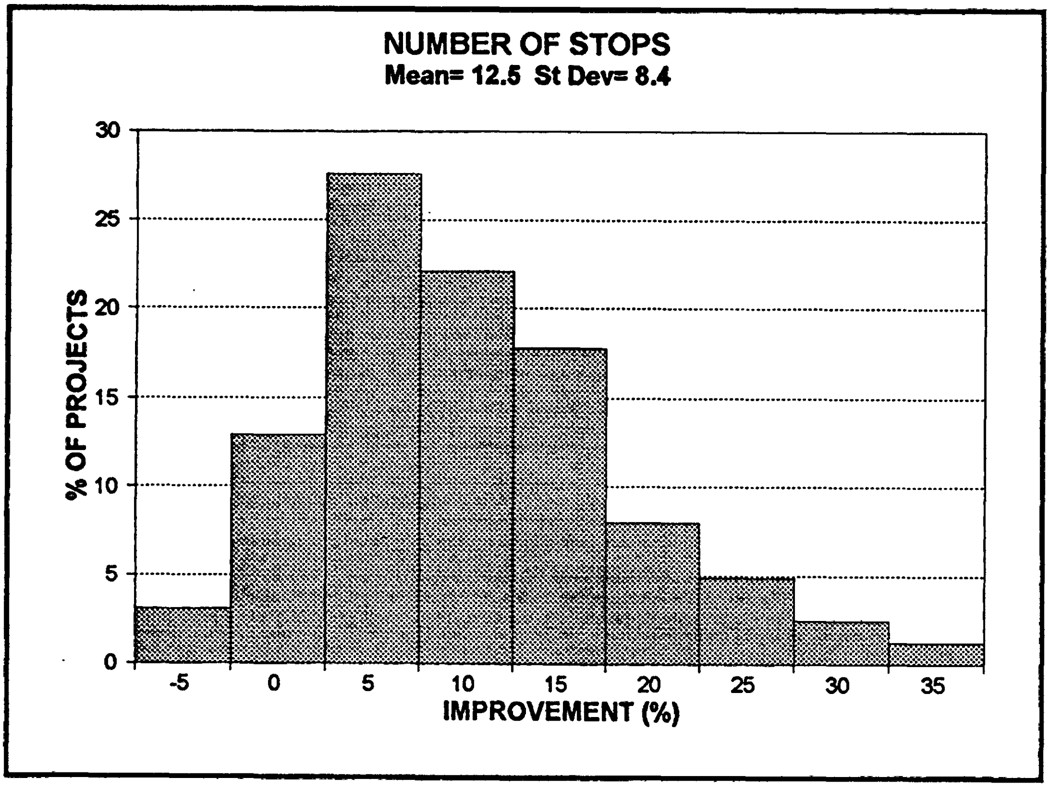
Because the TRANSYT model often overestimates savings at intersection approaches when oversaturation occurs, such links were eliminated (based on the model outputs when available) in calculating the average improvements for each project. This may result in a slight underestimation of the total benefits.

The results shown in Table 3.1 are based on 163 projects (49 percent) of the total 334 projects in the FETSIM program and 6701 signalized intersections (55 percent of the total retimed.) However, the actual proportion of projects included in the calculation of savings is about 65 percent of the projects that TRANSYT could be applied to simulate existing conditions. This is because most of the hardware demonstration projects and a significant portion of retiming projects, particularly in the 1990 through 1993 grant cycles, involved signals that were operating "free" as uncoordinated fully actuated signals. TRANSYT cannot model such type of control and estimates of savings were not available for most of those projects.

The level of improvements in traffic performance and fuel use varied considerably among the retiming projects (Figure 3.1). Some agencies found little or no improvement, and other reported gains of over 30 percent in delay and stops, and 20 percent reduction in fuel consumption. The analysis of the results indicates that the following factors account for most of the variability in the estimated savings:

FIGURE 3.1 DISTRIBUTION OF THE TRANSYT ESTIMATED SAVINGS





- **Quality of Existing Timing Plans:** Of the agencies that obtained little benefits, the majority reported that the existing timings were quite good, so the lack of substantial improvement appears to represent efficient operations "before" the signal timing optimization. Larger cities obtained somewhat lower benefits than smaller cities, which probably is due to better timings in the "before" case.

- **Network Configuration:** Larger savings were realized on arterials than on grid networks. Small improvements were obtained on simple systems (e.g., equally spaced arterials, one-way streets) that had been well timed with other methods (e.g., time-space diagrams.) Also, several systems that had to be coordinated with other adjacent systems did not gain significant benefits because the timing optimization, particularly the cycle length, was constrained to maintain compatibility with the other systems.

- **Traffic Patterns:** Larger savings were obtained on high volume systems with predominant through movements. The improvements were small on systems with low volumes and no predominant platoons (e.g., networks with minimal activity outside the peak periods.) In many of those systems optimized timing plans were not implemented and the signals continued to operate as isolated fully actuated. Also, marginal savings were found on systems with several congested intersections that are in need for capacity improvements.

- **Signal Equipment:** Higher benefits were obtained on systems with actuated signals and flexibility in choosing control parameters/options. The improvements on those systems depend on the understanding of the signal operations and implementation of the TRANSYT optimal settings into the actuated controllers. Equipment limitations (e.g., single dial controllers that permit only one cycle length and green times to be implemented) reduced the level of possible improvements in a number of projects. Large benefits were obtained on systems that were operating "free" before optimization. These savings, however, represent the impacts of both signal coordination and optimization, and as it was previously mentioned TRANSYT cannot accurately model uncoordinated signals.

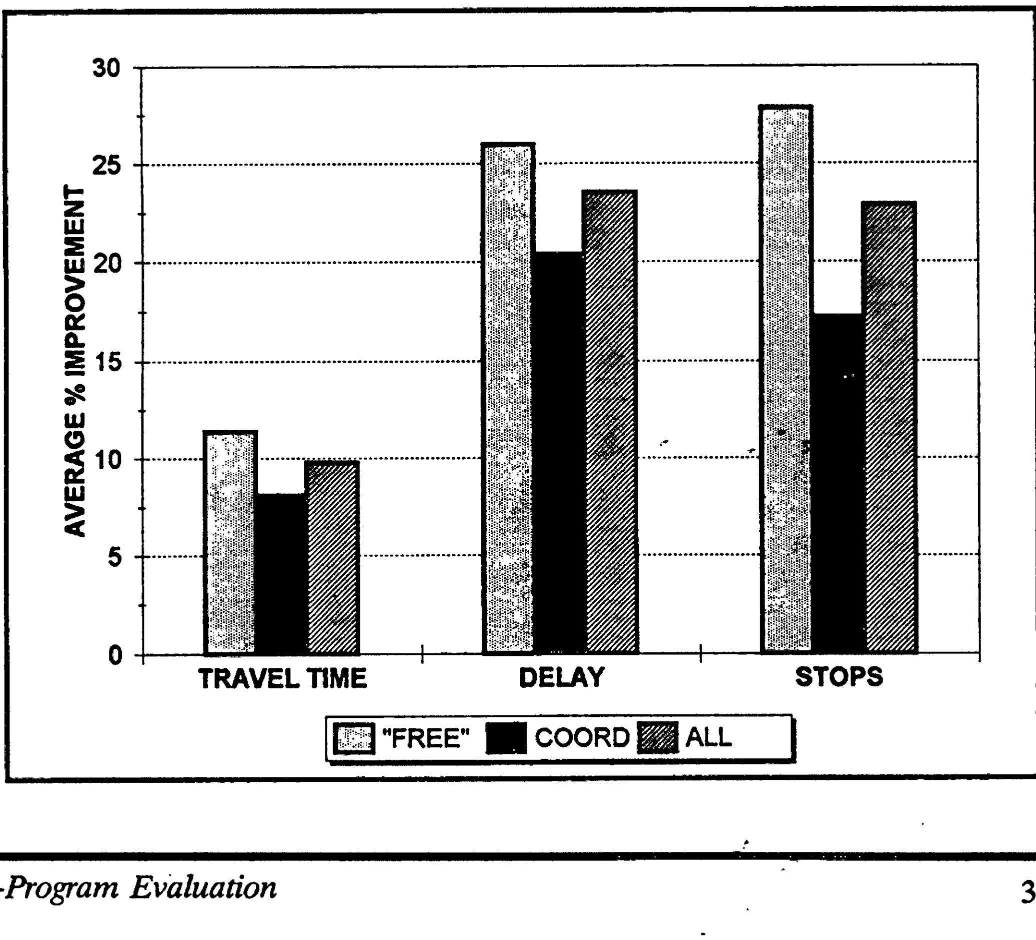
The level of percent improvement in performance does not necessarily translate into large amount of gallons of fuel and hours of travel time benefits. For example, modest improvements on heavily travelled systems would generate much larger benefits than high percent reductions in traffic impacts on small systems with light traffic volumes. Also, the TRANSYT generated timing plans produced substantial improvements over those they replaced, but in several cases they were not necessarily the "best timing plans possible." A number of model options in optimization often were not tested due to time and budget constraints and the level of sophistication required in the model use. Finally, some local agencies experienced problems; several found that errors made in data collection seriously compromised project results. Others had difficulty in modeling unusual features of their signal systems.

3.1.2 Field Studies Results

Field studies were performed "before" and "after" the implementation of the optimized timing plans to measure the improvements in traffic flow. All field tests were done using the floating car technique, in which a vehicle is driven on selected network routes at the perceived average speed of traffic flow and a recorder makes manual entries of as travel time, delay and stops. The first year, field studies were required the Program. Local agencies were not required, although strongly encouraged, to perform field studies in the subsequent FETSIM grant cycles, except for systems with actuated signals operating "free" in the "before" case. Appendix C includes the individual projects' field results for eight grant cycles that information was available to ITS.

Figure 3.2 shows the average measured improvements based on the field studies in 123 systems in all grant cycles. Travel times were cut by an average of 9.8 percent and stops and delays were reduced by 23 percent. The savings were considerable higher for signals operating "free" in the before case (an average improvement of 27 percent in stops and delays.) The average savings for coordinated systems were 17 percent in stops and 20 percent in delay, considerably higher than the TRANSYT estimates.

FIGURE 3.2 FIELD MEASURED SAVINGS
123 Systems--(1983-1993)



The difference between TRANSYT and field results is due to the selected survey routes, number of test runs and definitional differences. Most of the cities that did field tests selected survey routes that followed the major arterials of their systems (or the through traffic for systems involving a single arterial.) They usually covered less than half of the total number of street segments (but more than half of the total vehicle-miles traveled) and in general undersampled turning movements. Also, the number of test runs performed was not sufficient to produce statistically significant results.

The average improvements based on TRANSYT and field results were estimated separately for small systems, typically single arterials with up to 15 signals, and for larger systems (Table 3.2). For the larger systems, field and TRANSYT derived savings compare reasonably well, similar to the findings from the comparison of the 11 projects in the 1983 grant cycle. The differences are much larger for the small arterial systems pointing out the significance of route selection, sample size and definitions of performance measures.

TABLE 3.2 TRANSYT ESTIMATED AND FIELD MEASURED SAVINGS (%)*

Performance	Systems with <15 signals		Systems with >15 signals	
Measures	TRANSYT	FIELD	TRANSYT	FIELD
Travel Time	8.6	8.8	7.8	7.4
Total Delay	16.0	23.2	14.0	16.5
No of Stops	11.1	17.3	13.1	17.1

* *Based on the results from 70 systems operating as coordinated before retiming*

3.1.3 Benefits and Costs

The cost-effectiveness of the FETSIM Program was calculated on each grant cycle using the following approach:

- fuel costs was assumed to be the current price at the gas pump for the particular year, excluding local and state taxes (i.e, ranged from $1.0 to $1.30 per gallon.)
- operating costs (vehicle wear & tear) due to delays and stops were calculated using the method recommended by the American Association of State Highway and Transportation Officials (AASHTO, 1977) adjusted to reflect current California vehicle fleet.
- value of time ($) was estimated using AASHTO's procedures

Overall program transportation benefits are shown in Table 3.3 assuming that the benefits last for one year (300 days.) A total of $85.1 million, more than five times the total cost of the Program will be saved in avoided fuel expenditures during the first year following implementation. Other transportation benefits of the program include reduced vehicle wear and tear and travel time savings. Using the AASHTO figures for the costs of vehicular wear and tear due to stops and delays and value of time, the eleven cycle projects are saving motorists an additional $93.6 million each year in operating costs, and $95.7 million in travel time.

The net first year benefit/cost ratio of the total Program is 17:1. Benefits from improved signal timings usually continue for two to five years, depending on the rate of travel increases and growth and development in each area. Also, improvements in "hardware" demonstration projects would last considerably longer because of the longer effective life of the signal equipment (about 10-12 years.) At an average of three years of benefits for each program cycle, the eleven grant cycles together will save $255.3 million in fuel costs plus $287.1 million in travel time and $280.8 million in vehicle wear and tear. Total savings of $823.2 million can be compared to total costs of $16.1 million, for a benefit-cost ratio of 51 to 1. This benefit-cost ratio makes the FETSIM Program one of the most effective the State of California has ever offered.

The program produced several additional benefits that were not quantified and are not included in the estimated benefit/cost ratio. Those include:

- One important result of reduced stops and delays at traffic signals is a substantial decrease in air pollutant emissions on project areas.

- Improvements in traffic safety which result from smoother traffic flow.

- Bus operators and their riders benefit from better signal timing, since operating costs are reduced and average speeds improve.

- Better-functioning traffic signals, since the program provided the opportunity to systematically check and repair equipment. Also, the FETSIM program helped to make operational new advanced control systems in major California cities. Examples include the retiming of most of the signals under the ATSAC traffic control system in Los Angeles, and the newly installed central control systems in the cities of Anaheim, Pasadena, Sacramento and San Jose.

- A better traffic data base, which many cities are using in other transportation studies and project analyses.

- Strengthened professional skills of participating staff members, and enhanced awareness of the benefits of traffic signal management, particularly among local budget officers and public works staff.

TABLE 3.3 BENEFITS OF THE FETSIM PROGRAM: 1983-1993

Annual Benefits	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	11-Year Total
						(in millions of dollars)						
Savings in fuel	12.8	6.7	4.6	7.0	5.8	8.4	8.2	7.4	8.2	8.0	8.0	85.1
Savings in vehicle wear & tear due to												
reduced delays	0.8	0.4	0.3	0.7	0.3	0.6	0.5	0.5	0.6	0.6	0.7	5.8
fewer stops	16.3	7.7	5.1	8.3	8.4	7.3	8.6	7.4	5.6	5.5	7.5	87.8
Savings in time due to reduced delays	12.4	6.2	3.9	11.1	5.7	9.1	7.5	8.5	9.9	9.6	11.8	95.7
Total annual benefits	42.3	21.0	13.9	27.1	20.3	25.3	24.8	23.8	24.3	23.6	28.0	274.4
Total assuming benefits continue an average of three years	126.9	63.1	41.7	81.4	60.8	76.0	74.4	71.3	72.9	70.7	83.9	823.2
Three year benefit-to-cost ratio	58:1	56:1	48:1	53:1	42:1	51:1	49:1	48:1	44:1	52:1	60:1	51:1

The value of these benefits depends on the "base case" conditions in each project area. Air pollution reductions, for example, are more important in non-attainment areas than in cities with clean air; bus savings accrue when bus routes are affected. Nevertheless, these additional benefits could be significant at the local level and should be kept in mind in assessing the FETSIM results.

Finally, when the FETSIM Program was initiated, concerns were raised that improved traffic flows might induce additional auto trips, which in turn cancel out the delay, stops, fuel and air pollution savings initially estimated. However, the analysis of the program results indicate that this is not the case. The total travel time benefits of the program are large, but from the perspective of the individual driver they are too modest to be likely to induce mode shifts or additional travel. Even in the cities that gained the most from the project, auto travel times for the typical trip through the network improved by one minute or less. Thus, it seems safe to say that the benefits of the program will not be canceled out by program-induced traffic increases.

3.2 Training in Signal Control and Management

The benefits of the training program were assessed through surveys conducted at the completion of each grant cycle. Most of the local traffic engineers expressed strong satisfaction with the training workshops and materials, particularly with the hands-on experience with the software. Larger cities, carried out most aspects of their projects in-house. In the majority of instances the staff in these cities felt in the future they would be able to use the TRANSYT model for signal retiming on their own.

Mid-sized cities tended to rely on consultants for most of the project work. Consequently, most staff members did not gain enough expertise in the use of the model to be able to apply it independently. However, the majority of the local staff felt that they were sufficiently well versed in the model application to design projects and closely supervise consultants in the future.

The benefits of the training for staff in small cities (under 50,000 population) varied considerably throughout the FETSIM Program. For many of these participants, much of the content of the training program was at too advanced a level for them to assimilate more than the general principles, and they felt they would continue to be dependent on consultants in project design and management in the future. Beginning in 1990, however, with the availability of interactive model pre-processors on microcomputers and the hands-on training, several engineers in those cities conducted projects in-house and felt that they can use TRANSYT on their own.

Most of the participants felt the need for continuing the training program to cover new features of the models and to train additional local staff members.

3.3 A National Model Grant Program

A number of states have programs to retime traffic signals for improved operating efficiency. Several of those programs have followed the approaches used in the FETSIM Program in offering grants, and training and technical support, and Caltrans and ITS FETSIM Project staff has provided advice and support in the design and implementation of those projects.

The key characteristics of nationwide traffic signal management programs are summarized below:

Training/technical assistance: Training and technical support is provided in the use of TRANSYT and PASSER-II signal timing models for coordinated signals and the SOAP model for isolated intersections (Florida, Missouri, New York, Texas, Washington)

Signal retiming: statewide signal timing optimization of coordinated systems by consulting teams (Florida, Illinois, Michigan, New Mexico) and isolated intersections (New Hampshire, North Carolina)

Grant programs: funds to local agencies to retime their signal systems (Minnesota, New York, Texas, Washington)

CHAPTER 4

CONCLUSIONS

4.1 Summary of the Program Evaluation

The FETSIM Program provided the financial assistance, training and technical support to retime over 12,000 traffic signals in urban arterials and networks; about 80 percent of all the eligible traffic signals under local jurisdiction in the State of California. Also, provided funding for signal equipment that helped to develop better functioning systems especially in smaller cities. In addition, the timing plans developed under the FETSIM Program improved the efficiency of advanced traffic control systems recently installed in several California cities.

The results from the FETSIM Program have clearly demonstrated that traffic signal timing improvements are a cost-effective way to reduce stops, delays, and fuel consumption. Annual fuel savings alone outweigh the total program costs by more than 5:1, based on the TRANSYT model estimates and verified by field studies. Using a broader but widely-accepted measure of benefits, which includes travel time and vehicular wear and tear savings as well as fuel savings, a 51:1 benefit-to-cost ratio will be produced if benefits are sustained for three years on average. Both benefit-cost ratios compare very favorably with the performance of other transportation investments. Additional unquantified gains include a substantial decrease in air pollutant emissions resulting from reduced stops and delays, and safety improvements due to smoother traffic flow. Even transit benefit from better signal timing, since operating costs are reduced and average speeds improve.

The training and technical assistance provided through the FETSIM Program strengthened the capabilities of local traffic engineering staff and their consultants. Over 300 practicing transportation engineers attended the training workshops and gained hands-on experience with computerized methods for signal timing. The training materials have been extensively used in workshops throughout the country. Also, several enhancements to the existing modeling tools were originated from the FETSIM program findings. Improved analysis procedures and software developed in support of the Program significantly reduce the effort for developing timing plans, and improve the quality of retiming projects.

The FETSIM program has received recognition as a major success, and serves as a model grant program for both California and the nation. In 1985, the California Energy Commission and the California Department of Transportation received the Institute of Transportation Engineers' Transportation Energy Conservation Award for the Program (CEC & Caltrans, 1985.)

4.2 The Road Ahead

Continuous traffic growth and difficulties in building new highway facilities through developed areas will mean that existing arterials and networks controlled by traffic signals will have to carry at least a portion of anticipated traffic increases. Proposed transportation management centers (TMCs) incorporating freeway ramp metering and other access restrictions designed to protect mainline freeway capacity will introduce additional traffic on surface streets. New federal, state and regional programs also may provide an impetus for greater attention to signal systems, particularly along major arterials. Efficient traffic signal control has been recognized as an important component of the advanced traffic control and information systems (ATMIS) currently pursued as a way for improving the efficiency of existing transportation facilities. Furthermore, the recent federal and California Clean Air Acts require that higher priority must be given to projects which reduce emissions. Efficient signal timing which reduces overall stops and delays is one of the most effective transportation control strategies for air pollution.

The FETSIM program demonstrated that a well designed program can provide the impetus for transportation professionals to improve the state-of-the-practice and obtain major transportation benefits. It is therefore recommended that the activities of a FETSIM type program continue, with major emphasis on i) staff training, ii) continuation of grant program for retiming and hardware equipment where doing so could produce large benefits, and iii) testing advanced control strategies including multi-modal strategies. These proposed program directions are discussed below:

(1) **Training:** The training should be provided via mini-courses rather than combined with a grant or demonstration program. Providing training independently from signal retiming projects would permit greater flexibility in staffing and scheduling projects. Two types of courses are proposed:

Modeling course(s): training in the use of computerized techniques for advanced signal timing with hands-on experience. Examples include the QUICK-7F/TRANSYT-7F training course and the PASSER-II course developed by ITS for Caltrans. These courses will be designed for engineers who would carry out the technical analysis of retiming projects.

Traffic signal management course(s): Training for traffic engineers and managers who need to know less about the details of the models and more about the factual basis for coordinated signal timing, development and selection of control strategies, recent advances in hardware and software, and findings from ongoing demonstration projects. Examples, include the advanced traffic control courses developed by ITS.

(2) **Grant Program:** A grant program should be continued for local jurisdictions to retime their signal systems. Such a program may be administered by the regional planning agencies in cooperation with Caltrans and may include State highways. For example, the Metropolitan Transportation Commission (MTC) has initiated such a program for the Bay Area cities. Funding priority should be given on maintaining the benefits from the FETSIM program, to systems with highest benefits potential, and signal retiming efforts that involve advanced analysis (additional timing plans, different subsystems at different times of day, etc.) Examples may include:

Update of FETSIM optimized signal timing plans: Timing updates are highly cost effective and indeed necessary to maintain original benefits of the systems retimed under the FETSIM Program, especially for high traffic growth locations. It has been found that "ageing" of timing plans degrades traffic performance by 2-4 percent per year, which would produce substantial benefits for heavily travelled networks. The FETSIM Program funded projects for retiming systems previously timed through the program, provided that a five year period has elapsed since the original grant application and subject to the availability of funds remaining from the allocation to the first time participants. Only a few projects were repeats and were generally funded at a lower cost per signal (assuming that collection and coding of network characteristics would not need to be completely redone.)

Multi-jurisdictional applications: A number of major arterials cross several jurisdictional boundaries, and are timed in separate segments, which may not be the best traffic signal management strategy. The FETSIM Program encouraged multi-jurisdictional projects, but a few projects were carried out, largely because of hardware incompatibilities, differences in agencies' approach about managing signal systems, and concerns about who would serve as lead agency. Fiscal incentives as well as direct assistance should be provided for multi-jurisdictional projects to resolve hardware problems, negotiation of joint operating strategies and cost sharing, and application of sophisticated timing strategies (definition and operation of subsystems, handling of critical intersections, etc.)

Small systems: the retiming of small (less than 10 intersections) signal systems generally has not been as cost-effective as retiming larger systems along heavily travelled arterials or in dense grid networks. Such small projects if funded might be consolidated rather than carried out under several separate contracts to streamline contract administration and reporting. Technical assistance teams might be established to carry out the work in the consolidated project (data collection, development of timing plans. etc.) and prepare a single final report.

(3) **Demonstration projects:** The implementation of improved hardware and software on existing signal systems may produce substantial traffic flow improvements and energy and environmental savings. Priority should be given to i) demonstrations of advanced control systems and techniques for signal systems, and ii) signal equipment upgrades in networks with large expected benefits:

Advanced traffic control and management: A number of traffic signal systems and strategies have been developed to respond to on-line changes in traffic volumes and adjust to current changes in traffic demand. Recent experiments with coordinated freeway-arterial management, and with advanced roadside and in-vehicle information systems offer potential for significant traffic flow improvements. Demonstration projects applying new technologies and integrating corridor management concepts should be conducted to assess their effectiveness and develop guidelines for their practical implementation. Such demonstration projects may be conducted in cooperation with the testbeds established for the field operational tests under the ongoing ATMIS research activities, and may also involve testing of transit management concepts (e.g., signal preemption) with timing and control strategies to facilitate transit movements along major signalized arterials that are also are major bus routes. Also, further research is needed on developing and testing improved modeling tools for traffic signal timing.

Hardware and software assistance: Funding should be provided to those project locations where improved signal equipment will produce large savings, based on a thorough review of the specific network characteristics where improved equipment could be installed, and careful assessment of the expected benefits by investments in new equipment. For example, it may be more cost-effective to replace a few modern controllers to overcome compatibility problems or permit sophisticated timing plans to be implemented (e.g., replace old three dial electromechanical controllers with modern equipment capable of several timing plans in a congested network), than to add coordination equipment to a small system with relatively light traffic. While costs of equipment and software, particularly those requiring systemwide installation of state-of-the-art technologies, can be substantial, the benefits also may be very large.

Caltrans in cooperation with local and regional agencies could continue to play a major role in a continuation of a FETSIM type Program as described above. Possible activities might include i) administration and management, e.g., assist in selection of technical assistance teams for small systems, helping in the funding and coordination of large multi-jurisdictional projects, ii) training and technical assistance to local agencies in developing and strengthening in-house capabilities for ongoing traffic signal management, and iii) conducting research and evaluation studies involving advanced traffic control and management demonstrations and applications.

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APPENDIX A

LOCAL AGENCY PARTICIPATION IN THE FETSIM PROGRAM

1983-1993 (11 GRANT CYCLES)

TABLE A.1 LOCAL AGENCY PARTICIPATION IN THE FETSIM PROGRAM

#	YR	LOCAL AGENCY	COUNTY	N/S	POPUL	TOTAL # INT	#YRS	GRANT AWARD
#	YR	LOCAL AGENCY	COUNTY	N/S	POPUL	TOTAL # INT	#YRS	GRANT AWARD
1	85	Alameda	Alameda	N	75000	39	2	41,200
2	92	Alameda County	Alameda	N	1295000	18	1	23,400
3	89	Alhambra	Los Angeles	S	72000	62	2	177,550
4	86	Anaheim	Orange	S	265000	249	5	290,323
5	91	Antioch	Contra Costa	N	62032	14	1	11,550
6	86	Arcadia	Los Angeles	S	46100	15	1	17,670
7	92	Atascadero	San Louis Obispo	N	21000	10	1	10,500
8	88	Azusa	Los Angeles	S	36815	10	1	12,600
9	86	Bakersfield	Kern	S	161000	145	5	145,205
10	86	Baldwin Park	Los Angeles	S	56400	10	1	9,000
11	86	Bell	Los Angeles	S	27450	29	2	24,000
12	87	Bell Gardens	Los Angeles	S	36000	23	1	28,980
13	85	Bellflower	Los Angeles	S	53000	38	2	45,700
14	83	Berkeley	Alameda	N	105000	100	3	107660
15	83	Beverly Hills	Los Angeles	S	33000	45	1	48,555
16	89	Buena Park	Orange	S	65839	26	2	33,000
17	89	Cambell	Santa Clara	N	35000	9	1	13,975
18	87	Carlsbad	San Diego	S	52000	7	1	8,400
19	91	Carson	Los Angeles	S	88000	27	1	36,000
20	92	Cathedral City	Riverside	S	30000	16	1	16,425
21	85	Chino	San Bernardino	S	45350	43	2	42,555
22	86	Chula Vista	San Diego	S	128000	145	2	147,500
23	93	Clovis	Fresno	N	55300	14	1	14,000
24	83	Compton	Los Angeles	S	90000	83	2	89,300
25	83	Concord	Contra Costa	N	115000	115	3	144,200
26	84	Contra Costa County	Contra Costa	N	819000	17	1	16,949
27	89	Corona	Riverside	S	65000	65	3	69,600
28	83	Costa Mesa	Orange	S	90000	103	4	94,335
29	83	Culver City	Los Angeles	S	38500	36	3	40,496
30	83	Cupertino	Santa Clara	N	40354	45	2	46,135
31	91	Daly City	San Mateo	N	94000	22	2	46,000
32	91	Davis	Yolo	N	44000	8	1	12,840
33	90	Downey	Los Angeles	S	94444	170	4	133,207
34	83	Duarte/Monrovia	Los Angeles	S	57385	15	1	25,300
35	87	Dublin	Alameda	N	17377	9	1	10,800
36	89	East Palo Alto	Santa Clara	N	18200	8	1	53,100
37	83	El Cajon	San Diego	S	90000	127	8	142,408
38	90	Encinitas	San Diego	S	53000	22	1	58,900
39	83	Escondido	San Diego	S	68710	27	1	29,279

Notes:

YR: first year local agency participated in the Program
N/S: Location (Northern/Southern California)
#INT: Total number of intersections retimed under the FETSIM Program
#YRS: Number of grant cycles that local agency participated
AWARD: Total grant amount for all grant cycles

TABLE A.1 LOCAL AGENCY PARTICIPATION IN THE FETSIM PROGRAM (Cont.)

#	YR	LOCAL AGENCY	COUNTY	N/S	POPUL	TOTAL # INT	#YRS	GRANT AWARD
40	90	Eureka	Humboldt	N	25000	17	1	15,000
41	85	Fairfield	Solano	N	65000	25	1	23,810
42	92	Fontana	San Bernardino	S	87500	14	1	11,500
43	88	Foster City	San Mateo	N	29750	28	2	17,238
44	90	Fountain Valley	Orange	S	57500	41	2	33,000
45	83	Fremont	Alameda	N	175000	97	3	119,150
46	86	Fresno	Fresno	N	330000	281	5	299,350
47	86	Fresno County	Fresno	N	688000	11	1	16,172
48	86	Fullerton	Orange	S	109319	61	2	69,276
49	86	Garden Grove	Orange	S	136000	48	1	51,494
50	83	Gardena	Los Angeles	S	52288	84	3	96,787
51	91	Glendale	Los Angeles	S	180000	109	3	93,600
52	84	Glendora	Los Angeles	S	40000	16	1	13,900
53	93	Hanford	Kings	N	32000	21	1	21,000
54	83	Hawthorne	Los Angeles	S	55000	59	1	55,000
55	83	Hayward	Alameda	N	103000	44	3	50,915
56	93	Healdsburg	Sonoma	N	10000	11	1	11,000
57	90	Hesperia	San Bernardino	S	62500	17	2	51,386
58	85	Huntington Beach	Los Angeles	S	185000	90	3	113,193
59	89	Huntington Park	Los Angeles	S	51210	31	1	41,481
60	83	Inglewood	Los Angeles	S	110000	176	5	169,815
61	83	Irvine	Orange	S	114346	186	7	173,800
62	92	La Hambra	Orange	S	49000	16	1	20,800
63	88	La Mesa	San Diego	S	52000	20	1	64,875
64	91	Lancaster	Los Angeles	S	90000	15	1	16,231
65	93	Loma Linda	San Bernardino	S	18500	15	1	15,000
66	83	Long Beach	Los Angeles	S	406000	371	6	337,000
67	83	Los Angeles	Los Angeles	S	3500000	2645	11	2,688,036
68	89	Los Gatos	Santa Clara	N	32000	12	1	16,200
69	83	Lynwood	Los Angeles	S	56000	73	2	73,880
70	86	Manhattan Beach/El Segundo	Los Angeles	S	50000	40	1	37,400
71	93	Manteca	San Joaquin	N	42500	15	1	15,000
72	84	Menlo Park	San Mateo	N	26000	17	2	18,700
73	91	Mill Valley	Marin	N	13500	6	1	28,082
74	91	Mission Viejo	Orange	S	82000	49	1	55,125
75	89	Modesto	Stanislaus	N	165239	57	3	199,540
76	88	Monrovia	Los Angeles	S	32650	18	1	24,100
77	83	Montebello	Los Angeles	S	59000	69	3	83,400
78	83	Monterey	Monterey	N	28000	35	2	38,500
79	90	Monterey Park	Los Angeles	S	62887	12	1	46,475
80	92	Moreno Valley	Riverside	S	130000	36	2	32,675
81	87	Napa	Napa	N	60000	30	2	38,700
82	89	National City	San Diego	S	55000	23	2	24,300
83	83	Newport Beach	Orange	S	64500	11	1	16,250
84	83	Norwalk	Los Angeles	S	85000	40	1	44,000
85	83	Oakland	Alameda	N	343000	206	6	252,896

TABLE A.1 LOCAL AGENCY PARTICIPATION IN THE FETSIM PROGRAM (Cont.)

#	YR	LOCAL AGENCY	COUNTY	N/S	POPUL	TOTAL # INT	#YRS	GRANT AWARD
86	87	Oceanside	San Diego	S	140000	46	2	49,000
87	90	Ontario	Los Angeles	S	120000	52	2	51,733
88	86	Orange	Orange	S	105000	50	2	51,339
89	86	Orange County	Orange	S	2445000	50	1	45,920
90	83	Oxnard	Ventura	S	129000	63	4	66,352
91	87	Palm Desset	Riverside	S	30000	10	1	12,000
92	86	Palm Springs	Riverside	S	43000	25	2	26,720
93	84	Palo Alto	Santa Clara	N	56831	85	2	94,200
94	88	Paramount	Los Angeles	S	34000	29	1	26,100
95	87	Pasadena	Los Angeles	S	130000	334	6	305,500
96	88	Petaluma	Sonoma	N	40000	13	1	61,550
97	89	Pittsburg	Contra Costa	N	43000	9	1	47,950
98	92	Placentia	Orange	S	40000	37	1	36,490
99	89	Pleasant Hill	Contra Costa	N	30000	10	1	26,900
100	83	Pleasanton	Alameda	N	50000	35	3	41,292
101	84	Pomona	Los Angeles	S	100000	20	1	13,400
102	87	Poway	San Diego	S	37947	19	2	22,800
103	93	Rancho Cucamonga	San Bernardino	S	105000	42	1	42,000
104	83	Redding	Shasta	N	45000	26	1	26,890
105	88	Redondo Beach	Los Angeles	S	64000	13	1	11,412
106	83	Redwood City	San Mateo	N	56000	34	1	37,400
107	83	Richmond	Contra Costa	N	74676	30	1	36,750
108	88	Riverside	Riverside	S	209728	42	2	42,075
109	92	Riverside County	Riverside	S	1240000	8	1	11,433
110	85	Rosemead	Los Angeles	S	46100	60	2	47,400
111	88	Roseville	Placer	N	42500	21	2	16,623
112	86	Sacramento	Sacramento	N	339900	258	5	211,069
113	88	Sacramento County	Sacramento	N	1076000	28	1	35,000
114	86	Salinas	Monterey	N	113000	32	2	26,482
115	83	San Bernardino	San Bernardino	S	150000	106	3	100,478
116	83	San Diego	San Diego	S	1100000	808	8	688,728
117	92	San Fernando	Los Angeles	S	21000	8	1	24,400
118	83	San Francisco	San Francisco	N	726962	561	6	579,852
119	86	San Gabriel	Los Angeles	S	30000	27	1	30,000
120	83	San Jose	Santa Clara	N	755000	185	4	207,606
121	84	San Leandro	Alameda	N	65000	22	2	11,902
122	92	San Luis Obispo	San Louis Obispo	N	40000	33	1	54,900
123	91	San Marcos	San Diego	S	35000	12	1	14,000
124	83	San Rafael	Marin	N	50000	88	2	93,956
125	90	San Ramon	Contra Costa	N	35950	42	2	65,200
126	83	Santa Ana	Orange	S	215000	115	3	111,061
127	83	Santa Barbara	Santa Barbara	S	85000	190	3	118,500
128	87	Santa Barbara County	Santa Barbara	S	375000	23	1	30,590
129	85	Santa Clara	Santa Clara	N	90879	23	2	63,300
130	88	Santa Clara County	Santa Clara	N	1506000	5	1	46,768
131	91	Santa Clarita	Los Angeles	S	147000	50	1	52,500

TABLE A.1 LOCAL AGENCY PARTICIPATION IN THE FETSIM PROGRAM (Cont.)

#	YR	LOCAL AGENCY	COUNTY	N/S	POPUL	TOTAL # INT	#YRS	GRANT AWARD
132	92	Santa Cruz	Santa Cruz	N	50000	20	2	19,900
133	84	Santa Fe Springs	Los Angeles	S	33000	18	1	17,698
134	83	Santa Maria	Santa Barbara	S	40000	25	1	31,250
135	84	Santa Monica	Los Angeles	S	100000	190	6	150,601
136	83	Santa Rosa	Sonoma	N	88683	20	1	8,800
137	89	Santee	San Diego	S	59980	48	3	42,950
138	91	Sausalito	Marin	N	7500	10	1	13,000
139	91	Seaside	Monterey	N	38509	17	1	37,450
140	93	Signal Hill	Los Angeles	S	8300	20	1	20,000
141	92	Simi Valley	Ventura	S	95000	22	1	24,236
142	91	Solano Beach	San Diego	S	15000	9	1	21,600
143	88	South Gate	Los Angeles	S	76000	15	1	17,500
144	88	South San Francisco	San Mateo	N	60000	53	4	111,494
145	83	Stockton	San Joaquin	N	189192	132	3	143,350
146	88	Thousand Oaks	Ventura	S	100000	11	1	11,780
147	84	Torrance	Los Angeles	S	139000	127	3	128,260
148	83	Tracy	San Joaquin	N	32700	22	2	30,732
149	87	Turlock	Stanislaus	N	35000	8	1	65,480
150	84	Tustin	Los Angeles	S	40205	30	1	26,100
151	88	Union City	Alameda	N	49880	11	1	44,850
152	84	Upland	Los Angeles	S	50000	14	1	13,300
153	92	Vacaville	Solano	N	55000	10	1	29,000
154	85	Ventura	Ventura	S	90000	34	3	39,987
155	91	Victorville	San Bernardino	S	40734	7	1	7, 256
156	83	Walnut Creek	Contra Costa	N	53643	55	2	57,652
157	92	Watsonville	Santa Cruz	N	30000	10	1	49,000
158	86	West Covina	Los Angeles	S	97000	59	5	88,942
159	89	West Hollywood	Los Angeles	S	90000	84	2	48,500
160	88	West Hollywood/Beverly Hills	Los Angeles	S	90000	12	1	25,200
161	84	Westminster	Orange	S	73500	35	2	43,000
162	84	Whittier	Los Angeles	S	70000	41	1	32,595
163	89	Yorba Linda	Orange	S	39200	33	1	81,825

APPENDIX B

CHARACTERISTICS OF FETSIM PROJECTS

TRANSYT-7F ESTIMATED BENEFITS

EXPLANATION OF TABLE HEADINGS

LOCAL AGENCY

xxxxxx: Name of local agency
xxxxxx(H):Hardware demonstration project

#INT

xx: Total number of signals in the FETSIM grant

NETWORK TYPE

ART: Single arterial
- x: number of arterials in the project
- xx: number of signals on arterials

C-ART: Crossing arterials
- x: number of crossing arterials in the project
- xx: number of signals on crossing arterials

GRID: Grid network
- x: number of grid networks in the project
- xx: number of signals on grid networks

SIGNAL EQUIPMENT

#PR: Total number of pretimed signals

#ACT: Total number of actuated signals

COORD: Type of signal coordination
- HW: Hardwire interconnect
- TB: Time-based coordination
- PH: Phone lines

CONTROL: Type of master/signal controller
- ELECTR: Electromechanical fixed-time controller
- FT: Solid State fixed-time controller
- 90: NEMA Type 90 controller
- 170: Type 170 controller
- TRX xxx: Traconex controller/master (390/400)
- MS xxx: Multisonics controller (810/820)
- VMS xxx: Multisonics system (201/220)
- E-KMS xxxx: Econolite closed loop arterial systems (8000/10000)
- HWL xxx: Honeywell control system (L-6)
- UTCS: FHWA UTCS central control system

TRANSYT BENEFITS (%)

#INT: number of signals in the TRANSYT analysis
TTIME: Total travel time
DELAY: Total delay
STOPS: Number of Stops
FUEL: Fuel consumption
xx: % change from existing timings for average weekday (-:improvement)

TABLE B.1 1983 FETSIM GRANT CYCLE

LOCAL AGENCY	# INT	NETWORK TYPE						SIGNAL EQUIPMENT				TRANSYT BENEFITS (%)				
		ART		C-ART		GRID		# PR	#ACT	COORD	CONTROL	# INT	T TIME	DELAY	STOPS	FUEL
Berkeley	28					1	28	28	0	HW	ELECTR	28	-9.4	-19.6	-20.6	-10.8
Beverly Hills	45			1	45			20	25	HW	VARIOUS					
Compton	40					1	40	0	40	HW	HWL L-6	34	-12.7	-24.5	-36.0	-15.0
Concord	40					1	40	10	30	HW	VMS220	40	-5.5	-11.4	-11.2	-6.6
Costa Mesa	40			1	40			0	40	HW	VMS220					
Culver City	16			1	16			0	16	HW	VMS220					
Cupertino	30			1	30			0	30	HW	VMS220	22	-12.3	-31.2	-32.1	-16.7
Duarte/Monrovia	15	1	15					5	10	HW	170					
El Cajon	33			1	6	2	27	0	33	HW	HWL HMM-200					
Escondido	27					1	27	11	16	TB/PH	170/ 90	27	-7.0	-13.0	-17.0	-8.0
Fremont	17	1	6	1	11			0	17	HW	VMS201	15	-3.4	-5.2	-7.7	-4.5
Gardena	10	1	10					0	10	TB	170	8	-6.1	-9.8	-27.9	-11.8
Hawthorne	59					1	59	12	47	HW	VARIOUS	53	-7.1	-19.3	-30.6	-13.2
Hayward	12					1	12	12	0	HW	ELECTR	12	-21.0	-34.0	-26.0	-20.0
Inglewood	50					1	50	9	41	HW	UTCS/FT,170					
Irvine	20			1	20			0	20	HW	VMS220	17	-16.8	-25.7	-22.0	-16.5
Long Beach	91					1	91	91	0	HW	HWL HMC-1000	90	-4.0	-11.0	-13.0	-5.0
Los Angeles	267					2	267	112	155	HW/PH	170/ELECTR	250	-3.0	-8.0	-9.0	-4.0
Lynwood	32			1	32			0	32	TB	170	29	-3.0	-5.0	-14.0	-4.0
Montebello	24	2	24					4	20	PH	VARIOUS	19	-8.0	-20.0	-22.0	-11.0
Monterey	17					1	17	10	7	HW	TRX HMP290					
Newport Beach	11	2	11					0	11	HW	EMC-800/170	8	-12.5	-34.2	-28.3	-14.4
Norwalk	40			1	40			0	40	TB	170					
Oakland	27					1	27	27	0	HW	ELECTR	26	-3.0	-7.5	-5.0	-3.0
Oxnard	8	1	8					6	2	HW	90/ELECTR	8	-12.2	-26.4	-17.3	-10.6
Pleasanton	10	1	10					0	10	HW	VMS220	10	-2.0	-7.0	3.0	-0.3
Redding	26					1	26	26	0	HW	ELECTR	26	-14.2	-26.3	-6.8	-11.0
Redwood City	34					2	34	9	25	HW	VMS220					
Richmond	30	1	6	1	10	1	14	10	20	HW	MS/ELECTR	25	-6.9	-15.8	-15.8	-7.5
San Bernardino	54					1	54	54	0	HW	FT/90	50	-9.4	-24.5	-19.5	-10.0
San Diego	42					1	42	26	16	HW	VMS/ ELECTR	39	-6.0	-9.0	-8.0	-5.0
San Francisco	76					1	76	76	0	HW	ELECTR	75	-3.0	-7.0	-13.0	-5.0
San Jose	51	1	5			1	46	46	5	HW/TB	ELECTR/170	49	-6.0	-12.0	-15.0	-7.0
San Rafael	38					1	38	38	0	HW	ELECTR	37	-4.4	-9.5	-9.1	-3.0
Santa Ana	30					1	30	22	8	HW	VMS220	30	-10.0	-23.0	-21.0	-13.0
Santa Barbara	50	1	7			1	43	43	7	HW/PH	VMS/ FT,170	43	-9.2	-16.7	-12.8	-9.8
Santa Maria	25					1	25	0	25	HW	170					
Santa Rosa	20					1	20	12	8	HW	170,90	19	-23.0	-36.0	-28.0	-22.0
Stockton	31			1	31			0	31	HW	VMS220					
Tracy	11			1	11			0	11	PH	170	11	-6.9	-15.0	-13.0	-8.5
Walnut Creek	32					1	32	0	32	HW	VMS220					
Totals	1559	12	102	12	292	28	1165	719	840			1100				
Average % change													-8.6	-17.5	-17.2	-9.6

TABLE B.2 1984 FETSIM GRANT CYCLE

LOCAL AGENCY	# INT	NETWORK TYPE: ART		C-ART		GRID		SIGNAL EQUIPMENT: # PR	#ACT	COORD	CONTROL	TRANSYT BENEFITS (%): # INT	T TIME	DELAY	STOPS	FUEL
Contra Costa County	17					1	17	0	17	PH	170	16	-9.6	-15.3	-20.8	-12.2
Culver City	13			1	13			0	13	HW	VMS220					
Glendora	16			1	16			0	16	TB	TRX 290					
Irvine	19			1	19			0	19	HW	VMS220	19	-10.0	-15.0	-11.0	-8.3
Los Angeles	209					4	209	93	116	HW	UTCS/170	209	-3.5	-7.2	-7.9	-2.9
Menlo Park	7	1	7					0	7	HW/TB	VMS220					
Oakland	60					1	60	60	0	HW	ELECTR	60	-5.7	-17.0	-15.0	-5.9
Oxnard	13			1	13			0	13	TB	170	13	-5.0	-11.0	17.0	-9.8
Palo Alto	45	1	10			1	35	25	20	HW	VMS220	37	-4.0	-15.0	-19.0	-6.4
Pomona	20			1	20			0	20	HW	VMS201	20	-8.1	-21.0	-22.0	-12.0
San Diego	150					1	150	144	6	HW	UTCS/170	150	-7.5	-14.5	-17.5	-7.8
San Francisco	84			1	16	1	68	84	0	HW	ELECTR	78	-5.4	-13.4	-14.8	-7.7
San Leandro	14	2	14					0	14	HW	170	8	-8.4	-13.8	-10.7	-7.9
Santa Ana	41			1	41			10	31	HW	VMS220	41	-9.0	-16.9	-16.9	-10.0
Santa Fe Springs	18	2	18					0	18	TB	90	18	-7.0	-14.8	-15.0	-8.0
Santa Monica	46					1	46	40	6	HW	ELECTR					
Stockton	27			1	27			0	27	HW	VMS220	27	-2.4	-5.0	-7.1	-3.5
Torrance	36			1	36			26	10	HW/PH	ELECTR					
Tustin	30			1	30			10	20	HW/PH	E-KMC					
Upland	14	1	14					0	14	HW	E-TCS-30	14	-7.5	-12,3	-15.1	-9.5
Westminster	17			1	17			0	17	HW	E-D Series	17	-5.3	-9.6	-13.1	-8.1
Whittier	41			1	18	1	23	23	18	HW/PH	ELECTR/170	41	-5.0	-16.3	-17.4	-7.4
Totals	937	7	63	12	266	11	608	515	422			768				
Average % change													-6.5	-13.6	-12.9	-8.0

TABLE B.3 1985 FETSIM GRANT CYCLE

LOCAL AGENCY	# INT	NETWORK TYPE						SIGNAL EQUIPMENT				TRANSYT BENEFITS (%)				
		ART		C-ART		GRID		# PR	#ACT	COORD	CONTROL	# INT	T TIME	DELAY	STOPS	FUEL
Alameda	31					2	31	26	5	HW	ELECTR	31	-3.8	-9.4	-11.4	-5.0
Bellflower	25					1	25	11	14	HW	ELECTR/170	25	-5.4	-12.3	-21.6	-8.8
Berkeley	45	1	20			1	25	38	7	HW	VARIOUS	41	-4.6	-12.4	-10.0	-4.6
Chino	18			1	18			0	18	HW	170	18	-5.7	-10.5	-13.3	-7.7
Costa Mesa	21	1	21					0	21	HW	170					
Culver City	7	1	7					0	7	HW	VMS220	7	-8.8	-12.6	-13.7	-9.9
Fairfield	25	1	6	1	19			0	25	HW/TB	170	25	-3.5	-7.6	-19.5	-6.7
Huntington Beach	27	2	27					0	27	HW/TB	VMS220/TRX290					
Inglewood	60					1	60	0	60	HW	UTCS/FT,170	60	-7.7	-16.7	-18.0	-10.8
Irvine	21			1	21			0	21	HW	VMS220	21	-2.0	-4.4	-12.1	-4.2
Los Angeles	252					2	252	98	154	HW	UTCS/170	252	-3.4	-11.0	-7.9	-3.5
Montebello	15	1	15					0	15	HW	VARIOUS					
Rosemead	29			1	29			2	27	TB	170					
San Bernardino	21	2	21					11	10	HW/TB	FT/170					
Santa Clara	17	1	5			1	12	7	10	HW	FT/TRX 290	17	-6.1	-16.2	-16.2	-8.0
Santa Monica	45	3	45					25	20	HW	VARIOUS					
Torrance	32	3	32					20	12	HW/PH	VARIOUS					
Ventura	10	1	10					0	10	HW	170	10	-1.1	-1.9	-18.0	-7.6
Totals	701	17	209	4	87	8	405	238	463			507				
Average % change													-4.7	-10.5	-14.7	-7.0

TABLE B.4 1986 FETSIM GRANT CYCLE

LOCAL AGENCY	# INT	NETWORK TYPE						SIGNAL EQUIPMENT				TRANSYT BENEFITS (%)				
		ART		C-ART		GRID		# PR	#ACT	COORD	CONTROL	# INT	T TIME	DELAY	STOPS	FUEL
Anaheim	15	1	15					0	15	TB	CST T-1	15	-4.7	-7.1	-4.9	-4.9
Arcadia	15			1	15			0	15	HW	VMS220	15	-14.7	-27.0	-7.9	-11.3
Bakersfield	21					1	21	20	1	TB	170	21	-3.7	-3.9	-13.8	-3.7
Baldwin Park	10	1	10					0	10	HW	170	10	-22.0	-29.8	-16.3	-19.4
Bell	10	1	10					10	0	PH	ELECTR	10	-2.6	-6.1	-6.6	-2.8
Bellflower	13	1	13					3	10	TB	170	13	-12.3	-23.3	-20.0	-10.7
Berkeley	27			1	27			27	0	HW	ELECTR	27	-1.4	-2.7	-5.2	-2.4
Chula Vista	47					1	47	40	7	HW	ELECTR	47	-1.0	-2.4	-8.1	-3.0
Costa Mesa	20			1	20			0	20	HW	VMS220	20	-16.8	-24.7	-20.3	-16.3
El Cajon	22	1	10	1	12			0	22	HW/TB	170	12	1.1	1.5	-7.8	-1.8
Fresno	66					1	66	60	6	HW	MOD TMR-1	65	-4.0	-9.5	-12.0	-5.5
Fresno County	11	1	11					0	11	HW/TB	170	11	-7.6	-7.9	-2.5	-7.4
Fullerton	36	2	11	1	25			6	30	HW	VMS220/FT	14	-5.5	-7.3	-12.2	-6.7
Garden Grove	48					1	48	0	48	HW/PH	VMS220	48	-7.3	-2.0	-16.0	3.0
Long Beach	41					1	41	41	0	HW/TB	170/ELECTR	41	-3.7	-16.7	-11.2	-6.7
Los Angeles	239					3	239	113	126	HW/TB	UTCS/170	239	-3.9	-11.8	-9.5	-4.2
Manh Beach/El Seg	40	1	11			1	29	2	38	HW/TB	170	39	-11.5	-7.6	-12.2	-3.9
Menlo Park	10	1	10					0	10	HW	170					
Oakland	37	1	16			1	21	37	0	HW	ELECTR	37	-6.0	-12.0	-13.7	-7.2
Orange	18	1	18					0	18	HW	VMS220	8	-11.0	-16.8	-5.1	-8.8
Orange County	50	5	50					0	50	HW	VMS220	42	-17.1	-19.3	-7.6	-7.2
Oxnard	25	1	9	1	16			0	25	TB	170					
Palm Springs	15			1	15			0	15	TB	TRX 290					
Sacramento	50					1	50	50	0	HW	3M TSB	50	-7.8	-5.3	-9.4	-2.9
Salinas	12	1	12					9	3	HW	TRX TMP400	12	-4.7	-7.9	-16.3	-7.8
San Diego	32					1	32	0	32	HW	UTCS/170	32	-12.7	-19.9	-13.1	-11.2
San Francisco	86	1	36			1	50	86	0	HW	ELECTR	87	-3.6	2.0	-24.3	-5.8
San Gabriel	27			1	27			0	27	TB	170					
Santa Barbara	76	2	21			1	55	31	45	HW/TB	VMS220/FT	55	-11.7	-27.4	-8.8	-8.9
Walnut Creek	23	2	23					0	23	HW	VMS220	17	-4.3	-7.9	-12.4	-6.1
West Covina	9	1	9					0	9	HW	VMS220	9	-12.4	-21.2	-5.5	-8.2
Totals	1151	25	295	8	157	14	699	535	616			996				
Average % change													-7.9	-12.0	-11.2	-6.7

TABLE B.5 1987 FETSIM GRANT CYCLE

		NETWORK TYPE						SIGNAL EQUIPMENT				TRANSYT BENEFITS (%)				
LOCAL AGENCY	# INT	ART		C-ART		GRID		# PR	#ACT	COORD	CONTROL	# INT	T TIME	DELAY	STOPS	FUEL
Bakersfield	15	2	15					0	15	HW/TB	170	15	-3.0	-3.9	-2.1	-2.5
Bell Gardens	23			1	23			0	23	TB	ECON	23	-9.6	-15.9	-9.7	-8.3
Carlsbad	7	1	7					0	7	TB	170					
Dublin	9	1	9					0	9	HW	TRX TMP400	8	-4.5	-13.0	-5.7	-5.0
Fresno	48	2	14			2	34	11	37	HW/TB	170	52	-16.3	-16.3	-2.8	-8.4
Fullerton	25	3	25					0	25	HW	VMS220	25	-11.2	-15.5	-13.2	-10.9
Irvine	47	2	20	1	27			0	47	HW	VMS220					
Long Beach	41	2	41					14	27	HW/TB	170	41	-0.1	0.8	-19.1	-5.5
Los Angeles	216					1	216	193	23	HW/TB	UTCS/170	217	-10.4	-22.6	-23.8	-12.1
Napa	18					1	18	11	7	HW	VMS220	18	-26.2	-41.3	-18.4	-18.3
Oakland	25					1	25	25	0	HW	ELECTR	27	1.4	-4.2	-8.4	-3.6
Oakland (H)	*6*	*1*	*6*					*5*	*1*	*TB*	*FT*					
Oceanside	15	1	15					2	13	TB	170					
Oxnard	17	1	17					0	17	HW	170					
Palm Dessert	10	1	10					0	10	TB	90					
Palm Springs	10	1	10					0	10	TB	TRX 290					
Palo Alto	40	2	13			2	27	2	38	HW	VMS220	40	-14.0	-20.1	-12.2	-7.4
Pasadena	80					1	80	77	3	HW	E KFT-1800/FT	80	-0.8	-2.3	-0.7	-0.6
Poway	8	1	8					0	8	TB	170/90					
Sacramento	11	1	11					11	0	HW	3M TCP	11	-2.6	-4.0	-6.3	-3.4
San Francisco	154					1	154	154	0	HW	ELECTR	154	-3.2	-7.6	-15.7	-7.4
Santa Barbara Co (H)	*23*	*3*	*23*					*0*	*23*	*TB*	*170*					
Turlock (H)	*8*					*1*	*8*	*7*	*1*	*HW*	*170/ELECTR*					
West Covina	14	1	14					0	14	HW	VMS220	14	-5.7	-8.2	-16.6	-9.3
Totals	870	26	258	2	50	10	562	512	358			725				
Average % change													-7.6	-12.4	-11.1	-7.3

TABLE B.6 1988 FETSIM GRANT CYCLE

		NETWORK TYPE						SIGNAL EQUIPMENT				TRANSYT BENEFITS (%)				
LOCAL AGENCY	# INT	ART		C-ART		GRID		# PR	#ACT	COORD	CONTROL	# INT	T TIME	DELAY	STOPS	FUEL
Anaheim	65					2	65	0	65	HW	UTCS/170					
Azusa	10	1	10					4	6	HW	90					
Bell	19			1	19			0	19	TB	170	19	1.9	4.4	-2.2	-0.8
Compton	43			1	43			0	43	PH	TRX/90	43	-7.1	-15.4	-17.4	-8.2
Costa Mesa	22			1	22			0	22	HW	VMS220	20	-8.6	-12.7	-8.0	-8.4
El Cajon	22			1	22			0	22	HW	HWL HMC1000	22	-16.3	-30.2	-24.8	-23.9
Foster City	8	1	8					0	8	HW	TRX TMM-400	8	-8.2	-12.3	-14.7	-9.5
Fresno	92	1	17			1	75	17	75	HW/TB	ELECTR/170	86	-4.6	-4.1	-8.6	-1.5
Huntington Beach (H)	13	1	13					0	13	TB	TRX 390					
La Mesa (H)	20			1	20			0	20	HW/TB	170					
Long Beach	49	5	49					36	13	PH/TB	170/ELECTR	49	-9.1	-2.2	-19.8	-7.8
Los Angeles	264					2	264	78	186	HW/PH	UTCS/170	264	-4.1	-8.7	-8.7	-4.6
Monrovia	18	2	18					4	14	HW/TB	170					
Oakland	51	1	7			2	44	44	7	HW	ELECTR	51	-5.6	-3.9	-2.4	
Paramount	29			1	29			2	27	HW/TB	E-KMC 8000					
Pasadena	54					2	54	54	0	HW	FT	54	0.4	2.4	-1.1	-0.9
Petaluma (H)	13	1	13					2	11	TB	TRX 390	13	-6.9	-19.5	-14.4	-8.7
Rendondo Beach	13	1	13					12	1	TB	E-KMC 2000					
Riverside	33	3	33					0	33	HW	90					
Roseville	10	1	10					0	10	HW	170					
Sacramento Co	28	2	28					0	28	HW	VMS220					
San Diego	79			3	79			0	79	HW/TB	170	79	-3.8	-10.9	-5.3	-5.6
Santa Clara Co (H)	5	1	5					0	5	HW	E-KMC 11000	5	0.7	0.9	-2.8	-0.2
South Gate	15	1	15					3	12	HW/TB	E-KMC 10000	14	-5.5	-9.5	3.8	-1.5
S San Francisco (H)	5	1	5					0	5	HW	170	5	-8.6	-12.9	-12.0	-8.4
Thousand Oaks	11	1	11					0	11	TB	E-KMC 2000					
Union City (H)	11	1	11					0	11	HW	170					
W Hollywood/Bev Hill	12	1	12					0	12	HW	170					
Totals	1014	26	278	9	234	9	502	256	758			732				
Average % change													-5.7	-9.0	-9.2	-6.4

TABLE B.7 1989 FETSIM GRANT CYCLE

LOCAL AGENCY	# INT	NETWORK TYPE: ART		C-ART		GRID		SIGNAL EQUIPMENT: # PR	#ACT	COORD	CONTROL	TRANSYT SAVINGS (%): # INT	T TIME	DELAY	STOPS	FUEL
Alhambra (H)	*15*	*1*	*15*					*0*	*15*	*HW*	*E- KMCE*					
Buena Park	15	2	15					1	14	HW	90					
Cambell (H)	*9*	*2*	*9*					*0*	*9*	*TB*	*TRX/90*	*9*	*-7.1*	*-19.8*	*-12.6*	*-6.3*
Concord	28	3	28					0	28	HW	VMS220					
Corona	21			1	21			0	21	HW/TB	TRX 290/170					
East Palo Alto (H)	*8*	*1*	*8*					*0*	*8*	*HW*	*MS/170*					
El Cajon	6	1	6					0	6	HW	170					
Fremont	44			3	44			0	44	HW	VMS220	36	-0.1	-0.2	-5.4	-2.2
Gardena	22	1	22					0	22	TB	VARIOUS					
Huntington Park	31					1	31	0	31	HW	TRX TMP 500					
Inglewood	14	1	14					0	14	HW	170	14	-8.8	-14.7		-7.5
Long Beach	55			2	55			19	36	HW/TB	170/ELECTR	55	-3.1	-6.8	-7.6	-4.2
Los Angeles	253					2	253	93	160	HW	UTCS/170	253	-1.4	-3.1	-6.2	-2.6
Los Gatos	12	1	12					0	12	HW	TRX	12	-4.4	-8.8	-12.6	-5.5
Modesto (H)	*23*					*1*	*23*	*8*	*15*	*TB*	*170*	*23*	*-8.9*	*-5.5*	*-12.4*	*-4.5*
National City	8	1	8					0	8	PH	170					
Pasadena	58					1	58	36	22	HW	VARIOUS					
Pittsburg (H)	*9*			*1*	*9*			*1*	*8*	*TB*	*170*					
Pleasant Hill (H)	*10*	*1*	*10*					*0*	*10*	*TB*	*170*	*10*	*-3.8*	*-4.9*	*-9.5*	*-3.9*
Pleasanton	12	1	12					0	12	HW	VMS220	12	-1.3	-4.2	-1.9	-1.5
Rosemead	31					1	31	0	31	TB	170					
Santa Clara (H)	*6*	*1*	*6*					*0*	*6*	*HW*	*TRX TMP-390*	*6*	*-19.8*	*-30.4*	*-35.4*	*-19.4*
Santa Monica	11	1	11					5	6	HW/TB	FT/170					
Santee	21			1	21			0	21	TB	E-KMC10000	21	-5.0	-12.7	-28.5	-13.1
South San Francisco	11			1	11			0	11	HW	170	11	-12.2	-17.8	-8.4	-9.3
Stockton	74			2	74			53	21	HW/TB	VMS220/FT	74	-7.9	-15.3	-14.4	-8.1
West Covina (H)	*10*	*1*	*10*					*0*	*10*	*HW*	*VMS220*	*10*	*-3.5*	*-8.7*	*0.8*	*-1.9*
West Hollywood	30			1	30			0	30	HW	170					
Westminster	18			1	18			0	18	HW	MS820					
Yorba Linda (H)	*33*			*1*	*33*			*0*	*33*	*TB*	*TRX TMP390*					
Totals	898	19	186	14	316	6	396	216	682			546				
Average % change													-6.2	-10.9	-11.9	-6.4

TABLE B.8 1990 FETSIM PROJECTS

LOCAL AGENCY	# INT	NETWORK TYPE: ART		C-ART		GRID		SIGNAL EQUIPMENT: # PR	#ACT	COORD	CONTROL	TRANSYT BENEFITS (%): # INT	T TIME	DELAY	STOPS	FUEL
Alhambra (H)	47	2	9	3	38			8	39	HW/TB	90					
Anaheim	97					2	97	8	89	HW	UCTS/T1,170					
Bakersfield	22			1	22			0	22	TB	170	11	-1.6	-2.3	-0.1	-0.5
Buena Park	11	1	11					0	11	HW	90/MS820					
Chino	25					1	25	0	25	HW	E-KMC8000					
Chula Vista	98	1	11			1	87	36	62	PH	170					
Concord	47					2	47	0	47	HW	VMS220	47	-10.8	-8.1	-12.6	-16.2
Corona	14			1	14			0	14	TB	E-KMC5000/90					
Downey	37	1	14	1	23			0	37	TB	170					
El Cajon	7			1	7			0	7	TB	170					
Encinitas (H)	22			1	22			0	22	TB	170	21	-26.4	-33.5	-23.4	-20.7
Eureka	17					2	17	0	17	PH	170	17	2.0	-8.7	-3.8	-4.4
Fountain Valley	9	1	9					0	9	TB	MS820/911					
Gardena	52					1	52	15	37	TB	170/VARIOUS					
Hayward (H)	8	1	8					3	5	TB	170					
Hesperia (H)	7	1	7					0	7	TB	TRX /VARIOUS					
Inglewood	29			1	29			0	29	HW	170	29	-5.2	-7.3	-5.7	-5.6
Los Angeles	244					3	244	79	165	HW	UTCS/170,FT	241	-0.3	-4.5	-2.1	-1.5
Modesto (H)	17					1	17	2	15	TB	VARIOUS	17	-3.2	-8.5	-6.3	-4.0
Monterey Park (H)	12	1	12					0	12	TB	90/170					
National City	15			1	15			0	15	HW	90/170					
Ontario	20	2	20					0	20	TB	E/CSC					
Riverside	9	1	9					0	9	HW	VMS220	9	-10.4	-21.4	-5.5	-6.9
San Bernardino	31					1	31	0	31	HW/PH	170					
San Diego	12	1	12					0	12	TB	170					
San Francisco	81					1	81	81	0	HW	ELECTR	81	-8.5	-16.7	-3.8	-5.9
San Jose	22			1	22			0	22	TB	90					
San Ramon	21	3	21					0	21	HW	170					
Ventura	12			1	12			4	8	HW/TB	170/FT,90					
West Covina (H)	18	1	4	1	14			0	18	HW/TB	MS/820,911					
Totals	1063	17	147	13	218	15	698	236	827			473				
Average % change													-7.2	-12.3	-7.0	-7.3

LOCAL AGENCY	# INT	NETWORK TYPE: ART		C-ART		GRID		SIGNAL EQUIPMENT: # PR	#ACT	COORD	CONTROL	TRANSYT BENEFITS (%): # INT	T TIME	DELAY	STOPS	FUEL
Antioch	14			1	14			0	14	HW	170					
Carson	27	1	27					0	27	TB	170/VARIOUS					
Daly City (H)	12			1	12			0	12	HW	TRX TMP-390	7	-13.9	-21.9	-3.4	-9.7
Davis (H)	8	1	8					0	8	HW	E-KMC 8000					
Downey	29	2	29					0	29	TB	170					
El Cajon	13			1	13			0	13	HW	170					
Foster City	20			2	20			0	20	HW	TRX TMP-390					
Fountain Valley	32					1	32	0	32	HW/TB	MS/820,911					
Fresno	35			1	35			0	35	HW/TB	170	10	-12.6	-30.4	-31.8	-17.6
Glendale	19	2	19					0	19	HW	170					
Inglewood	23	2	23					0	23	HW	170	23	-5.9	-8.3	-6.6	-6.2
Irvine	37	2	37					0	37	HW	VMS220	13	-19.2	-26.6	-7.2	-11.7
Lancaster	15	1	15					0	15	HW	170					
Los Angeles	252					1	252	78	174	HW/PH	170/FT,90	94	-0.3	-0.8	-4.1	-1.5
Lynwood	41			1	41			0	41	TB	170					
Mill Valley (H)	6	1	6					0	6	TB	170	4	-11.7	-24.5	-10.4	-17.7
Mission Viejo	49					1	49	0	49	HW	VMS220					
Modesto	17					1	17	14	3	TB	170/FT					
Montebello	30	3	30					0	30	HW/TB	170					
Napa	12			1	12			0	12	HW	VMS330	12	-14.6	-21.2	-16.1	-10.6
Orange	32	1	5	1	27			0	32	HW	VMS220					
Pasadena	34					1	34	27	7	HW	170	34	1.1	4.7	2.7	1.0
Roseville	11			1	11			0	11	TB	170	11	-26.9	-45.7	-31.6	-23.0
Sacramento (H)	10	1	10					0	10	HW	TRX 390					
San Diego	219			1	59	1	160	160	59	HW	UTCS/170	44	-11.4	-17.4	-3.6	-8.6
San Jose	87	8	76			1	11	0	87	HW	90	3	-17.6	-27.8	-7.1	-14.1
San Marcos (H)	12	1	12					0	12	HW	170					
San Ramon	21	2	21					0	21	HW	170	13	-7.6	-16.6	-8.1	-7.7
Santa Barbara	64					1	64	48	16	HW	170	64	-3.0	-7.2	-15.7	-5.7
Santa Clarita	50			4	50			0	50	TB	170					
Santa Monica	15	1	15					0	15	HW	E-KMC 8000					
Sausalito	10	1	10					0	10	TB	E/VARIOUS					
Seaside (H)	17			1	17			0	17	TB	170	16	-9.4	-15.4	-14.1	-7.4
Solano Beach (H)	9	1	9					0	9	TB	170					
Torrance	59			2	59			0	59	HW/TB	E-KMC-8000					
Tracy (H)	11			1	11			0	11	TB	170					
Ventura	12	1	12					0	12	TB	170					
Victorville	7	1	7					0	7	TB	170					
Totals	1371	33	371	19	381	8	619	327	1044			348				
Average % change													-10.9	-18.5	-11.2	-10.0

TABLE B.10 1992 FETSIM GRANT CYCLE

		NETWORK TYPE						SIGNAL EQUIPMENT				TRANSYT BENEFITS (%)				
LOCAL AGENCY	# INT	ART		C-ART		GRID		# PR	#ACT	COORD	CONTROL	# INT	T TIME	DELAY	STOPS	FUEL
Alameda	8	1	8					0	8	HW	170					
Alameda County	18	2	18					0	18	TB	170	9	-15.7	-20.7	-18.2	-11.0
Anaheim	22	2	22					0	22	HW	UTCS/170					
Atascadero	10	2	10					0	10	TB	170					
Bakersfield	46					1	46	45	1	TB	170	5	-19.0	-22.5	-9.4	-13.2
Cathedral City	16			1	16			0	16	HW	KMC-8000					
Downey	27			1	12	1	15	0	27	TB	170					
El Cajon	12					1	12	0	12	TB	170					
Fontana	14			1	14			0	14	PH	ECON					
Fresno	40			1	40			0	40	HW/TB	170					
Glendale	51					1	51	0	51	HW	VMS/170					
Hesperia (H)	10	1	10					0	10	TB	TRX390					
Huntington Beach	50			1	50			0	50	HW/TB	VMS/TRX390					
Irvine	21			1	21			0	21	HW	VMS220					
La Habra	16			1	16			0	16	OTHER	TRX290	16	-3.5	-11.3	-2.7	-2.6
Long Beach	94					1	94	84	10	HW	170					
Los Angeles	185					2	185	100	85	HW	90,170,FT					
Moreno Valley	19	3	19					0	19	HW	TRX500/390					
Ontario	32	2	11	1	21			0	32	HW/TB	170,ECON					
Pasadena	18			1	18			9	9	HW/TB	170	18	-22.5	-29.2	-9.4	-8.8
Placentia	37					1	37	0	37	HW	KMC-10000					
Poway	11			2	11			0	11	HW	170					
Riverside County	8	1	8					0	8	HW	TRX290	8	-4.8	-9.0	-12.0	-5.8
Sacramento	110					1	110	110	0	HW	VARIOUS					
San Diego	160	2	31	2	86	1	43	0	160	HW/TB	170	17	-5.2	-11.2	-7.0	-4.2
San Fernando (H)	8	1	8					0	8	TB	170					
San Jose	25					1	25	7	18	TB	TRX390	12	-9.0	-28.0	-28.0	-6.5
San Leandro	8	1	8					0	8	TB	ECON	8	-7.3	-14.8	-8.1	-7.1
San Luis Obispo (H)	33			1	33			0	33	HW/TB	VARIOUS					
Santa Ana	44					1	44	0	44	HW	VMS220					
Santa Cruz	8			1	8			0	8	TB	TRX290					
Santa Monica	36					1	36	36	0	HW	KMC4000					
Santee	11			1	11			0	11	OTHER	ECON					
Simi Valley (H)	22	4	22					0	22	HW	KMC-8000					
South San Francisco	26			1	26			0	26	HW/TB	170					
Vacaville (H)	10	1	10					0	10	HW	170					
Watsonville (H)	10	1	10					0	10	TB	170					
West Hollywood	54					1	54	0	54	HW	170					
Totals	1330	24	195	17	383	14	752	391	939			93				
Average % change													-10.9	-18.3	-11.9	-7.4

TABLE B.11 1993 FETSIM PROJECTS

		NETWORK TYPE						SIGNAL EQUIPMENT				TRANSYT BENEFITS (%)				
LOCAL AGENCY	# INT	ART		C-ART		GRID		# PR	#ACT	COORD	CONTROL	# INT	T TIME	DELAY	STOPS	FUEL
Anaheim	50			1	50			0	50	HW	UTCS/T-1,170					
Bakersfield	41	1	6	1	35			0	41	TB	170					
Clovis	14	1	5			1	9	0	14	TB	170					
Corona	30	3	30					0	30	TB	170/390					
Cupertino	15	2	15					0	15	HW	VMS 330/ 911	9	-0.6	-0.6	-2.8	-0.8
Daly City	10			1	10			0	10	HW/TB	170/390					
Downey	77					3	77	0	77	TB	170					
El Cajon	12			1	12			0	12	TB	170					
Fremont	36	1	6	2	30			0	36	HW/PH	VMS220					
Glendale	39	2	39					2	37	HW	170					
Hanford	21			1	21			5	16	TB	90					
Hayward	24	2	24					0	24	HW/TB	170/90					
Healdsburg	11	1	11					2	9	TB	170					
Irvine	21			1	21			0	21	HW	VMS220					
Loma Linda	15			1	15			0	15	TB	170, 90					
Los Angeles	264			3	264			48	216	HW/TB	170/FT	264	-3.0	-10.8	-0.6	-2.6
Manteca	15					1	15	0	15	TB	170	9	-5.0	-12.2	-10.0	-7.0
Monterey	18					1	18	7	11	HW	TRX TMP390					
Moreno Valley	17	2	17					0	17	HW	90/390					
Oceanside	31	4	31					0	31	OTHER	170					
Pasadena	90					1	90	0	90	HW	UTCS/170	90	-11.0	-21.2	-16.0	-11.1
Pleasanton	13			1	13			0	13	HW	VMS220					
Rancho Cucamonga	42			1	42			0	42	HW/TB	170/390					
Sacramento	77					1	77	77	0	HW	S2000/170,FT					
Salinas	20	3	20					0	20	TB	TRX TMP-390					
San Diego	114	7	92			1	22	9	105	HW/TB	170	21	-12.3	-23.5	-28.4	-17.4
San Francisco	80					1	80	0	80	HW	ELECTR					
San Rafael	50					2	50	8	42	HW/PH	E-KFT 1800					
Santa Cruz	12	2	12					0	12	TB	TRX TMP 390					
Santa Monica	37					1	37	37	0	HW	90					
Santee	16			1	16			0	16	PH	ASC8000					
Signal Hill	20	2	6	1	14			6	14	HW/TB	170/FT	20	-22.2	-36.2	-28.3	-23.0
South San Francisco	11	1	11					0	11	HW	170					
West Covina	8	1	8					0	8	HW	VMS330/820					
Totals	1351	35	333	16	543	13	475	201	1150			413				
Average % change													-9.0	-17.4	-14.4	-10.3

APPENDIX C

"BEFORE" and "AFTER" FIELD STUDIES RESULTS

TABLE C.1 FIELD RESULTS--1983 GRANT CYCLE

LOCAL AGENCY	SYSTEM(S)	SUB-SYSTEM(S)	#INT	T TIME	DELAY	STOPS
BERKELEY	Downtown	Downtown	28	-10.6	-16.3	-11.1
LONG BEACH	CBD	CBD	91	-5.3	-3.9	-4.8
LOS ANGELES	Hollywood	Hollywood	267	-3.3	-12.0	-13.5
MONTEBELLO	Arterials	Arterials	24	-9.8	-22.0	-21.8
OAKLAND	North CBD	North CBD	27	-2.2	-3.3	-9.2
PLEASANTON	Hoppyard Rd	Hoppyard Rd	10	-2.6	-11.1	-6.2
SAN DIEGO	San Diego	Arterials	42	-6.2	-16.5	-7.7
SAN FRANCISCO	SW CBD	SW CBD	76	-7.2	-20.1	-23.1
SAN RAFAEL	CBD	CBD	38	-4.5	-8.9	-9.0
SANTA BARBARA	CBD	CBD	50	-6.9	-15.1	-25.5
SANTA MARIA	Arterials	Arterials	25	-12.3	-30	-24.1
Total	11	11	678			
Average % change				-6.4	-14.5	-14.2

TABLE C.2 FIELD RESULTS--1984 GRANT CYCLE

LOCAL AGENCY	SYSTEM(S)	SUB-SYSTEM(S)	#INT	T TIME	DELAY	STOPS
CONTRA COSTA CO	San Ramon	San Ramon	16	-4.1	-22.0	
LOS ANGELES	Wilshire	Wilshire	209	-7.2	-23.0	-21.0
MENLO PARK	El Camino	El Camino	7	-3.5	-6.9	-27.0
PALO ALTO	Downtown	Downtown	45	-3.4	-13.0	-20.0
SAN FRANCISCO	Mission	Mission	84	-12.0	-18.0	-32.0
SAN DIEGO	CBD	CBD	150	-26.0	-43.0	-29.0
SANTA ANA	CBD	CBD	41	-7.7	-23.0	-7.7
SANTA FE SPRINGS	Arterial	Arterial	18	-6.3	-23.0	
STOCKTON	Arterials	Arterials	27	-8.0	-24.0	-3.4
UPLAND	Arterials	Arterials	14		-29	
Total	10	10	611			
Average % change				-8.7	-22.5	-20.0

TABLE C.3 FIELD RESULTS--1986 GRANT CYCLE

LOCAL AGENCY	SYSTEM(S)	SUB-SYSTEM(S)	#INT	T TIME	DELAY	STOPS
ANAHEIM	Katella Avenue	Katella Avenue	15	-1.6	-11.5	
ARCADIA	Bald/Hunt	Bald/Hunt	15	-23.7	-43.9	-42.1
BALDWIN PARK	Ramona	Ramona	10	-19.2	-46.2	-44.5
BELL	Gage Avenue	Gage Avenue	10	-12.4		27.7
BELLFLOWER	Bellflower	Bellflower	13	-9.0	-17.6	-15.6
BERKELEY	North Berkeley	North Berkeley	27	-2.7	6.7	9.6
CHULA VISTA	CBD	CBD	47	-5.3	-16.3	-18.3
EL CAJON	Fleet Parkway	Fleet Pkwy	6	-3.4	-25.5	-18.6
		Johnson Avenue	6	-10.6	-40.3	-8.7
FULLERTON	Harbor Blvd	Harbor Blvd	9	-8.5	-14.6	3.8
GARDEN GROVE	Downtown	Chapman/Euclid	48	-0.9		-2.9
LONG BEACH	Citywide	Anaheim/10th/7th/4th	41	-6.0		-28.3
MANH BEACH/EL SEG	Aviation Blvd	Aviation Blvd	11	9.5		-8.3
	El Sequndo Blvd	El Sequndo Blvd	7	-7.2		-11.9
	E. Manhattan Blvd	E. Manhattan Blvd	6	-6.7		-4.3
ORANGE COUNTY	Paseo De Valencia	Paseo De Valencia	8	-6.3	-17.3	-8.5
	Marguerite	Marguerite	14	-0.7	-2.6	-2.9
	Lake Forest	Lake Forest	7	-3.7	-4.7	-26.4
	Alicia	Alicia	7	-6.7	-7.2	-7.9
	El Toro	El Toro	14	-0.4	7.0	-11.3
OXNARD	S Road/C Blvd	C Street	8	-2.9		
SAN DIEGO	Grant/Garnet	Grant/Garnet	25	-6.3	-8.6	-16.1
	Mission Blvd	Mission Blvd	7	-9.2	-10.1	-2.5
WEST COVINA	Sunset Avenue	Sunset Avenue	9	6.1	23.0	13.1
Total	23	24	370			
Average % change				-5.1	-12.0	-11.6

TABLE C.4 FIELD RESULTS--1987 GRANT CYCLE

LOCAL AGENCY	SYSTEM(S)	SUB-SYSTEM(S)	#INT	T TIME	DELAY	STOPS
BELL GARDENS	Garfield/Florence	Garfield/Florence	23	-12.7	-27.3	-31.4
DUBLIN	Dublin Blvd	Dublin Blvd	8	-4.5	-13.0	-5.7
FULLERTON	Gilbert/Hughes	Gilbert/Hughes	14	-19.1	-26.8	8.9
	Bastunchury	Bastunchury	7	-20.4	-37.0	-42.4
LONG BEACH	Ocean Blvd	Ocean Blvd	25	-5.3		-40.9
	Artesia Blvd	Artesia Blvd	16	-3.9		-16.5
NAPA	Downtown	First Str/Third Ave	12	-18.2		-36.5
PALO ALTO	Arboretum	Arboretum	7	-19.0		-19.7
	Embarcadero	Embarcadero	7	9.6		12.6
PASADENA	Downtown	Downtown	80	-7.3		-25.0
Total	10	10	199			
Average % change				-9.0	-26.3	-23.7

TABLE C.5 FIELD RESULTS--1990 GRANT CYCLE

LOCAL AGENCY	SYSTEM(S)	SUB-SYSTEM(S)	#INT	T TIME	DELAY	STOPS
ALHAMBRA	Atlantic Avenue	Atlantic Avenue	10	-18.9	-39.2	-18.9
	Fremont Ave	Fremont Ave	11	-6.9	-3.6	-3.2
ANAHEIM	Downtown - Loara	Anaheim	10	-0.7	-4.4	10.4
		Broadway - Westbound	9	-8.0	-12.7	7.4
		East Street - Southbound	10	-7.8	5.6	-31.4
		Harbor	11	-8.8	-15.8	-24.4
		Broadway - Eastbound	9	3.1	0.6	0.6
		East Street - Northbound	10	5.8	5.8	-37.2
		Lincoln2 - Eastbound	18	-7.8	-20.7	9.3
		State College - SB	12	-10.1	-23.3	0.0
	Western	Ball	5	-6.4	-23.4	-22.4
		Orange	6	-6.7	-20.6	-6.5
		Magnolia - Southbound	8	-15.2	-36.6	-62.0
BAKERSFIELD	Oak Street	Oak Street	8	-18.8	-35.5	-40.9
	Stockdale	Stockdale	6	-12.0	-25.9	-32.6
	California	California	11	-8.5	-31.9	-27.3
CHULA VISTA	Section 1	Broadway & L - South-EB	14	0.3	-0.0	0.5
		H Street	7	-11.7	-27.1	-23.6
	Section 2	East L/Telegraph	4	-8.5	-9.4	-3.2
	Section 4	East H Street	6	-0.5	-5.9	-2.5
EL CAJON	Airport System 5	Bradley	4	-9.4	-22.0	-45.2
		Cayamuca	4	-3.1	-12.1	-14.4
ENCHINITAS	First Street (I)	First Street (I)	4	-30.3	-33.8	-41.7
FOUNTAIN VALLEY	Brookhurst	Brookhurst	8	-6.3	-13.7	-5.9
FRESNO	McKinnley	McKinnley	7	-20.0	-80.6	-68.3
GARDENA	Section 12	Section 12	14	-17.1	-49.0	-46.3
	Section 34	Section 34	19	-21.3	-75.4	-60.6
HAYWARD	A Street	A Street	8	-23.0	-58.3	-47.4
INGLEWOOD	Florence	Florence	11	-6.1	-11.5	-6.7
	La Brea	La Brea	10	-6.8	-7.9	-7.6
	Prairie	Prairie	8	-4.4	-7.8	-5.0
MONTEREY PARK	Atlantic	Atlantic	12	-19.8	-62.9	-64.8
ONTARIO	Grove Avenue	Grove Avenue	10	-29.3	-37.5	-61.6
	Vineyard Avenue	Vineyard	9	-24.9	-10.8	-69.7
RIVERSIDE	14th Street	14 Street	9	2.9	-18.0	8.6
SAN DIEGO	Rancho Bernardo	RB East to BCD North	12	-1.2	-32.4	-33.5
		BCD North -RBR East	12	-8.6	-26.7	-34.2
		BCR West -RBR West	12	-0.4	-7.9	-6.4
SAN JOSE	Cambrian Area	Cambrian Area	22	-1.8	-7.1	-27.6
WEST COVINA	Cameron Avenue	Cameron	8	-3.8	-9.1	-10.7
	Merced Avenue	Merced Avenue	4	-3.6	-4.9	-3.7
	Vincent Avenue	Vincent Avenue	4	-2.1	-7.3	-2.2
Total	29	42	396			
Average % change				-9.1	-23.1	-23.6

TABLE C.6 FIELD RESULTS--1991 GRANT CYCLE

LOCAL AGENCY	SYSTEM(S)	SUB-SYSTEM(S)	#INT	T TIME	DELAY	STOPS
CARSON	Carson	Avalon	28	-12.9	-15.4	-27.4
DOWNEY	Imperial	Imperial	14	-14.1	-27.6	-23.5
FOUNTAIN VALLEY	Slater	Slater	9	-1.1	0.3	2.0
	Bushard	Bushard	6	-0.6	0.3	-6.3
	Newhope	Newhope	6	-4.7	-14.9	-4.5
FRESNO	Cedar n/o Shaw	Cedar n/o Shaw	12	-25.5	-78.1	-60.9
	Herndon e/o 41	Herndon e/o 41	16	-10.9	-27.2	8.0
GLENDALE	Colorado Blvd	Colorado	6	-14.6	-53.1	-54.3
	South Glendale	Glendale Avenue	8	-33.2	-62.0	-66.9
INGEWOOD	La Brea	La Brea	9	-8.5	-7.5	-6.6
	Crenshaw	Crenshaw	14	-11.5	-11.0	-9.1
LYNWOOD	Imperial-Atlantic	Imperial	11	-8.8	35.3	-11.9
		Atlantic	8	-6.3	-54.1	-58.7
	Long Beach Blvd	Long Beach Blvd	9	-9.3	-30.8	-14.6
	M. L. King Jr	M. L. King Jr	15	-19.7	-50.5	-5.6
MONTEBELLO	Montebello Blvd	Montebello Blvd	7	-9.3	-40.1	-38.0
	Wilcox	Pomona	7	-4.3	-7.5	-8.6
NAPA	Trancas / Jefferson	Trancas	8	-33.3	-66.3	-56.1
ORANGE	Batavia	Batavia	8	-8.2	-49.1	-22.5
	Main	Main	8	-21.4	-45.0	-42.5
PARAMOUNT	Paramount	Paramount	16	-13.5	-28.4	-39.5
PASADENA	Pasadena	Orange Grove	10	-0.5	-32.7	-20.0
		Washington	10	-7.7	-57.9	-57.3
SACRAMENTO	65th Street	65th Street	10	-24.2	-62.4	-40.9
SAN DIEGO	El Cajon-West	El Cajon-West	12	-5.7	-22.9	-17.0
SAN JOSE	Bird Ave.	Bird Ave.	12	-4.8	-13.8	-27.3
	Coleman Ave.	Coleman Ave.	7	-17.6	-70.0	-56.1
	Tully Road	Tully Road	14	-16.3	-35.9	-33.5
	Alameda System	Alameda System	7	-21.2	-68.4	-58.4
	Winchester Blvd.	Winchester Blvd.	10	-20.4	-42.3	-35.6
SAN RAMON	Crow Canyon Rd	West Corridor	12	-5.2	-39.6	-28.4
SANTA BARBARA	CBD	CBD	64	-13.1	-24.4	-36.9
SANTA MONICA	Pico	Pico	16	-22.8	-36.3	-43.1
SEASIDE	Seaside	Fremont Blvd	9	0.3	-34.9	-49.7
TORRANCE	Anza	Selpuveda	7	-10.5	-44.2	-34.5
		Anza	11	-8.7	-32.4	-32.1
	Torrance	Torrance East	10	-11.7	-21.3	-17.4
		Madrona	8	-12.9	-24.0	-10.7
VICTORVILLE	Seventh St.	Seventh St.	7	-5.9	-8.4	-12.0
Total	35	39	461			
Average % change				-12.7	-31.2	-29.6

TABLE C.7 FIELD RESULTS--1992 GRANT CYCLE

LOCAL AGENCY	SYSTEM(S)	SUB-SYSTEM(S)	#INT	T TIME	DELAY	STOPS
ANAHEIM	Lakeview	Lakeview	7	-5.8	-22.8	-21.7
BAKERSFIELD	South H Street	South H Street	8	-13.1	-30.2	-57.3
DOWNEY	SouthEast Downey	Woodruff	8	-12.7	-28.9	-23.3
		Brookshire	7	-16.5	-28.3	2.1
		Downey	6	-22.8	-67.4	-49.3
		Stewart/Gray	7	-4.8	-41.0	-33.4
EL CAJON	Chase Arterial	Chase Arterial	5	-8.6	-23.5	-11.0
HUNTINGTON BEACH	Adams	Adams	6	-23.8	-39.1	-25.6
	Brookhurst	Brookhurst	8	-6.7	-1.5	-10.3
	Endifer	Endifer	12	-21.2	-13.1	-39.8
	Golden West	Golden West	12	-5.1	-7.0	-16.8
	Warner	Warner	12	-8.8	-9.3	-19.6
LA HABRA	La Hambra	La Hambra	16	-9.7	-70.0	-66.8
POWAY	Central Poway	Central Poway	7	-3.6	-9.3	-6.7
RIVERSIDE CO	Mission Blvd	Mission Blvd	8	-4.2	-20.9	4.3
SAN DIEGO	Gand/Garnet	Gand/Garnet	17	-9.7	-21.0	-30.2
SAN LEANDRO	Washington Ave	Washington Ave	8	-16.7	-41.7	-25.0
SANTA ANA	Euclid Avenue	Euclid Avenue	6	7.0	24.8	-2.2
	Fairview Str	Fairview Str	13	-11.3	-31.7	-10.9
	Harbor Blvd	Harbor Blvd	11	-7.6	-35.8	-36.9
SANTA CRUZ	Laurel Street	Laurel Street	5	-11.6	-17.3	-41.2
SANTA MONICA	Mid-city Grid	Mid-city Grid	30	-17.9	-23.3	-24.1
SANTEE	Carlton Oaks Drive	Carlton Oaks Drive	5	-36.6	-32.5	-18.2
VACAVILLE	Alamo Drive	Alamo Drive	10	-7.9	-25.2	-56.0
Totals	21	24	234			
Average % change				-11.7	-26.2	-27.6

TABLE C.8 FIELD RESULTS--1993 GRANT CYCLE

LOCAL AGENCY	SYSTEM(S)	SUB-SYSTEM(S)	#INT	T TIME	DELAY	STOPS
BAKERSFIELD	Baker Street	Baker Street	6	-19.0	-35.6	-33.5
	Gosfoed Road	Gosfoed Road	11	-10.7	-32.7	-41.9
	Ming Ave	Ming Ave	6	-17.1	-42.0	-44.5
	Stine/New Stine Rd	Stine/New Stine Rd	7	-14.8	-45.7	-44.9
	Stockdale Hwy	Stockdale Hwy	8	-10.5	-37.2	-31.2
CUPERTINO	De Anza Blvd	De Anza Blvd	9	-13.9	0.0	0.0
PASADENA	Downtown	Colorado Blvd	17	-7.8	-9.5	-10.8
		Del Mar Blvd	12	-26.5	-58.4	-51.5
		Fair Oaks Ave	7	-27.6	-61.8	-47.7
		Lake Ave	8	-20.5	-34.0	-23.9
PLEASANTON	Stanley/First/Sunol	Stanley/First/Sunol	8	-0.6	40.4	-28.8
	Valley	Valley	6	-3.0	6.0	-5.3
SAN DIEGO	Clairmont Mesa Blvd	Clairmont Mesa Blvd	10	-12.8	-29.1	-33.7
	Imperial Ave East	Imperial Ave East	8	-14.6	-28.9	-31.8
	North Park	North Park	10	-27.1	-39.5	-41.5
SIGNAL HILL	Cherry Avenue	Cherry Avenue	7	-11.7	-55.3	-37.1
	Orange Avenue	Orange Avenue	7	-35.7	-50.8	-33.7
	Willow Street	Willow Street	8	-28.5	-63.1	-56.7
Total	15	18	155			
Average % change				-16.5	-31.1	-32.5

APPENDIX D

LIST OF CONSULTANTS THAT PARTICIPATED IN THE FETSIM PROGRAM

I. Engineering Consultants

ASL Consultants, Inc.
Associated Transportation Engineers
Austin-Foust Associates
Barton Aschman Inc.
Basmaciyan-Darnell Inc.
Bather Belrose Bose, Inc.
BSI Consultants, Inc.
DKS Associates
E.C. Jiu Associates
Edwards and Kelcey, Inc.
FPL & Associates
Frederic R. Harris, Inc.
Herman Kimmel & Associates
Jeff Knowles & Associates
JHK & Associates
Kimley-Horn & Associates, Inc.
Kittelson & Associates, Inc.
Lau Engineering
Meyer, Mohaddes Associates, Inc.
Mohle, Grover & Associates
Multitrans
Omini-Means
Patterson Associates
PRC Voorhies
Santina & Thompson, Inc.
TJKM Transportation Consultants
Traffic Engineering Services
TRANSTECH
Traffic Safety Engineers
Van Dell Associates
Warren C. Sieke
Willdan Associates

II. Data Collection Consultants

CALTAP
Car Counter Company
Counts Unlimited
CSD Traffic Data
EIP Associates
G.E. Traffic Surveys
H.K. Traffic Data
Lopez and Lopez Engineering
Metro Design and Technology
Newport Traffic Studies
O'Rourke Engineering
PH Associates
Stephen George & Associates
Trac-Data
Traffic Counts, Inc.
Transcount
Trans Data Systems
WILTEC

APPENDIX E

LIST OF REPORTS AND PUBLICATIONS IN SUPPORT OF THE FETSIM PROGRAM

Institute of Transportation Studies
University of California, Berkeley
109 McLaughlin Hall
Berkeley, CA 94720-1720

1. Deakin, E.A., A. Skabardonis, C. Monsen, and C. Valbuena, "Fuel Efficient Traffic Signal Management Program--Results of the 1983 Program," Summary Report, July 1984.

2. Deakin, E.A., A. Skabardonis, and A.D. May "Energy-Savings with Signal Timing Optimization - Evaluation of California's Statewide Program," Compendium of Technical Papers, 54th Annual ITE Meeting, San Francisco, September 1984.

3. Deakin, E.A., A. Skabardonis, and A.D. May, "The Fuel-Efficient Traffic Signal Management Program: Evaluation of the First-Year Activities," Research Report, UCB-ITS-RR-84-12, October 1984.

4. Deakin, E.A. and A. Skabardonis, "Assessing the Traffic Impacts from Land Development Scenarios," Working Paper, UCB-ITS-WP-85-8, June 1985.

5. Deakin, E.A., A. Skabardonis, and C.E. Monsen, "Market Potential for the Fuel Efficient Traffic Signal Management Program," Working Paper UCB-ITS-WP-85-6, June 1985.

6. Deakin, E.A., and A. Skabardonis, "The Future of the FETSIM Program", Institute of Transportation Studies, Research Report, UCB-ITS-RR-85-13, October 1985.

7. Deakin, E.A., and A. Skabardonis, "Assessing the Traffic Impacts of Transportation and Land Development Scenarios," Transportation Quarterly, Vol XXIX (4), October 1985.

8. Deakin, E.A., and A. Skabardonis, "Fuel Efficient Traffic Signal Management Program: Evaluation of the Second and Third Funding Cycles," Research Report UCB-ITS-RR-85-14, October 1985.

9. Deakin, E.A., and A. Skabardonis, "Fuel-Efficient Traffic Signal Management: Three Years of Experience," Summary Report, December 1985.

10. Deakin, E.A., A. Skabardonis, and A.D. May, "Fuel Efficient Traffic Signal Timing as a TSM measure: The California Experience," Transportation Research Record, No. 1081, 1986.

11. Deakin, E.A., "California's Traffic Engineers--Endangered Species?," ITE Journal, June 1986.

12. M. Kuntemeyer, E.A. Deakin, and A. Skabardonis, "Survey of Signal Equipment and Hardware Needs: Results and Recommendations," Research Report UCB-ITS-RR-87-5, June 1987.

13. Skabardonis, A., and M.C. Kleiber, "Traffic Signal Timing: A Select Bibliography," Library References UCB-ITS-LR-83-1, April 1983.

14. Skabardonis, A. and M.C. Kleiber, "Signal Timing Optimization: A Bibliography," Library References UCB-ITS-LR-83-4, August 1983.

15. Skabardonis, A., and E.A. Deakin, "Guidelines for Conducting "Before" and "After" Studies," Report to the California Energy Commission, September 1983.

16. Skabardonis, A., and M.C. Kleiber "Traffic Signal Timing-Before and After Studies: A Bibliography," Library References UCB-ITS-LR-83-5, November 1983.

17. Skabardonis, A., "Computer Programs for Traffic Operations," Technical Document UCB-ITS-TD-84-3, August 1984.

18. Skabardonis A., and A.D. May, "Computer Applications in Traffic Signal Management," Compendium of Technical Papers, 54th Annual ITE Meeting, San Francisco, September 1984.

19. Skabardonis A., "FETSIM WORKSHOP--Student Workbook," Course Notes, 3 Vols, 1983-84. (Updated 1986-87)

20. Skabardonis A., and P.S. Loubal, "Applications of Computer Graphics in Traffic Control," Proceedings of the ASCE Specialty Conference on Microcomputers in Transportation, San Diego, June 1985.

21. Skabardonis A., and A.D.May, "Comparative Analysis of Computer Models for Arterial Signal Timing," Transportation Research Record No. 1021, October 1985.

22. Skabardonis, A., and S. Gidwani, "TR7FP: An Interactive Preprocessor for the TRANSYT-7F Model", Technical Document, ITS-UCB-TD-85-8, December 1985.

23. Skabardonis A., "Microcomputer Applications in Traffic Engineering," Transportation Engineering Journal of ASCE, Vol. 112 (1), January 1986.

24. Skabardonis A., and N. Lermant, "Optimal Offsets for Arterials: An Analytical Model," paper presented at the 65th Annual Meeting of the Transportation Research Board, January 1986.

25. Skabardonis, A., "Guidebook for Improving Traffic Signal Timing," Research Report, UCB-ITS-RR-86-10, November 1986.

26. Skabardonis, A., "Signal Timing Optimization in Networks with Actuated Controllers," paper presented at the 66th Annual Meeting of the Transportation Research Board, January 1987.

27. Skabardonis, A., "Traffic Signal Timing: Computer Models and Applications," Tech Transfer, No. 16, January 1987.

28. Skabardonis, A., "Estimating the Impacts of Signal Hardware Improvements," paper 870545, presented at the 67th Annual Meeting of the Transportation Research Board, January 1988.

29. Skabardonis A., E.A. Deakin and R. Singh "Fuel Efficient Traffic Signal Management Program: Evaluation of the Fourth and Fifth Grant Cycles," Research Report UCB-ITS-RR-88-8, March 1988.

30. Skabardonis A., and E.A. Deakin, "Assessment of the Benefits from Signal Hardware Improvements," Research Report, UCB-ITS-RR-88-9, April 1988.

31. Skabardonis A., and A. Weinstein, "TRANSYT-7FC: A Transyt Model for Actuated Signals," Research Report, prepared for the California Department of Transportation, July 1988.

32. Skabardonis A., "FETSIM Training Manual," Course Notes, December 1991.

33. Skabardonis, A., "QUICK-7F/TRANSYT-7F Training Manual," Course Notes, September 1994.