Computer-Generated Films to Document and Demonstrate Transportation Simulation Models

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Although simulation has been shown to be a valuable tool for the design and analysis of complex transportation systems, the use of available simulations by transportation planners has been constrained by the difficulties in assessing the applicability of a particular model and, then, understanding the operation of the model well enough to apply it effectively. The use of computer-generated films to supplement conventional documentation is proposed as a means to efficiently disseminate information about models to potential users. These films can show which real-world features are and are not explicitly represented in the model and show in an easily assimilated graphic form the complexities of model dynamics. Two computer-generated color films have been produced that illustrate the application of this type of documentation. One film shows the operation of the urban traffic network simulation model. The second film illustrates the application of the film techniques that document the transit station simulation model.

For many years, use of computer simulation has been recognized as an effective means of analysis for large-scale transportation systems such as airports, rapid transit systems, and urban highway traffic networks. Since there has been an increase in the complexity and cost of such systems, the U.S. Department of Transportation has recognized the need for using more scientific quantitative techniques to design these systems and has sponsored the development of a number of simulations that are being made available for general use by the planning community (1, 2, 3).

Although these simulations are generally supported by comprehensive multivolume documentation, the complexity of the models is such that it requires a major investment of the potential user's time to learn about the model and to determine if it is applicable to the user's particular problem. To use the model effectively, the user must understand it well enough to be able to translate the real-world problem into the often abstract structure of the model and to set the model parameters correctly. If widespread use of the available models is to be encouraged, and the potential user's understanding of the model operation is to be assisted, then improved forms of documentation are required.

One attractive possibility is the use of computer-generated films that can show, in an easily assimilated visual form, how the model works. Such films have been used successfully to demonstrate operations of a complex system (4) and to aid in the validation of simulations (5). The models used for these films, however, were microscopic simulation models that were specifically designed to provide graphics output. However, most existing simulation models were not designed with graphics in mind. Therefore, modifications might be required in the program, and an interface program will have to be developed to produce the graphics. If the graphics are to show movement of individual entities, it is necessary that the simulation be microscopic. If entities are aggregated, as in macroscopic simulations, flow and other quantities can be indicated by analog symbols such as arrows with the size of the symbols proportional to the flow rate or the quantity being indicated.

The effectiveness of the computer-generated films for showing simulation operation can be substantially enhanced if the computer-drawn images are superimposed optically, during film processing, on a pictorial art work background that depicts the environment in which the system operates. I have used this technique extensively for the production of airport simulation films (4) and a rapid transit film (5). A second technique for showing environmental features is the use of colors for the computer-generated images. This technique was used to produce the two test films. These films demonstrate use of the technique to document and demonstrate the operation of the two simulations developed by the U.S. Department of Transportation. Although neither of these simulations was originally developed with graphics in mind, they are both microscopic simulations, and interface programs were developed to demonstrate the operation of the simulation.

URBAN TRAFFIC NETWORK SIMULATION MODEL

The use of color for the computer-drawn images was of particular interest in the films made by the Federal

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Figure 1. UTCS1 network schematic for case study.

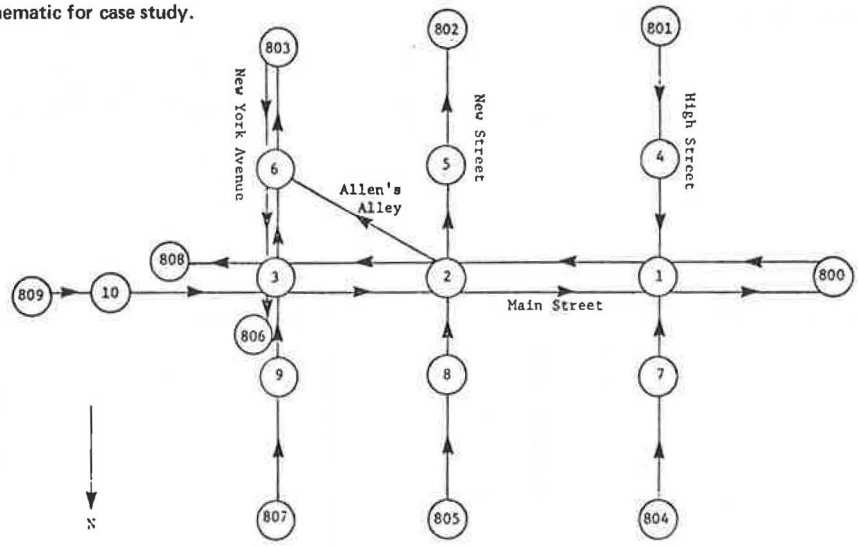
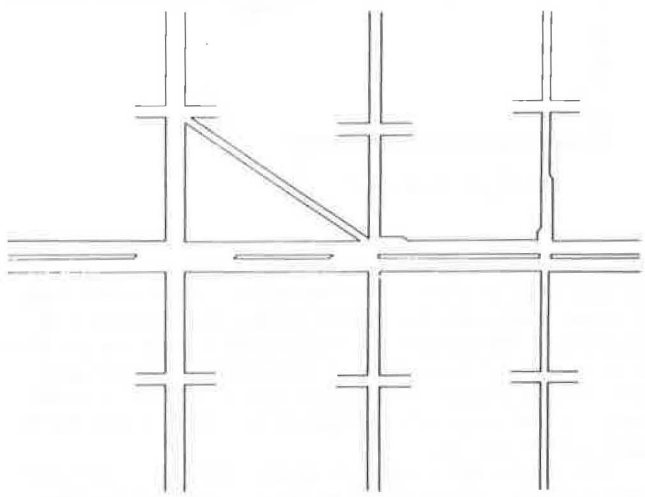


Figure 2. UTCS1 network geometry for case study.



Highway Administration for the Urban Traffic Network Simulation Model (UTCS1). This model is a microscopic network flow simulation that was designed for investigating urban traffic control strategies by emphasizing the relatively sophisticated signal control schemes.

The use of color made it easy to show the red, green, and amber traffic light operation in a sufficiently realistic manner so that the operation of traffic control over a portion of network can be easily assimilated by the viewer. The vehicles (buses, trucks, and cars) are shown as white figures of appropriate length and width, and street outlines, bus stops, and other aspects of the environment are shown in a subdued blue. The ratio of projection speed to real time can be varied to achieve different effects. For large networks shown at high speeds, the gross flow patterns and platooning of vehicles are clearly evident. For the relatively small networks shown at slow speeds, the microscopic logic of the simulation can be easily studied. The UTCS1 capabilities that are demonstrated in this film include car following, lane switching, queue discharge, left-turn gap acceptance, stop-street gap acceptance, lane blockage, fixed-cycle and actuated signals, turn pockets, lane channelization, pedestrian-vehicle conflict, bus operations and station dwell, left-turn jumpers, and amber phase response.

Shown in Figure 1 is the network adopted for the test film. This network was also the case study network used in the UTCS1 manual (3). Since the model was not designed for graphic output, the links are characterized only by length (stop line to stop line), and the intersections do not have explicit X and Y coordinate assignments. Before the model is run for graphics purposes, it is necessary to establish a street geometry on an XY grid such as that shown in Figure 2. This grid is compatible with the model input data. The UTCS1 model was modified to produce the necessary data for input to the graphics program. Since turning behavior at intersections is not explicitly modeled in the UTCS1 program, the graphics program, in addition to generating the graphics, must augment the UTCS1 model to develop a rational turning behavior of the vehicles at intersections. The relation of these programs is shown in Figure 3.

A variety of traffic control techniques is illustrated in the film. Some intersections are controlled only by stop signs and some have fixed-cycle controllers. The intersection at New York Avenue and Main Street has an actuated signal with traffic passage detectors located 15.2 m (50 ft) from the intersection on New York Avenue and left-turn presence detectors located in the left-turn pockets on Main Street. The signal cycle for phases A and B is given below.

Phase A	Phase B
Advance green (may be actuated)	Green
Green (30-s minimum)	Amber (3 s)
Lagging green (red)	All red (2 s)
Amber after lagging green	
Amber (3 s)	
All red (2 s)	

A comprehensive documentation film using this film technique would also demonstrate the effect of variation of parameters on intersection behavior. Therefore, the user could obtain an intuitive feel for the significance and sensitivity of these parameter settings. A number of sensitivity tests that could be used for this purpose and that were performed during the validation of the model are described in the users manuals. These tests use star and linear networks to illustrate the effects of signal (cycle length), flow rates, pedestrian movements, speeds, traffic mix, and signal offsets. In addition to the demonstration of signalization concepts, the film technique can also be used to demonstrate dedicated lane and street concepts and bus priority systems that are of current interest.

Figure 3. Development process for simulation film.

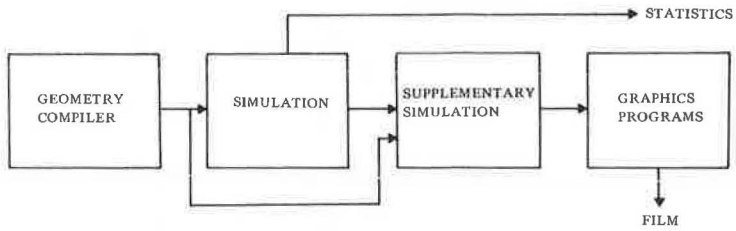


Figure 4. Movement area concept demonstration.

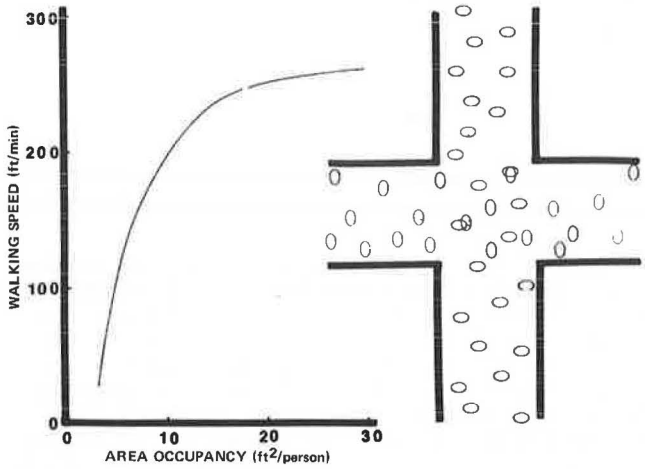


Figure 5. Service device concept demonstration.

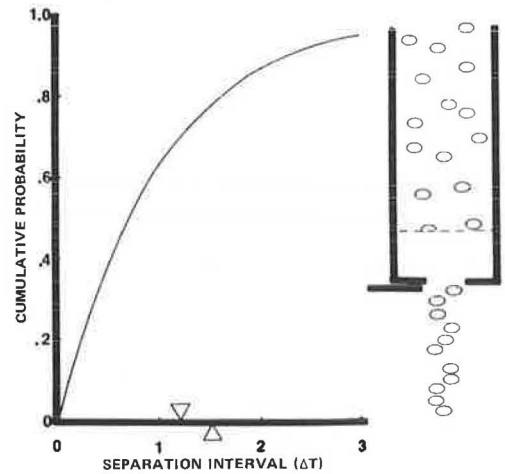
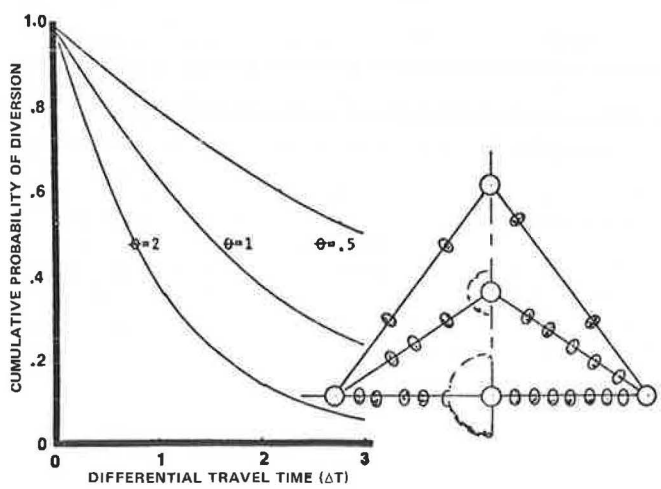


Figure 6. Path selection concept demonstration.



TRANSIT STATION SIMULATION MODEL

Another simulation model that is available from the Urban Mass Transportation Administration is the Transit Station Simulation Model (1, 2). This model has been developed to provide architects and transportation system planners with a tool that is capable of evaluating the alternative transit station designs with respect to pedestrian flow and processing requirements. Pedestrian flow dynamics are of particular significance for transit stations because of the high volumes of pedestrians that must be processed and the transient loading characteristics that result from the discrete nature of transit vehicle arrivals and departures.

Through the use of this simulation model, the transit station designer will be able to experiment with different system configurations, number of fare collection gates, number of escalators, and the sizing of stairways and platforms. This experimentation will enable the designer to arrive at the most cost-effective design while maintaining high standards of pedestrian safety and comfort over the full range of anticipated variation in passenger and vehicle loading.

The simulation model incorporates a rather generalized concept through which submodels provide for the basic elements of the system. These elements are assembled by the user to represent a complete transit station or any other pedestrian-processing type of system. Although this generality is desirable, it does require user sophistication in the area of modeling concepts and a detailed understanding of the operation of the individual modeling elements. These qualifications are necessary for translating real-world features into the abstract model formulation and for interpreting the results obtained.

The users manuals and program documentation that have been developed will provide the ultimate reference source for the user. However, these documents may not be the most effective means for apprising the potential users of the existence and nature of the model or for explaining the dynamic characteristics of the model elements and the relation of these elements to their real-world counterparts.

The transit station simulation model, like the UTCS1 model, is microscopic in nature with each pedestrian and vehicle modeled individually. In addition to these moving entities the simulation world view is comprised of three basic elements:

1. Movement areas (links),
2. Service devices (nodes), and
3. Path selection mechanisms.

To use the model effectively, the user must under-

stand thoroughly the operation of these elements and the effect of their parameter settings on system operation. This understanding is necessary for the user to assemble the elements into a network that represents an actual transit station (corridors, lobbies, fare collection devices, escalators, and platforms).

By showing the dynamic operation of each type of element individually and the variation of its parameters in a computer-generated film, an intuitive understanding of the model can be developed. The pictorial representation used to illustrate the three elements in the film is shown in Figures 4 through 6.

Figure 4 demonstrates how the walking speed of each pedestrian is selected at random with the mean speed a function of the congestion of the movement area (square feet per person) (6). (SI units are not given for the variables in this model inasmuch as its operation was developed in U.S. customary units.) Pedestrians moving vertically in the diagram are shown in green, and pedestrians moving horizontally are shown in red. The incidence of conflicts is shown by overlapping areas of the individual figure in yellow. On the right side of the screen, the functional relations between average speed and area occupancy are shown in coordinated colors since these parameters are varied.

Figure 5 shows the format for the film segment on service devices such as fare collection gates that are represented as nodes in the simulation. This sequence illustrates that (a) the queue provides high-density storage of pedestrians, (b) the service device can be activated by doors, (c) the mean processing rate of the service device and the spacing between pedestrians leaving the device are controlled by a statistical distribution function, and (d) the queue buildup depends primarily on the relative means of arrival and departure service time distributions.

The probability distribution function for the device is plotted against time interval on the right of the screen. The path selection mechanism incorporated in the model is based on a model described by Dial (7). This model distributes pedestrians over reasonable paths as an inverse function of the travel time for the path. A parameter (θ) must be set by the user to adjust diversion sensitivity to differential travel time.

Figure 6 shows the format used in the film to show the operation of the concept and the effect of this parameter setting in a simple five-node, six-link network. Pedestrians are shown by the moving ellipses and the queues are shown by shaded concentric semicircles at the three service device nodes, which are intermediate between the diversion node and the destination. At low pedestrian flows or low values of θ, most of the flow is along the shortest path from origin to destination. As either one of these increases and as the queue length (travel line) along the direct path increases, the flow will divert to other routes.

After the user has been introduced to the operation of the individual elements of the model in the manner described in this paper, a case study can be presented that shows how a network of these elements can represent an existing or planned transit station. In this case study, the passenger demand rates, transit vehicle headways, transit vehicle sizes, number of service devices (such as escalators), and other features can be varied to show how alternative designs would be investigated by using the model.

Other applications of computer graphics to the planning of transportation systems that may be of interest to the reader are reviewed elsewhere (8, 9).

CONCLUSION

The use of simulation models has been shown to be an effective technique for designing new and complex urban transportation systems. However, the use of sophisticated tools such as these has been constrained by the complexity of the models. Better means are therefore needed to disseminate information about the models and about user training. The use of computer-generated films that show the dynamics of model operation can be a valuable aid in this process.

REFERENCES

1. New Systems Requirements Analysis Program. Detailed Technical Specifications for a Transit Station Simulation Model. Urban Mass Transportation Administration, U.S. Department of Transportation, Vols. 1-2, 1973.
2. Software Systems Development Program: Transit Station Simulation Users Guide. Urban Mass Transportation Administration, U.S. Department of Transportation, Vols. 1-2, Jan. 31, 1975.
3. Network Flow Simulation for Urban Traffic Control System. Federal Highway Administration, U.S. Department of Transportation, Vols. 1-5, May 1973 and March 1974.
4. E. S. Joline and J. C. Hayward. Application of Computer-Drawn Motion Pictures for Demonstration of Urban Transportation Concepts. Technical papers presented at 1975 International Conference on Personal Rapid Transit, Univ. of Colorado, Boulder, 1975.
5. E. S. Joline. Application of Computer-Drawn Motion Pictures to Visualization and Validation of Airport Simulations. Winter Simulation Conference, New York, Dec. 1971.
6. J. J. Fruin. Designing for Pedestrians: A Level-of-Service Concept. HRB, Highway Research Record 355, 1971, p. 3.
7. R. Dial. Transportation Research. In A Probabilistic Multipath Traffic Assignment Model Which Obviates Path Enumeration, Pergamon Press, Great Britain, Vol. 5, 1971, pp. 83-111.
8. J. B. Schneider. Interactive Graphics in Transportation System Planning and Design. Univ. of Washington, Seattle, Jan. 1974.
9. Computer Graphics. Proc., IEEE, New York, April 1974.