

## CONCLUSIONS

Planning for the future of the nation's railroads is one of the most difficult and complex tasks facing the U. S. Department of Transportation. The problem is particularly difficult in that it demands a great deal of data and the results of any action will affect specific regions of the country and have obvious political repercussions. Consequently, federal rail system planners must, in a short time, test many alternatives to arrive at a feasible solution. In this planning context, interactive graphic analysis has great potential for application. The speed of the large computer coupled with the facility of APL makes it possible for the analyst to generate many solutions in a short time, and the graphic display permits him or her to grasp, almost at a glance, the geographic implications of the analysis. Finally, the power and clarity of the graphical display permit the analyst to communicate results immediately to policymakers and to the public.

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# Computer Graphic Animation of UTCS-1/NETSIM Traffic Flows

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The development of a program for computer graphic animation of network traffic flows to increase the potential effectiveness of the UTCS-1/NETSIM network simulation package by visually displaying vehicle movements through street networks is described. The program is a tool that can aid traffic engineers in generating and evaluating alternative control strategies by enabling them to view network traffic in real time. It thereby provides them with additional information, such as lane-specific delays and queue buildups, that would not be readily available through the standard statistical output of UTCS-1.

As traffic flows through street networks, it experiences periods of congestion that may result from inadequate geometric design or signalization or simply excessive demand. Traffic simulation techniques are becoming important tools for the traffic engineer in investigating the impacts of various traffic control strategies. These simulation experiments can yield an enormous amount of data that could not be obtained in real life for economic or other reasons.

Among the network traffic simulation models, the Urban Traffic Control System (UTCS-1) model produced for the Federal Highway Administration (FHWA) has

been the most popular. UTCS-1 has been extensively validated and is generally considered to yield reasonable results. It is excellent for evaluating signal control schemes and the effect of buses on traffic movement. The UTCS-1/NETSIM model is a fully microscopic model that collects and updates statistical network data at 1-s intervals. At the end of the simulation period, link-specific and system-wide data are printed out for use by the traffic engineer in evaluating the operational characteristics of the network. The aggregated nature of the data makes it useful in defining the existence of potential traffic problems. However, the user would be likely to get a more intuitive understanding of the conditions that gave rise to these potential problems and be more capable of isolating effective control strategies if vehicle flows were displayed visually.

The use of computer graphic techniques and computer-generated films for visual displays of traffic flow information is a relatively recent development. Parakh (1) proposed to improve the analysis of large-scale flow problems by visually displaying the output of computer simulation.

The proposed model, graphical interactive traffic simulation (GRITS), can produce local and global displays of simulated network conditions. More specifically, the program has the capacity to display, at each intersection, three-dimensional plots of stops and delays as a function of split and cycle time. Traffic densities on the network links can also be displayed. Global displays include saturation, queues, and stops on all links in the network. The simula-

Figure 1. Description of computer-graphic system.

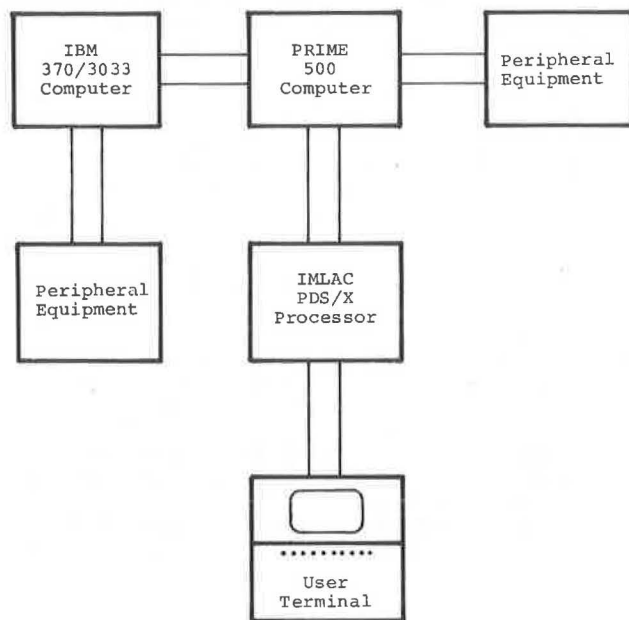
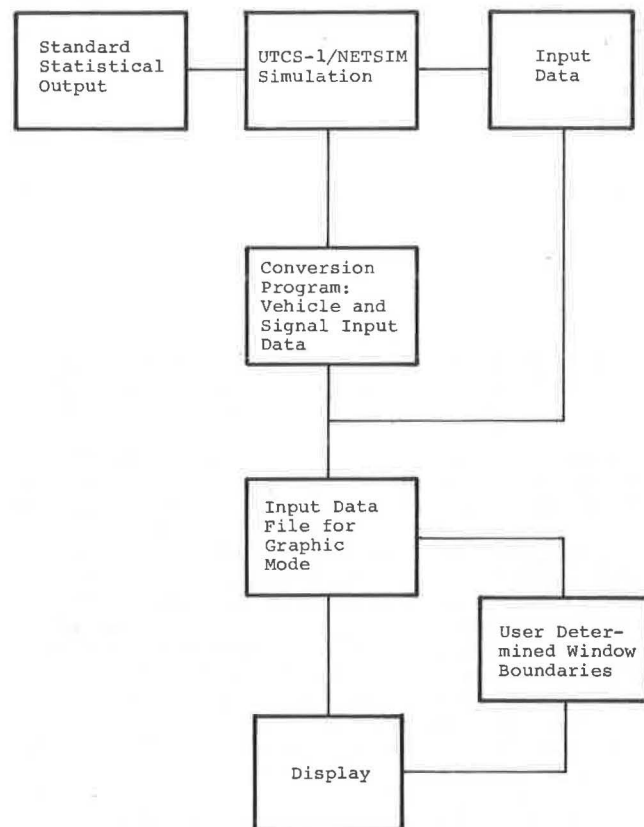


Figure 2. Operation of GRANT module.



tion model used in GRITS is a deterministic "platoon-level" model.

The Stark/NBS model (2) has the capability of producing a movie of the simulation that is cathode ray tube (CRT) based. Unfortunately, the simulation model is deterministic and not very flexible in admitting input data. Moreover, it has not been validated. Along the same line, the Aerospace Corporation VPT model (2), although it contains the feature of movie presentation, is not flexible and has poor validation. Joline (3) has developed a movie presentation of the UTCS-1 but, because of the proprietary nature of the model, user documentation is not available.

Computer graphics has been extensively used in transportation planning. Rapp and others (4, 5) applied computer graphics for planning node-oriented transit systems, and Rapp and Gehner (6) proposed interactive graphics to identify the characteristics of high-performance bus rapid transit systems for riders who reside in a generalized suburban corridor and are bound for the central business district. Schneider and Porter (7) conducted a study to determine the amount of improvement that could be achieved by designing a bus rapid transit system by using interactive graphics rather than conventional methods. The results of the study indicate that computer graphics can be a cost-effective tool in design.

Other areas in which applications of computer graphics were investigated include community participation (8, 9), land plots (10), allocation of nodal services (11), and highway design (12). An updated bibliography of computer-graphic applications in transportation is included in a recent paper by Schneider (13).

These applications of computer graphics in transportation illustrate that computer graphic routines, either alone or in combination with existing packages, are potentially very cost-effective tools that can be used by the practicing transportation engineer in analyzing data, generating and evaluating alternative solutions, and presenting the results. The objective of the research reported here was to develop computer graphic displays for the animation of UTCS-1/NETSIM vehicle flows through a network and thereby improve the capability of the model by providing the user with the option to visually display vehicle movements through a network of streets and highways or any portion of a network.

## SYSTEM DESCRIPTION

The interactive computer graphic facility used in this study consists of two PRIME 500 digital computers that are interconnected to the Rensselaer Polytechnic Institute (RPI) IBM 370/3033. In addition, a number of IMLAC graphic terminals and tape and disk drives and a Versatec printer-plotter are available. Many of the software programs were obtained from other sites and converted to run on the PRIME-IMLAC system; others were written at RPI. The graphic terminals run on IMIGE, an IMLAC-supplied FORTRAN graphics package. The overall system is shown in Figure 1.

## COMPUTER GRAPHICS

The UTCS-1/NETSIM program is completely microscopic and updates the position of every vehicle in the network at the end of each 1-s scanning subinterval. This information is contained in the vehicle array  $V(M, K)$  in terms of the lane and the link that the vehicle occupies and its distance from the upstream intersection. Similarly, link signal data are also updated and contained in the link array  $LINK(L, K)$  as the signal code facing the link. The display of the information contained in these two arrays results in the animation of vehicle movements through the network.

Operation of the program graphic animation of network traffic (GRANT) is shown in Figure 2. Initially, the roadway network is drawn with specified coordinates for all nodes, lanes, and links. This defines the network in the  $(x, y)$  coordinate system. At the end of each scanning sub-

Figure 3. Display of test network.

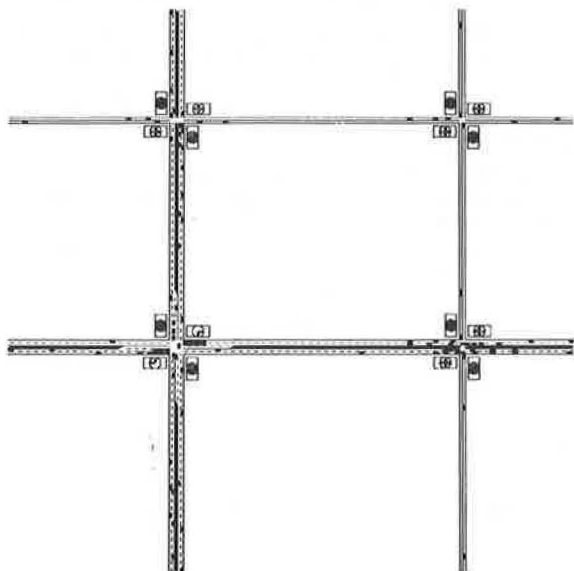
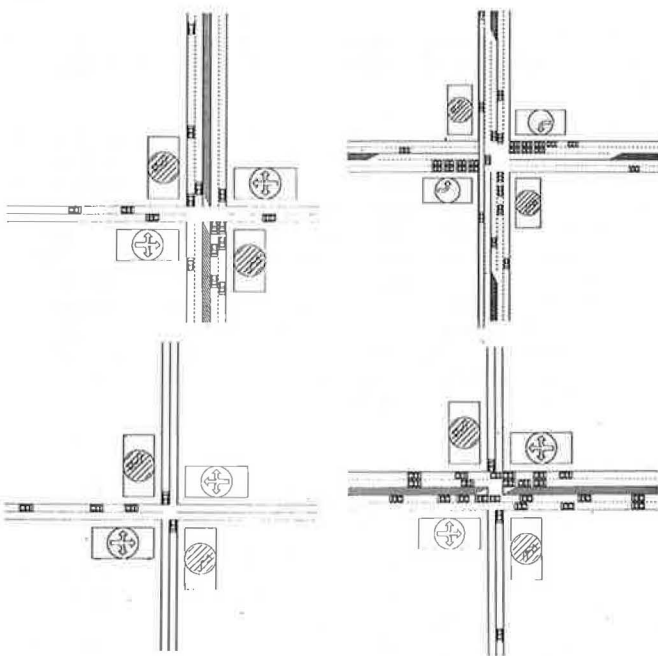


Figure 4. Intersection windows.



interval, a computer program is used to convert the link, lane, and distance data for every vehicle in the vehicle array to (x,y) coordinates in correspondence with the externally defined network coordinate system. This information and the signal code data are accumulated in a temporary file that constitutes the input data file for the graphic mode.

In the graphic mode, existing and developed FORTRAN-based software routines are used to draw the network and to draw and superimpose the vehicles and signal indications on it at 1-s intervals. This gives the impression of real-time movements of vehicles through the network. All the computer programs are written in FORTRAN IV so that they can be transferred from this system to others.

Since most networks of interest are moderate to large in size and since the size of the display is limited, GRANT has the capability to create windows or "zoom in" on any

portion of the network. That capability is available on the IMLAC-PDS graphic terminals that operate in conjunction with the PRIME 500 system. The "zoom-in" effect is achieved by generating an enlarged image space that is clipped by the boundaries of the defined window. These boundaries are input interactively by the positioning of cross-hair cursors to mark the lower left and upper right corners of the window. The user can stop the display at any time, define new window boundaries, and zoom in on another portion of the network.

Figure 3 shows the CRT display of one time frame of a simple four-intersection network. Figure 4 shows the CRT displays of the enlargements of the four intersections achieved by defining windows about these intersections. Ten signal indications that correspond to those defined in UTCS-1/NETSIM are possible. Figure 4 shows these signal indications displayed for each link. Although it is not of primary importance in this research, different vehicle types, including buses and trucks, can also be displayed.

Note that the network geometry input to the UTCS-1/NETSIM program does not have to be graphically consistent—graphic consistency as used here meaning that the distance between any two vertices in the network is a euclidean distance. For graphic displays, consistency is essential. Currently, if one wishes to display the simulation of a graphically nonconsistent network, link free-flow speeds must be adjusted to reflect the differences in link lengths.

#### CONCLUSIONS

The GRANT module demonstrates the feasibility of graphically displaying the animation of vehicle flows through networks, as simulated by the UTCS-1/NETSIM program package. GRANT provides additional information that would not be easily obtainable through the standard statistical output of UTCS-1/NETSIM. More precisely, lane-specific delays and queue buildups can be visualized. Additional information of this type can help in generating and evaluating alternative control schemes cost-effectively. In addition, the visual display can aid in the demonstration of alternative solutions.

Further research in this area would address the problem of making the package totally interactive with respect to data input and program control. On a more macroscopic scale, it would be beneficial to display some performance measures for links and intersections so that the user would be able to predetermine which network segments should be focused on. This would act as a screening stage for further analysis. In addition, program documentation that is consistent with existing UTCS-1/NETSIM documentation remains to be developed.

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## Interactive and Graphic Techniques for Computer-Aided Route Selection

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The development of the GCARS system of computer-aided highway corridor selection and its application in an environmental impact analysis in western New York State are discussed. Current versions of GCARS use an efficient minimum-path algorithm to generate route alternatives by accessing digital data bases that define engineering, socioeconomic, and environmental factors. These data bases are manipulated interactively by a companion computer system called GMAPS. The GMAPS and GCARS systems clearly show the desirability of low-cost, easy-to-operate, interactive systems for regional transportation planning studies. Graphical and statistical displays are essential, and a variety of black-and-white and color display options have been developed. Because each product has unique cost-benefit characteristics, the choice of display type must be matched to audience needs and costs of production. The use of GMAPS-GCARS in a corridor-selection study for a 160-km (100-mile) four-lane highway in western New York is described. The study shows a marked reduction in planning time at no increase in planning costs. This suggests that more widespread use of computer-aided analysis systems may result in large savings during periods of rapid inflation.

The process of highway corridor selection was revolutionized by the passage in 1969 of the National Environmental Policy Act (NEPA). Today, the "best" location for a transportation system is no longer necessarily the one that produces the greatest reduction in travel time or the one that results in the lowest capital or user costs. Rather, it is the design that yields the highest social return on the transportation investment and reconciles most effectively the conflicting interests of the various groups affected by the proposal. Location engineers are faced with analyzing larger numbers of interacting and conflicting location factors. Decisions must be made on the number of factors and the relative importance of all factors. Sensitivity analyses are required.

The digital computer offers an efficient means of applying models that describe the regional environment to the task of corridor selection. This requires the integration of a wide variety of digital models, each of which defines some component of the regional environment. The success of such applications depends on many factors, the most critical of which are

1. Efficient, low-cost methods of data entry, checking, and display;
2. The ability to accept and manipulate many kinds of data;
3. Easy-to-use, preferably interactive, methods of determining which data are available and for manipulating such data; and

4. Statistical and graphical display methods to allow for rapid assimilation and assessment of data by the system user.

This paper discusses the design philosophy that underlies one such system, the Generalized Computer-Aided Route Selection (GCARS) system. GCARS has been under development for at least 10 years (1); however, the development of smaller, economical interactive computers over the past 4 or 5 years, accompanied by recent development of low-cost graphical display hardware, has greatly assisted the transition of research concepts into a practical, commercially viable system. The integration of these new hardware capabilities with appropriate software design is illustrated in this paper by a recent application of GCARS to a highway location study in New York State.

### SYSTEM DESIGN GOALS

Development of the GCARS system has been guided from the beginning by six design goals:

1. The system should be machine independent; that is, it should be easily implemented on a variety of computers built by different manufacturers.
2. The system should be economical to use. This goal was interpreted as modest computer core-storage requirements and short calculation times.
3. The system should provide effective and convenient methods of person-machine information interchanges. This goal appeared necessary in order to allow engineers to apply their decision-making capabilities.
4. The system should have sufficient flexibility to allow (a) suitable quantitative measures of all pertinent factors and (b) the analysis of pertinent factors alone or in varying combinations.
5. The system should have sensitivity to the factors being analyzed and include techniques of ranking and discriminating between the alternatives generated.
6. The system should be generally compatible with existing planning methodology and available, more detailed design systems in terms of resolution and data requirements.

Obviously, these design goals represent the ideal case. It was recognized that conflicts within and among these