First-Generation UTCS Simulation

AMIR EIGER AND SHIH-MIAO CHIN

The development of an urban traffic control system (UTCS) simulation program that comprises the first-generation UTCS software (extended version) and a network traffic simulation model (NETSIM/ICG) is described. The simulator provides pseudo-real-time graphic displays of surveillance data and system performance measures in addition to the printed outputs of both the UTCS software and the NETSIM model. It can simulate both automated and manual modes of control. The development of the simulator supports current and future research in urban traffic control systems, provides a tool for evaluation before implementation of these systems, and is potentially useful as a training aid for UTCS operators.

Urban street traffic volumes exhibit fluctuations that necessitate signal control systems capable of appropriately adapting to the changing demand conditions. To date, several generations of such computerized urban traffic control systems (UTCSs) have been developed and implemented. These systems are centralized control systems that gather field data on traffic volumes and network link occupancies from vehicle detectors (sensors); on the basis of that information, they alter the signal settings at intersections in order to aid traffic flow. UTCSs can be described by a functional block diagram such as the one shown in Figure 1.

FIRST-GENERATION CONTROL STRATEGY

In implementing a first-generation control (1-GC) system, a set of timing plans is generated off-line and stored in computer memory in the form of a timing plan library. Corresponding to each timing plan is a plan signature, given by

$$\underline{S}_j = (s_{j1}, s_{j2}, \ldots, s_{jn}) \tag{1}$$

where s_{ji} is the design value of the traffic flow parameter(s) on link i for plan j. During the operation of the system, individual timing plans are selected for implementation either by time of day (TOD), traffic-responsive (TRSP), or manual (MAN) modes of operation. In the TRSP mode, timing plan selection is based on the computed deviations of the timing plan signatures from the actual signatures derived from field detector data. Thus, corresponding to each library plan there is a computed deviation:

$$D_j = \sum_i f(s_{ji} - v_i) \tag{2}$$

where v is the measured value of the flow parameter and f( ) is a measure of distance. Furthermore, in most current systems,

$$v_i = \text{vol}_i + \text{weight} \times \text{occupancy}_i \tag{3}$$

The selection algorithm is essentially twofold:

1. The alternative plan with the minimum signature deviation is considered for implementation.
2. The existing plan is retained if its signature deviation is within some threshold percentage value of the minimum deviation.

Most 1-GC systems also include a critical intersection control (CIC) feature that enables split adjustment on a cycle-by-cycle basis.

This paper reports on the development of a first-generation UTCS simulator that has been developed as part of an overall program to investigate various aspects of 1-GC operation, including (a) the effectiveness of manual intervention, (b) evaluation of CIC control, and (c) operation during transition periods. In addition, the simulator is potentially useful as a training aid for UTCS operators and may be used to investigate emergency vehicle routing strategies.

UTCS SIMULATOR

With reference to Figure 1, the UTCS simulator must have the capability to appropriately simulate the system control mechanism, the operation of the signals and signal controllers, the traffic movements generating the detector data, and operator control and display. Figure 2 shows the general framework of the simulator.

Traffic Simulation Module

The traffic simulation module is the Network Simulation-Interactive Computer Graphics (NETSIM/ICG) model (1), an enhanced version of the NETSIM model originally developed for the Federal Highway Administration (2).

Figure 1. UTCS functional block diagram.

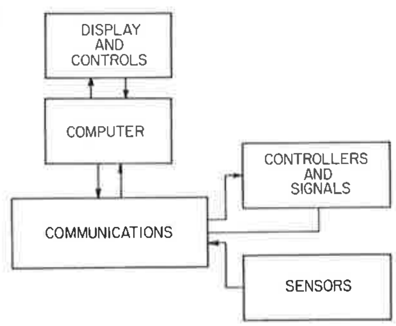


Figure 2. Description of UTCS simulator.

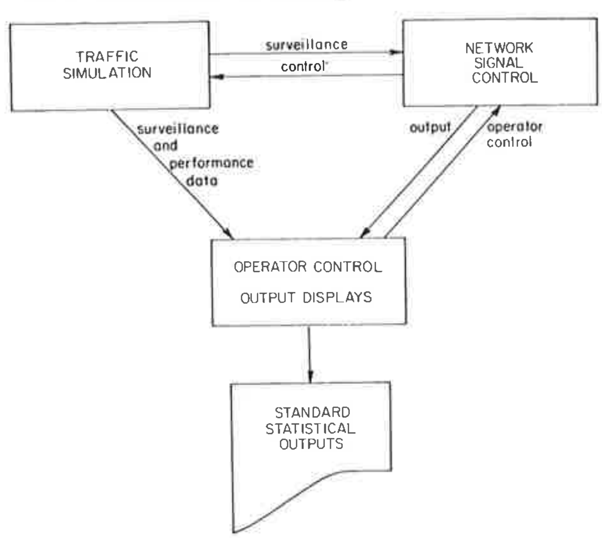


Figure 3. Dual-screen graphics workstation.

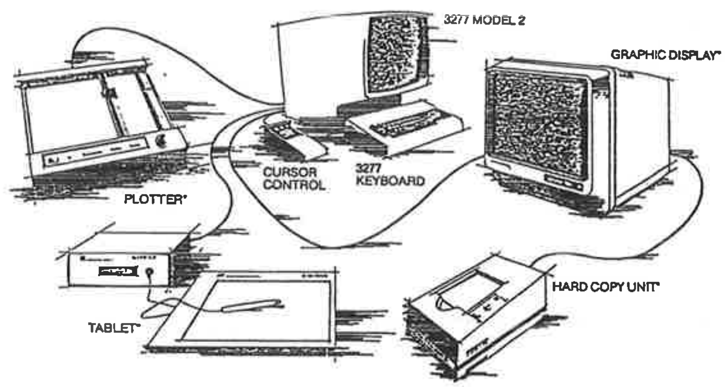
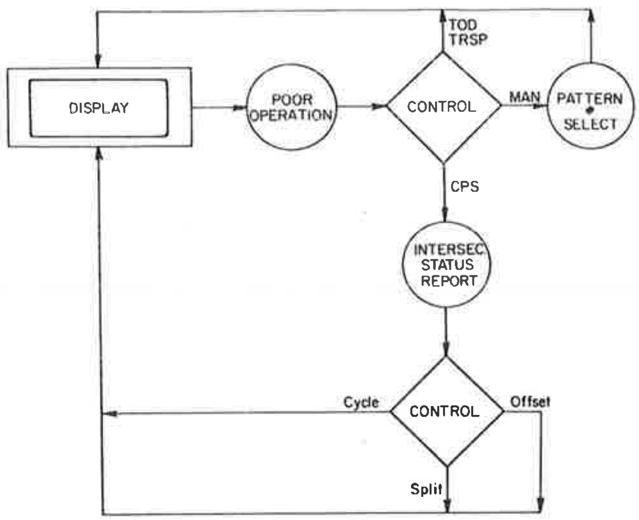


Figure 4. Procedural diagram for manual intervention.



NETSIM is the time-based microscopic traffic simulation program in which each vehicle traversing the network is treated as a separate entity. Its motion is governed by a set of microscopic car-following, queue discharge, and lane-changing algorithms. All vehicles are processed once every second, their positions are updated, and statistics are accumulated.

A variety of traffic controls can be imposed on this network. Intersection controls may take the form of STOP or YIELD signs; simple, fixed-time traffic signals operating either independently or as part of a coordinate system; and vehicle-actuated signals. As many as nine different signal phases can be incorporated in any given signal cycle. Detectors can be located at various points within any one link, with a maximum of three in any one lane.

Network Signal Control Module

The network signal control module is a modified version of the UTCS software (extended version) as implemented in Charlotte, North Carolina (3). The primary function of the control module is to command the traffic signal controllers through defined timing sequences.

The signal control module provides for selection and implementation of predefined signal timing plans in one of three modes: MAN, TOD, and TRSP. In the MAN mode, the operator specifies the number of the signal timing plan that he or she wants to impose on the signal network. In the TOD mode, the control module automatically selects and sets traffic signal timing plans in accordance with a predefined sequence organized by the day of the week and the time of the day (data input). In this mode, signal timing plans can be selected automatically as often as every 15 min. In the TRSP mode, the control module automatically selects the predefined traffic signal timing plan that is best suited to accommodate the current traffic flow conditions in the signal network as generated by the traffic simulation module. Pattern selection and implementation are accomplished through a traffic flow data matching technique that is executed every 15 min on the quarter-hour mark.

Three other modes of system control are provided and can be selected by the operator: off-line, critical intersection control, and controller parameter set (CPS). In the off-line mode, no communication (i.e., data transfer) is maintained between the control module and the traffic simulation. The controllers will operate in accordance with the signal logic in the traffic simulation module. In the critical intersection control mode, controller splits are adjusted once per cycle at controllers that are instrumented for critical intersection control. The split at any controller is apportioned according to the ratio of traffic demands on the conflicting intersection approaches. In the CPS mode, the operator may specify the cycle length, split, and offset of a particular controller. The controller will operate at the specified control parameters until the CPS is released and a new signal timing plan is called for by a MAN, TOD, or TRSP mode signal timing plan selection process.

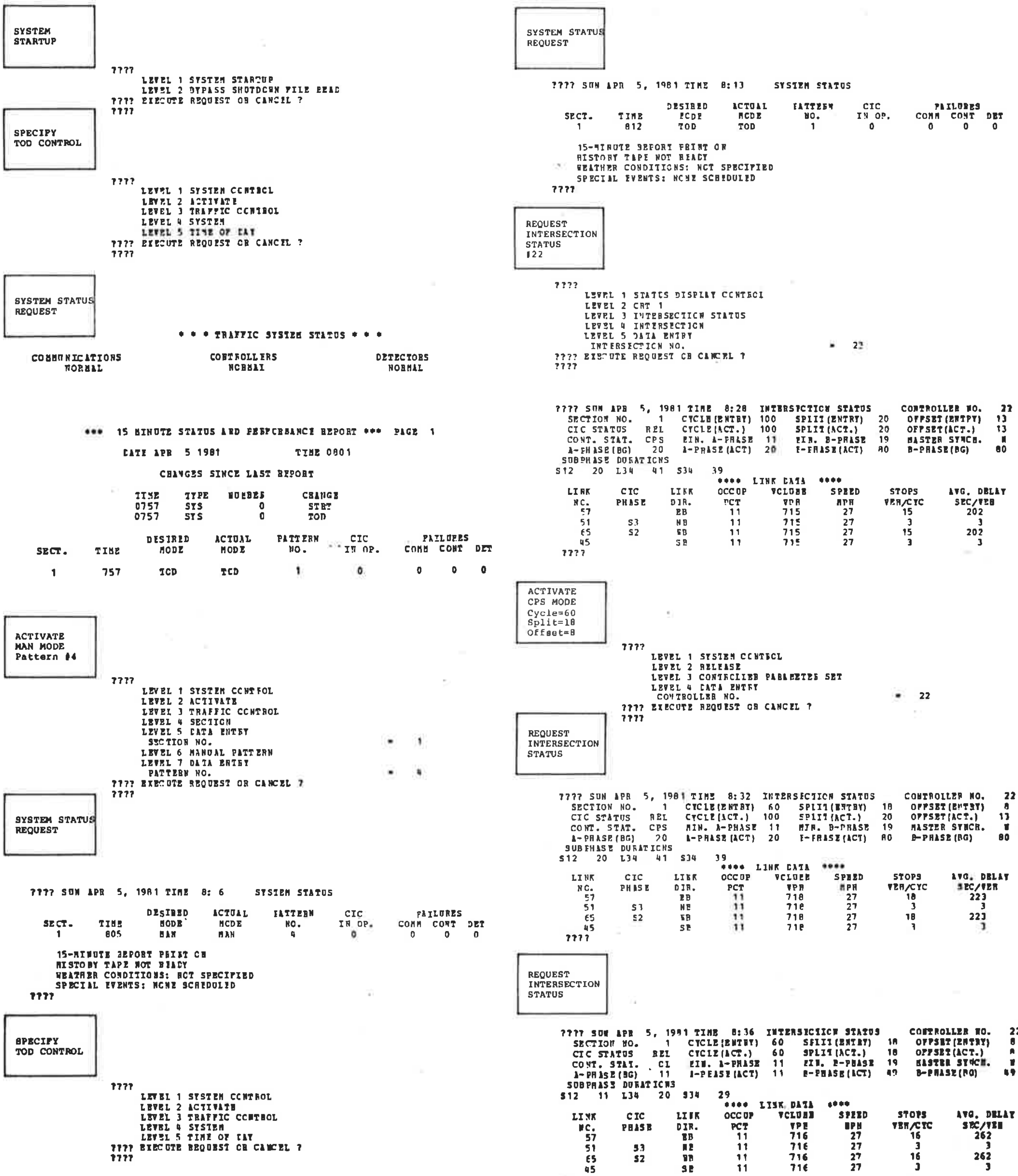
Interface Between Network Control and Traffic Simulation

The interface between the NETSIM and UTCS modules is through two routines that emulate the communication function shown in Figure 1. The first routine essentially translates and transfers the controller timing commands generated by the UTCS module to the appropriate signal indication codes needed by the NETSIM module. This is done for all controllers that are under network control. The function of the second interfacing routine is to determine for every detector whether a vehicle has crossed that detector during the previous 1-s time step and, if so, transfer that information to the UTCS module, where the appropriate volume and occupancy counters are updated.

Operator Control and Visual Display Capabilities

The UTCS simulator was developed on an IBM 370/3033 with graphics attachment system (see Figure 3). It has the capability to provide several different types of CRT displays for the user's selection. Two basic types of graphic display options are provided. The first is the display of link performance information, which is cumulative in nature--namely, delay time, average speed, average occupancy, stops per vehicle, etc. Queue length displays that are instantaneous in nature can also be displayed. Note that both types of displays are generated in pseudo real time [additional information is provided in the report by Chin and Eiger (4)]. In addition, both performance and display types are under operator control; i.e., the operator can interrupt the program execution, alter either display or performance type, and resume program execution. In addition to

Figure 5. Operator commands and system responses.



the graphic displays above, various alphanumeric displays are available, including system status, controller status, and intersection status. These displays are provided on the IBM 3277 screen. The system status display provides information on the current mode of operation of the system, broken down by section. The controller status display lists the current mode of operation of each controller in the signal system. Possible modes are on-line, off-line, critical intersection, or controller parameter set. The intersection status display provides the traffic signal timing and traffic flow parameters for a user-selected intersection.

Operator system control is achieved by operator commands selected from a display menu on the IBM 3277 screen. As discussed previously, various options are available. Note that the manual and controller parameter set options permit operator intervention in the automated control of the system; as a result, investigations concerning the possible impacts of manual intervention in automated control can be conducted. The operator's decision to preempt the automated control can be based on the surveillance information displayed on the CRT or any prior information that warrants such intervention. The sequence of operations for operator intervention is shown in Figure 4.

The operator control inputs are accomplished via the IBM 3277 keyboard as shown in the system configuration of Figure 3. The sequence of operator commands and system responses shown in Figure 5 illustrates the selection of several possible modes of control.

SUMMARY

The UTCS simulator described in this paper was developed to support current and future research in first-generation UTCSs. The simulator comprises a traffic simulation component (NETSIM/ICG) and a UTCS component. These components are interfaced through several routines that emulate the communication functions in a traffic control system. To test the UTCS simulator, a test network was coded. Hypothetical peak-period origin-destination volumes were assigned on the network. On the basis of the resulting link volumes, several traffic patterns were identified. For each traffic pattern identified, the TRANSYT signal optimization program (5) was used to find the optimal network signal timing plan. In all, eight histories and four timing plans were generated. The simulator was tested in all modes of control. The ratio of program run time to real time ranges from 1:50 to 1:10 depending on the size of the network, the number of vehicles in the network, and whether or not the graphic display options are used.

ACKNOWLEDGMENT

The development of the UTCS simulator was supported by a grant from the Office of University Research, Research and Special Programs Administration, U.S. Department of Transportation. The technical monitor for the project was Paul Ross of the Traffic Systems Division of the Office of Research, Federal Highway Administration.

REFERENCES

1. A. Eiger and S.M. Chin. The Development of UTCS/NETSIM/ICG: An Integrated Urban Traffic Control System-Network Simulation-Interactive Computer Graphics Program. U.S. Department of Transportation, Final Rept., Feb. 1982.
2. Traffic Network Analysis with NETSIM. FHWA, Implementation Package FHWA-IP-80-3, Jan. 1980.
3. Urban Traffic Control System First Generation FORTRAN IV Overlay Software (Extended Version). FHWA, Implementation Package FHWA-IP-79-4, May 1979.
4. S.M. Chin and A. Eiger. Network Simulation Interactive Computer Graphics Program. TRB, Transportation Research Record 835, 1982, pp. 52-66.
5. The TRANSYT Signal Timing Reference Book. FHWA, 1978.

Publication of this paper sponsored by Committee on Traffic Signal Systems.

Evaluation of a Bus Preemption Strategy by Use of Computer Simulation

DAVID A. BENEVELLI, A. ESSAM RADWAN, AND JAMIE W. HURLEY, JR.

The effects of implementing a bus preemption strategy on an arterial corridor (Monument Avenue) in Richmond, Virginia, were studied. The Urban Traffic Control System/Bus Priority System microscopic traffic simulation model was used to simulate the bus preemption system operation for various bus flow rates and bus stop locations. A benefit-cost analysis found bus preemption to be unjustified for the network. A comparison of benefit-cost ratios for the individual intersections showed a parabolic shape in the corridor. The benefits of bus preemption were found to be limited by the preemption algorithm structure and the bus stop location. A far-side bus stop was found to minimize the negative effects of bus preemption on automobile travel delay. The results were related to the control algorithm studied, and it was recommended that a more sophisticated control algorithm be developed for simulation studies and that similar studies be performed for other control algorithms.

Transportation system management (TSM) strategies have evolved because of the significant increase in travel demand in urban areas, the lack of additional land to expand the transportation system, and the increase in construction costs. These factors have led to the search for methods to improve the level of service of existing facilities with small investment costs. During the past several years, the need to reduce dependence on foreign petroleum imports has become an important fact of American life. The measure of effectiveness, passenger miles per gallon of fuel consumed, can be greatly improved through