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Improved Criteria for Timing Traffic Signal Systems in Urban Networks

An NCHRP staff digest of the essential findings from the final report on NCHRP Project 3-5, "Improved Criteria for Designing and Timing Traffic Signal Systems," by Fredrick A. Wagner, Frank C. Barnes, and Daniel L. Gerlough, Planning Research Corporation, Los Angeles, California

THE PROBLEM AND ITS SOLUTION

This project involved the development, computer simulation testing and comparison, and field verification of advanced methods of traffic signal control in urban networks. The emphasis was on developing reliable and inexpensive methods of improving traffic operations through simple modifications of fixed-time signal settings. A secondary objective was to verify, through field studies, the ability of computer simulation methods to predict accurately the effects of signal timing modifications.

A large number of traffic signal timing plans were developed for controlled testing by simulation. The following concepts were employed in various combinations as tools in developing alternative signal timing plans: (1) Webster's cycle and split optimization method; (2) the delay-difference method for optimizing signal offsets; (3) the volume-priority method of establishing a network offset plan; (4) the preferential street method of establishing a network offset plan; (5) the mixed-cycle method of signalized network operation; (6) Little's maximal bandwidth method for optimizing offsets; (7) the SIGOP traffic signal optimization method; (8) the British combination method for optimizing offsets; and (9) Allsop's graph theory method for optimizing offsets. One tactical control concept, the basic queue control technique, was also studied.

Two California grid networks were used as test sites; a 26-intersection network in Los Angeles, and a 22-intersection network in the San Jose CBD. Simulation tests were conducted in the Los Angeles network for 3:00 to 6:00 p.m. traffic conditions. The tests were divided into offpeak and peak subperiods of 90 minutes each. In San Jose, simulation tests were performed for the 4:00 to 6:00 p.m. traffic conditions.

Comprehensive field studies were conducted in Los Angeles after the simulation tests. Two purposes were served: (1) three different signal system timing alternatives were tested under actual operating conditions; and (2) large quantities of operational data were gathered to test the validity of the simulation predictions.

These field studies lead to the belief that the traffic signal system timing methods developed by this project can be immediately applied in practice with reasonable assurance of their success.

FINDINGS

The research indicates that all of the traffic signal timing methods investigated can result in substantive improvements in network traffic operation. Given a network of signalized intersections that has not recently been the subject of intensive traffic engineering attention devoted specifically to signal operation improvements, it is highly probable that initiation of systematic study, analysis, and implementation of signal timing changes will produce significant upgrading of performance. The findings of this study suggest that it is not so important which of the signal system improvement alternatives is selected for use. Rather, the important thing is to select one of the approaches, collect the necessary traffic data, and implement the signal timing improvements.

The research findings indicate that improvements in operation produced by the relatively simple methods are equal, or nearly equal, to results produced by the complex methods.

Simple Methods

The simple methods include Webster cycle and split optimization, Little's maximal bandwidth program, the delay-offset difference program, and several straightforward approaches for "building" the network timing plans (e.g., preferential streets, volume-priority, and mixed-cycle approaches). It has been found that these so-called simple methods, when applied together, properly result in highly effective strategic plans for signal operation. In applying the so-called simple methods, there is a minimum degree of reliance on the computer, and the computer programs that are used are uncomplicated and easy to understand and operate.

Complex Methods

The complex methods investigated include SIGOP, the British combination method, Allsop's graph theory augmentation of the combination method, and TRANSYT, the traffic network study tool. These methods all involve the use of complicated computer programs, the understanding of which requires investment in a substantial intensive study and consultation period. All of the methods incorporate either a formalized mathematical optimization, or the attainment of a near-optimum condition through a formal simulation and search procedure. Of the four complex methods, only SIGOP is considered feasible for use by operating agencies in grid networks.

Signal Cycle Length

Several previous studies have been made involving the influence that cycle length has on operational effectiveness. Previous NCHRP research has shown that cycle length is the single most important variable affecting signal operation, whether it be at a single intersection or along an arterial. As a general rule, longer cycles are associated with longer delays and lower average speeds, and shorter-cycle operation produces reductions in delay and increases in average speed. The previous findings are strongly corroborated by this research in urban networks. Figure 1 depicts the approximate relationships between average network speed and signal cycle length. The plotted points represent simulation results for the different control alternatives tested.

APPLICATIONS

This project was heavily applications-oriented, and conscious efforts were made to emphasize investigation of improved traffic control techniques that could be used immediately and widely, without expending large sums of money. The results stand alone and do not have to be combined with other research in order to be useful. They are in understandable terms and are explicit enough to permit the signal optimization procedures to be immediately put to work by traffic engineering departments, regardless of their size.

As noted under Findings, the most important recommendation to the traffic engineer set forth in this report is to initiate a systematic program of signal system operational analysis. Application of any one of the following methods will result in worthwhile operational improvements: (a) Webster optimization of cycles and splits; (b) delay-offset difference method using either the volume priority approach or the preferential street approach; (c) the maximal bandwidth method; (d) SIGOP; and (e) whenever appropriate, the mixed-cycle approach. From among these alternatives, the traffic engineer should select the set of methods that he judges can be efficiently executed by his department. Under typical circumstances any systematic set of signal optimizing procedures should produce operational improvements on the order of 10 to 20 percent.

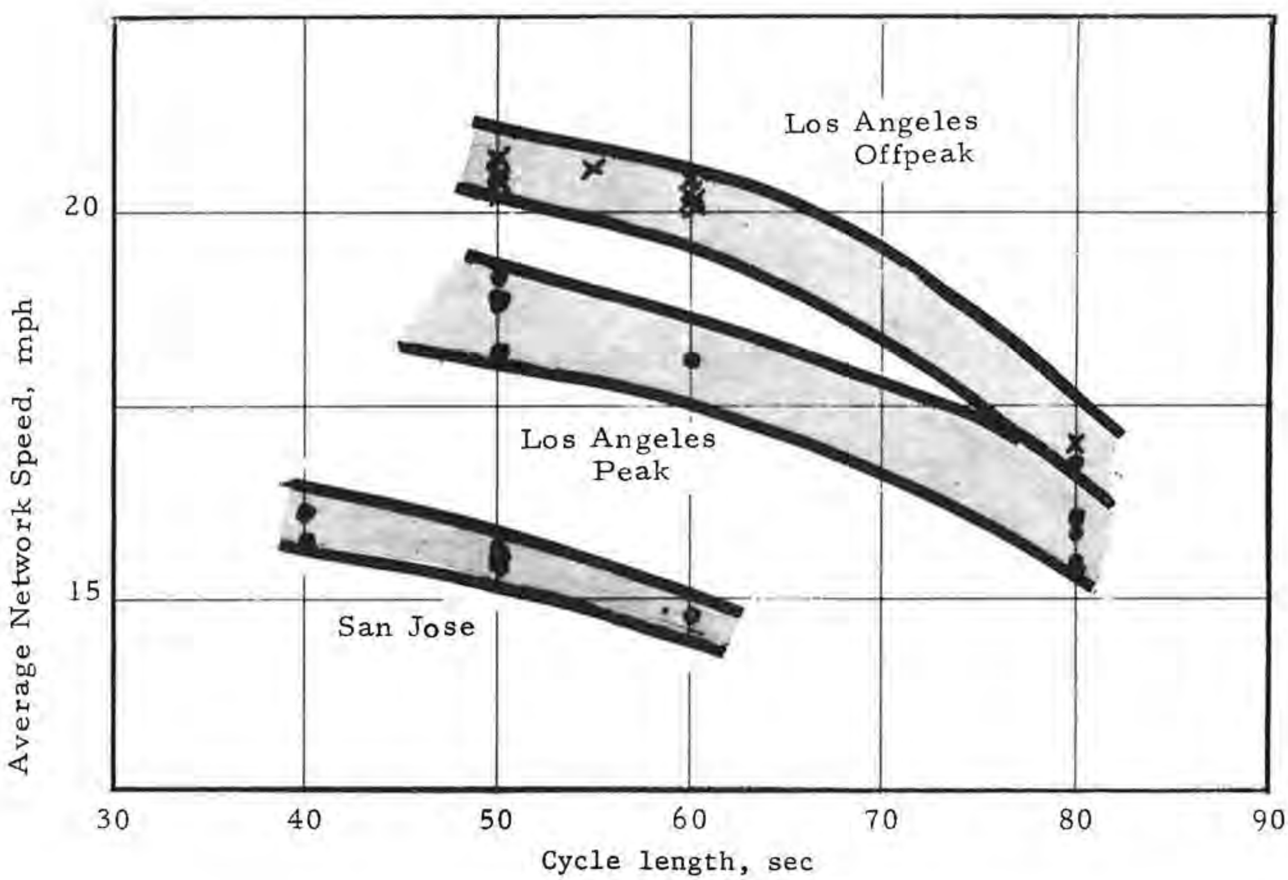

Figure 1. Approximate relationships between network speed and cycle length.