National Cooperative Highway Research Program

RESEARCH RESULTS DIGEST

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Control Logic for Traffic Signal Networks

An NCHRP staff digest of the essential findings from the Interim Report of NCHRP Project 3-18(1), "Improved Control Logic for Use with Computer-Controlled Traffic," by D. W. Ross, T. L. Humphrey, and G. L. Williams, Stanford Research Institute

THE PROBLEM AND ITS SOLUTION

During the past few years, a number of general-purpose digital-computer-controlled traffic signal systems have been installed. Although the potential of these systems to improve operation and increase capacity has been demonstrated, there still exists a sizeable gap between the inherent hardware capabilities and the know-how (software) necessary to use these systems at optimum efficiency. The objective of this research, in short, is to close that gap.

The need to develop and to spread the know-how for effective and innovative methods of computer traffic control is recognized in this project. Consequently, the research effort is resulting in formulation, development, and evaluation of an operational software system that represents a significant step in the direction of attaining self-adjusting, real-time control, applicable in both light traffic and heavily congested conditions.

Practicality is stressed. The entire software system is being tested and evaluated on an installed control system with actual traffic. As a result, traffic engineers and highway officials will be provided a verified alternative for improving traffic operations.

FINDINGS

Inasmuch as this digest derives from an interim report, the findings presented are basically the rationale for program development and evaluation rather than final research results. Therefore, the following discussion describes the design features of the traffic control system and the methodology and hardware employed in its evaluations. A comprehensive description of the traffic surveillance and control software can be found in the 66-page Appendix A of the Interim Report. Similarly, floating-car evaluation procedures are fully detailed in Appendix B of the Report.

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Software Development

The ASCOT (Adaptive Signal Control Optimization Techniques) software system has a basic structure and design features that permit many control schemes to be implemented with modest reprogramming on low-cost mini-class computers. It is designed to achieve very flexible modes of traffic control, such as:

1. On-line signal plan computation.
2. Cycle-to-cycle split variation at specified intersections.
3. Cycle-length adjustment, coupled with offset changes at congested intersections.
4. Phase-skip on designated signal phases in the absence of demand.

The logic can adapt to conditions affecting an entire network, such as adverse weather, as well as to localized conditions that may affect only a single intersection. Furthermore, the logic is divided into three levels of control that offer different degrees of adaptation: Level I, background control; Level II, variable-split control; and Level III, congested intersection control.

Table 1 summarizes the characteristics of these three control levels. It can be seen that the background and variable-split control logics can be applied simultaneously, but that the congested intersection control logic overrides the first two levels in congested conditions. Both variable-split control and congested intersection control are applied on a cycle-by-cycle basis, with the latter being more complex.

The ASCOT software, developed from the preceding logic, consists of computer programs that may be functionally grouped in four categories:

1. Detector Sample Processing and Traffic Parameter Routines: These programs monitor the status of the system's detectors and compute detector-measured traffic parameters, such as volume, occupancy, speed, demand, and queue-length estimates.

2. Controller Actuation, Monitoring, and Maintenance Routines: These programs actuate, monitor, and maintain proper control of the intersection controllers.

3. Control Logic and Signal-Timing Routines: These programs perform traffic control scheme computations and decision-making resulting in the signal-timings that are to be implemented.

4. Executive Control Routines: These programs schedule and control the execution of the various computer programs of the traffic control system.

The ASCOT programs comprise only a portion of a traffic control system's software requirements. In Figure 1, a block diagram of an entire traffic control software system, the shaded portions comprise the ASCOT programs. Other software components, machine-oriented rather than application-oriented, can generally be supplied by the computer manufacturer.

ASCOT Software Implementation

The City of San Jose, Calif., is the test site for the program evaluation. Its computer-controlled signal system, installed in 1964, currently controls 63 signalized intersections. Figure 2 shows the network, which is essentially the downtown street grid and San Carlos Street, a major arterial. The signals are controlled by an IBM 1800 computer having a 32,768-word, 2-us memory core, of 16-bit word length; a Model 1810 disk storage unit with three disks; a Model 1442 card reader and punch; a Model 1443 line printer; a Model 1053 (logging) printer; and a Model 1816 printer/keyboard. Prestored timing tables have been the basis for signal control in the past.

The IBM 1800 computer, although no longer new, was designed specifically for efficient handling of problems involving a large number of external sensors (such as the more than 400 loop vehicle detectors in this system). Thus, it is representative of the type of computer that even small- to medium-size cities can be expected to purchase for traffic control systems. Similarly, the San Jose controllers are also older electro-mechanical types of equipment. They are part of a three-dial interconnected system and have been adapted to computer control by the installation of three relays in each controller. When the computer is off-line, the interconnect system is still used for control.

Performance Evaluations

The evaluation of the control logic is based primarily on comparison of total travel times for all vehicles operating in the controlled network. Travel time is a well-known measure of effectiveness that correlates highly with other accepted measures; it can be easily translated into dollars for input into benefit/cost analysis.

Travel-time data are collected by floating-car techniques, and expressed in vehicle-hours per hour as a function of service rate in vehicle-miles per hour. These measurement parameters make the control logic evaluation independent of diurnal and time-of-day factors. Furthermore, the floating-car method separates the evaluation data from computer-gathered control and evaluation data, thereby diminishing the chances of biased results.

The travel-time analysis based on synthesizing network characteristics from times and volumes by street link will culminate in control logic comparisons, as shown in Figure 3. Here, for instance, at a given level of network utilization, X, Logic A provides better performance than Logic B. The approach is essentially that taken in recent FHWA research, in the Glasgow experiment, and in previous NCHRP research.

The field evaluation studies are being made with newly devised event recorders. Each unit consists of a 20-key, hand-held keyboard, and a portable equipment box housing a paper tape perforator and the necessary electronic memory and logic control circuit. The equipment box also contains two sets of thumbwheel switches that are used to set car identification, weather, date, route number and clock synchronization before starting a run. Power is obtained through an inverter from the automobile 12-v battery system.

APPLICATIONS

The ASCOT program package is expected to be especially relevant in light of the aid programs established for developing and implementing area-wide traffic operation improvements. The TOPICS program is an example of such funding made available to both state highway departments and local traffic engineers. In the final report, therefore, ASCOT'S functional specifications will be sufficiently detailed to enable the widest possible application on a variety of digital computers and a variety of city networks. The specifications are expected to include:

1. Descriptions of traffic-flow control models that are the basis of the control concept.
2. A summary of detector traffic parameters and other detector-related recommendations.
3. A summary of computer-controller interface characteristics.
4. Definition of all computer functions, formats, and operating procedures.
5. Control logic programming flow charts and listings.
6. Functional requirements of the computer and peripheral equipment, including detectors and controllers.

Table 1
CHARACTERISTICS OF CONTROL LEVELS

Control Level	Effect on Intersection Signal-Timing Parameters		
	Cycle Length	Split	Offset
Background control	Set for a control period duration	Nominal values set for a control period, but can be varied by the variable-split control	Set for a control period
Variable-split control	Unaffected	Variable from cycle to cycle	Unaffected on major street
Congested intersection control[a]	Variable from cycle to cycle	Variable from cycle to cycle	Variable from cycle to cycle

[a] Overrides background control and variable-split control.

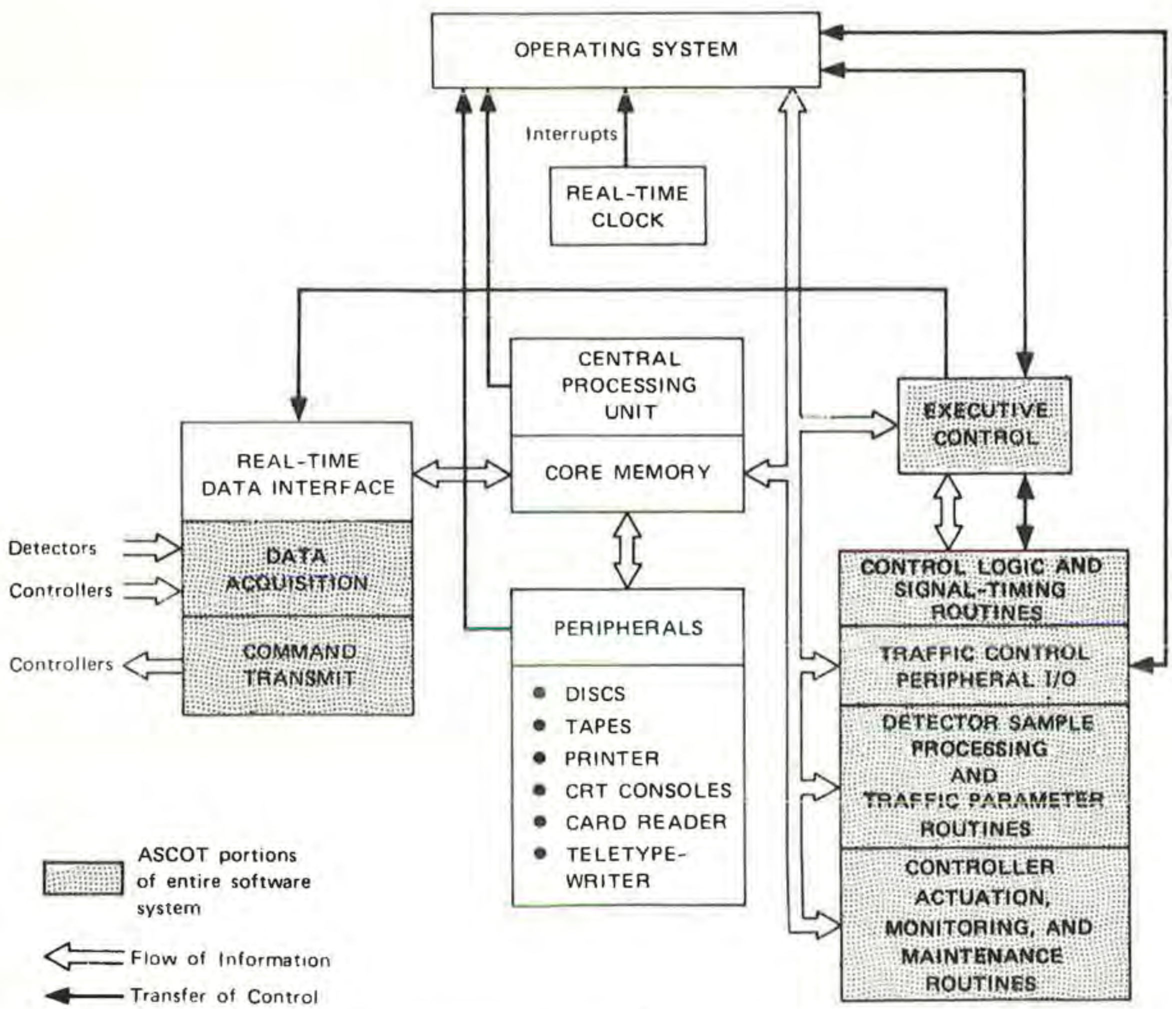

Figure 1. Block diagram of traffic control system software.

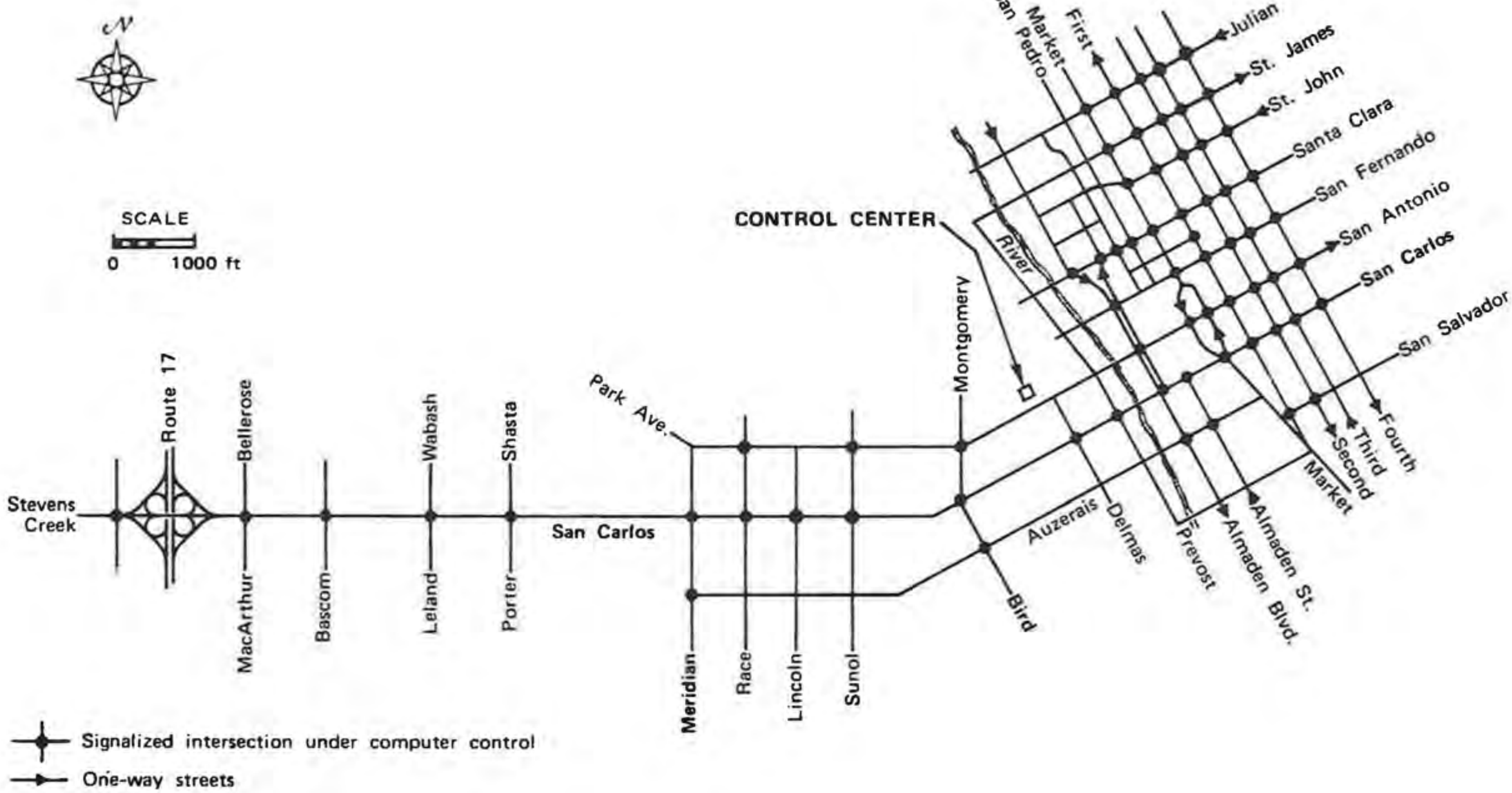

Figure 2. San Jose computer-controlled traffic network.

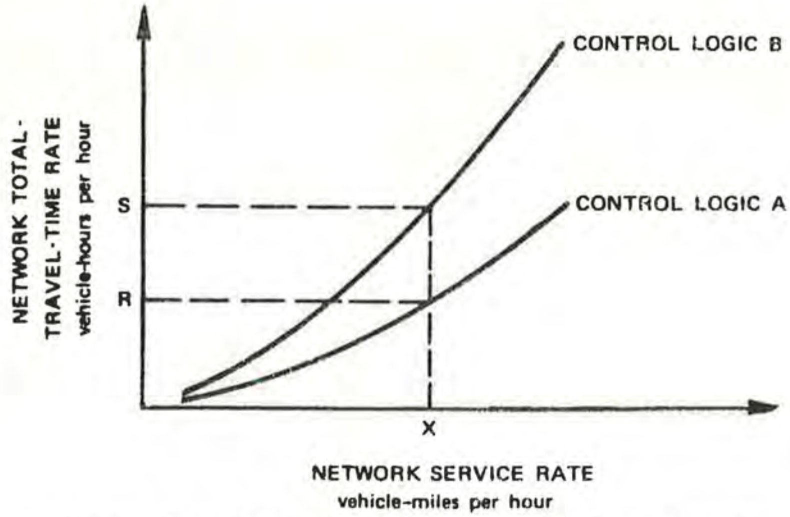

Figure 3. Network total travel time versus network service rate.

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