Conference Summary, Findings, and Recommendations

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System simulation is a technique of solving problems by following the changes over time of a dynamic model of the system. Simulation of vehicular traffic on highways and on street networks has been a natural application of computer modeling since the early stages of digital computation. The traffic environment is complex and stochastic in nature. Individual vehicles move along specified guideways constrained by the presence of other vehicles and restricted by control devices, while they attempt to satisfy individual objectives. Although analytical treatments such as queuing models can describe local behavior with some degree of accuracy, no such approach has been applicable for adequately describing the operational performance of traffic over street and freeway networks.

Traffic simulation models are computer programs that are designed to represent realistically the behavior of the physical system. Such models are themselves systems, in the sense that they are a collection of analytical models that describe such highly variable motorist responses as car following, lane changing, queue formation, discharge, etc. Such models are integrated into a logical structure in the form of computer software.

Traffic simulation models can be classified as either microscopic or macroscopic in design. Microscopic models describe the detailed, time-varying trajectories of individual vehicles in the traffic stream. Macroscopic models represent the traffic stream in some aggregate form (e.g., employing a fluid flow analogy or a statistical representation). Although the latter approach is usually less accurate and more limited in scope than the former, it offers the advantage of lower computational cost.

Inputs to models include known attributes of the system such as the geometrics of each link (e.g., length and number of lanes), network topology, properties of the control devices, and the time-varying traffic-demand volumes and circulation patterns. This initial preparation of the input data must be undertaken with care and represents the largest investment by the user.

All simulation models accumulate statistics in the course of representing the dynamic behavior of traffic. These statistics are output as measures of effectiveness (MOE) that describe the operational performance of traffic on each link (i.e., street or roadway segment) of the analysis network. Representative MOEs include vehicle miles, vehicle hours, speed, stops, delay, density, queue length, spillback, mass transit operations, fuel consumption, and vehicle emissions.

By exercising the simulation model and carefully analyzing the resulting statistical output, the engineer can study the operational effects of several policy and/or design alternatives rapidly and economically. Careful examination, combined with the engineering knowledge of the user, can provide the insight needed to identify the optimal design or policy. In this procedure, the simulation model is the tool that provides the necessary information; it is the engineer or analyst who must correctly interpret this information, apply his or her expertise to form the proper conclusions, and use this skill to arrive at the best solution.

The digital computer is particularly effective in providing the medium for exercising traffic simulation models and their interaction with external management and control measures. Thus, it provides the analyst with a very convenient laboratory for experimentation, evaluation, and design.

This conference was to be a signpost in the continuous process of development and application of traffic simulation models. It brought together developers, users, and prospective users of models to facilitate the accomplishment of the following objectives:

1. Demonstrate through user experience reports the availability and effectiveness of existing models for traffic simulation analysis,
2. Discuss a wide range of issues and problems encountered in using existing models in order to enhance their applicability and usage,
3. Communicate to the user community pending and future model developments, and
4. Prepare an agenda of needs for future research.

The proceedings of the conference are presented in this report. An overview of the resource and contributed papers, the main findings of the conference, and the conclusions and recommendations emerging from the workshop discussions are summarized here.

BACKGROUND MATERIAL

Available Models for Simulation Analysis

Four papers were presented on existing models for traffic simulation analysis. Gibson and May each present a comprehensive survey of existing models. Gibson provides a catalog of 104 documented computer models for traffic operations analysis that are listed in a handbook on this topic being prepared by FHWA. The models are classified according to the geometrics of the application--that is, intersections, arterials, networks, freeways, and corridors. Ten of these models are considered practical in the sense that they produce practical and useful results. The models are

SOAP--intersection optimization
TEXAS--detailed intersection simulation
PASSER II--arterial optimization
PASSER III--diamond interchange optimization
SUB--arterial bus simulation
TRANSYT-7F--network optimization
SIGOP III--network optimization
NETSIM--network simulation
PRIFRE--freeway optimization
FREQ3CP--freeway simulation

Most of these models are being made available by FHWA; SOAP, PASSER II, and TRANSYT are included in the Arterial Analysis Package (AAP). NETSIM is currently available and an enhanced version will be included in the TRAF family. TRANSYT-7F and SIGOP III are undergoing extended testing before their planned release. The FREQ family (including PRIFRE) is available from the University of California at Berkeley.

The FHWA implementation support is directed toward making effective use of these models. In order to get traffic engineers to use simulation and optimization models they have to be made easy to use and have to be proven reliable and valid. The first of these objectives is addressed through training and implementation support, while the other objectives involve demonstration and testing.

May provides a comprehensive survey of models for freeway corridor analysis, including their historical development and applications. An extensive bibliography of the model descriptions and their application reports is also given. May argues the need for integration of research, education, and implementation activities as keys to the enhancement of simulation modeling practice.

Lieberman describes a variety of enhancements recently incorporated into NETSIM as part of the development of the Integrated Traffic Simulation Software System, which has been given the name TRAF. These enhancements include (a) modifications to facilitate user access, (b) minimization of computer resource requirements, (c) new model features, and (d) extended input-output capabilities.

Courage and Wallace describe and compare the computational characteristics of five traffic signal optimization and evaluation models with which they had extensive experience. These are SOAP, PASSER II, PASSER III, TRANSYT, and SIGOP II.

User Experience

Three papers report user experience with the most widely used traffic network simulation model--NETSIM. The first two reports are by members of state departments of transportation and the third by university researchers. Hagerty and Maleck demonstrate the extent to which a computer simulation model (NETSIM) can be effectively used in a wide range of traffic engineering and transportation planning applications. In the course of three years, more than 15 000 simulation runs were made at the Michigan Department of Transportation (MDOT) using about 500 networks. The major use has been in analyzing geometric and signal system alternatives. It is also used to evaluate corridors at the transportation planning level and to evaluate signal installation requests. This model has become a very effective tool to aid decision making at MDOT. While listing a number of problems and limitations of the model, Hagerty and Maleck nevertheless conclude that the "growth and acceptance of NETSIM have exceeded all expectations."

Labrum describes the experience with NETSIM studies at the Utah Department of Transportation. The NETSIM model has been used extensively to evaluate traffic control strategies for single intersections, arterials, and grid networks, as well as to analyze pedestrian control problems, bus system plans, and fuel consumption and emission rates. It has also been used for economic analysis in many studies as well as for decision making in design projects. The NETSIM model has been found to be a very useful tool in solving a wide variety of traffic control problems.

Hurley and Radwan describe the experiences of using NETSIM for research in a university environment. Most of the research described analyzes the effects of traffic signal timing on fuel consumption and delay. Recommendations are made for improvements in internal program logic, program output, and program documentation.

Current and Future Developments

Two papers examine current and future development. Radelat points out that the development of traffic simulation models requires two distinct skills: modeling and computer programming. Modeling is the representation of a real-life system by a simplified logic. Programming is the translation of the modeling logic into computer language. In general, six types of traffic simulation activities can be defined:

1. New model development,
2. Testing,
3. Implementation,
4. Enhancement,
5. Application, and
6. Maintenance and support.

For continuous successful application of a simulation model it is necessary to pursue all of these activities in concert.

Radelat then proceeds to describe the new TRAF system. This system is being developed in light of these principles and will consist of both microscopic and macroscopic model components for urban networks and freeways and a microscopic component only for two-lane rural roads.

Ross speculates on possible long-range futures of traffic simulation modeling in view of current trends and projected developments in computational hardware and software. He foresees major developments in graphic displaying capabilities, interactive computations, and, ultimately, on-line simulations.

Contributed Papers

Part 5 of this report contains papers that were presented at workshop sessions and papers submitted by conference participants for the proceedings. The first five contributed papers (Maki and Branch, Maki and Saller, Slee, Schaffer, and Greyson) briefly describe user experiences in evaluating traffic control alternatives by using simulation modeling analysis (NETSIM and TEXAS). The next three papers address the evaluative capabilities of simulation models. Davis and Ryan compare NETSIM results with field observations and Webster discusses model predictions for isolated intersections. Yagar and Case present a summary evaluation of NETSIM's forerunner (UTCS-1) on an arterial street in Toronto. Model predictions of travel times are compared with floating car field measurements. In a second paper, Yagar and Case assess the evaluative capability of the TRANSYT model for the same Toronto arterial. Chin reviews some of the recent developments in interactive computer graphics user interface with existing traffic simulation packages. He concludes that such user interface is an invaluable aid to the understanding of traffic simulation models, preparation of input data, detection of errors, and interpretation of outputs.

WORKSHOP RECOMMENDATIONS

Twelve workshops were conducted. Their themes were divided into two categories--the application of simulation models by different user groups and the technical issues in simulation modeling and application--and were held on two different days. Consequently, each participant had the opportunity to attend one workshop in each category. Discussions reflected views from different organizational entities making use of the models as well as issues relating to the technical performance of the models in a variety of applications. It was no surprise that many of the viewpoints expressed and issues raised were common to several of the discussion groups.

Because many of the conference participants were primarily NETSIM users and because this simulation model seems to have found wide applicability in traffic operations analysis, most of the discussion items refer to this model specifically. The workshop discussions and recommendations followed along four main lines:

1. Promotion and implementation,
2. Maintenance and support,
3. Computer-user interface, and
4. Technical issues in modeling.

Promotion and Implementation

While it is widely recognized that analytical models are invaluable tools for use by traffic engineers in their analysis and design functions, it is also clear that these models have not yet found the widespread implementation they deserve and have not yet been used to the fullest. One of the principal objectives of this conference was to address this problem and to make recommendations for its alleviation. The following items were seen as keys to the achievement of this goal:

1. Management Support. The decision makers are the ultimate users--the implementors of the model outputs. They need to be aware of the availability of these tools and must be convinced of their utility relative to their needs.

2. Education and Training. A majority of practicing traffic engineers, at all levels of the profession, are not sufficiently knowledgeable concerning the use of computer models and their potential benefits. Expanded education and training materials will help improve this situation and provide a basis for informed judgment in model use.

3. Facilitation of Model Use. Both current and potential users would be encouraged to make better use of available models through improvements in their applicability--namely, centralized maintenance and support, improved documentation, development of user guidelines and case studies, and improvements in data management, input-output processing, and computer-user interface.

Maintenance and Support

Various needs in the maintenance and support area were also discussed. The following summarizes these needs and the views of the conference participants on the proper role of FHWA in providing maintenance and support services.

1. Program Distribution. FHWA should be responsible for both the initial and continuing distribution of the programs. After development of a program, FHWA should release it to a limited number of "expert" users for use on a test basis. The programs should be revised based on the users' experience, and then general release should follow. Conference participants expressed concern that this process currently consumes too much time and needs to be accelerated.

FHWA should also periodically distribute updated versions of the programs. After a number of minor revisions have been made, the new version of the program should be distributed to all users. This should occur no more frequently than annually.

2. Program Documentation. The need for improved documentation was universally viewed as a critical element in the support of all other activities. This need was expressed in a number of forms: (a) overview and promotion materials for managers; (b) text on general principles of traffic simulation and optimization; (c) minitexts for training purposes on all aspects of model implementation; (d) handbook of case studies and typical applications, including guidelines on when to use various models; and (e) user guidelines on such issues as parameter values, data-collection procedures, input-output procedures, etc. It was stressed, in particular, that there is a need for appropriate documentation to accompany updated and newly released program versions.

3. Training. FHWA should provide training courses for potential users of the programs. Specific suggestions in this area include (a) mailing materials for precourse study; (b) a course session on model theory; (c) hands-on experience during the course through structured laboratory sessions; and (d) preparation of adequate materials to accompany the aforementioned program, e.g., guidebooks, slides, etc.

4. Technical Assistance. FHWA should keep all models operational and have experts available to provide technical assistance to users of these programs. This service could be provided by telephone (a hot-line concept was discussed) or through electronic mail. State highway departments should be encouraged to develop this capability at their level so as to decentralize and improve the timeliness of the technical support function. Realizing, however, that not all states will be able to develop this capability, FHWA should maintain a strong centralized role and serve the clearinghouse function.

5. User Communication Network. Conference participants expressed interest in the formation of a users' group to allow for exchange of ideas, problems, and solutions. This communication could be facilitated through a newsletter, technical committees of the Institute of Traffic Engineers or TRB, and sessions at national meetings and future conferences like this one. In this context, a nationally representative technical advisory committee should be formed to review needs and program objectives.

Computer-User Interface

Suggestions noted here on computer-user interface could be applied to any simulation-optimization model. Included are potential improvements in the model's data-handling capabilities and user interfaces.

For the short-term, the most promising improvement appears to be the development of interactive input forms displays (such as those used by the Michigan Department of Transportation for NETSIM). The development and use of these displays would simplify greatly the burdensom task of keypunching or otherwise entering data in specified formats via a terminal.

For the long term, the development of a traffic-engineering data base system would enable a user to run any simulation-optimization program from a centralized pool of data used in common by these programs. The system would automatically produce an input data deck from the data pool in the appropriate format for the program to be run. The development of such a system would further simplify the input data process.

Another promising improvement is the use of computer graphics to display program outputs. Research still needs to be conducted on what is the most useful form of graphics display. The problem of portability among different terminals of graphics display presents a potential problem.

Finally, the use of microcomputers is inherent throughout all the above suggestions. Micros could be programmed for forms displays, as well as to interact with a data base system, to display computer graphics, and to provide a wide variety of diagnostics. Since they are affordable, the traffic engineer could have these capabilities available at his or her desk.

Issues in Modeling

As evidenced in the workshop discussion reports and, in fact, throughout the conference proceedings, most users had considerable experience with the NETSIM model. Therefore, most of the modeling issues raised and problems discussed concerned this model. The long list of suggestions for improvements should not be taken as an indication of weakness. Quite to the contrary, it is an indication of vigorousness and of the wide range of possible applications to which the model was subjected. It is also an indication of the usefulness of communication among users, developers, and nonusers that this conference has afforded.

Among the most pressing needs mentioned were the following:

1. Improving and validating the traffic-actuated signal control logic,
2. Providing capabilities to model traffic-responsive system controls and coordinated operation of semi-actuated and actuated traffic signal controllers,
3. Inputting a specified headway distribution or field-collected arrival patterns,
4. Updating the fuel consumption and emission tables to reflect current vehicle population,
5. Modeling a four-way-stop controlled intersection,
6. Providing for left turns and lane discipline (i.e., a lane containing both left-turning and through traffic as well as a lane facing opposing left turners),
7. Modeling a center dual-left turning lane,
8. Handling railroad crossing,
9. Handling pedestrian traffic, and
10. Seed random numbers (the dependence of NETSIM on a single random number string was considered a weakness that may compromise the validity of pairwise comparisons).

Another category of modeling issues concerned the interface of traffic simulation software with transportation planning software. Traffic simulation models, NETSIM in particular, are already used for several types of planning and transit analyses and it would seem worthwhile, in the longer range, to strengthen this interface through integratory measures, such as sharing of data bases, and through the formalization of the traffic system design process. The latter, eventually, would involve the addition of automated optimization capabilities to the descriptive simulation models. In this way, the models would expand their existing predictive capabilities to include also normative functions.

CONCLUSION

Realizing and agreeing that the use of computer simulation and optimization models is strong today and will continue to gain strength in the future, the conference participants and steering committee recommend that FHWA take a strong role and lead in the continuing development, promotion, and implementation of such models for improving traffic operations and management throughout the country.

[Editor's note: Since the conference, a TRAF support service has been set up. It can be reached at 516-549-9829.]