Models for Freeway Corridor Analysis

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This paper has two major themes: (a) to describe existing traffic simulation models and their applications in freeway corridor analysis and (b) to demonstrate the need for integration of research, education, and implementation activities as a key for the enhancement of simulation modeling practice. The overall objective of this paper is to provide a state-of-the-art document on freeway corridor models and to encourage researchers and practitioners to work closer together in simulation modeling. The paper also includes an extensive bibliography, which is an attempt to include all published papers that describe the development and application of available freeway corridor models.

FREEWAY CORRIDOR MODELS

After a brief review of earlier models for freeway corridor analysis, five families of currently available models are described. Particular emphasis is given to the historical development of the models and to real-life applications. The five families of models are CORQ, FREQ, INTRAS, MACK, and SCOT.

Early Models

Hsu and Munjal provide a good starting point for this paper with their paper on freeway digital simulation models (1). Their paper identified and reviewed 15 simulation models associated with various aspects of freeway vehicular traffic, and the models are compared against a baseline of eight desirable model features. Space here does not permit a description of these 15 models and the reader is referred to the Hsu-Munjal paper. The identified models were

1. Arizona Transportation and Traffic Institute Traffic Simulation Model (2),
2. Midwest Research Institute Freeway Simulation Model (3,4),
3. Midwest Research Institute Mountainous Terrain Model (5),
4. Northwestern University Lane-Changing Model (6),
5. Sinha Freeway Simulation Model (7,8),
6. Connecticut Department of Transportation Expressway Simulation Model (9),
7. Texas Transportation Institute Freeway Merging Model (10),
8. System Development Corporation Diamond Interchange Model (11),
9. System Development Corporation Freeway Simulation Model (12),
10. Mikhalkin Freeway Simulation Model (13),
11. Georgia Model (15),
12. Scot Corridor Model (14,16-18),
13. Priority Lane Model (19,20),
14. Aggregate Variable Models (21), and
15. Aerospace Corporation Freeway Simulation Model (22).

These earlier models in many cases were forerunners of later models described in the following sections. For example, Lieberman and Bullen used model 4 in the development of the INTRAS model, while model 12 was the early version in the SCOT model family. Model 13 was an early priority-lane version in the FREQ model family, and model 14 was the early version in the MACK model family.

The CORQ-CORCON Model Family

The CORQ model developed by Yagar during the period 1969-1976 and the related CORCON model developed by Easa and Allen during the period 1971-1978 are the two models in this model family. In addition to their development, these models have been applied in Ottawa, San Francisco, and Toronto by the developers. An illustration of the chronological development of the CORQ-CORCON family of models is shown in Figure 1.

Yagar began work on the CORQ model as part of his dissertation at the University of California (23). He incorporated dynamic traffic assignment and queuing in order to model the time-varying nature of peak demands (24). By 1972, the CORQ model was completed. Incorporated in it were a number of traffic-specific factors such as the sharing of capacity at the merge of an on-ramp and freeway. In 1972-1973, it was applied to the eastbound corridor serving Ottawa for the morning peak period (25). The most comprehensive description of the current CORQ model is contained in Yagar (26). Descriptions of the assignment procedure model summary (27,28) and some required theoretical modeling details have also been published.

The CORQ model predicts flows and queues in a road corridor and combines the techniques of dynamic traffic assignment, emulation of queue spillback, ramp control strategies, combines iterative and incremental assignment, and determination of mutually dependent capacities (29).

Figure 1. Chronological development and application of CORQ/CORCON model family.
The FREQ Model Family

Demand-supply modeling efforts for freeway corridor operating environments were initiated in 1968 at the University of California when a California Department of Transportation (Caltrans) research project required the evaluation of alternatives for improving 140 miles of the existing San Francisco Bay Area freeway system. The system was too extensive and the alternative improvements too numerous to consider manual analysis. This first model called FREQ or FREQ1 was developed and was a forerunner of a freeway system. The system was too extensive and required the evaluation of alternatives for improving freeway corridors. The model was designed to incorporate priority entry control, design configurations, priority lane(s), and automated turn prohibitions. A significant data collection-reduction and model calibration-validation effort was undertaken. The diversion parameter and the origin-destination (O-D) demand patterns were calibrated for the after-control period, and the CORCON procedure was validated by comparing the predicted and the observed conditions for the before control period.

As the modeling effort continued, greater attention was given to the surrounding street system (CORQ1C model) (49), impact assessment (FREQ4CP model) (50), and traveler demand responses (FREQ5CP and FREQ6CP models) (51,52). The most recently developed FREQ models in use today are the FREQ6PE and FREQ6PL models (52,53). The FREQ6PE model is undergoing final testing and is planned for distribution in 1981 (54). The FREQ6PL model is a macroscopic decision model of a freeway corridor and is used primarily for the evaluation of priority entry and normal entry control on a directional freeway (52). The model can also be used for evaluating design improvements with or without freeway entry control. The model predicts a time stream of impacts and traveler responses due to the interaction between ramp control strategy and traveler responses. The impact assessment includes travel time, fuel, emissions, and noise; demand forecasting includes spatial and modal traveler responses in increments during the first year of operation.

The FREQ6PL model is a macroscopic model of a freeway corridor and is used primarily for the evaluation of priority entry and normal entry control on a directional freeway (52). The model can also be used for evaluating design improvements with or without priority operation. The user selects the priority lane(s), design configuration, priority cut-off level, and time duration of priority operations. The model automatically modifies the demand and supply sides of the model and predicts a time stream of impacts and traveler responses. The impact assessment includes travel time, fuel, emissions, and facility costs; demand forecasting also includes spatial and modal traveler responses in increments during the first year of operation.

Figure 2. Chronological development and applications of FREQ model family.
Table 1. Selected examples of FREQ model applications.

<table>
<thead>
<tr>
<th>Year</th>
<th>Principal Investigator</th>
<th>Description</th>
<th>Site</th>
<th>FREQ Model</th>
<th>Description</th>
<th>Ref. No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1970</td>
<td>Allen</td>
<td>University of California</td>
<td>Oakland Bay Bridge</td>
<td>1970</td>
<td>3C</td>
<td>Evaluate design and control alternatives</td>
</tr>
<tr>
<td>1971</td>
<td>Aido</td>
<td>University of California</td>
<td>I-80, Cleveland</td>
<td>1971</td>
<td>3C</td>
<td>Evaluate design and control alternatives</td>
</tr>
<tr>
<td>1972</td>
<td>Capdile</td>
<td>Vroomkes</td>
<td>I-80, Cleveland</td>
<td>1972</td>
<td>3C</td>
<td>Determine feasibility of priority lanes</td>
</tr>
<tr>
<td>1978</td>
<td>English</td>
<td>Texas Department of Transportation</td>
<td>US-19, Houston</td>
<td>1978</td>
<td>3C</td>
<td>Compared operations and design improvements</td>
</tr>
<tr>
<td>1978</td>
<td>Schneider</td>
<td>University of Washington</td>
<td>I-80, Berkeley</td>
<td>1978</td>
<td>3C</td>
<td>GRAF</td>
</tr>
<tr>
<td>1980</td>
<td>Michalopoulos</td>
<td>University of Minnesota</td>
<td>I-394, Minneapolis</td>
<td>1980</td>
<td>3C</td>
<td>Design and control strategy evaluation</td>
</tr>
<tr>
<td>1980</td>
<td>Immers</td>
<td>Delft University</td>
<td>A-12, Hague</td>
<td>1980</td>
<td>3C</td>
<td>Measured impacts of design and operations</td>
</tr>
<tr>
<td>1980</td>
<td>Michalopoulos</td>
<td>University of Minnesota</td>
<td>North Freeway, Auckland</td>
<td>1980</td>
<td>3C</td>
<td>Evaluated fuel consumption strategies</td>
</tr>
<tr>
<td>1981</td>
<td>Meyers</td>
<td>Colorado Department of Transportation</td>
<td>I-25, Denver</td>
<td>1981</td>
<td>3C</td>
<td>Estimated metering impacts on city streets</td>
</tr>
<tr>
<td>1981</td>
<td>Howard</td>
<td>Bartholomew</td>
<td>I-95, Miami</td>
<td>1981</td>
<td>3C</td>
<td>Experimented feasibility of TSM techniques</td>
</tr>
<tr>
<td>1981</td>
<td>Deskin</td>
<td>Lockner</td>
<td>I-95, Miami</td>
<td>1981</td>
<td>3C</td>
<td>Evaluated feasibility of ramp metering</td>
</tr>
<tr>
<td>1981</td>
<td>Berg</td>
<td>Parsons</td>
<td>I-5, Seattle</td>
<td>1981</td>
<td>3C</td>
<td>Evaluation of TSM-type strategies</td>
</tr>
<tr>
<td>1981</td>
<td>O'Neill</td>
<td>Washington Department of Transportation</td>
<td>I-495, Seattle</td>
<td>1981</td>
<td>3C</td>
<td>Priority lane evaluation</td>
</tr>
</tbody>
</table>

The FREQ models have been applied by a number of investigators analyzing freeway corridor traffic. Time and space limitations permit only the presentation of a sample of model applications and then only a brief description of highlights of selected applications. These applications are identified and described in Table 1.

The INTRAS model

The INTRAS model is a stochastic, microscopic model especially developed for studying freeway incidents. INTRAS stands for Integrated TRAFFic Simulation and is a vehicle-specific time-stepping simulation designed to realistically represent traffic and traffic control in a freeway and surrounding surface street environment. The model development and/or applications have occurred in at least four organizations since work began in 1975. An illustration of the chronological development and application of the INTRAS model is shown in Figure 3 and the following description is keyed to this illustration.

A program of major emphasis was undertaken by FHWA that included the design, programming, calibration, validation, and demonstration of a computer simulation model for the evaluation of incident detection strategies. The project had six major tasks and included the adaptation of the UTCS-1 network simulation model for freeway applications, validation of candidate components, programming the simulation model, validation and refinement of the simulation model, validation of incident detection algorithms, and application of the simulation model.

Four interim reports were prepared (70-73). At the end of the project in mid-1977, a final report in four volumes was submitted to FHWA (74-77). The four volumes dealt with program design, parameter calibration and freeway dynamics component development (74); user's manual (75); validation and application (76); and program documentation (77).

Two parallel activities have been undertaken since 1977 with the INTRAS model. FHWA staff have been reviewing the submitted project reports and have undertaken a series of investigations with the INTRAS model in anticipation that it will be released soon to operating agencies. The other activity is one undertaken by the ORINCON Corporation in which both the INTRAS and MACK models were used to evaluate freeway ramp control strategies under incident situations.

The ORINCON study for FHWA was undertaken during 1978-1980 and KLD Associates was the subcontractor responsible for production runs with the INTRAS model. ORINCON Corporation prepared an initial report (78) that compared the INTRAS and MACK models and then a final report (79) that described the project including the use of the INTRAS model.

The MACK Model Family

The MACK model and its later versions are deterministic, macroscopic models that basically consist of a set of conservation equations and a corresponding set of dynamic speed-density equations. Payne and associates began work in the late 1960s and models in this family include MACK I, MACK II, MACK III, FREFLO, and TRAFLO. The model development and/or application have occurred in at least 10 organizations. An illustration of the chronological development and application of the MACK model family is shown in Figure 4 and the following description is keyed to this illustration.

The MACK I model was developed at the University of Southern California and applied to the Hollywood Freeway in Los Angeles for evaluation of ramp control under incident and recurring congestion conditions (80-85). Detailed instructions for its use and an indication of its capabilities were well documented (86).

The MACK II model was developed at ORINCON and was compared with the INTRAS model (87,88). It predicted change in the dynamic-speed relationship that involved the parameters were introduced. The MACK II and INTRAS models were applied to a segment of the Shirley Highway with incident-free and incident
Figure 4. Chronological development and applications of MACK model family.

1967
1
PACK I

1968
2

1969
3

1970
4

1971
5

1972
6

1973
7

1974

1975

1976

1977

1978

1979

1980

1981

PACK II

TTI/DBQ

MACK III

FREFLO

INTRAS

TORONTO

ONTARIO

VERAC

KLD

VCC

A continuation of an earlier NCHRP project, entitled Guidelines for Design and Operation of Ramp Control Systems, was initiated in 1977 and a final report draft was prepared in January 1980 (96). The major objective of the study was to prepare specific guidelines for determining the feasibility of ramp control and, if feasible, to identify which mode of ramp control is appropriate: pretimed, local actuated, or system. The initial research plan called for the determination of the improved benefits of the various control models from successive field trials of each mode on selected freeway sites. After due consideration, it was determined that the use of a freeway simulation model provided the best research approach. The FREFLO model was selected and 153 simulation runs were used. Numerous technical memoranda were prepared and include plans for simulation runs (89), FREFLO acceptance tests (91), FREFLO acceptance tests (92), and FREFLO baseline scenarios (95).

Rober continued the work of Payne at ORINICON in using the FREFLO model (unofficially called MACK IIII) and the INTRAS model to evaluate freeway ramp control strategies under incident situations. The project was sponsored by FHWA and began in early 1978; a final report was submitted in April 1980 (98). The MACK III model was modified to handle incidents and simulate a variety of ramp control strategies. Several hundred simulation runs were made and the MACK III model was the key analytical tool employed along with the INTRAS model.

Hauer and Hurdle of the University of Toronto were selected as discussors of Payne’s paper on the FREFLO model and their discussion and the author’s closure were published at the end of the paper (93). The discussors applied the FREFLO model to a simple freeway example with no ramps and a bottleneck in the middle. They hypothesized expected traffic results. Computer outputs did not provide anticipated results. Hauer and Hurdle pointed out the difficulties encountered and speculated about possible explanations. Payne, in his closure, reviewed the previous successful uses of FREFLO and stressed the importance of selecting appropriate model parameters. Particular attention was drawn to the nominal capacity parameters and their relationship to the traditional concept of roadway capacity.

Lieberman and Andrews described the TRAFLO model, which is a software system, programmed in FORTRAN, and which consists of five component models that interface with one another to form an integrated system (97). The freeway traffic simulation model included in TRAFLO is an extension and refinement of the earlier MACK model. In addition to the refinements to the FREFLO model described earlier, another extension allows buses, carpools, automobiles, and trucks to be distinguishable as three vehicle types. As of 1980, the TRAFLO program had been completed and was undergoing in-house testing by FHWA personnel.

The Institute of Transportation Studies, under sponsorship of the Caltrans with the cooperation of FHWA, began an on-line freeway entry control research project in late 1979. The project consists of two phases. In phase I, selected control strategies are to be evaluated through the use of a freeway simulation model applied to a specific site. In phase II, the most promising control strategies are to be evaluated in the field at the specific site. The first working paper was directed toward the selection of site, model, and candidate strategies (99). The FREFLO model was selected for use in this project because of the dynamic nature of the model and the anticipated short control intervals. The FREFLO model has been modified to simulate more realistically congested flow conditions, to enhance user ease in interpreting model outputs, and to permit the evaluation of fixed-time, local-responsive, system-responsive control, and other control strategies. A phase I report is expected in 1981.

Derszko, Ugge, and Case prepared an informal paper in which they reported the evaluation of two dynamic freeway flow models: one using the Queen Elizabeth Way in Ontario, Canada (100). The MACK II model and one of Phillips kinetic models were the two dynamic models evaluated. The preliminary results of their investigation indicated the models both exhibited instabilities in their behavior and did not track their real road data correctly.

Work with the FREFLO model continues on at least
The SCOT Model Family

For purposes of this paper, the DAFT, SCOT, SCOT-Q, and DIVSIM models are classified as members of the SCOT family of models. Work began in this modeling effort in the late 1960s and continues today. The initial work on this family of models was undertaken by Lieberman and associates at KLD. Researchers at Sperry also worked on this family of models and recently integrated the more advanced SCOT-Q model into their DIVSIM model. The following highlights the development and applications of this family of models (see Figure 5).

The DAFT model was the first model developed in this family and is a macroscopic simulation of traffic along a network of freeways, ramps, and arteries. Lieberman developed this model and first applied it to a portion of the Central Expressway north of Dallas (101). In the model the vehicles are grouped into platoons and move along the freeway according to a specified speed-density relation. Along the nonfreeway links, the platoons travel at specified free-flow speed and are delayed at the downstream end of links based on g/c ratios and approach volumes. Input data include O-D demands that may vary with time. The model includes a minimum travel cost algorithm and hence produces a dynamic assignment of traffic as a by-product of the simulation.

Lieberman and associates then created the SCOT model, which represented an evolutionary development based on combining the freeway portion of the previously described DAFT model and the UTC-1 model for urban street networks (103,104). While the freeway traffic is modeled macroscopically in essentially the same manner as the DAFT model, the urban street network is modeled microscopically in essentially the same manner as the UTC-1 model. A key design element of the SCOT model is the interface features between the macroscopic and microscopic characteristics of the two submodels. The traffic demands may be entered into the model either in the form of turning movements at each node or O-D volumes. The model was developed as a testing real-time control policies for an entire corridor: freeway ramps, frontage roads, and adjoining feeder and parallel arterials.

During 1973-1976, two parallel efforts were undertaken that involved the SCOT model. The first of these two efforts was undertaken by KLD and was directed toward developing user and program documentation manuals for the SCOT model. The other effort was undertaken by the Transportation Systems Center (TSC) and was directed toward the application and evaluation of the SCOT model. KLD, under contract to TSC, prepared a plan for data acquisition, data reduction, model calibration, and model validation (105). This was followed by the preparation of user and program documentation manuals (108,113).

TSC applied the SCOT model to the central business district of Minneapolis (109) and to a 1.2-mile test network of the Dallas North Central Expressway (110). In the Minneapolis application, the SCOT model was used to predict the effect on bus service and general traffic performance of implementing candidate bus priority strategies. The SCOT model was calibrated to current peak-hour traffic conditions within an urban street grid representative of the central business district of Minneapolis. In the Dallas North Central Expressway study, the SCOT model was calibrated and validated. Tests showed no significant differences between field and simulation results for the basic parameters of traffic speed, flow, and saturation. A demonstration of the O-D traffic assignment capability of the model indicated that the minimum time-path criteria used have not been conclusively shown to be the correct criteria for traffic assignment.

Sometime in 1976, a new effort was directed toward the development of the SCOT-Q model. The initial work on SCOT-Q was undertaken by KLD, which essentially adopted the SDC approach to the NETSIM portion of the SCOT model (120). A larger time-step was employed and, with some simplifying assumptions, the SCOT-Q model had a faster running time than the SCOT model for simulation. The SCOT-Q model was used by Sperry to aid in assessing the feasibility of an Integrated Motorist Information System (IMIS) for the Northern Long Island (N.Y.) corridor. Phase I (feasibility) of this FHWA-sponsored project, entitled Integrated Motorist Information System Feasibility and Design Study, was completed in 1977 (114). A series of more than 130 computer runs was made, and the SCOT-Q model reduced running time by 50 percent compared with the SCOT model.

In phase II, Sperry developed a generalized IMIS feasibility methodology and, to validate the methodology, applied an enlarged version of the SCOT to a freeway corridor just east of downtown Los Angeles (118). The simulation was calibrated to the test corridor by using special data collected for that purpose. The enlarged SCOT model was used to test three scenarios: recurrent congestion situation without control, incident situation without control, and controlled response to minimize major congestion.

Phase III is planned to result in the final design of IMIS in the Northern Long Island corridor. In a parallel effort, Sperry researchers worked on a FHWA-sponsored project concerned with the development of traffic logic for freeway corridor control (116,119). This effort included development of DIVERТ, a corridor optimization program embedded in the SCOT simulation. The optimization portion of this program was termed DIVERT and is intended as
making a transition from a period of intensive model development to one of intensive application" (121). This section describes the educational and implementation support effort undertaken in regard to the FREQ family of models. The purpose is to demonstrate the need for such efforts and to encourage others to become involved with similar efforts with this and other freeway corridor models. Such educational and implementation activities are shown in Figure 6.

Limited educational and implementation support activities with the FREQ model were undertaken before 1975. The model had been applied by the developers and had been used by a consultant in one research effort concerned with establishing guidelines for priority lanes on freeways. Almost all effort was devoted to extending and refining the model, and there was little interest shown by others in using the model.

By 1975, the FREQ3CP model had been developed with sponsorship from FHWA. At the same time, there was a growing awareness to encourage travel by carpool and bus by preferential treatment on highway facilities. Because of this awareness, the model's capabilities, and the recognition for training, FHWA sponsored the development of a FREQ3CP instructor and student workbook (122), the conduct of five workshops, and the distribution of computer program and sample input-output listings.

The FREQ3CP model became a part of the FHWA's BACKPAC computer program system and, while formal implementation support for the model was not available, these workshops stimulated extensive model use in several cities including Houston, Minneapolis, Boston, and Denver. In late 1976, the FREQ4CP program became available and a new workbook was prepared (123).

The FREQ model developers and Caltrans recognized a need for implementation support beyond the workshop and entered into an agreement, in which Caltrans professionals could continuously seek advice and assistance from the FREQ developers. The implementation support activities began in 1977 and have been in continuous operation since that time. Assistance includes a wide variety of activities such as

1. Placing FREQ model on Caltrans computer facilities and continuous update for use from district terminals;
2. Phone conversations to advise on preparation of input data, problems with unsuccessful runs, and interpretation of output results;
3. Review of input data sets and output results, initially through mail and now on-line through a terminal facility at the university;
4. Field visits to district offices for personal discussion with model users and brief presentations of current status of models;
5. Preparation of additional documentation for model users as users deem necessary;
6. Individual or team instruction at the university for model users on critically timed projects;
7. Formal workshops on basic theories incorporated in model and also on model usage;
8. Extension and refinement of model due to user need and feedback.

By the beginning of 1979, the model had been applied in selected districts of the Marysville, San Francisco, Los Angeles, and San Diego areas.

In late 1976, the FREQ6PE and FREQ6PL models became available and, because they included many significant improvements over earlier versions, a series of workshops was proposed. The implementation activities continued with Caltrans with the FREQ6PE and FREQ6PL models replacing the FREQ4CP model.

the real-time version of the DIVSIM corridor optimization algorithm.

In a parallel effort, researchers at Sperry began work on another family of models in the early 1970s when they developed a simulation model of a system that balances vehicular flow between two parallel routes through the use of real-time surveillance and variable signing control (102). The model was a hydrodynamic macroscopic model, employed shock-wave analysis, and was designed considering the type of roadway and signing in use on the New Jersey Turnpike.

Sperry researchers continued the development of this model on a FHWA-sponsored project, entitled Diversion of Intercity Traffic at a Single Point, with application to the Harbor Tunnel Thruway and I-695 Bypass Route in Baltimore. A final report (106), simulation model description (107), and several technical papers (111,112) resulted from this effort. The simulation model was named the SPAR model and provided a multiple roadway-freeway simulation capability. It essentially consisted of two major components: a hydrodynamic traffic flow model and a traffic diversion model. The resulting optimized policies have been incorporated into the design for a practical real-time alternate routing system applicable to the Baltimore site.

THE NEW FRONTIER—MODEL APPLICATIONS

Greater use of existing simulation models and the relevant development of future simulation models require a major educational and implementation support effort today. The developers of simulation models have an important role to play, in fact a major responsibility for such activities. As Lieberman has pointed out, "While the development of simulation models can hardly be considered an activity which has reached its full potential, we are nevertheless

<table>
<thead>
<tr>
<th>YEAR</th>
<th>YEAR REPORTS</th>
<th>EDUCATIONAL WORKBOOKS</th>
<th>WORKSHOPS</th>
<th>IMPLEMENTATION</th>
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<tr>
<td>1975</td>
<td>SCP</td>
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<td>ST, AUSTIN</td>
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<td>1976</td>
<td>4CP</td>
<td>SACRAMENTO</td>
<td>DELFT</td>
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<td>WASH, DC</td>
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<td>1978</td>
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<td>1980</td>
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<td>LOS ANGELES</td>
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Conversations began with FHWA representatives to work toward an educational and implementation support program at the national level patterned after the Caltrans experience.

The technical assistance phase began immediately after a series of workshops and was patterned after the Caltrans support activities. Inquiries on the order of 3-5 per week were received and responses varied from direct answers to computer runs on our computer facilities. Means for periodic communications with all model users were recognized and FREQ/TRANSYT bulletins were published in August 1980, December 1980, and April 1981. The bulletin is distributed to approximately 250 readers and includes responses to frequently asked questions, lists of model users, new and novel applications, and programming errors and improvements.

Three user exchange conferences were held: one for FREQ model users and two for TRANSYT model users. Both Caltrans and FHWA-sponsored implementation support projects are continuing.

In summary, attention has been drawn to the need for improved and extended simulation model application. For most successful applications, educational and implementation support activities are required. Such activities in regard to the FREQ family of models have been described. It is hoped that the results of such activities will encourage others to become involved in similar efforts.

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Enhanced NETSIM Program

E. Lieberman

The NETSIM traffic simulation model (1) has been applied extensively over the past seven years to a wide variety of problem areas by a large number of public and private agencies. The experience gained with NETSIM has prompted many suggestions for improving and extending the program with the view to further enhancing its value as an engineering and research tool.

In an informal survey conducted by KLD Associates a few years ago, the following suggestions were made:

1. The input preparation effort should be eased,
2. The cost of computing should be reduced,
3. Many additional features should be introduced, and
4. The output capabilities should be extended.

Interestingly, the last two suggestions conflict with the first two. Whenever additional features are introduced, some added input requirements are usually implied. Furthermore, any additional feature leads to the development of additional software that, in turn, occupies computer memory and consumes computer resources. Similarly, enhanced output capabilities imply the need to compute and to store additional data; writing output is also costly in computer time. Such conflicting user requests impose a burden on the designer to be responsive in the most cost-effective manner.

This paper describes the enhancements incorporated into the new version of NETSIM. This version constitutes the result of the first development stage of the Integrated Traffic Simulation Software System known as TRAF.

The techniques that have been applied to produce a cost-effective, enhanced version of NETSIM will also be described.

NETSIM ENHANCEMENTS

Specific NETSIM enhancements are described briefly here.

Blockers and Parkers

Blockers are defined as illegal parkers who occupy a