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Developing Interconnection Guidelines for Isolated Traffic Signals

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ABSTRACT

The increase in levels of traffic congestion along major urban signalized arterials makes efficient traffic management and utilization of arterial facilities important considerations. Significant improvements in traffic flow and reductions in vehicular delay may be realized by interconnecting individual, isolated intersections into a coordinated signal system, or by adding an adjacent signal to an existing progression system. Current analytical methods and computer programs offer capabilities of optimizing traffic signal coordination for a series of signalized intersections. Recently, transportation research has been directed toward the alternative development of short-range, low-capital improvements for the safe and efficient movement of people and goods. The criteria measuring these alternative improvements include the following: traffic volume distribution, travel time, delay, and quality of traffic flow. However, the proper procedures and methods for analyzing the effects of coordinating isolated signalized intersections are insufficient. Because interconnection can be significant to the total signalized operation, guidelines are needed to identify where to implement signal interconnections. Summarized in this paper is research sponsored cooperatively by the Texas Department of Highways and Public Transportation and the FHWA, U.S. Department of Transportation. In the study, guidelines and procedures are developed to identify where interconnection of signalized intersections should be implemented. Efforts were made to evaluate interconnection of isolated traffic signals into a progression system to provide coordinated operations. Described are the study approach and development of good coordination of isolated traffic signals by using both simulation analysis and field validation. In this way, better signal interconnection, efficient utilization of the street system, and smooth traffic operations can be provided.

The increase in levels of traffic congestion along major urban signalized arterials makes efficient traffic management and utilization of arterial facilities important considerations. Significant improvements in traffic flow and reductions in vehicular delay may be realized by interconnecting individual isolated intersections into a coordinated signal system, or by adding an adjacent signal into an existing progression system.

Current analytical methods and computer programs offer capabilities of optimizing traffic signal coordination for a series of signalized intersections. Recently, transportation research has been directed toward the alternative development of short-range, low-capital improvements for the safe

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and efficient movement of people and goods. The criteria measuring these alternative improvements include the following: traffic volume distribution, travel time, delay, and quality of traffic flow. However, the proper procedures and methods needed to analyze the effects of coordinating isolated signalized intersections are insufficient. Because interconnection decisions can be significant within the total signalized operation, guidelines are needed to identify where to implement signal interconnection.

Summarized in this paper is research sponsored cooperatively by the Texas State Department of Highways and Public Transportation (TSDHPT) and the FHWA, U.S. Department of Transportation. In the study, guidelines and procedures are developed to identify where interconnections of signalized intersections should be implemented. Described are the study approach and the development of good coordination of isolated traffic signals by using both simulation analysis and field validation. A simple procedure for analyzing whether interconnection of isolated signalized intersections will be beneficial with respect to the increasing traffic volume is applied. In this way, better signal interconnection, efficient utilization of the street system, and smooth traffic operations can be provided.

Efforts were made to evaluate interconnection of isolated traffic signals into a progression system to provide coordinated operations. Specific study objectives were to

1. Identify factors that influence interconnection feasibility of isolated signalized intersections;
2. Evaluate effectiveness of isolated versus interconnection control, and isolated control versus interconnection with progression phasing;
3. Develop guidelines to identify where interconnection of a series of signalized intersections into a progression system should be implemented; and
4. Develop a simple, easy-to-use evaluation procedure for examining the need for signal interconnection.

STUDY BACKGROUND

Modern traffic control strategies utilize optimization of signal-timing plans, installation of control equipment, and provision of interconnection to reduce vehicular delay and fuel consumption (1). Wagner (2) found that "it is fuel efficient if traffic can be kept moving (without stopping). Lost fuel by stopped vehicles may be reduced with more efficient traffic control systems, especially during the off-peak periods when the number of stops and the overall delay may be improved through traffic control improvements." Suhbier and Byrne determined that one-half of vehicular fuel usage was caused by traffic delay at arterial intersections (3). Because arterial traffic occupies the major portion of areawide travel, improvements in arterial traffic control can effectively reduce fuel consumption throughout the day.

The coordination of adjacent signals can (a) reduce overall travel time and stops and delays, and (b) decrease fuel consumption and air pollution. Even though fewer publications exist addressing when to interconnect a series of isolated signalized intersections, interconnection has been recognized as a viable alternative in traffic control improvement. Wagner studied the four possible traffic control system improvements (4) and found that the typical improvement in average travel time was as follows:

Traffic Control Improvement	Travel Time Savings (%)
Interconnection and optimization of signals	25
Signal timing optimization	17
Advanced master control system improvements	15
Freeway surveillance and control	20

Wagner found that "the most dramatic improvements in traffic performance on signalized arterials and networks are those resulting from the combined action of interconnecting previously uncoordinated pretimed signals with a master controller, together with the introduction of new optimized timing plans." He indicated that "simply retiming signals that were already interconnected without any hardware changes averaged a 12 percent improvement in speed or travel time" (4). In addition, Wagner also found that signal-timing reoptimization was the most-cost-effective enhancement action. However, possible improvement by signal-timing optimization depends on the quality of the signal-timing plan, geometric constraints of the arterial street, traffic characteristics, and quality of the existing arterial progression system.

Several attempts were made to relate factors for coordination. In several studies conducted by Yagoda, Whitson, White, Messer, and others, a coupling index (I) was developed, which was the simple ratio of link volume and link length (5-7):

$$I = V/L \tag{1}$$

where

I = coupling index,
V = approach link volume [vehicles per hour (vph)], and
L = link length to next signal (ft).

By computing this index for each link in the potential coordinated system, a measure of the signal interconnection needs could be determined.

The Traffic Control System Handbook indicated that "any two or more signals which are less than one-half mile apart or within a cycle length of travel time should be coordinated" (6). Pinnell identified various factors that affect arterial signal control strategies (6):

- Distance between signalized intersections,
- One-way versus two-way street operations,
- Signal phasings,
- Arrival characteristics, and
- Traffic fluctuations with time.

Other researchers found that a number of factors are important in determining the need for interconnection (7-14), including

- Geographic relationship--Distance between intersections. Intersections to be interconnected should be adjacent to each other without being affected by the natural and artificial boundaries, such as rivers and controlled-access facilities.
- Volume levels--Presence of larger link volumes usually implies a greater need for coordination between adjacent traffic signals.
- Traffic flow characteristics--If traffic arrivals are uniform throughout the cycle, the red phase of the cycle would produce the same delays and stops as would the green phase. On the other hand,

controlled flow in platoons enhances the coordination benefits with the extra consideration of platoon dispersion.

Presented in this paper is a model for arterial traffic signal design; the study developed to evaluate the feasibility for interconnection of isolated traffic signals is described (7-9).

Model Development

Intersections should be interconnected only if the arrival flow rates downstream can be guided into compact platoons through effective traffic signal timing. Fluctuation in arrival rates is influenced primarily by two factors to bring flow rates away from uniformity over time: (a) degree of volume variation at the upstream intersection, and (b) amount of platoon dispersion occurring between intersections.

Volume Considerations

It is not necessary to interconnect a system of intersections if the volume level is uniform and balanced during most operational periods. However, because of the different green time used during each signal of the progression system, the amount of delay and stops could be affected by the coordinated offsets under normally fluctuated arrival conditions. Several factors may contribute to the uniform arrival of vehicles at an intersection:

- An intersection isolated by distance relative to the other upstream arterial signalized intersection,
- Consequential traffic volumes entering at midblock, and
- Significant truck movement between intersections.

Thus, the desirable condition for interconnection is the imbalance in level of volume entering at the upstream intersection. In addition, significant traffic volume entering at midblock or a large truck traffic volume between intersections will force arriving flows to slow down such that interconnection can not eliminate the traffic congestion problems.

Consider the typical link flow pattern between two adjacent intersections, as shown in Figure 1. The entry volume for the downstream intersection (Link 3) consists of the right-turn volume (Link 2), through volume (Link 1), and left-turn volume (Link 4) from the upstream intersection. The degree of traffic flow imbalance at the upstream intersection is represented by the ratio between the maximum link traffic volume feeding from the upstream intersection and the sum of all the link traffic volume arriving at the upstream intersection. It can be stated as shown in Equation 2:

$$\text{Imbalance} = q_{max} \div \bar{q} \qquad (2)$$

where

I = imbalance index;
q_{max} = maximum flow, usually the through-movement flow (vph); and
$\bar{q}$ = average flow rate entering a link (vph).

The flow entering on the downstream intersection is influenced by the arriving flow over time. The imbalance index, as calculated from the maximum link flow divided by the average upstream link flow, is an index representing the fluctuation of traffic volume along a downstream link. It varies as

$$1 \leq (q_{max} \div \bar{q}) \leq X \qquad (3)$$

When this factor is 1, uniform flow exists. That is, cross-street, midblock, and turning traffic at the upstream intersection are approximately equal to the major entering flow. Interconnection of upstream and downstream signalized intersections in this case is not desirable. However, when the imbalance factor approaches X, or the total number of approach lanes, the effect of flow rate is at its maximum on the downstream intersection. This condition of heavy imbalance will create the most desirable situation for progression. The existence of imbalance can describe the relationships between flow rates and vehicle platoon formation. However, the additional effects of platoon dispersion have not yet been considered by this equation.

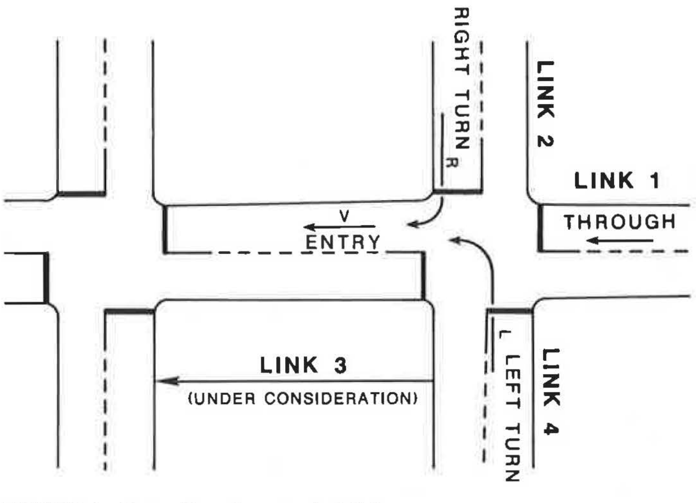

FIGURE 1 Entry flow for a typical link.

Platoon Dispersion

Platoon dispersion results from the drivers' adjusting the relative distance between their vehicle and adjacent leading and trailing vehicles. The dispersion of a platoon of vehicles leaving a signalized intersection has been described in previous research by Nemeth and Vecellio and in the North Dallas Corridor study. It approximated dispersion rate in terms of percent of platoon length by the following equation (7,8):

$$\text{Rate of dispersion, } D = (L + \Delta L)/(L * 1 + t) \tag{4}$$

where

L = length of the standing platoon (sec),
ΔL = change in length over distance and time (sec), and
t = average travel time (sec).

The change in platoon length related to the time and distance traveled can be further expressed by simplifying Equation 4 into Equation 5:

$$D = 1/(1 + t) \tag{5}$$

Interconnection Model

By combining the previous volume and platoon dispersion concepts, an interconnection desirability index (I) can be used to describe both the characteristics of platoon dispersion and traffic signal system as follows:

$$I = [(X * q_{max})/(q1 + q2 + q3 + \ldots qx)] - \{(N - 2) * [1/(1 + t)]\} \tag{6}$$

Equation 6 may have a value ranging from 0 to 2. By normalizing for a range of 0 to 1 and rearranging Equation 6, it can be simplified as shown in Equation 7:

$$I = [1/(1 + t)] * [(X * q_{max})/(q1 + q2 + q3)] - (N - 2) \tag{7}$$

where

t = link travel time, link length divided by average speed (min);
X = number of departure lanes from the upstream intersection;
q_{max} = straight-through flow from the upstream intersection (vph);
$q1, q2, \ldots, qx$ = traffic flow arriving at the down-stream approach from the right-turn, and through movements of up-stream traffic signals (vph); and
N = number of arrival lanes feeding into the entering link of the down-stream intersection.

In other words, the coordination requirements of each one-way link are measured in this approach by incorporating the platoon dispersion effect through use of I. In Equation 7, a value of 1 indicates the most desirable condition for interconnection and 0 indicates the least desirable condition. The scale shown in Figure 2 is suggested as a possible tool for applying the signal interconnection in the traffic control strategy. As indicated, when I has a value of 0.25 or less, isolated operation is recommended. On the other hand, when I has a value of 0.50 or greater, interconnected system operation is recommended. Other evaluation indicators are needed to assist in the interconnection decision if the calculated value of I is between 0.25 and 0.50. The interconnection of traffic signals at a study intersection is warranted when the I equals or exceeds 0.35. The relative need for traffic signal interconnections at possible locations could be indicated by the relative interconnection desirability index on both sides of the study intersection.

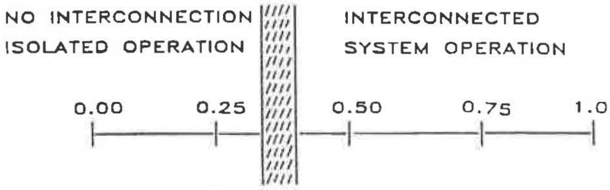

FIGURE 2 Interconnection desirability index.

It should be noted that this approach considers the potential benefits resulting from the interconnection of an isolated intersection or intersections by measuring the combined effects of geographic relationships, traffic volume levels, and traffic flow characteristics. However, this formula does not hold for the case when straight-through flow from the upstream intersection (q_{max}) is 0, yet turning flows are relatively high and the intersections are closely spaced, in which case interconnection may be desirable. Treating the heavy turning flows as through movements in the equation could solve the problem in this extreme case. By using this approach, an interconnection desirability index of 1 would indicate the most desirable condition for interconnection, and 0 the least desirable. It could be suggested that the scale shown at the bottom of Figure 2 be used as a tool for the delineation of the traffic signal control strategies.

STUDY PROCEDURE

In this study, the experimental simulation and field study were designed to develop guidelines for traffic signal interconnection. They were developed based on geographic relationships, volume levels, and traffic flow characteristics. Simulation models were used as theoretical test bases to investigate conditions that cannot easily be reproduced in the field. Field data were then collected on selected arterials to validate the simulation results.

Simulation Study

It is suggested by current technology that intersection spacings, percentages of turning traffic, and general volume levels are candidate elements. A review of existing traffic models suggests that PASSER II, TRANSYT-7F, and NETSIM can be used to determine interconnected traffic signal operations. Basically, PASSER II and TRANSYT-7F were used to optimize phase sequence and offsets for pretimed traffic signals under isolated versus interconnected operations. However, the simulation of existing isolated traffic control conditions could not be thoroughly evaluated by the first two models. The NETSIM model was also used to evaluate the coordinated operations of a series of isolated actuated traffic signals. It was further used as a base to analyze isolated versus interconnected actuated traffic control.

Alternative traffic control strategies under different geometric and traffic levels were devised to test the effectiveness of interconnection. The experimental simulation plan, as shown in Figure 3, was used to collect simulation data and establish numerical guidelines under different intersection spacings and left-turn percentages. The PASSER II runs were made to provide the optimal settings of cycle length and proper phase sequence. The TRANSYT-7F runs primarily examined the detailed effects of intersection spacings and the percentages of traffic turning left onto the arterial.

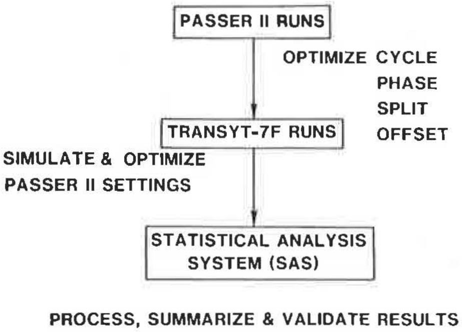

FIGURE 3 Experimental simulation design plan.

The major variables studied include

- Numbers of signal phases,
- Preferred phase sequences,
- Allowable cycle length ranges based on volume levels,
- Volume levels,
- Speed variations,
- Left-turn movement percentages, and
- Intersection spacings.

This means that a large number of simulation cases would be required if all the combinations of variables were to be used. Scenario runs of the computer program were made for the range of factors identified in order to determine the practical accuracy, sensitivity, and applicability of the simulation model.

It was assumed in this simulation study that

1. Approach volumes are constant over the study time period;
2. Platoon structure remains coherent along the arterial;
3. The link speed remains uniform;
4. Origin-destination turning traffic volumes are consistent:
   a. All side-street left-turn traffic flows into through movement;
   b. All main-street left-turn traffic is originally from the through movement on the main street;
   c. Downstream through traffic on the main street is equal to the arterial through traffic plus side-street left-turn and right-turn traffic, and minus the downstream left-turn traffic; and
5. Directional link volumes are balanced.

A synthetic four-node arterial street, as shown in Figure 4, was used to obtain separate but compatible simulation results by using both the PASSER II and TRANSYT-7F models. Sets of PASSER II runs were first made to choose appropriate signal phase sequence and phase length for both two-phase and four-phase operations with different intersection spacings. The TRANSYT-7F was then used to simulate and optimize PASSER's best settings. These TRANSYT-7F results were further compared with the results from PASSER II studies. Because of the amount of data reduction required, a simplified version of the PASSER II program was developed for direct data processing by the statistical analysis system (SAS). Performance measures of effectiveness (MOEs)--such as delay, stops, and queue clearance--were analyzed under regular PASSER II runs, TRANSYT-7F-simulated PASSER II best-setting runs, and TRANSYT-7F optimization runs.

Figure 5 shows an example of the performance measurement of average delay on one approach compared with the spacing variations given that all other variables remain constant. The simulation result also indicated the wide variation of operational performance with respect to the spacings of progression systems. It also showed the results from different platoon dispersion models applied in these two models. They both confirmed that the rule-of-thumb or ideal spacing for good arterial progression is between the distance of 1/4 mile (1,320 ft or 440 m) and 1/3 mile (1,760 ft or 580 m).

Traffic control scenarios were devised to test the effectiveness of signal interconnection under different geometric and traffic levels. Guidelines under conditions of different intersection spacings and left-turn percentages were established. The TRANSYT-7F was primarily used to examine the effects of intersection spacings and the percentages of traffic turning left both off and onto the arterial. The computer program evaluated needs for interconnection. Selected NETSIM runs, similar to the TRANSYT-7F runs, were conducted for investigating actuated arterial control on a four-intersection

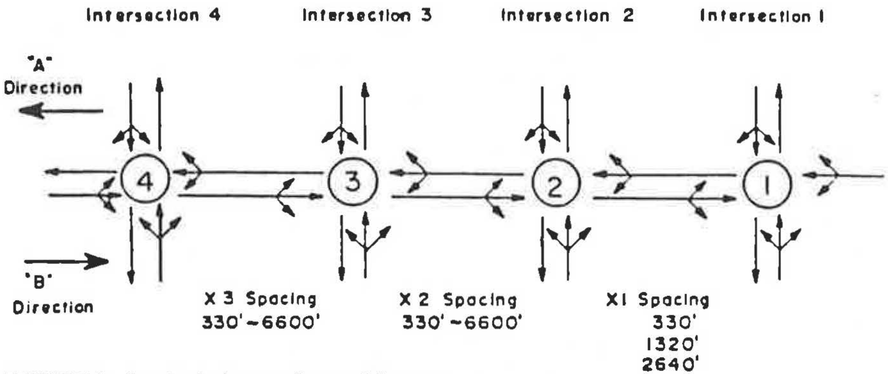

FIGURE 4 Synthetic four-node arterial street.

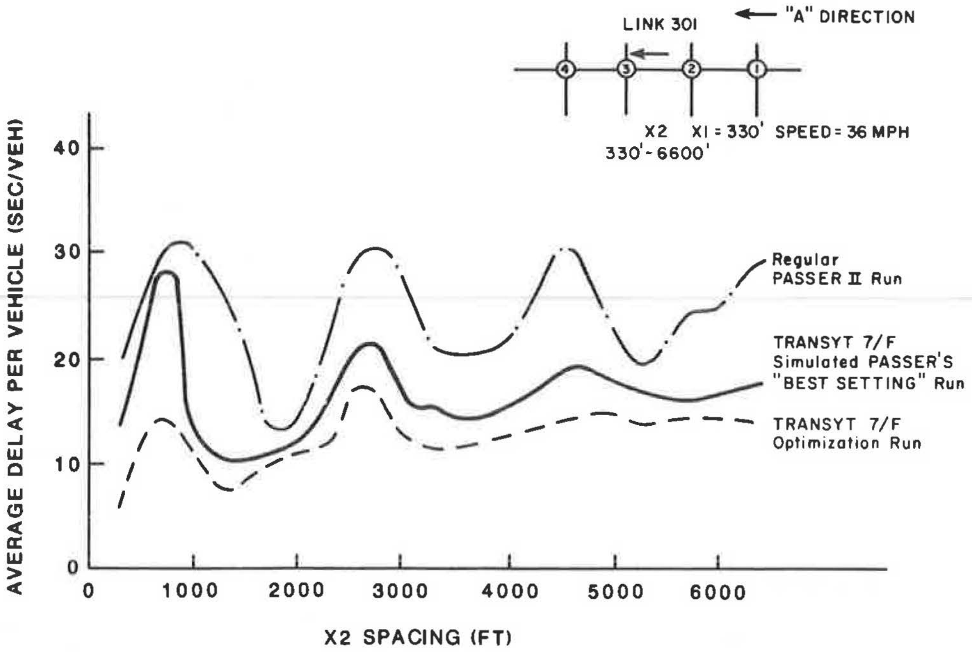

FIGURE 5 Selected link performance MOE versus intersection spacing under PASSER II run, TRANSYT-7F-simulated PASSER II run, and TRANSYT-7F optimization run.

system. It evaluated whether intersection spacing and the percentage of turning traffic would affect actuated control similar to how they affected pretimed control.

Field Study

Two field studies were performed in the travel time and delay study. The first field study was made on Lamar Boulevard and U.S. 183 in Austin, Texas. Both are high-volume high-type facilities; Lamar Boulevard has low-to-medium speed operations and U.S. 183 has medium-to-high-speed operations. The study showed that good progression was available throughout the two systems regardless of the variable spacing and the saturated operations along the two arterials. However, the field study did not provide enough validation of the simulation analysis because the percentage of left-turn traffic volume and the corresponding traffic volume were not properly identified.

Nevertheless, it was indicated in the travel time and delay study that a positive relationship existed between the travel time delay and the travel time versus background cycle length used. As indicated in Figure 6, the travel time delay was plotted against the travel-time-to-cycle-length ratio for both signal systems. It is suggested by Figure 6 that travel time delay within the interconnected signal system decreases gradually from 0.4 to 0.6 of travel-time-to-cycle-length ratio and then increases as travel time increases. It also indicated that the combined travel time and background cycle length ratio can provide a better indicator than can distance alone to represent relationships among distance, travel speed, progression design speed, and level of traffic volume for a coordinated system.

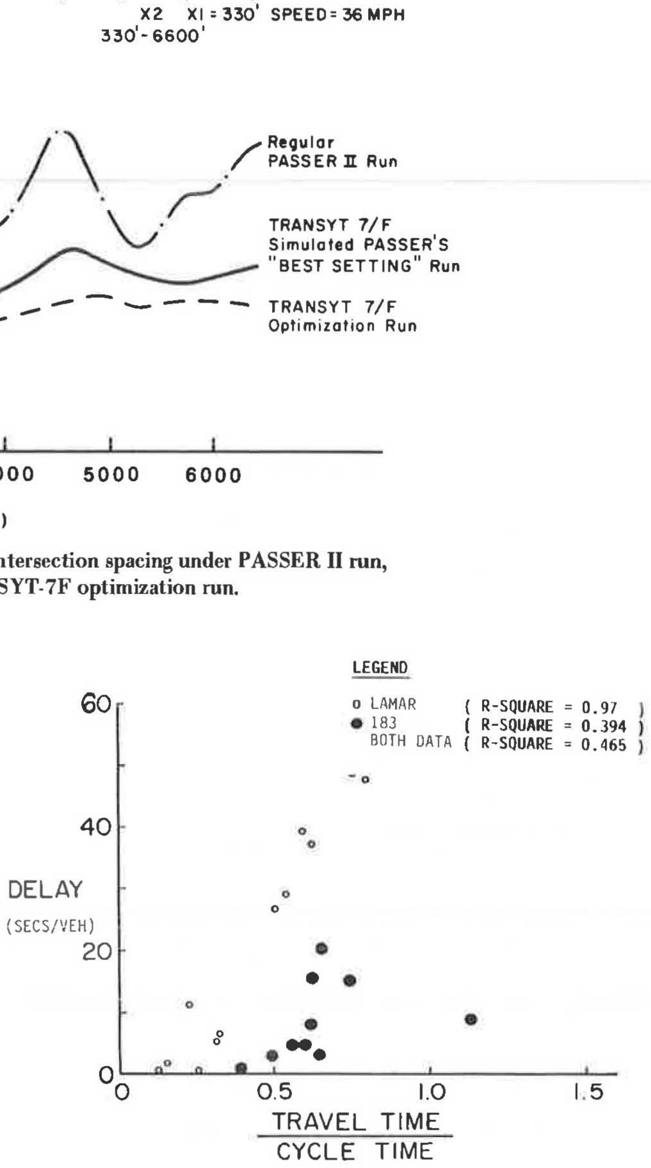

FIGURE 6 Summary of field study results in Austin, Texas: travel time delay versus travel-time-to-cycle-length ratio.

The second detailed field data collection was performed on TSDHPT's NASA 1 FACTS system to collect data on signal timing, travel time, delay, and queue stops. The NASA 1 computerized traffic signal control system, south of Houston, was selected to calibrate the computer models. The cross streets were Kings Row, El Camino, Space Park, Nassau Bay, Point Lookout, and Upperbay, as shown in Figure 7. Field data were collected during the noon rush and off-peak periods. Calibration of the combined PASSER II and TRANSYT-7F runs and validation of operational measures were then completed. Interconnected studies were conducted on Tuesday, Wednesday, and Thursday of one week and isolated intersection studies were made during the following week. PASSER II optimized phasing was used at all intersections during both simulation and field studies. Data collected for the test arterial were used to calibrate the operational scenarios and factor levels in the PASSER II and TRANSYT-7F runs. The basic data include the following measurements: arterial street, arterial link, cross street, intersection, and arterial performance.

Field data were used to calibrate computer models and provide real-world data in evaluating the computer models. Essentially, this field study was used

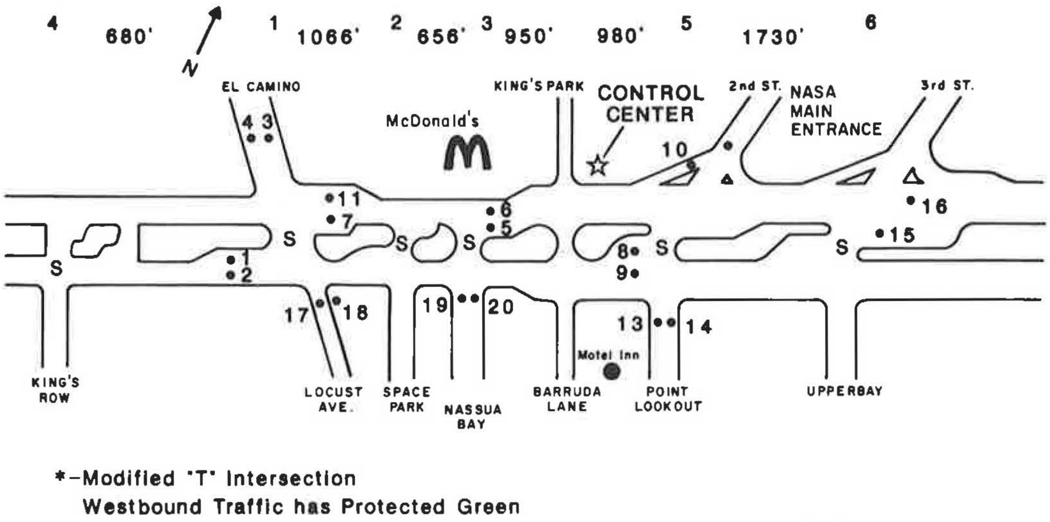

FIGURE 7 Texas SDHPT NASA 1 FACTS system.

to investigate the effects of intersection spacings, offsets, and average delay measurements in response to the different signal-timing settings in the field. These data were then applied to establish guidelines for interconnection of isolated traffic signals. The data were collected from the stop-delay study, travel time and delay study, and platoon dispersion study. The volume count was collected with assistance from TSDHPT's D-19 personnel by using the NASA 1 FACTS system sampling detectors. Selected queue counts and stop delay measurements were collected manually at each signalized intersection location.

STUDY RESULTS

Both the simulation and field data were summarized to study the conditions for effective arterial traffic signal control. In this study, realistic and quantitative relationships were established among the study factors important to the interconnection decisions. One factor used for predicting the potential interconnection benefits is the interconnection desirability index. Another measure is the estimated arterial delay experienced by the motorists.

Simulation models were used as a theoretical testbed to enumerate study conditions that cannot be easily reproduced or controlled in the field. Emphasis was placed on investigating the generalized relationships among the study factors and their sensitivities with respect to systemwide performance. This simulation mainly establishes linkage between the estimated arterial link delay and the proposed interconnection conditions. Test scenarios were examined for accurate and reliable representation of the candidate application sites.

In the study, the operational performance for various conditions was investigated, assuming that the potential interconnection became operational. Two separate analyses were investigated: the interconnection index analysis, and the combined PASSER II and TRANSYT-7F analysis. In the first analysis, the basic variation of the interconnection desirability index was studied as a function of intersection spacings, progression design speed, intersection volume levels, and left-turn percentages. In the second analysis, estimated arterial street performance statistics were combined by applying the approaches of both the PASSER II and TRANSYT-7F programs.

Because of the inherent variability of the various field conditions, this study evaluated whether the interconnection can provide effective operation without undue delay to the arterial signal system for given already-installed traffic signals. The combined PASSER II and TRANSYT-7F runs evaluated the effectiveness of interconnection versus interconnection with progression phasing under different volume levels. In this approach, the detailed simulation capability of TRANSYT-7F was applied to predict platoon travel behavior, and the optimized cycle length and phase sequence optimization in PASSER II were used.

The field and simulation data were used to determine where interconnection of a series of isolated signals is desirable in improving traffic operations. It was found that the factors influencing the arterial link delay the most are the following: traffic volume level (the resultant Webster's minimum delay cycle length), intersection spacings, travel speeds, and left-turn movement percentages. Three types of sensitivity analyses were made to investigate the variability of an average link delay per vehicle against the major study variables. The results are shown in Figures 8-10. Figure 8 shows the effects of intersection spacing on average link delay; spacing ranges from 330 ft to 2,640 ft. Figure 9 shows the average link delay versus low, medium, and high volume levels; it has a saturation flow ratio of from 0.50 to 0.83. Figure 10 shows the average link delay according to three different progression design speeds of 27 mph, 36 mph, and 45 mph. It was also found that the dispersion effects of the progression platoon and the background cycle used can influence the total progression system operations.

The results indicated that the lower arterial link delay occurs at a distance of 1/4 to 1/3 mile or 0.4 to 0.5 cycle length of travel time during a two-phase operation, or 0.35 to 0.55 cycle length during a four-phase operation. This finding confirmed that the ideal progression spacing is approximately the travel time of one-third to one-half of the cycle length multiplied by the design speed for any generalized arterial.

The results demonstrated that highly fluctuated relationships existed between the potential arterial link delay and the intersection spacings. It also showed that the circular pattern of average vehicular delay due to the possible progression platoon

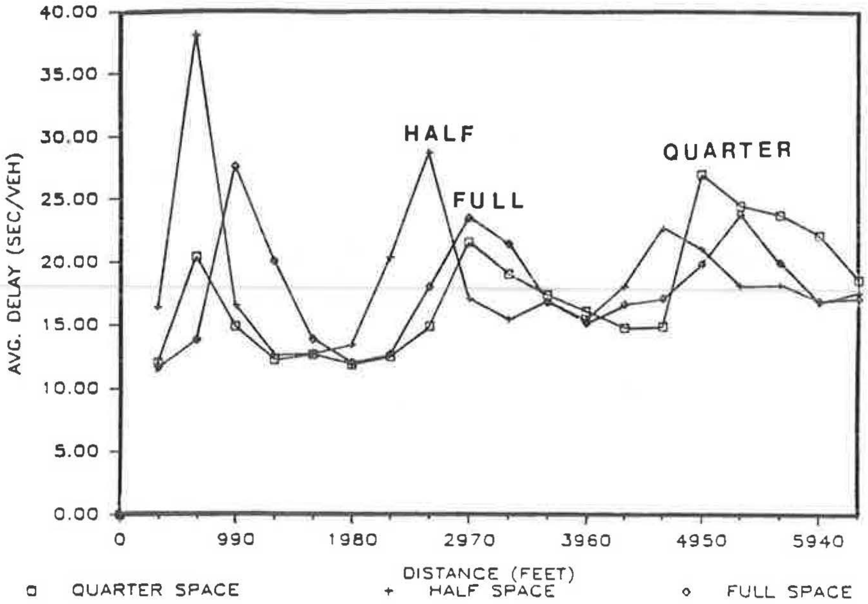

FIGURE 8 Summary of simulation study results: effects of intersection spacing.

propagated downstream from the upstream traffic signal even under good arterial progression operation. As indicated, the effectiveness of the traffic signal interconnection relies heavily on the following study factors:

- Location of ideal spacing,
- Intersection traffic volume,
- Left-turn percentage,
- Intersection spacing,
- Progression design speed, and
- Arterial platoon travel speed.

CONCLUSIONS AND RECOMMENDATIONS

Improving urban mobility requires the efficient utilization of existing urban arterial facilities. Signalized arterial design requires concurrent functioning of existing traffic control devices and proper signal-timing settings as one unit in the field. The ability of signalized intersections to move traffic depends on the physical intersection layouts as well as the signalization used. An efficient procedure was developed with which traffic engineers can make decisions about interconnections of isolated arterial traffic signals to optimize arterial traffic operations. Described is the development of interconnection guidelines for minimizing arterial systemwide delay and maximizing progression in multiphase traffic signal systems.

Traffic signal optimization depends heavily on the relationships of the intersection spacings, travel speed, cycle length, roadway capacity, and side friction along the arterial. Effective traffic signal operations will provide a safe crossing gap

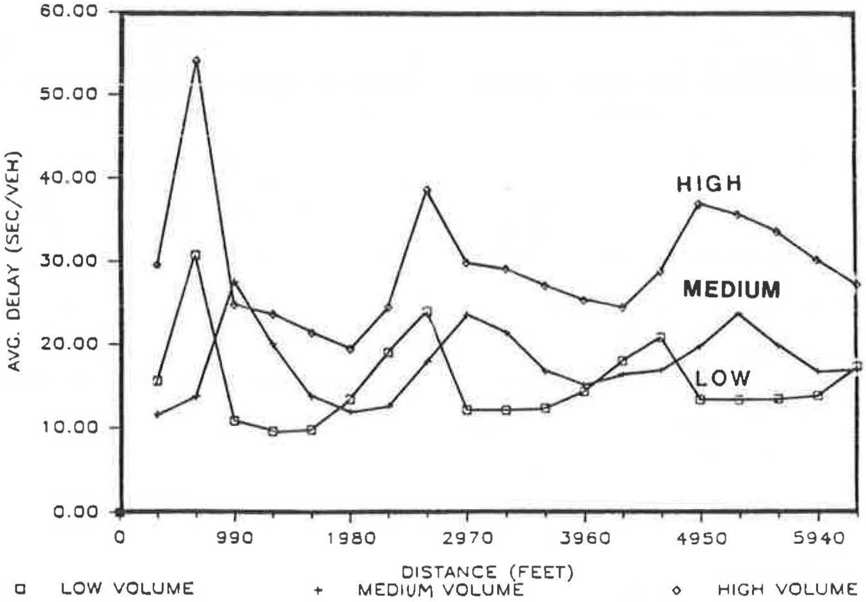

FIGURE 9 Summary of simulation study results: effects of traffic volume level.

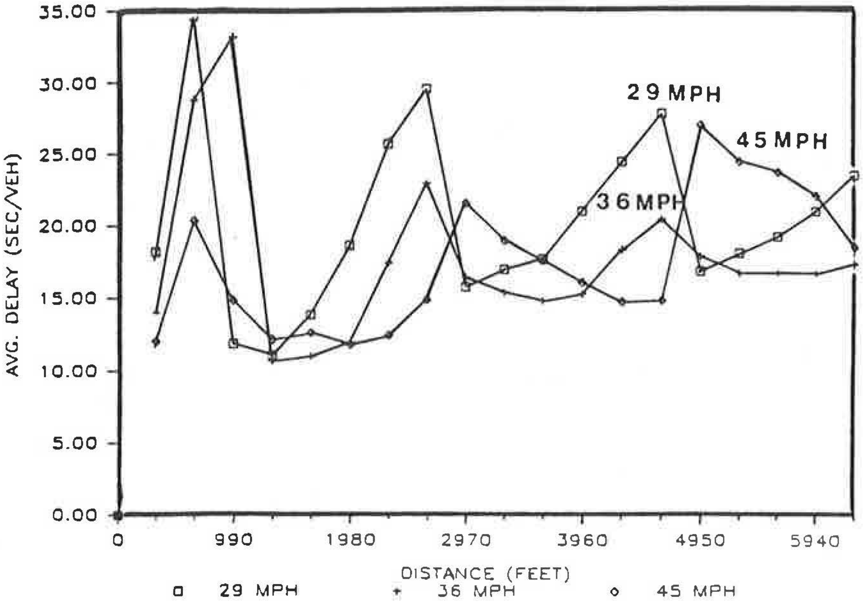

FIGURE 10 Summary of simulation study: effects of travel speed.

for the cross-street turning traffic and guide the randomly arriving traffic into compact platoons. Guidelines can assist traffic engineers in making decisions about proper arterial traffic signal interconnection. Although the interconnection index system provides a realistic analysis of the effect of interconnection of a traffic signal at a specific location, it is recognized that it can serve only as a tool to aid the judgment of the traffic engineer, and is not an absolutely final answer that would overcome the need for experienced and objective analysis.

Faced with highly fluctuated patterns of traffic arrival, good signal patterns can tailor the arterial traffic signal control to suit sensitive traffic demand. It was found that a proper interconnection operation could alleviate total system traffic loading to a certain extent without sacrificing good progression operation. However, care should be taken to monitor travel speeds against design speeds to suit traffic demand for successful arterial progression. It was also found that close monitoring of the traffic flow in the field is necessary to assure successful signal-timing implementation and minimize delay from the maximum progression calculation.

Additional research is recommended on (a) calibration of platoon dispersion models under various traffic signal control strategies, (b) field validation of the interconnection warrants, (c) evaluation of the impact of traffic progression in arterial signal optimization, and (d) development of better measurements for describing the quality of arterial progression of traffic signal systems. Studies are needed to extend this research to permit on-line traffic control network configuration of traffic signal control systems in order to control open networks rather than closed networks.

Revision of the internal simulation mechanism should be made inside the NETSIM program to reduce the step size. Thus, the simulation cost for coordination of fixed-time and actuated signals under isolated or interconnected operations is decreased. Special study is recommended that will compare the progression platoon size and the progression bandwidth in order to use green time efficiently without sacrificing the progression solution to further minimize total arterial system delay measurement.

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Control of Congestion at Highly Congested Junctions

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ABSTRACT

The results are reported of experiments in Bangkok designed to test fixed-time signal control as a replacement for manual police control at highly saturated junctions with flows of up to 15,000 vehicles per hour. Data collection methods, use of video techniques, analysis procedures, and resulting traffic-junction performance parameters are described. The results demonstrate that it is possible to replace police control at such junctions, and that at linked junctions substantial savings in travel time can be obtained. However, existing computer-based techniques do not readily produce optimum control strategies, and additional work is needed to enable them to do so. The problems caused by substantial fluctuations in demand and in operating conditions are discussed, and proposals for further work are outlined.

The results to date are reported of a study of the appropriateness of using procedures of the United Kingdom for traffic signal control in a highly congested developing city, Bangkok, and the feasibility of using fixed-time signal settings to release traffic policemen for more important duties.

The design of individual signalized junctions follows long-established procedures (1); although some recent studies have suggested modifications to the values used for saturation flow and passenger car unit (pcu) equivalents (2), others suggest that there has been little change in parameters during at least 20 years (3). Similar techniques are applied elsewhere in the developed world (4,5). Procedures for optimizing the fixed-time control of networks of signal-controlled junctions are also long established, and the Transport and Road Research Laboratory's TRANSYT program (6) is generally accepted as the most successful optimization method. Recent developments in vehicle-actuated control of signal networks offer the potential for significant improvements in the TRANSYT method (7).

However, it is suggested by recent experience in Bangkok that neither the procedures for individual junction design nor those for network control may be appropriate for the much more heavily congested conditions experienced in cities in the developing world. Bangkok has a widely dispersed land-use pattern; only 9 percent of its land is allocated to

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