procedures could be developed to provide a better estimate.

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Evaluation of Signal Timing Variables by Using A Signal Timing Optimization Program

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This paper presents the results of a limited study to evaluate the effects of signal timing variables on the selection of the signal timing plan and the resulting measures of effectiveness from a signal timing optimization program. The TRANSYT computer program was used for the evaluation. Several series of sensitivity tests were performed to study the interrelations among number of signalized intersections, signal spacing, cycle length, and traffic flow conditions. The evaluation showed varying effects of the signal timing variables on the results. There appeared to be consistency in results for different signal system configurations (number of signals). With fixed signal spacing and number of signals, the measure of effectiveness (performance index) increased with volume level and cycle length. The effect of signal spacing illustrated differences in the behavior of the performance index. These results show the trade-offs between signal spacing and cycle length for a fixed number of signals and traffic volume level. As the cycle length was increased, the performance index also increased (although sometimes only slightly). This may suggest the use of the shortest practical cycle length for a progressive operation.

With ever-increasing loads being placed on urban traffic facilities from growing traffic demands, the retention of urban mobility depends to a very large extent on the effective use of urban street signal systems. The signalized intersections of urban arterials are a critical element of the urban street system. Traffic congestion and other operational deficiencies are common along arterial streets. Excessive or unnecessary delays, stops, and fuel consumption are experienced due to the inefficient operation of the signalization system. The safe and efficient movement of arterial traffic is almost totally a function of the signal timing variables. By virtue of their operation, traffic signals cause delay to motorists (1). The intersection characteristics usually determine the efficiency and capacity of the entire street system (2). The need exists to develop improved traffic control technology for facilitating the optimal use of available capacity (3).

Improvement of the effectiveness of the traffic control parameters would contribute to reducing the congestion and to relieving those conditions that impede the flow of traffic. The selection of a signal timing plan is complicated by the large number of alternatives available and the interrelations among the signal timing parameters (4). A considerable amount of research has been done on coordination of traffic signals on urban arterial streets (5). Efforts have been directed toward computerized signal timing optimization programs that would provide for signal timing plans superior to those in use.

The maximum bandwidth progression solution has been the approach preferred by traffic engineers (6-8). This arises in part from the lack of computational complexity in use and the ability to visualize the goodness of the results. Although progression has been widely accepted and used, concerns have arisen as to whether it provides a good arterial solution at the expense of the cross street traffic. Other methods for setting arterial traffic signals are the minimum delay solution and the combination of minimum delay with fuel consumption. Even with the theoretical development and computational efficiency of progression and minimum delay techniques, the final criteria is that both techniques have been accepted as providing a good solution (9).

Settings for fixed-time coordinated traffic signals are based on safety of traffic, capacity of the intersection, and delay minimization (10). Signal timing plans must take into account not only the needs of the individual intersections but also the requirements that arise from the time relations between adjacent intersections and their signals (11).

SIGNAL TIMING VARIABLES

The signal timing variables that determine a signal timing plan are cycle length, green splits, phase sequence, and offsets. The relative efficiency of a coordination timing plan is dependent on traffic and movement volumes, signal spacing, speeds, intersection capacity, and the number of signals. Although all of these variables determine which timing plan is the best for fixed-time signal timing optimization, these variables are considered to be fixed and deterministic for any specific solution.

To evaluate the effect of these variables on the signal timing plan selected as best from a signal timing optimization program and the resultant measures of effectiveness, a set of cases were developed to study several of the variables and their interrelations. Several series of sensitivity tests were performed to study the interrelations by using the results from the TRANSYT6B program and its measure of effectiveness, performance index (PI) as the basis for comparison. The variables that were considered were signal system configuration, intersection spacing, cycle lengths, and traffic flow conditions.

BASE CONDITIONS

Several assumptions were made to simplify the hypo-

Figure 1. PI versus number of signals for varied spacing and fixed volume and cycle length.

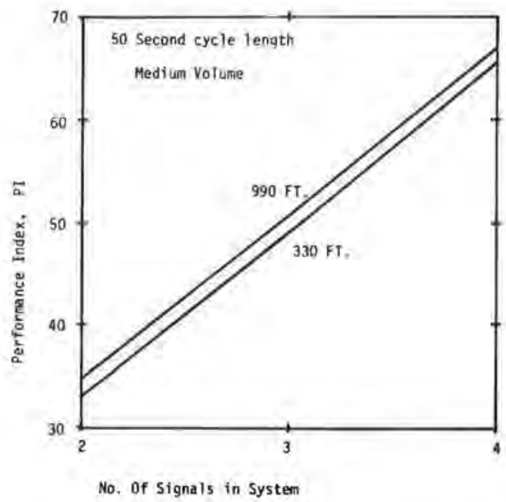


Figure 2. PI versus cycle length for varied volumes and fixed number of signals and spacings.

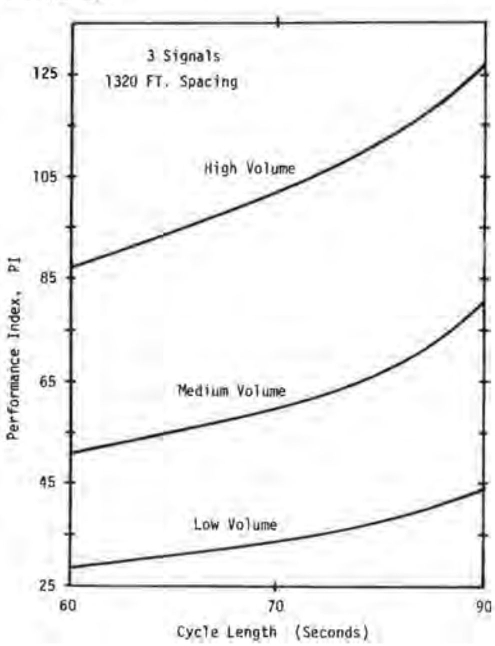


Figure 3. PI versus cycle length with varied volumes and spacings for two-signal system.

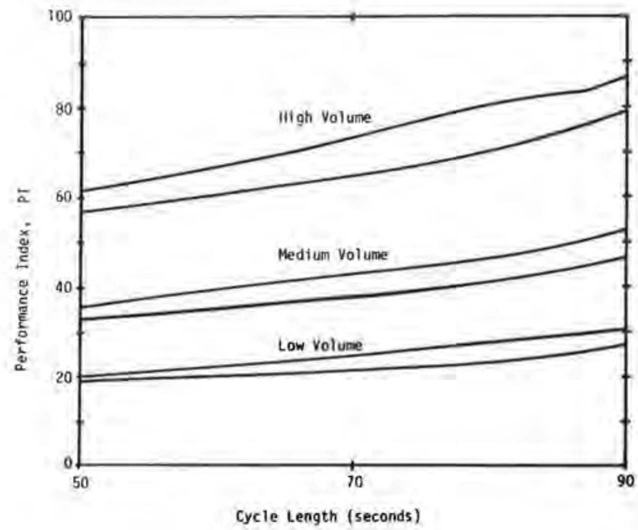
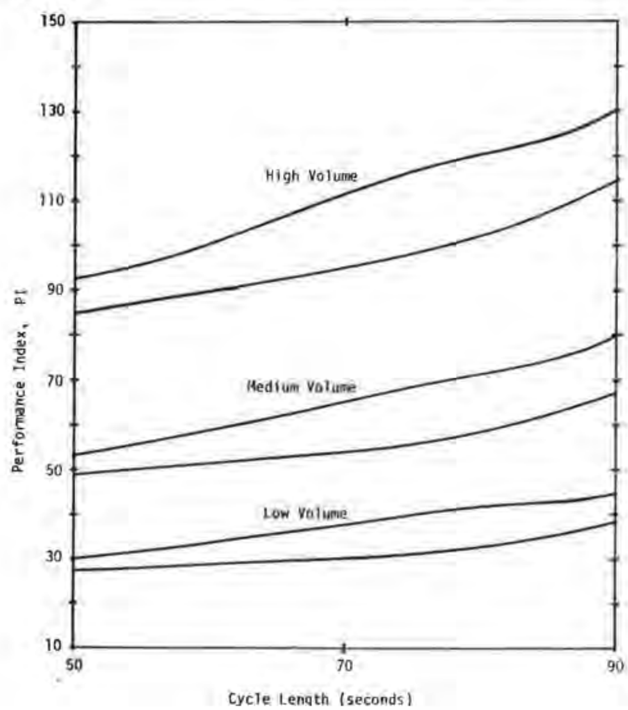


Figure 4. PI versus cycle length with varied volumes and spacings for three-signal system.



thetical street scenario. It was assumed that the basic arterial street and signal control consisted of the following:

1. Uniform arterial grid spacing;
2. Traditional two-phase signal operation;
3. Three lanes at the intersection for each approach consisting of a separate left-turn lane, a through lane, and a combined through plus right-turn lane;
4. Twelve-ft traffic lanes;
5. Saturation flow rates per hour of 1750 pcus for through plus right turns and 1200 pcus for left turns ;
6. Turning movements for an approach of 10 percent for left turns and right turns and 80 percent for through movements; and
7. Average operating speed throughout the system of 34 mph (55 km/h) in both directions.

Signal System Configuration

The signal system configuration concerned the number of signalized intersections. The signal system configurations considered were

1. A signal system comprised of two signals,

Figure 5. PI versus cycle length with varied volumes and spacings for four-signal system.

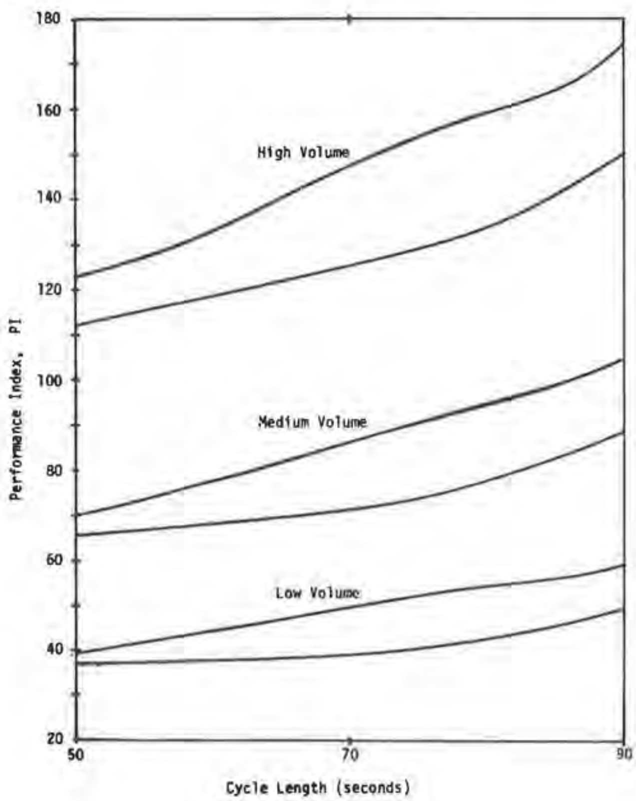


Figure 6. PI versus cycle length with varied spacings and fixed volume for two-signal system.

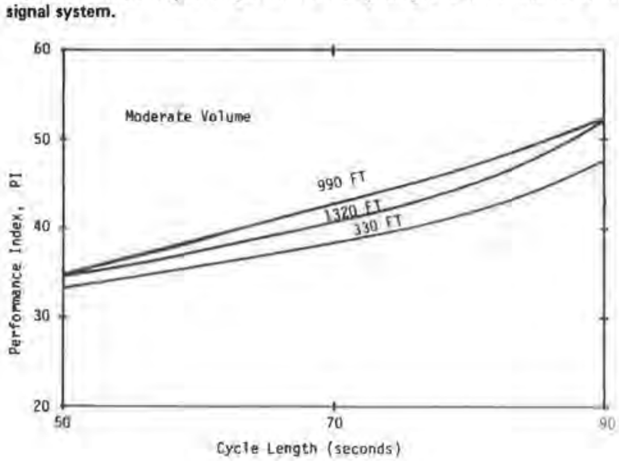


Figure 7. PI versus cycle length with varied spacings and fixed volume for three-signal system.

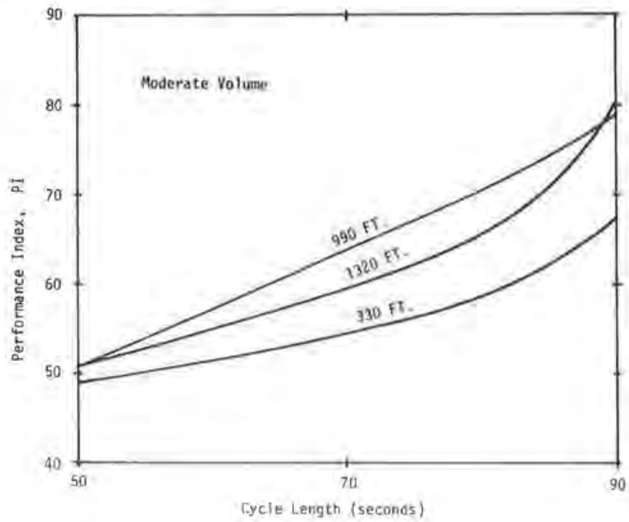


Figure 8. PI versus cycle length with varied spacing and fixed volume for four-signal system.

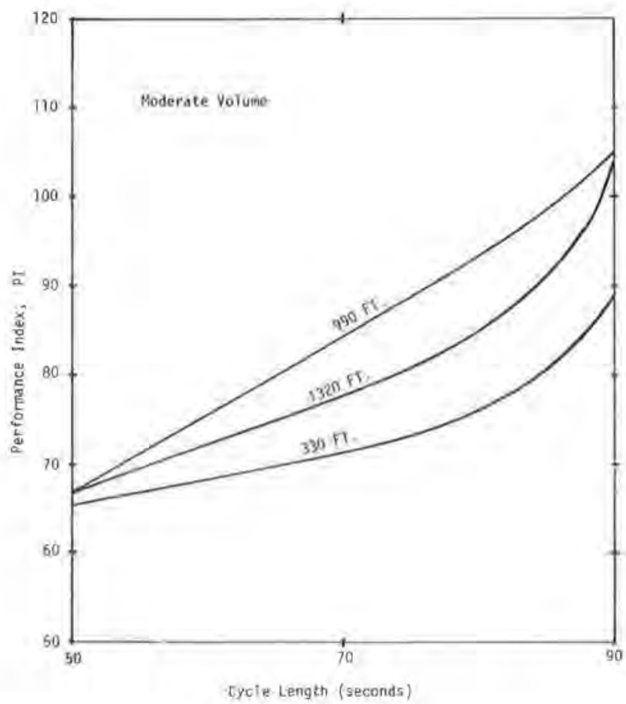


Figure 9. PI versus signal spacing with varied cycle length and fixed volume for two-signal system.

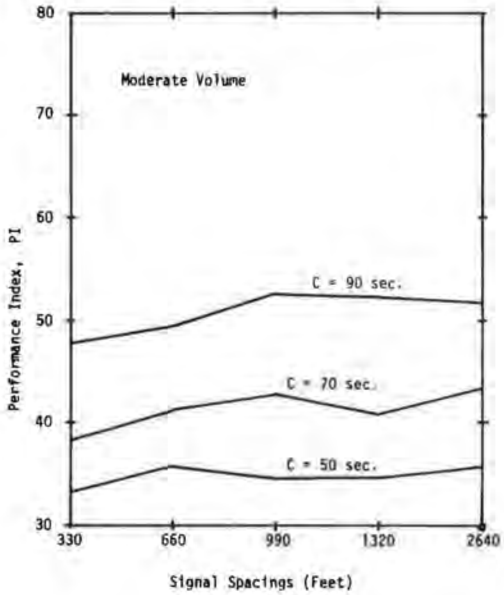
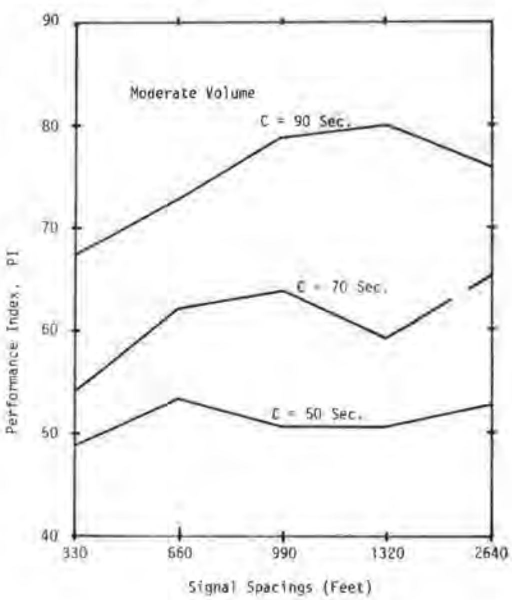


Figure 10. PI versus signal spacing with varied cycle length and fixed volume for three-signal system.



2. A signal system comprised of three signals, and
3. A signal system comprised of four signals.

Traffic Flow Condition

Traffic volume was another variable that was evaluated at three levels. The first level was 80 percent of the saturation flow capacity to represent high-volume traffic conditions on the arterial street. The second level was 60 percent of the saturation flow capacity to represent medium-volume traffic flow conditions. The third level was 40 percent of the saturation flow capacity to represent low-volume traffic conditions.

Figure 11. PI versus signal spacing with varied cycle length and fixed volume for four-signal system.

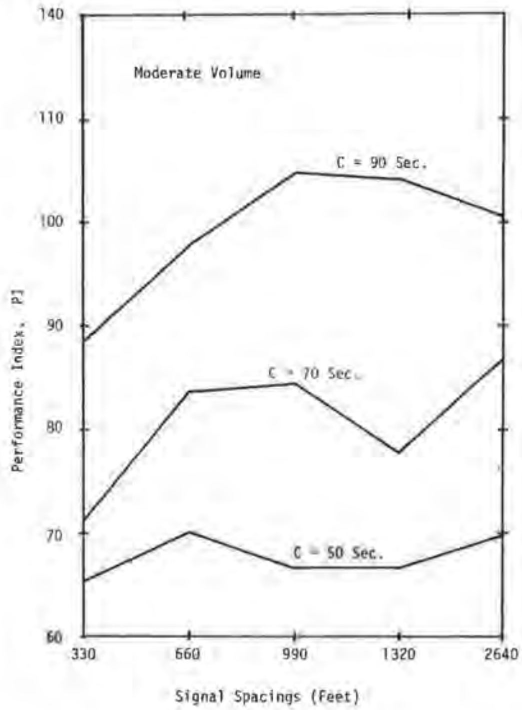
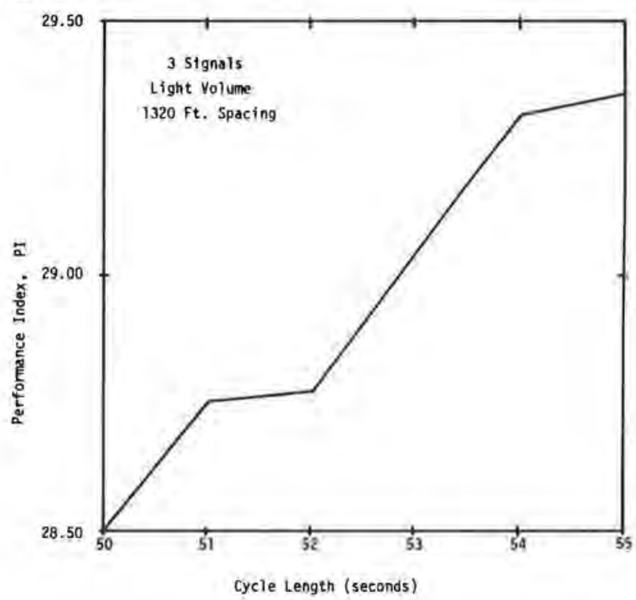


Figure 12. PI versus cycle length for fixed volume, spacing, and number of signals.



Signal Spacing and Cycle Time

Five different spacings between the intersection stop lines were established as the variable levels for signal spacing. This permitted a more detailed evaluation of the spacing effect on choosing cycle lengths. The spacings considered were 330 ft (101 m), 660 ft (201 m), 990 ft (302 m), 1320 ft (402 m), and 2640 ft (805 m).

Three common cycle times of 50, 70, and 90 s were selected for the cycle lengths considered.

EVALUATION AND ANALYSIS

A total of 140 cases were analyzed to study the effects of traffic signal variables on the performance of a signal system. For each combination, the optimal result obtained from the TRANSYT6B program was used for the basis for the evaluation. TRANSYT's performance index (a weighted measure of stops and delay) was used as the comparative measure of effectiveness.

For the two signal spacings used in Figure 1, the shape of the PI curves is nearly straight lines. The slope of these curves is almost identical. This would indicate that consistency exists for the different signal system configurations.

For the conditions of a fixed signal spacing and number of signals, an increase in the traffic volume levels increased the PI. An increase in the cycle length also increased the PI. This is shown on representative Figure 2. Whenever the PI increases, the quality of the traffic conditions becomes worse and the level of service goes down.

The range of PI was evaluated in terms of the five signal spacings considered. The PI for signal system configuration is shown in Figures 3-5. For a given cycle length and volume level, the range of values of the PI is due to the differences in the quality of progression for the signal spacing considered. The range of PI is greater at the higher volume condition. The range of PI is also greater as the number of signals is increased. The interaction of cycle length and a fixed signal spacing is also indicated by the varying slope of the PI curve.

Three of the spacings (330, 990, and 1320 ft) are illustrated in Figures 6-8 to show the inconsistent characteristics of signal spacing versus cycle lengths for the signal system configurations. The effect of the number of signals on PI for the signal spacing can also be seen. The quality of progression is the cause for these inversions. The shape of the PI curves are similar at the short and intermediate cycle lengths for the number of signals. The shape of the PI for the long signal spacing for the larger cycle length has different characteristics.

The relation between PI and signal spacing was further studied at the three cycle lengths for the different signal configuration and traffic volume conditions. The PI varied with the signal spacing. The minimum and maximum values of the PI did not coincide for the three cycle lengths. These differences in PI and signal spacing for the cycle lengths are illustrated in Figures 9-11 for the three signal system configurations. The figures show the trade-offs between signal spacing and cycle length to change the PI. For the same cycle length the differences in the value of the PI are due to the differences in the quality of progression. The shape of the PI curves appears similar for the three signal system configurations. The effect of increasing the number of signals appears to increase the slope and range of the PI curves. The minimum and maximum performance values for the signal spacing, however, appear to change for the three signals and the 90-s cycle length.

To further study the effect of cycle length on the value of PI as the cycle length is varied, a range of the cycle length near the optimal cycle length for a 1320-ft signal spacing and a progression speed of 34 mph was evaluated. Based on the space periodicity concept of progression for the 34-mph speed and 1320-ft spacing, the optimal cycle length falls within the range of 50-55 s. To study the effect of the cycle length on the value of the PI near this optimal progression cycle length, the cycle length was varied from 50 to 55 s in 1-s increments. The effect on PI is displayed in Figure 12. Comparison of the PI value to the cycle length for the conditions modeled as the cycle length is increased shows that PI always increases, although sometimes it may be only slightly.

SUMMARY OF FINDINGS

The findings of this limited hypothetical study are that, in all cases studied, an increase in the traffic volume increased the performance index. An increase in the cycle length also increased the PI in all cases studied. The effects of signal spacings depend on the resulting quality of progression. For a given set of traffic volume, cycle length, and signal spacing, the signal system performance appears to be optimized by operating at the lowest practical cycle length with the best progression possible for that cycle length.

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