Freeway Simulation Models Revisited

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The purpose of this paper is to update and assess the continued development and application of freeway simulation models in the 1980s. Several activities were undertaken to meet this objective. First, literature searches were undertaken utilizing the University of California Institute for Transportation Studies library and the author's personal library. Second, the identified references were classified by freeway simulation model family and placed in a historical perspective. The references were then carefully studied to identify and assess new developments and applications. Finally, identified authors were contacted to determine omissions and to confirm the current status of their freeway-modeling efforts.

The Conference on Traffic Simulation Models was conducted by the Transportation Research Board in Williamsburg, Virginia, June 1981. The conference was sponsored by the Federal Highway Administration and the conference proceedings were published by the Transportation Research Board as *Special Report 194: The Application of Traffic Simulation Models*. The author's paper presented at that conference, Models for Freeway Corridor Analysis, was published in Special Report 194. The paper had 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 to the enhancement of simulation modeling practice. After a brief review of earlier models for freeway corridor analysis, five families of currently available models were described. Particular emphasis was given to the historical development of the models and to real-life applications. The five families of models were

- CORQ
- FREQ
- INTRAS
- MACK
- SCOT

The paper also included an extensive bibliography, which was an attempt to include all published papers in which the development and application of available freeway corridor models were described.

UPDATING PROCESS

The purpose of the current paper is to update and assess the continued development and application of freeway simulation models in the 1980s. Several activities were undertaken to meet this objective. First, literature searches were undertaken utilizing the University of California Institute for Transportation Studies (ITS) library and the author's personal library. Second, the identified references were classified by freeway simulation model family and placed in a historical perspective. The references were then carefully studied to identify and assess new developments and applications. Finally, identified authors were contacted to determine omissions and to confirm the current status of their freeway-modeling efforts. The authors of the various freeway models were most cooperative in identifying omissions and confirming the current status of development, and their responses have significantly aided in completing this updating and assessment process.

The remaining portions of this paper are organized by freeway model family, which is complemented by an extensive list of references.

THE CORQ-CORCON MODEL FAMILY

CORQ and CORCON are the two freeway simulation models in this family. CORCON has been applied to four freeway sites in the Toronto area by the Ontario Ministry of Transportation and Communications since 1978 (*1*). A CORCON6F user's manual has been prepared (*2*).

Yagar prepared a paper in 1980 addressing the question of origin-destination (O-D) demand data requirements for CORQ, because a key ingredient of this model is the assignment (or reassignment) between the freeway and alternative routes in the corridor (*3*). For the past 2 years, Yagar has been making significant improvements in CORQ with sponsorship by the Ontario Ministry of Transportation and Communications. Primary attention has been given to "look ahead" features, computer efficiency, and user-friendliness (*4*). CORQ has not been applied in practice since about 1980. It is anticipated that this model will be a proprietary one.

CORQ has been extensively compared with other models and was selected as the leading one for traffic networks (*5-7*).

THE FREQ MODEL FAMILY

Development and application of the FREQ model family continue during the 1980s at a fairly significant level of activity. These activities will be described in the following paragraphs under priority-entry model development, priority-lane model development, training and technical assistance programs, and model application.

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FREQ7PE was a revised and extended version of FREQ6PE (*8*). Modifications included improved input and output flexibility, fuel and emission options, user-supplied metering plans, queue-length limits, and improvement to traveler-response modeling.

On the basis of extensive training and technical assistance programs, which will be described later, users suggested a number of further improvements for FREQ7PE. The improvements were incorporated into FREQ8PE (*9*). One of the major improvements was the incorporation of the synthetic O-D formulation within FREQ8PE so that users would have the option of directly entering O-D information or entering ramp counts and having the model generate synthetic O-D information.

Two current developments with the priority-entry model family that have not been documented are FREQ9PE and the microcomputer version of FREQ8PE. FREQ9PE is capable of analyzing a 50- to 100-mi length of freeway in one computer pass. In essence, the maximum number of subsections has been increased from 40 to 160, whereas the maximum number of entrances and exits has been increased from 20 to 80 each. The microcomputer version of FREQ8PE is in the final testing stage and release is expected in early 1987.

Turning to the further development of priority-lane models, FREQ6PL was modified and called FREQ8PL (FREQ7PL was never publicly released) (*10*). FREQ8PL became the sister model of FREQ8PE and incorporated many of the features of the latter model that were appropriate for priority-lane investigations, including the synthetic O-D formulation. Currently there is no further development on FREQ8PL, but in the future an increased size version (FREQ9PL) and a microcomputer version are envisioned.

The need for training and technical assistance in the application of simulation models was one of the major conclusions of the June 1981 Williamsburg conference. On the basis of earlier training activities from 1975 to 1981 with FHWA and the California Department of Transportation, and discussion and workshops at the Williamsburg conference, a comprehensive training and technical assistance program was undertaken with the Texas Department of Highways and Public Transportation. Two series of programs were undertaken, one in 1981-1982 (*11-13*) and the second in 1983 (*14-16*). For example, the second series in 1983 consisted of five major stages. In April Workshop 1 was held, which emphasized freeway simulation and calibration (*14*). From April until July, the professionals returned to their urban districts, and with technical assistance, collected input data, made FREQ7 simulation runs, and calibrated model parameters. In July Workshops 2 and 3 were held, with emphasis on ramp-metering simulation using FREQ7PE and priority-lane simulation using FREQ7PL (*15, 16*). From July to December, the professionals, with technical assistance, used FREQ7PE or FREQ7PL, or both, to investigate freeway problems in their districts and possible solutions through entry control and priority lanes. In December the final workshop was held in which the professionals shared their experiences with regard to freeway problem model application and results. Discussions are currently under way with several state departments of transportation, and training and technical assistance programs will probably be undertaken in 1987.

There have been a number of reported applications of the FREQ models during the early 1980s. They are as follows (published reports are indicated by reference number):

- *Impact of Ramp Metering on Carbon Monoxide Emissions,* Maricopa Association of Governments (*17*);
- *I-5 South HOV Project,* Parsons Brinckerhoff (*18*);
- *Santa Monica Freeway Inbound Research Project,* University of California (*19*);
- *Simulation Analyses of Proposed Improvements for the Southwest Freeway,* Texas Transportation Institute (TTI) (*20*);
- *Simulation Analyses of Proposed Improvements for the Eastex Freeway,* TTI (*21*);
- *Dallas Area High-Occupancy Vehicle Study,* TTI (*22*);
- *I-25 Ramp Metering Final Evaluation Report,* Colorado Division of Highways (*23*);
- *Computer Simulation To Compare Freeway Improvements,* TTI (*24*);
- *Use and Effectiveness of Synthetic Origin-Destination Data in a Macroscopic Freeway Simulation Model,* TTI (*10, 25, 26*);
- FREQ applications and evaluations of QEW Expressway, Ottawa Queensway, and Highway 401, Ontario Ministry of Transportation and Communications (*27-31*);
- Freeway-tunnel approach study in New Jersey, URS Company, Inc.;
- Phoenix I-10/I-17 freeway study, JHK & Associates;
- Evaluation of control and performance on Garden Grove Freeway, University of California; and
- Montreal freeway study, DELCAN Corporation.

THE INTRAS MODEL FAMILY

There has been considerable activity with INTRAS during the 1980s. These activities will be described in three parts: development and testing, applications, and further development and testing.

KLD Associates completed their development and testing of the INTRAS model in 1980 with a series of reports describing this development and validation (*32-34*). The model was applied in an investigation of the effect of location of freeway traffic sensors on incident detection and in the evaluation of control strategies in response to freeway incidents (jointly with Orincon Corporation) (*35-37*).

There have been a number of reported applications of INTRAS by other organizations and one draft report describing an application was located in the literature search (*38*). The reported applications include the following:

- Energy conservation studies, JFT Associates (*38-40*);
- Evaluation of reconstruction of a Detroit freeway, Michigan State University;
- Evaluation of the effect of truck accidents, University of California, Irvine;

- Jones Falls Freeway study in Baltimore, KLD Associates;
- QEW Freeway study in Toronto, Ontario Ministry of Transportation and Communications (*7, 28, 30, 41*);
- Fourteenth Bridge study in Washington, D.C., FHWA;
- Kennedy Expressway Study in Chicago, FHWA;
- Theodore Roosevelt Bridge study in Washington, D.C.; FHWA (*42*);
- Minneapolis Freeway KRONOS simulation program testing, University of Minnesota.

Further development and testing of INTRAS continue. In 1982 Bullen reported the development of FOMIS based on INTRAS (*43*). The intent was to overcome some of the traffic operations difficulties with INTRAS, improve model speed, and provide for use on limited-capacity computers. The model was applied to a weaving section on I-95 in Dade County, Florida.

Another major development is currently under way by JFT and Associates, sponsored by FHWA. This will consist of reprogramming INTRAS according to structured design techniques and enhancing it to make it more user-friendly and applicable to a wider range of applications. The revised model will be called FRESIM and will be incorporated into the TRAF family of programs being developed by FHWA.

THE MACK MODEL FAMILY

Several applications in the early 1980s revealed the need for some improvements of FREFLO (earlier versions were called MACK), particularly in the modeling of congestion when capacities or demand, or both, along a freeway changed significantly. Two earlier applications are presented first and then the work of several research teams attempting to analyze and improve FREFLO will be discussed.

TTI and Daro Associates undertook an NCHRP project to develop guidelines for the selection of ramp-control systems (*44*). Extensive use was made of MACK in assessing the effect of ramp control. About the same time the Ontario Ministry of Transportation and Communications applied FREFLO to the QEW Freeway near Toronto in an attempt to calibrate and validate the model (*45*). The overall conclusion was that the model exhibited instabilities and did not track real-world data correctly.

The author of MACK performed additional work on FREFLO, with particular attention to discontinuity in the equilibrium relationship between speed and density (*39*). The author reported a greatly improved quality of FREFLO predictions using the results of this research.

In 1980 a group of researchers at the University of California, Berkeley (UCB), sponsored by the California Department of Transportation and FHWA, began work on the first of a series of three research projects dealing with dynamic traffic-responsive control strategies for freeways. FREFLO was selected as a starting point, extensively modified, and renamed FRECON (*46-50*). The modifications included automatic selection of subsection lengths (to overcome the earlier-identified problem with modeling congestion), the output of point detector signals, and the incorporation of pretimed and local traffic-responsive entry control algorithms. The model was applied to the Santa Monica Freeway and tested on the Ottawa Queensway by the Ontario Ministry of Transportation and Communications.

The second UCB research effort emphasized segmentwide control and corridor evaluation (*51-54*). The major outcome of this research included the development of a freeway corridor model (named FRECON2), development and evaluation of segmentwide traffic-responsive freeway entry control strategies, and field implementation guidelines. The model was applied to the Santa Monica Freeway, and a user's manual is available (*55*). The Ontario Ministry of Transportation and Communications experienced problems in their application and encountered excessive CPU time.

The current research effort is concerned with developing an on-line algorithm for determining when detector data are acceptable and responsive control strategies under incident conditions (*48, 56*). Complementing this research effort, one researcher has suggested further possible improvements to FRECON2 (*57*) and another researcher has suggested another model formulation (*58, 59*). Current plans call for the application of FRECON2 to the Garden Grove Freeway in Southern California and to the San Francisco-Oakland Bay Bridge.

Under support from FHWA, KLD Associates recently implemented some modifications in the FREFLO formulation designed specifically to resolve its difficulties in properly representing congested conditions (*60*). The simulation results for some test and actual networks indicate that the model is now capable of describing moderate and severe freeway congestion.

Further development of FREFLO is currently under way by JFT and Associates, sponsored by FHWA. No reports were located in the literature search describing this activity.

THE SCOT MODEL FAMILY

In the early 1980s Reiss et al. described the traffic control algorithm development for SCOT (*61*). Also in the early 1980s it is believed that SCOT or a refined version was applied to the Long Island Expressway as part of the IMIS project. However, the literature search did not reveal any published papers.

Review of the literature and discussions with several freeway modelers have not identified any further development in applications with the SCOT model family since the early 1980s.

OTHER RECENTLY DEVELOPED MODELS

Several additional models are currently available that have been developed either as new models or as significantly modified, previously reported models. These additional models are FREESIM, KRONOS, TRAFLO, and ROADRUNNER.

FREESIM, developed at Ohio State University, is a microscopic simulation model designed particularly for evaluation of the effects of freeway lane closures. A number of papers describe the development and application of FREESIM (*62-66*). There is no evidence that the model has been applied by others.

After studying several existing models, a research team at the University of Minnesota developed a new one, KRONOS. They wanted to develop a new model that would be efficient in structure and formulation but include the treatment of merging, weaving, and diverging traffic. A significant number of papers have been published and the most recent ones describe an interactive, menu-driven microcomputer version (*67-78*). In addition to the applications by the developers, KRONOS has been applied to a section of the Ottawa Queensway and possibly used by the Minnesota Department of Transportation. Following experimentation and testing, a new version of the KRONOS program (version V) is now being developed and will be released in early 1987. This version includes improved graphics, collector-distributor (C-D) roads, construction zones, left-hand side entrances and exits, and other geometric and demand complexities. The program is also being extended to corridors.

TRAFLO is actually a set of five components that integrates traffic simulation with traffic assignment. The traffic simulation portion includes options for modeling freeways, corridors, urban and suburban arterials, and grid networks. A number of papers are available that describe the development, application, and user's guide (*79-83*). TRAFLO-M is an extended version of TRAFLO that substitutes the DYNEV submodel for the FREFLO submodel and adds the ability to simulate ramp-metering strategies (*84-88*).

The ROADRUNNER freeway model was developed at the University of Toronto for the Ontario Ministry of Transportation and Communications in 1978 (*89*). The model is intended to be used to characterize global system performance and is macroscopic in nature, dealing with average quantities of flow, density, and speed. ROADRUNNER is an attempt to join the use of the numerical integration approaches of MACK with the hydrodynamic theory of FREQ. There is no evidence that the model has been applied by others.

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