4. S. Yagar. An Analysis and Investigation of Philosophical Contrasts in Traffic Models. Proc., Seventh International Symposium on Transportation and Traffic Theory, (T. Sasaki, ed.), Kyoto, Japan, 1977, pp. 69-93.

5. G. Vincent, R. Loucks, and J. McGill. Sensitivity Analysis of TRANSYT. Univ. of Waterloo, Ontario, Canada, Undergraduate Project Report, 1980.

Interactive Computer-Graphics User Interface for Traffic Simulation Models

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The sustained dependence on automobiles and decreasing availability of urban land has intensified the urban traffic problem. The practicing traffic engineer has long needed a problem-solving aid to deal with the increasingly sophisticated and complex urban traffic flow problem. In order to understand the behavior of an urban street system and to evaluate various corrective strategies implemented on such a system, one has to construct a model that best represents the internal relationship among components and accurately predicts the system performances. Due to the size of the urban street network and the random nature among vehicles and drivers, it is impossible to use an analytical approach to model such a system. On the other hand, a simulation model becomes appealing in modeling the large urban network. Furthermore, with the aid of modern digital computer technology, it is economical and practical to apply digital computer simulation modeling in solving vehicular movement problems on a large urban street network. Subsequently, many computer traffic simulation models have been developed in order to help the traffic engineer to deal with complex urban traffic flow problems. Among these, NETSIM, TRAFLO, INTRANS, and FREQ6PE are the most widely known.

ISSUES WITHIN TRAFFIC SIMULATION MODEL

Although computer traffic simulation models are useful in predicting the performance of urban networks, certain deficiencies quickly become apparent. A simulation model is only a simplification of an actual system. The results obtained from such a model are only as good as its capacity to reflect, in this case, a real-world urban street network. The vehicular flow within an urban network is a very complex phenomenon. In order to fully describe and/or accurately predict such a system, the traffic simulation model must be relatively complex. Consequently, computer traffic simulations require extensive input data bases.

One study (1) shows that 85 percent of the total cost of an initial NETSIM model run consists of information coding costs. For succeeding runs, approximately 65 percent of the total cost is in input data modifications. There are several probable reasons for such high input data preparation costs. Conceptually, most traffic simulations are modeled on a simplified link-node network. A node represents the intersection, and a link represents the street segment between intersections. Some microscopic models even require more detailed representation of traffic lane configuration within the link. Unfortunately, the digital computer cannot process such a link-node network. Every necessary piece of information must be digitized. A clerical service is required to "translate" the link-node network into rows and columns of machine-acceptable digital data. The intuitive physical meaning of the geometry and signal information is oftentimes lost during the translation process. The coder is consequently faced with the problem of constantly referring to the network diagram and user's manual. This is time-consuming and confusing. In addition, much of the required input data does not always follow a logical order. As a result, some input information is duplicated. This interrelated information requires the coder to recall prior input data, a situation which in many cases leads to inconsistencies. Finally, options have to be provided within the input field in order to accommodate a variety of situations. Such option spaces are often scattered throughout the input data field and may not follow any apparent pattern from the user's point of view. Consequently, many errors may result in the input data file. The traffic simulation model has the capability of detecting errors and prints out error messages. However, the error message is often in numerical format and does not clearly indicate the mistake made by the coder. More decoding and encoding clerical work is required between the network diagram and the alphanumerical input data listing.

On the other hand, the traffic simulation model also requires many different and sometimes conflicting measures of effectiveness (MOEs) to describe the overall performance of the network. The number of MOEs is frequently further complicated by the size of the network. As a result, voluminous outputs are generated by the computer. Although they are presented in an appealing format, they are sometimes difficult to interpret. While the outputs are useful in defining the existence of potential problems, it may be difficult for the user to understand how such problems have evolved during the simulation. It is difficult for such a large amount of information to be conveyed to and assimilated by the user within a short period of time.

INTERACTIVE COMPUTER-GRAPHICS USER INTERFACE

With regard to the problems associated with the use of computer traffic simulation models, interactive computer-graphics user interface, in conjunction with existing simulation packages, can aid in reducing or even eliminating many of the deficiencies. Since pictures convey more information than do tables and in a more easily assimilated manner,

Figure 1. Display of one time frame for a four-intersection network generated by GRANT.

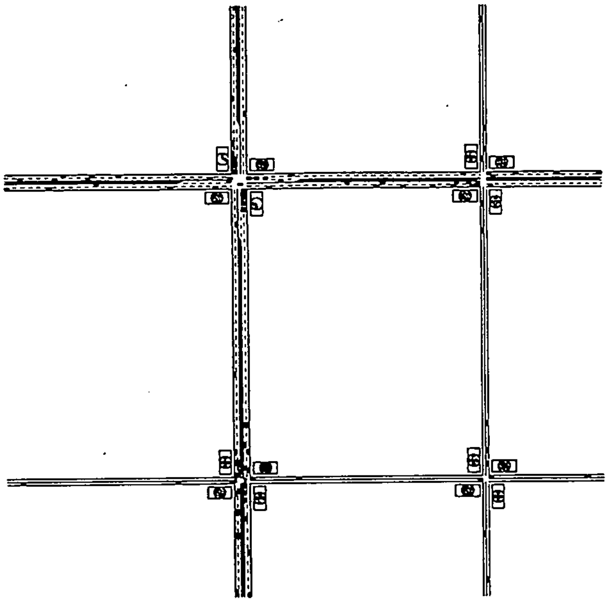
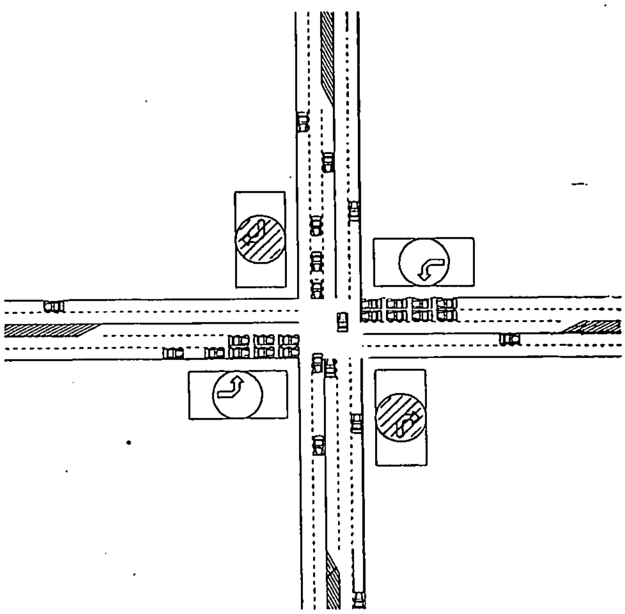


Figure 2. Display of enlarged intersection generated by GRANT.

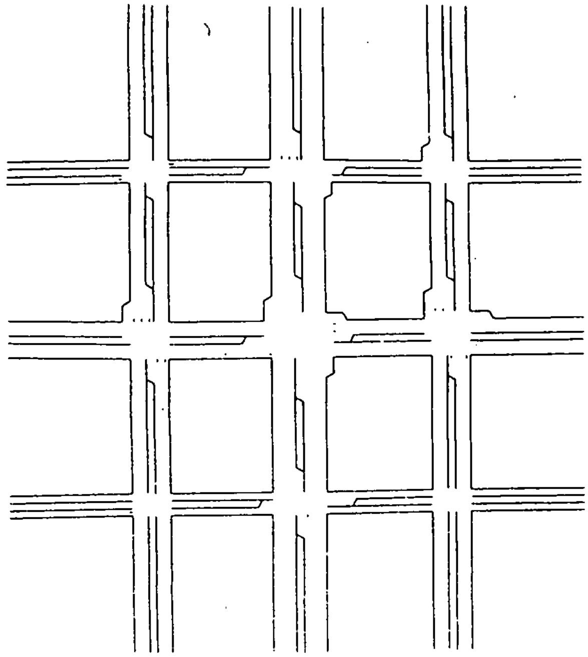


computer graphics aid immensely in demonstrating the operation of the traffic simulation models. Therefore, such user interface is an invaluable aid to the understanding of the traffic simulation models, preparing input data, detecting errors, and interpreting their results.

RECENT DEVELOPMENTS

The use of interactive computer-graphics user interface alone or combined with existing packages is relatively recent. Generally these developments can be categorized into three major groups according to their utilities, namely, generation of animated traffic flow, graphics display of generated MOEs, and computer-graphics-aided data preparation and debugging.

Figure 3. Queue length display generated by NETSIM/ICG.



Animated Traffic Flow

The STARK/NBS (2) model is a fairly detailed simulation model that uses deterministic traffic behavior rules including such factors as lane-changing logic, gap acceptance, right-of-way, and car following. However, the model is not flexible in admitting input data. The model has the capability of producing a CRT-based movie of the simulation. This gives the model the appearance of realism. The Aerospace Corporation Model VPT (Vehicle Performance in Traffic) (2) is an exceptionally detailed, totally microscopic network model. The user may choose desired output from a wide variety of traffic-related MOEs including movie representation of the network flow. NETSIM (3) is an extension of the UTCS-1/SCOT model. The model is a microscopic simulation, dealing with the movement of individual vehicles in an urban street network, according to car-following, queue discharge, and lane-changing theories. Joline (4) of Aviation Simulation International developed a movie presentation of the UTCS-1 model that displays the movement of individual vehicles within an urban network. This film has been useful in demonstrating the relationship among traffic flow patterns and signalization timing and illustrating the model's functions to potential users. This work also has helped to identify errors in the model that have led to various modifications.

The movie representation of the animated traffic flow is expensive and its applications are limited. Despite the movie representation, Eiger, Chin, and Woodin (5) have developed a program, GRANT, that generated NETSIM-based passive displays of animated network vehicle flows on a CRT (Figures 1 and 2). Modifications of the network geometry or related parameters can be easily accommodated. Such animated displays can be used in searching for high-performance traffic management strategies. Subsequently, a revised program NETSIM/ICG (6) has been developed that can provide both real-time and passive animation of traffic flow. Furthermore, the animated queue length display is also provided by NETSIM/ICG (Figure 3). With this capability, the

Figure 4. Four network MOE graphs generated by NETGRAF.

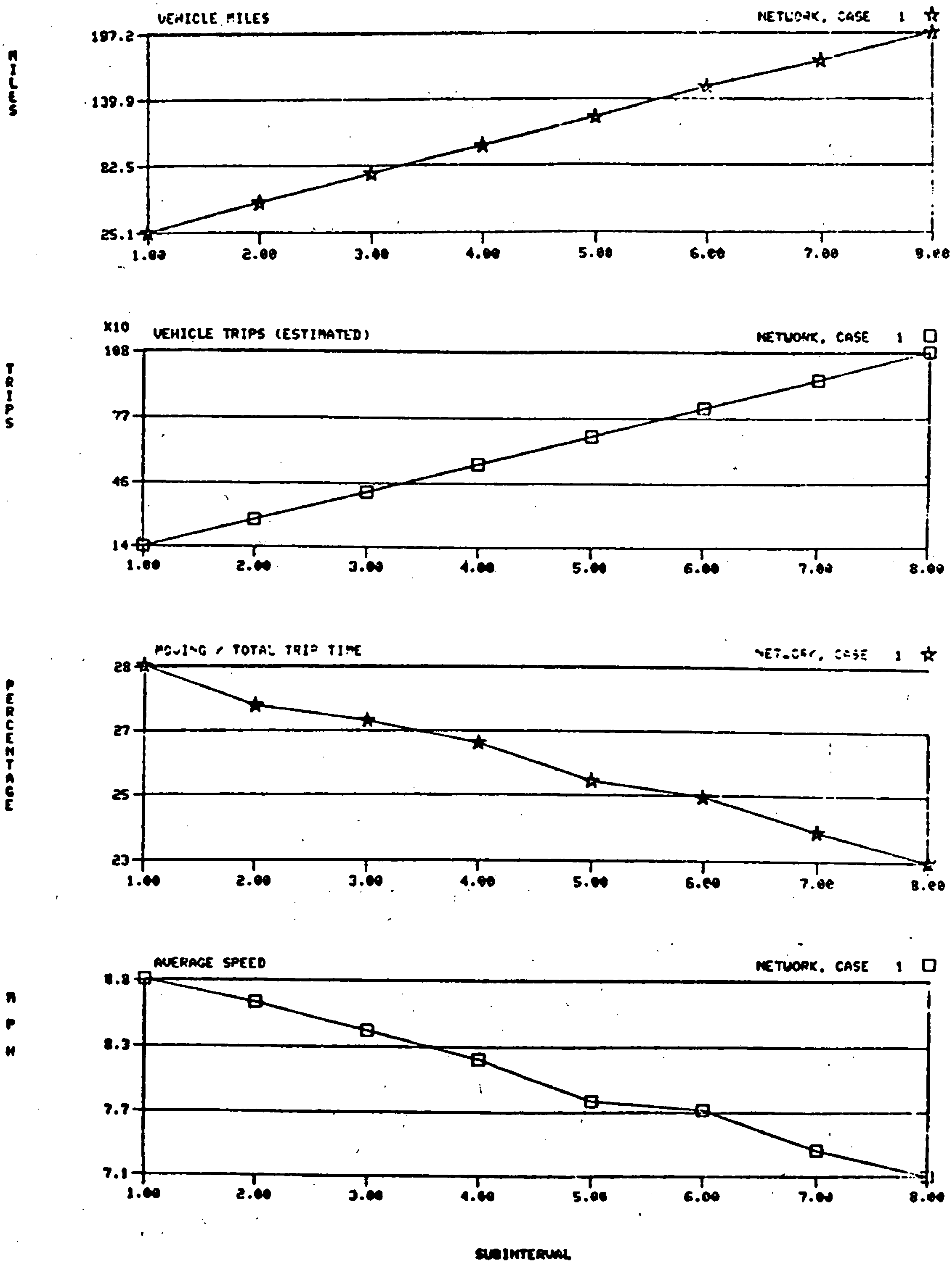
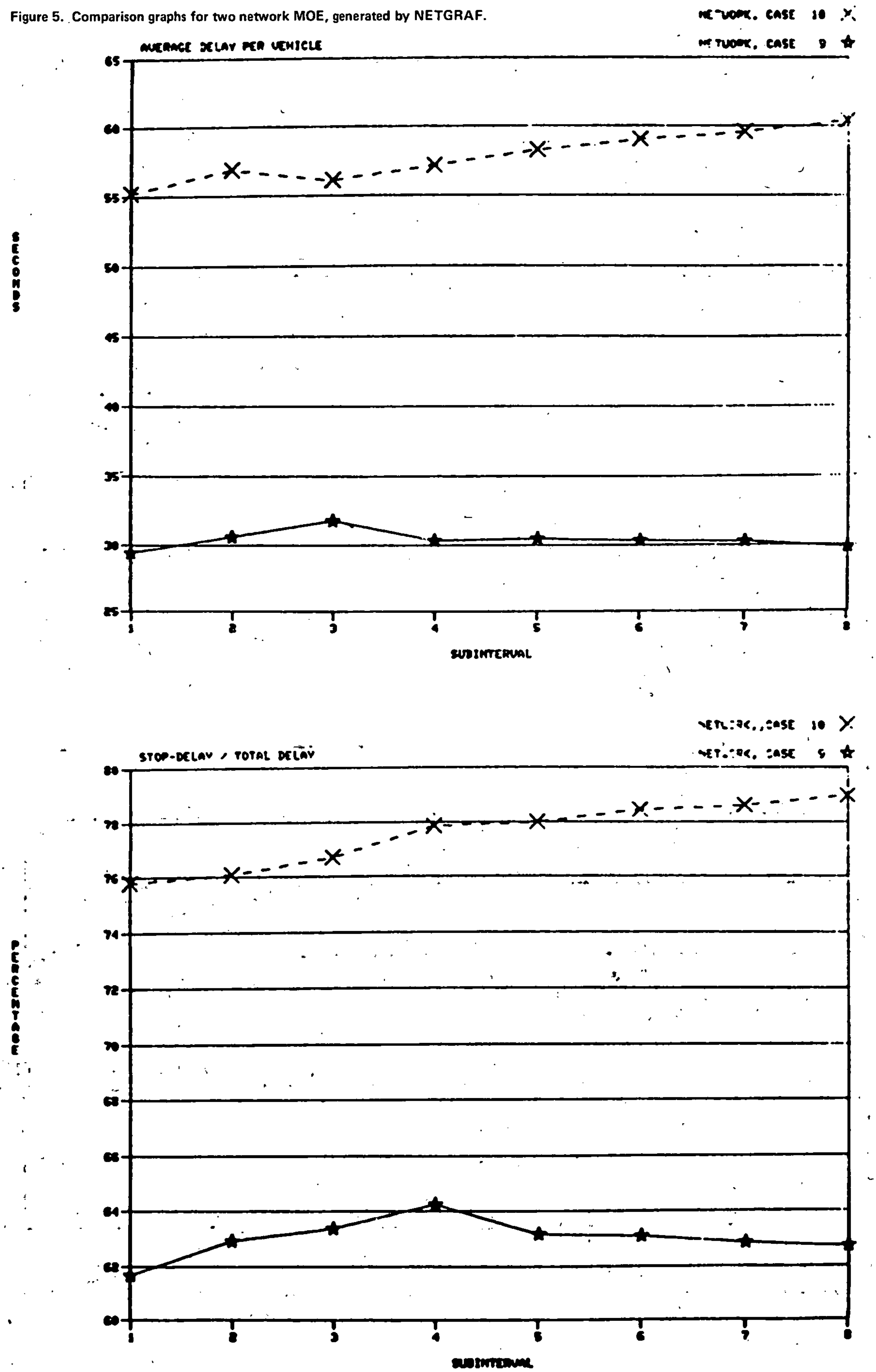


Figure 5. Comparison graphs for two network MOE, generated by NETGRAF.



traffic engineer can obtain similar information as animated traffic flow but with less computation and display.

MOEs Display

Parakh (7) proposed to improve the analysis of a large-scale flow problem by visually displaying the output of a computer simulation. His proposed Graphical Interactive Traffic Simulation (GRITS), a deterministic platoon-level model, can produce local-global displays of simulated network conditions. More specifically, the program has the capacity to display, at each intersection, the three-dimensional plots of MOEs as a function of signal split and cycle time.

Schneider and others (8-10) have developed the NETGRAF system, which is a graphics system designed to aid the use and interpretation of NETSIM results. The MOE data can be displayed for one NETSIM model run (Figure 4) or comparisons between different simulation runs (Figure 5). These graphs can be used by the traffic engineer to aid in the development of new strategies designed to achieve higher performance levels. NETGRAF is easy to operate and inexpensive. A novice user can learn to operate it with only a few hours of training and, with less than a week's experience, can easily generate 40 graphs/h. Limited experience with a small test network has shown that the computer time cost of producing the graphics is less than fifty cents each.

Along the same line, Schneider and others (11,12) also developed the FREGRAF system, which is a computer graphics program to aid the use and interpretation of a macroscopic freeway simulation model FREQ6PE. This simulation model was designed to assist the formulation and evaluation of entry control plans for freeway ramps. The user first defines the problem, develops an appropriate data base, and then uses FREQ6PE to simulate the existing condition. After studying the output and graphs (Figures 6 and 7) generated by FREGRAF, an objective function would be selected and an optimization process is performed to find the optimal ramp control plan. FREQ6PE would then be used again to simulate the problem area under the optimal control plan. New output and graphs would then be generated, with which the user would try to modify the control plan to eliminate or reduce some MOEs to an acceptable level. With limited testing, the objective of finding a control plan by using a graphic aid, FREGRAF, that can outperform the strategy generated by the optimization program in FREQ6PE is not entirely achieved. However, it is believed that further tests with an experienced traffic engineer would obtain more desirable results. Like NETGRAF, FREGRAF is also inexpensive to operate as a limited-experience user can easily produce 40 graphs/h at a computing cost of less than fifty cents each.

NETSIM/ICG developed by Chin and Eiger provides

Figure 6. Existing queue length, speed, and on-ramp spillback relationship generated by FREGRAF.

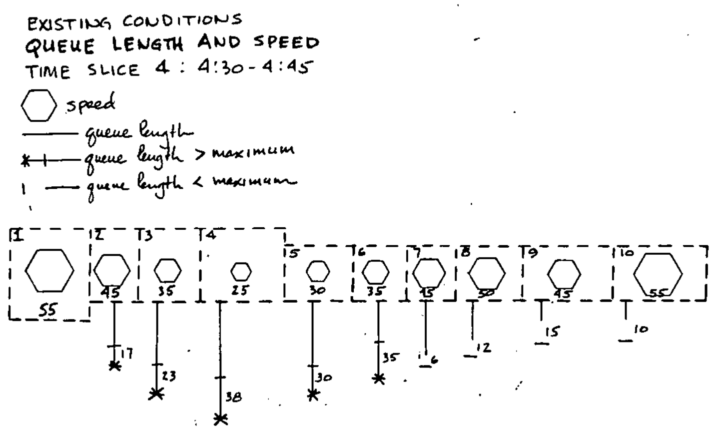


Figure 7. Speeds on all freeway segments over all time slices generated by FREGRAF.

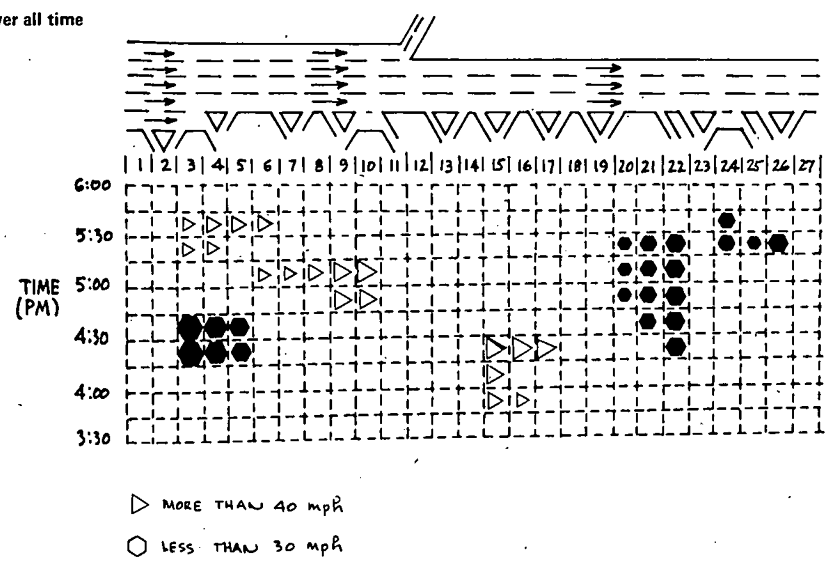
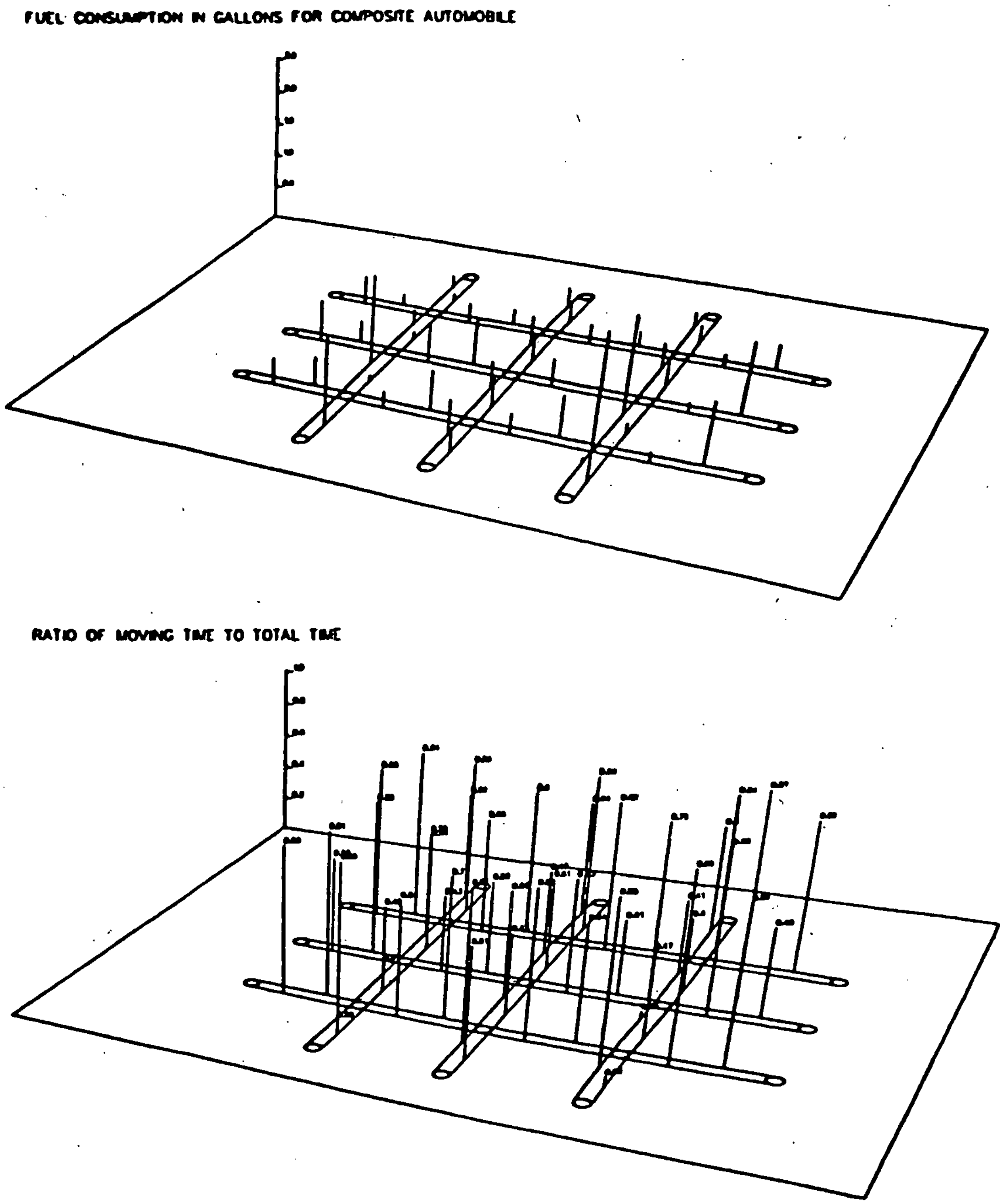


Figure 8. Perspective plot of MOE generated by NETSIM/ICG.



both real-time and passive three-dimensional display of link-specific MOEs as generated by the NETSIM model (Figure 8). Such displays provide the user with more easily assimilated information with which he or she can comprehend the operation of the network.

Graphics-Aided Data Preparation and Debugging

The major and most interesting feature of the NETSIM/ICG is that the program provides an alternate method for preparation of input data required by the NETSIM model. The program uses the interactive computer graphics capabilities that allow the user to work on a physically meaningful link-node diagram. The interactive data input, both graphically and through the keyboard, is in free format that also follows a systematic procedure without referring to the user's manual. The program also provides the capability to graphically display, to as great a degree as possible, the input data. When preparing the signal time information, for example, the user actually works with both link-node diagrams and signal-phasing diagrams. The link-node diagram shows overall intersection orientation and phasing diagrams show detail and tedious signal-timing information. For the actuated signal, the user in effect graphically 'puts' the detectors on each approach on a lane-detailed network diagram (Figure 9). The graphic displays of input data can also be used in detecting errors within the input data file. The displays would either produce an erroneous or obvious inconsistency (Figure 10). Finally the program allows the user to retrieve and modify

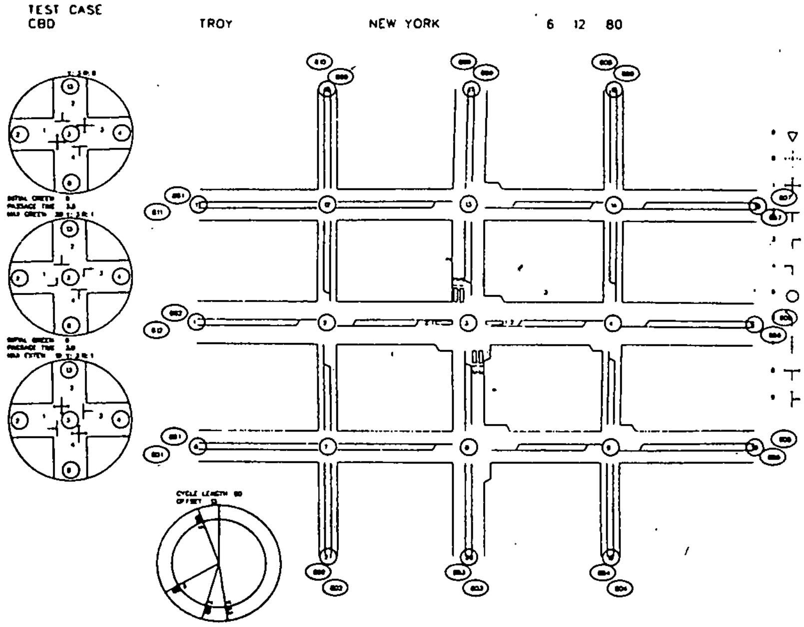


Figure 9. Actuated signal-phasing diagram with detectors in land-detailed plot generated by NETSIM/ICG.

Figure 10. Error messages with associated plots generated by NETSIM/ICG.

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**** CANNOT LOCATE LINK (  2,  6) FROM LINK   4.  SIGI ARRAY-     1     2     3     4     0
**** NON-ZERO TURN MOVEMENT ( 10 PERCENT) FROM LINK   4 TO NON-EXISTING DESTINATION
**** LINK   8 (  2,  5) ENTERS NODE   5 BUT IS NOT SPECIFIED ON SIGNAL CARD.
       UPSTREAM NODES OF ENTERING LINKS ARE        1        801
   **** ALL TURNING MOVEMENTS ARE NOT SERVICED AT NODE   2 FOR LINK   3
   **** ALL TURNING MOVEMENTS ARE NOT SERVICED AT NODE   2 FOR LINK   1
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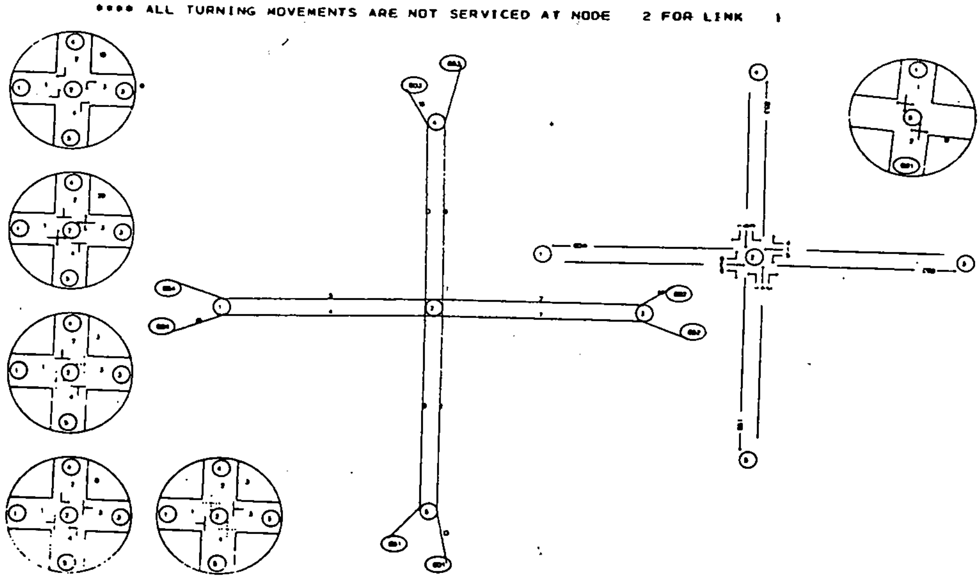

the previously defined data. Consequently, NETSIM/ICG provides the user with an intuitive, direct, and efficient method to prepare and debug the NETSIM input data.

The NETSIM/ICG is easy to operate. Each input step is preceded by a full description of required information. The user can easily code a network without referring to the user's manual. Limited experiences indicate that the costs, both in staff and computer time, associated with using NETSIM/ICG in data preparation vary from network to network. For example, a 20-intersection network with two actuated signals and two bus routes (Figure 9) requires approximately 5 person-hours and $50 worth of computer time. However, a 27-intersection network with only fixed-time signal and no buses (Figure 11) requires approximately 3 person-hours and $25 worth of computer time. The five-intersection network (Figure 10) requires 0.5 person-hour and $5 worth of computer time.

SUMMARY AND CONCLUSION

Recent developments of interactive computer-graphics user interface for traffic simulation models are discussed. Each developed interface is using the capability provided by computer graphics to graphically "translate" the alphanumerical information needed and/or generated by the digital simulation program into a display with a more easily assimilated format. Such graphic capability enables the traffic engineer to reduce, or on occasion even

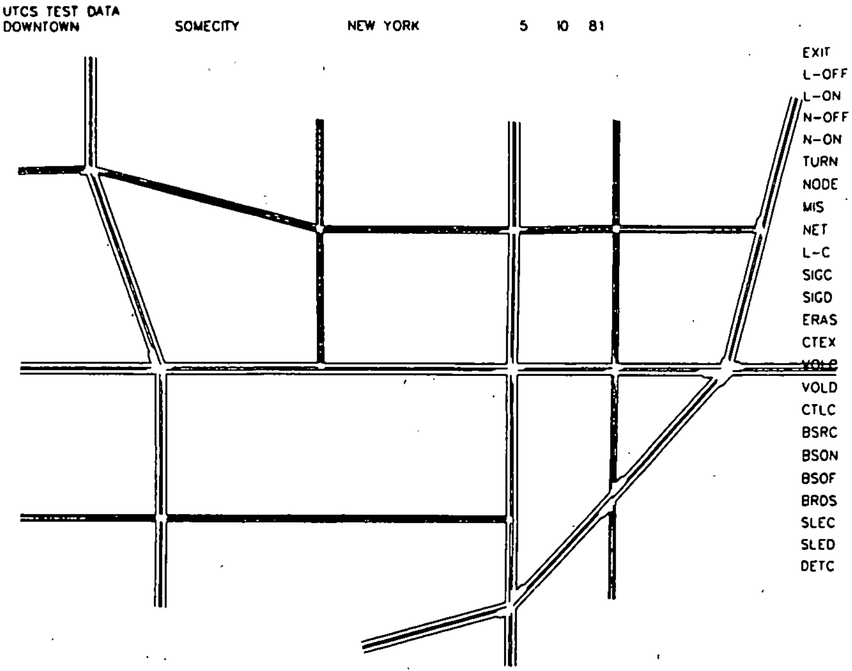

Figure 11. A-27 intersection land-detailed network plot generated by NETSIM/ICG.

eliminate, some of the difficulties associated with traffic simulation models such as extensive data preparation, tedious debugging, and voluminous printouts. It is my hypothesis that computer graphics aid in input data preparation, and debugging would achieve a greater benefit for the traffic engineer compared with applications like animation of traffic flow or output information display. Therefore, future research efforts should concentrate on the development of algorithms that use as little additional geometry data as possible and to generate sufficient network diagrams as needed by the simulation model. A typical example of this is to design an algorithm that would generate the lane-detailed urban street network mixed with freeways and their on-and-off ramps.

Most of the interactive computer-graphics user interface systems discussed in this paper, unfortunately, are not production-level softwares. In some cases this is because of the proprietary nature of the work. Some systems need further testing and contain several errors that are as of yet uncorrected. In addition, the overall potential utility of these user interface systems has yet to be assessed. The lack of opportunity to test these programs is probably due to the lack of availability of computer-graphics hardware, the lack of portability of the computer-graphics language, and the fact that most practicing traffic engineers are not graphics-oriented people. An effort should be made, within developing future interface situations, to use as few machine-dependent graphics subroutines as possible. Furthermore, all graphics subroutines should be grouped into a simple, basic subroutine library such as MOVE, DRAW, OPEN (subpicture), CLOSE (subpicture), etc. In this way, only a few changes are needed when the program is being transferred to another machine. Emphasis on the use of computer graphics should be placed at the college level. Prospective traffic engineers should be exposed to the computer-graphics environment and realize the potential benefit of such technology. Subsequently, computer graphics will become an integral part of their engineering task when they graduate.

The use of interactive computer-graphics user interface with traffic simulation models is relatively recent. Substantial efforts are still needed in research, development, and implementation of such a new technique.

REFERENCES

1. L. Kubel, G. Bloodgood, F. Workmon, and D. Gibson. What Network Simulation (NETSIM) Can Do for the Traffic Engineer. Public Roads, Vol. 41, No. 4, March 1978.
2. D. Gibson and P. Ross. Simulation of Traffic in Street Networks. Transportation Engineering, Dec. 1977.
3. Traffic Network Analysis with NETSIM, A User Guide. FHWA, Implementation Package FHWA-IP-80-3, 1980.
4. E. Joline. Computer-Generated Films to Document and Demonstrate Transportation Simulation Models. TRB, Transportation Research Record 619, 1976.
5. A. Eiger, S.M. Chin, and D. Woodin. Computer Graphic Animation of UTCS-1/NETSIM Traffic Flows. TRB, Transportation Research Record 729, 1979.
6. S.M. Chin and A. Eiger. Network Simulation Interactive Computer Graphics Program (NETSIM/ICG). Presented at 60th Annual Meeting, TRB, Jan. 1981.
7. B. Parakh. Traffic Signal Design. Case Western Reserve University, Ph.D. dissertation, 1977.
8. J.B. Schneider, D.M. Combs, and T.C. Folsom. NETGRAF: A Computer Graphics Aid to the Operation and Interpretation of NETSIM, A Traffic Simulation Model: Part I, Overview and Experimental Results. U.S. Department of Transportation, DOT-RSPA-DPB-50/80/10, 1980.
9. D.M. Combs, T.C. Folsom, and J.B. Schneider. NETGRAF: A Computer Graphics Aid to the Operation and Interpretation of NETSIM, A Traffic Simulation Model: Part II, User's Guide. U.S. Department of Transportation, DOT-RSPA-DPB-50/80/11, 1980.
10. D.M. Combs, T.C. Folsom, and J.B. Schneider. NETGRAF: A Computer Graphics Aid to the Operation and Interpretation of NETSIM, A Traffic Simulation Model: Part III, Programmer's

Guide. U.S. Department of Transportation, DOT-RSPA-DPB-50/80/12, 1980.
11. J.B. Schneider, C.L. Jette, and B.T. Lewis. A Graphic Freeway Simulation Model FREGRAF. Computer Graphics World, Vol. 3, No. 5, 1980.
12. C.L. Jette and J.B. Schneider. Preliminary Design and Use Concepts for the FREQ6PE Graphics System (FREGRAF). Univ. of Washington, Seattle, DOT-RC-82021-WP63, Working Paper No. 63, 1979.